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Effects of context change upon retrieval of first and second-learned information in human predictive learning

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Two experiments were conducted to evaluate the context switch effect upon retrieval of the information about a cue-outcome relationship in human predictive learning. The results replicated the well-known effect of renewal of the cue-outcome relationship due to a context change after a retroactive interference treatment, as much as the null effect of the context change upon acquisition before retroactive interference training had taken place (Experiment 2). However, retrieval of an unambiguous cue-outcome relationship was also impaired by a context switch when this relationship was established in a context where a different cue had received an interference treatment (Experiments 1 and 2). Once the interference treatment was given to participants in one context, unambiguous cue-outcome relationships learned in a different context also became context specific (Experiment 2). The implications of these results for retrieval theory are discussed.

Forgetting is operationally defined as a decrease in performance between acquisition and testing. This decrease in performance may be shown either as a decrease or as an increase in responding, depending on whether the forgotten information is excitatory or inhibitory. Forgetting can be produced by different manipulations, typically conducted between the time in which the information is acquired, and the time when the information is tested. There are three typical manipulations developed in the literature to produce forgetting. The first one is the *learning of new information* that may compete with the information originally learned (i.e., retroactive interference; e.g., García-Gutiérrez & Rosas, 2003d; Pavlov,

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1927). The other two manipulations are the simple *passage of time* (i.e., spontaneous recovery from extinction; e.g., Pavlov, 1927), and *a context change* between the retroactive interference treatment and testing (i.e., renewal; see Bouton, 1993 for a review). Most of the studies of forgetting have been conducted to answer one or several of the following questions: The sources of forgetting (*when* forgetting occurs), the mechanisms of forgetting (*why* forgetting occurs), and the type of information that is forgotten (*what* it is forgotten).

The version of retrieval theory proposed by Bouton (1993, 1994) is one of the most comprehensive theoretical accounts of forgetting, giving answers to the three questions stated above. Retrieval theory assumes that there are two main sources of forgetting: Retroactive interference, and context change. Information is forgotten –its retrieval is impaired– when either acquisition of new information makes first-learned information difficult to retrieve (retroactive interference), or when a change in the context where interfering information is acquired impairs retrieval of second-learned information. Forgetting occurs because either the new learned information inhibits the expression of first-learned information, or because the information was coded along with the context where it was learned. In that case, such information is not retrievable in a different context.

According to retrieval theory, contexts are the set of stimuli that surround the target stimuli, and that are not relevant to perform the task. This set of stimuli includes physical, and temporal stimuli (the temporal features of the situation, when the information is learned). In fact, this theory assumes that both, the effects of time change (e.g., spontaneous recovery) and the effects of context change (e.g., renewal) are the result of manipulating the same factor (*the context*) in two different ways (e.g., Bouton, 1993; Rosas & Bouton, 1997, 1998; Rosas, Vila, Lugo, & López, 2001).

With respect to the third question stated above, *which information is forgotten*, there have been two main approaches in the literature. In the first approach, it is assumed that inhibitory information is more easily affected by forgetting processes than excitatory information. Pavlov (1927) suggested that inhibition was simply "labile" and easily disrupted by external events (see also Hull, 1943). Bouton (1993) brought up a similar idea within a memory framework in his theory of interference and forgetting to explain the differential effects of physical and temporal context changes upon simple conditioning and extinction. Simple conditioning does not seem to be affected by either a retention interval or a context change, while the memory of extinction is clearly affected by both (for a review see Bouton, 1993).

Renewal and spontaneous recovery have also been found within interference situations different from extinction. For instance, in counterconditioning the same stimulus is sequentially followed by two different outcomes. Retrieval of the second-learned association is impaired when the context is changed (e.g., Bouton & Brooks, 1993; García-Gutiérrez & Rosas, 2003c; Rosas et al., 2001). It could be assumed that learning of the second meaning of the cue (i.e., the tone is now followed by food, rather than by shock) implies extinction of the association between the cue and the first outcome (i.e., the shock). However, context dependency of extinction is not enough by itself to explain the retrieval of the first learned association that a context change produces in this procedure. Typically, renewal in this situation implies loss of the second-learned association as well (e.g., García-Gutiérrez & Rosas, 2003c; Rosas et al., 2001). For this reason, Bouton (1993) proposed that context change differentially affected either inhibitory or second-learned associations.

More recently, Nelson (2002) has found that it is the second-learned association what it is context dependent, regardless of whether that association is inhibitory or excitatory. Thus, according to Nelson (2002) there is a symmetry between excitation and inhibition. Both types of information are remembered when they are the first meaning the subject learns about the cue. Conversely, retrieval of both types of information is negatively affected by a context change when they are the second meaning learned by the subject about the cue.

To explain context specificity of second-learned information, Bouton (1997) has suggested that subjects begin to pay attention to the context once the information becomes ambiguous during the interference treatment (extinction or counterconditioning), coding the interfering information as specific to that context. However, if one would follow this reasoning in depth, context specificity would not depend on the information having some specific feature (being second-learned or interfering information) but on a specific feature of the situation that leads subjects to pay attention to the context. Following up with this idea leads to the following hypothesis, which is the general approach of the experiments presented in this paper: If what makes information context specific is that subjects begin to pay attention to the context, once the context is made relevant by the presentation of ambiguous information, any information that is presented in that context should become context specific, regardless of whether that information is the first or the second meaning of the cue.

We used an human predictive learning task similar to the one used by García-Gutiérrez & Rosas (2003d). Participants had to predict whether different kinds of foods would produce different gastric malaises in people that had ingested them. A specific food (X) was first paired with a gastric malaise (i.e., diarrhea), and subsequently paired with another gastric malaise (i.e., constipation). Previous experiments conducted in our laboratory that used this task found clear evidence of retroactive interference; participants began judging that X was followed by diarrhea rather than by constipation, but ended judging that X was followed by the second outcome, rather than by the first one (García-Gutiérrez & Rosas, 2003a, b). Similarly, García-Gutiérrez & Rosas (2003c) found that a change in the context between the interference treatment and the test led to attenuation of retroactive interference. In the two experiments presented in this paper the effects of a context change on a cue-outcome consistent relationship that was learned during the interference treatment were tested. Experiment 1 used a between subjects design. Experiment 2 tried to replicate the results of Experiment 1 in a within subject design, testing at the same time the effects of a context change upon interfering, second-learned information.

EXPERIMENT 1

Recent results in the literature show that second-learned information is context dependent (e.g., Nelson, 2002). The reason proposed to explain this context dependency of second-learned information is that subjects begin to pay attention to the context when the information becomes ambiguous during the interference treatment (e.g., Bouton, 1997). As it was stated in the general introduction, following this explanation further would lead to suggest that once the interference treatment makes subjects to pay attention to the context, any information presented in that context should become context-specific, regardless of whether that information is the first or the second meaning of the cue.

The design of this experiment is presented in Table 1. Participants were randomly ascribed to two different groups. Both groups were trained with different cues (foods) and outcomes (gastric malaises) in two different contexts (restaurants). The Interference group received pairings between a cue and an outcome (X-O1) followed by pairings between the cue and a different outcome (X-O2) during Phase 2, always in Context A. The control group received pairings between the same cue and a single outcome (X-O2) along Phases 1 and 2 in Context A. Both groups received Y-O1 pairings during Phase 2 in Context A. Finally, all participants were requested to evaluate the predictive power of Y in Context B (a different, but equally familiar context).

Table 1. Design of Experiment 1.

Group	Pre-Test	Phase 1	Test 1	Phase 2	Test 2
Control	B: Y?	A: X-O2, D-O1, F- B: Z-O1, E-O2, F-	B: Y?	A: X-O2, Y-O1, F- B: Z-O1, E-O2, F-	B: Y?
Interference	B:Y?	A: X-O1, D-O2, F- B: Z-O1, E-O2, F-	B: Y?	A: X-O2, Y-O1, F- B: Z-O1, E-O2, F-	B: Y?

Note: A and B were two different restaurant' names (The Canadian cabin and The Swiss cow). X and Y were cucumber and garlic. O1 and O2 were diarrhea and constipation. Contexts, stimuli and outcomes were counterbalanced across participants, except for Z, D, E, and F that were Eggs, Tuna fish, Caviar, and Corn, respectively.

According to the general hypothesis, it was expected that the interference treatment would lead participants to pay attention to the context, coding the new information presented in that context as context-dependent. If that were the case, a context change should have a disruptive effect on the predictive judgments given by participants about the Y-O1 relationship in the Interference group.

Training on Context B, and the rest of the cue-outcome relationships were intended to equate participants' experience with contexts, cues and outcomes across phases before the test.

METHOD

Participants. Thirty-two undergraduate students of the University of Jaén participated in the experiment. They were between 18 and 25 years old and had no previous experience with this task. Approximately 75% were women, and 25% were men. Participants in this and the following experiment received course credit for their participation. Two participants were eliminated from the analysis because the software failed to record their response at some point of the experiment. Two new participants were added to complete the groups.

Apparatus. Participants were cited in groups of sixteen in a 45 square meters cubicle where 16 IBM compatible personal computers were placed. Half of the computers were set with the task corresponding to the interference group, and the other were set for the task corresponding to the control group. Each participant was randomly assigned to one of the computers. There was a 1.5 meter distance between participants. Participants were additionally separated by cardboard shields placed between them. The procedure was implemented using the program SuperLab Pro (Cedrus Corporation).

Cues (food names) were chosen from the pool selected by García-Gutiérrez & Rosas (2003d). Cucumber and Garlic were counterbalanced as Cues X and Y. Cues Z, D, E, and F were Eggs, Tuna fish, Caviar and Corn, respectively.

Diarrhea and constipation were counterbalanced as outcomes O1 and O2. Contexts A and B were the names of two fictitious restaurants (The Canadian Cabin, and The Swiss Cow) counterbalanced across participants.

Procedure. Participants sat in front of the computer. The following instructions were presented in Spanish in successive screens (800 x 600 pixels). Instructions were presented using a black Times New Roman 18 bold font against a white background. A yellow button with the sentence “click here to continue” was presented at the right bottom of the screen. Participants had to click with the mouse within the button to continue with the next instructions screen.

Before presenting the specific instructions for the experiment, a screen was presented where participants were informed of the general features of the research. This screen read as follows.

"First, we would like to thank you for your participation in the experiment. Without collaboration of people like you this research would not be possible. You should know that in the task you are about to do there are no right or wrong responses. What we are trying to study are mechanisms that appear in all people. Because of that, we need you to participate with the best possible attention, if you decide to do so. You do not need to identify yourself. Your data will be added to the group total, and your results will be completely anonymous. Once the task is finished, if you would like to know what the task was about, ask the experimenter. If you do not wish to continue you may leave the room."

Instruction screens specific to the experiment were presented sequentially immediately afterwards.

(1st screen). "Recent developments in food technology lead to chemical synthesis of food. This creates a great advantage as its cost is very low, and it is easy to store and transport. This revolution in the food industry may solve hunger in third world countries. (2nd screen). However, it has been detected that some foods produce gastric problems in some people. For this reason we are interested in selecting a group of experts to identify the foods that lead to some type of illness, and how it appears in each case. (3rd screen). You are about to receive a selection test where you will be looking at the files of persons that have ingested different foods in a specific restaurant. You will have to indicate whether gastric problems will appear. To respond you should click the option that you consider appropriate, and then click on the button that appears at the bottom corner of the screen. It is very important to respect this order, given that only your first choice will be recorded. Your response will be random at the beginning, but you do not worry, little by little you will become an expert".

At this point participants had to call the experimenter that continued giving the instructions by demonstration. These instructions were given to all the participants in the experimental set at once. Two different types of screen were shown. The first screen was devoted to recording the probability judgments (which is the probability of this food causing this outcome?). The second screen was devoted to recording trial-by-trial predictive judgments (which outcome is going to follow the ingestion of this food?). During demonstration a new cue was used (Pasta). Diarrhea was used as a demonstration illness on the probability judgments screen. The experimenter showed participants how to respond in each of these screens.

On the top of the predictive judgments screen the sentence "One person ate at restaurant… (Restaurant's name)" appeared. In the center of the screen the sentence "This person ate… (food's name), and suffered…" appeared; outcomes were presented in one of three rectangles horizontally arranged at the bottom of the screen. Rectangles were red for diarrhea, pink for constipation, and green for nothing. Immediately after this screen, and independently of the chosen option, the participants received a 1500 ms.

feedback screen indicating the problem the person had (diarrhea, constipation or nothing). The intertrial interval was 1500 ms. and it was indicated by a screen with the sentence “Loading file of… (a randomly chosen full name)”. Full names were always different to keep the impression that each file was from a different person.

On the top of the probability judgments screen there was a sentence that read “One person ate at restaurant… (name of the restaurant)”. In the middle of the screen it was written “This person ate… (name of the food)”. Below that sentence there was a 0 to 100 scale containing 21 small green buttons. Each button had a number representing a 5-point interval on the scale. On top of the scale, beginning on zero, finishing in 100, and equally separated from each other appeared the words “None”, “Little”, “Quite” and “Great”, respectively, written in bold font.

The name of the restaurant “The Canadian Cabin” was written in capital cobalt blue within a turquoise blue rectangle. The name of the food appeared in capital letters in a cobalt blue font. The name of the restaurant “The Swiss Cow” appeared within a yellow oval. The rest of the text appeared in black fonts. Screen background was white.

Participants were requested to respond by clicking first on top of the option they considered appropriate, and then on the screen change button (click here to continue). Before the beginning of the experiment participants were randomly assigned to one of two groups, Interference and Control. The experiment was conducted in two phases.

Phase 1. Participants received 27 trials separated in 3 identical blocks in each context. In each block of trials, participants in the Control group received 4 trials of each combination X-O2 and D-O1, and 1 trial F- in Context A. Participants in the Interference group received 4 trials of each combination X-O1 and D-O2, and 1 trial F- in Context A. Both groups received the same treatment in Context B with 4 trials of each combination Z-O1 and E-O2, and 1 F- trial in each block. Trials within each block were randomly intermixed. Thus, experience with cues, outcomes and contexts was equated throughout the acquisition phase within and between groups. The blocks of trials in each context were sequentially presented preceded by the sentence “Now you should analyze the files of people that ate at restaurant… (Restaurant’s name)”. The order in which blocks of trials (and contexts) were presented was counterbalanced within and between participants (ABBAAB or BAABBA).

Phase 2. It was identical to acquisition, except for the following. The outcome of X was changed in the Interference group (X-O2). In both groups, D was not presented, and a new cue was added and associated with

O1 (Y-O1). This ensured that the experience with the outcomes and the contexts would remain equal along interference.

Predictive judgments were recorded throughout training. A test requesting probability judgments about the relationship between Y and O1 in Context B was conducted before the beginning of Phase 1, between Phases 1 and 2, and after Phase 2. The pre-acquisition test was preceded by the sentence “Before starting, please answer these questions”. Besides this, transition between tests and phases was not marked.

Dependent variables and statistical analysis. Predictive judgments were recorded for each stimulus along training. Probability judgments to Y-O1 were recorded in each of the tests. Predictive judgments are not reported; they were not requested during the test, and thus they were not informative with respect to the main aim of the experiment. Probability ratings were evaluated with an analysis of variance (ANOVA). Planned comparisons were made by using the methods discussed by Howell (1987, pp. 431-443). The rejection criterion was set at $p < .05$.

RESULTS

Figure 1 presents mean probability judgments given by participants about the Y-O1 relationship in the test conducted before Phase 1 (Pre-Test), the test conducted between Phases 1 and 2 (Test 1), and in the final test conducted after training Y in Context A (Test 2) in groups Control and Interference. All tests took place in Context B. As it was expected, there were no differences between groups in Pre-Test and Test 1. Y-O1 relationship was judged low in those tests, reflecting the fact that Y had not been trained yet. However, mean judgments were higher in the Control group than in the Interference group when Y was tested in Context B after being trained in Context A. Statistical analysis confirmed these impressions. A 2 (group) x 3 (test) ANOVA found a significant main effect of test, $F(2, 60) = 33.44$ ($MS_e = 666.32$). The main effect of group was not significant, $F < 1$. The group by test interaction fell just short of significance, $F(2, 60) = 2.93$ ($MS_e = 666.32$), $p = .06$.

Although the group x text interaction did not reach conventional levels of significance, planned comparisons were conducted derived from the interaction. The simple effect of group only was significant in Test 2, $F(1, 89) = 6.20$ ($MS_e = 708.23$). It was not significant in pre-Test and Test 1, $Fs < 1$. Therefore, the context change between Phase 2 training and the final test had a greater effect in the Interference group, than in the Control group.

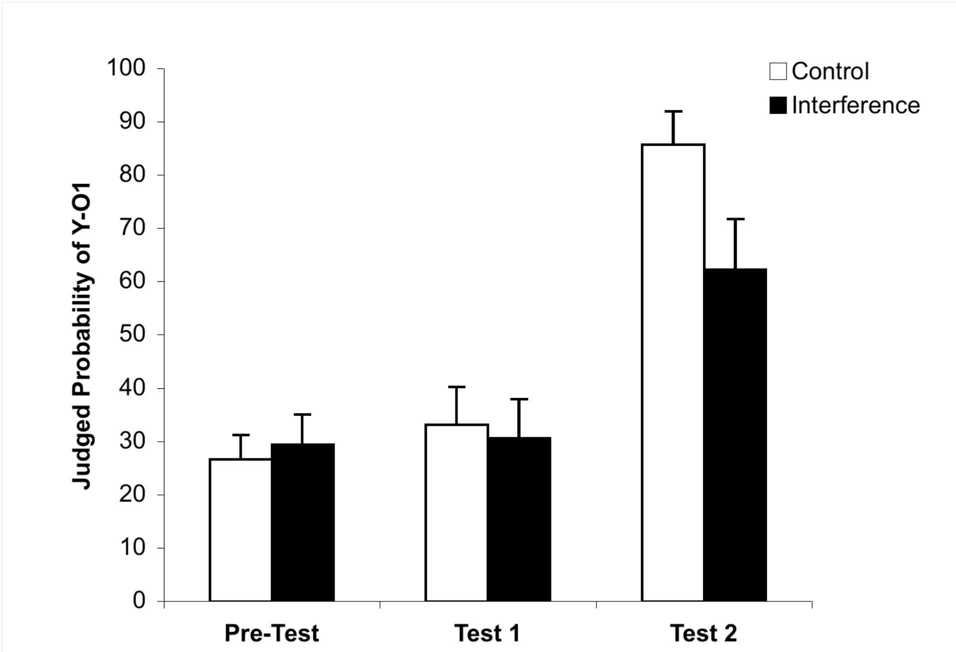

Figure 1. Mean probability judgments given by participants about the Y-O1 relationship in the test conducted before Phase 1 (Pre-Test), the test conducted between Phases 1 and 2 (Test 1), and in the final test conducted after training Y in Context A (Test 2) in groups Control and Interference. All tests took place in Context B. Error bars denote standard errors of the mean.

The simple effect of test was significant in both groups, $Fs(2, 60) = 8.30$ and 28.07 ($MS_e = 666.32$) for the Interference and Control groups, respectively. Probability judgments in Test 2 were greater than in the previous two tests, $Fs(1, 60) = 12.93$ and 11.96 in the Interference group and 41.88 and 48.78 in the Control group for comparisons with Pre-Test and Test 1, respectively ($MS_e = 666.32$). This reflects the effects of Y-O1 training between Tests 1 and 2. There were no significant differences between Pre-Test and Test 1 judgments in any of the groups, $Fs < 1$.

DISCUSSION

The context change effect between Y-O1 training and Test 2 was greater in the Interference group than in the Control group. However, the context change effect was not big enough as to eliminate the effects of training in the Interference group, given that judgments at Test 2 were still greater than in the tests conducted before training.

Since the only difference between the Interference group and the Control group was the interference training with a different cue during Phase 2 received by the Interference group, it can be concluded that concurrent interference training boosted the context switch effect upon a cue that received training with a single outcome. Note that this design does not allow to know whether the context change produced any effect upon simple acquisition in the Control group. In a conservative conclusion, it seems that the deleterious effect of context change upon simple acquisition is greater after concurrent interference training.

To explain the differential effects of context change upon acquisition and interference, Bouton (1993, 1994) suggested that the change in the outcome of a cue would lead participants to pay attention to the context where that interference treatment was taking place. If we accept that hypothesis, the results of this experiment would suggest that once participants begin to pay attention to the context, the information presented in that context would become context-dependent, even when that information is a simple, unambiguous relationship between a cue and an outcome, something that would question the proposed asymmetry between retrieval of inhibition and acquisition (e.g., Bouton, 1993; Hull, 1943) or between first and second-learned information (e.g., Bouton, 1993; Nelson, 2002).

Nevertheless, the results obtained in this experiment leave some questions open in relation with the context change effects upon retrieval of the information. Although previous results in our laboratory have shown that a context switch does not affect retrieval of acquisition before the interference training using a similar procedure to the one used in these experiments (e.g., García-Gutiérrez & Rosas, 2003c; Paredes-Olay & Rosas, 1999), it seems necessary to test the effect of a context switch prior interference within this experimental series. An additional question that prompts from the results of this experiment is whether the context change effect is specific to the information presented in the context where the interference takes place. Following our theoretical interpretation of the results, if interference makes participants to pay attention to the context, would participant begin to pay attention to all the contexts where the task is taking place regardless of whether interference has taken place in them? If that were the case, simple acquisition would become context dependent after interference independently of whether the learning takes place within a context where another cue received the interference treatment or in a context where only consistent information was presented. Experiment 2 was conducted to answer these questions.

EXPERIMENT 2

The results obtained in Experiment 1 suggest that unambiguous information about the relationship between a cue and an outcome may become context-specific when a different cue has been trained with two different outcomes in the same context.

Experiment 2 was conduced to further explore the context dependency of first-learned information, trying to replicate the effect in a within subject design. Additionally, the experiment allowed for testing context dependency of first-learned information before the interference treatment took place, and after the interference treatment was received in a context different from the context where that first learned information was acquired. Finally, the design allowed for testing context-dependency of the interference treatment (i.e., renewal).

Table 2. Design of Experiment 2.

Phase 1	Phase 2
A: X-O1, D-O2, F-	A: X-O2, Y-O1, F-
B: Z-O1, E-O2, F-	B: Z-O1, E-O2, F-

Note: A and B were two different restaurant' names (The Canadian cabin and The Swiss cow). X and Y were cucumber and garlic. O1 and O2 were diarrhea and constipation. Contexts, stimuli and outcomes were counterbalanced across participants, except for Z, D, E, and F that were Eggs, Tuna fish, Caviar, and Corn, respectively. Participants received a test about the relationship of Cues X, Y, and Z with O1 and O2 in Contexts A and B, before Phase 1 (Pre-Test), between Phases 1 and 2 (Test 1), and after Phase 2 (Test 2).

The design of the experiment is presented in Table 2. Participants were sequentially trained with X-O1 and X-O2 relationships in Context A. While trained with the X-O2 relationship (Phase 2), participants were exposed to the relationship between Y and O1 in the same context. Additionally, they were consistently exposed to Z-O1 relationship in Context B throughout the experiment. During the final test participants were asked to rate the relationship between each of the cues (X, Y, and Z) and each of the outcomes (O1 and O2) in the two contexts where training took place (A and B). For Cues X and Y, test Context A was the same context where training took place, while Context B was a different context. The contrary was true for Cue Z. According to the results reported in the literature we expected to find renewal of X-O1 relationship in Context B (Bouton & Ricker, 1994; Garcia-Gutierrez & Rosas, 2003c; Rosas et al., 2001). According to the results obtained in Experiment 1, a decrease in judgments to Y-O1 when tested in Context B was expected. Results with respect to Z were not clearly predictable beforehand. If context-dependency depends on the information being learned in the same context where interference has taken place, then no effects of context change should be found in Z, given that the Z-O2 relationship was learned in Context B, where all the cues had the same meaning throughout the training. However, if interference would boost the attention that participants pay to any context, then a detrimental effect of context change should be observed with Z when tested in Context A, outside the training context. The rest of cues and outcomes were presented to keep outcome and context experience equated within and between phases.

METHOD

Participants and apparatus. Twelve undergraduate students of the University of Jaén participated in the experiment. Four participants were discarded because the data of some of the tests were missing due to a software failure. They were replaced by four new participants. Apparatus were the same used in Experiment 1. Cucumber, Garlic and Eggs were counterbalanced as Cues X, Y, and Z. Cues D, E, and F were Tuna fish, Caviar, and Corn, respectively.

Procedure. Procedure is presented in Table 2. It was identical to the one used for the interference group in Experiment 1, except for what follows. All participants received exposure to the different cue-outcome combinations presented for the interference group in Table 1. Pre-Test, Test 1 and Test 2 were conducted with Cues X, Y and Z in Contexts A and B. In each of those tests, participants were requested to evaluate the relationship between each of the cues and each of the outcomes (O1 and O2). Context exposure order and test order were orthogonally counterbalanced.

Dependent variables and statistical analysis. Probability judgments to X, Y and Z were recorded at test. To simplify the presentation of the data, we calculated the difference between percentage ascribed to O1 and O2 for foods X, Y, and Z in each participant. Positive differences indicated that participants rated the stimulus as causing O1 rather than causing O2. Negative differences indicated that participants rated the stimulus as causing O2 more than O1. A difference of zero indicated that participants rated the stimulus as causing O1 as much as O2. It should be noted that differences may be ambiguous. The same difference may be caused by quite different judgments to the relationship with each outcome. To avoid this ambiguity, we present the critical final test ratings separately for both outcomes in Table 3. Ratings were evaluated with analysis of variance (ANOVA). Planned comparisons were made by using the methods discussed by Howell (1987, pp. 431-443). The rejection criterion was set at $p < .05$.

RESULTS

There were no differences between cues at the Pre-Test regardless of the context. Differences at Test 1 were highly positive for Cues X and Z, and close to zero for Cue Y reflecting the training received by the cues up to that moment. Results at Test 1 were the same in Contexts A and B, reflecting that there was no context change effect upon the information received before interference took place for Cue X during Phase 2. At the final test (Test 2) there was a context change effect in all the cues. When tested in the same context where training took place differences were negative for Cue X, reflecting the effects of the interference treatment received by this cue, and highly positive for Cues Y and Z. When tested in the alternate context (different), differences were more positive for Cue X (reflecting attenuation of retroactive interference), and decreased for Cues Y and Z (reflecting the disruptive effect of context change upon performance).

Mean differences at the Pre-Test were –7.5, 1.66 and –7.5 in Context same, and -11, 2.08 and –0.8 in Context different for Cues X, Y and Z, respectively. Mean differences were close to zero without differences among cues or between contexts. A 2 (context) x 3 (cue) ANOVA found no significant main effects of context, cue, nor cue by context interaction, $Fs<1$.

The left part of Figure 2 presents the mean differences between the ratings given to Cues X, Y and Z with respect to their relationship with O1 and O2 in the same context were they were trained (same) and in the alternate context (different) during the test conducted at the end of Phase 1

(Test 1). Differences were high for Cues X and Z, while remained close to zero for Cue Y. This was true regardless of the context where they were tested. A 2 (context) x 3 (cue) ANOVA found a significant main effect of cue, $F(2, 22) = 45{,}21$ ($MS_e = 1067.39$). Neither the main effect of context, nor the context by outcome interaction were statistically significant, $Fs < 1$. Subsequent analysis conducted to explore the significant main effect of cue found that differences were greater in Cues X and Z than in Cue Y, $Fs(1, 22) = 35.41$ and 32.32 ($MS_e = 1067.39$), respectively. There were no differences between ratings to X and Z, $F < 1$. Thus, mean differences reflected the treatment received by the cues before the test. Cues X and Z were paired with O1, and O1-O2 differences were highly positive. Meanwhile, Y was not presented during Phase 1, and ratings remained close to zero. Note that the context change at testing had no effects upon ratings to any cue.

The right part of Figure 2 presents the mean differences between the ratings given to Cues X, Y and Z with respect to their relationship with O1 and O2 in the same context were they were trained (same) and in the alternate context (different) during the test conducted at the end of the experiment (Test 2). In Context same, mean differences were negative for Cue X, and positive for Cues Y and Z. The context change made differences to become more positive in Cue X, while decreased positive differences in Cues Y and Z. A 2 (context) x 3 (cue) found significant main effects of context, $F(1, 11) = 5.98$ ($MS_e = 1695.55$), and cue, $F(2, 22) = 5.60$ ($MS_e = 7274.96$). Most important, the cue by context interaction was also significant, $F(2, 22) = 7.28$ ($MS_e = 2442.98$).

Subsequent analysis conducted to explore the cue by context interaction found that the simple effect of context was significant in every cue, $Fs(1, 32) = 4.12$, 5.85, and 10.97 ($MS_e = 2193.78$) for Cues X, Y and Z, respectively. Thus, there was a significant increase in the value of the differences for Cue X, and a decrease for Cues Y and Z with the context change. In other words, the context change led to an increase in X-O1 relationship while relationships between Y and Z and O1 decreased, leading to a decrease in the O1-O2 differences. The simple effect of cue was significant in Context same, $F(2, 35) = 11.30$ ($MS_e = 4858.93$) reflecting higher values in our dependent variable in Cues Y and Z than in Cue X, $Fs(1, 35) = 17.54$ and 16.33 ($MS_e = 4858.93$) respectively (Y and Z were no different, $F < 1$). There were no significant differences among cues in context different, $F < 1$.

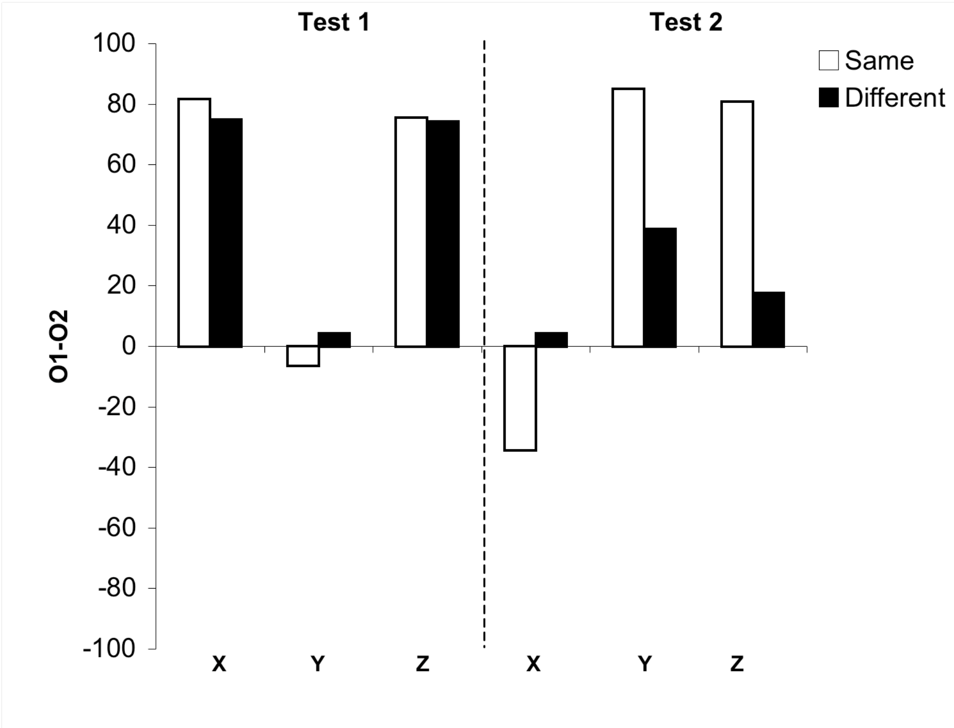

Figure 2. Mean differences between the ratings given to Cues X, Y and Z with respect to their relationship with O1 and O2 in the same context were they were trained (same) and in the alternate context (different) during the test conducted at the end of Phase 1 (Test 1), and at the end of Phase 2 (Test 2).

Table 3 presents the judged relationships between Cues X, Y and Z and outcomes O1 and O2 separately during the final test of Experiment 2. Judgments to X-O1 increased with the context change, while decreased judgments to Y-O1 and Z-O1. A 2 (context) x 3 (cue) found a significant main effect of cue, $F(2, 22) = 4.36$ ($MS_e = 2087.84$). The main effect of context fell just short of significance, $F(1, 11) = 4.61$ ($MS_e = 1392.67$), $p = .054$. However, there was a significant context by cue interaction, $F(2, 22) = 8.90$ ($MS_e = 706.21$). Subsequent analysis conducted to explore the context by cue interaction found that the simple effect of context was significant in Cues Y and Z, $Fs(1, 29) = 7.67$ and 10.48 ($MS_e = 935.03$), but it was not significant in Cue X, $F(1, 29) = 2.15$ ($MS_e = 935.03$). The simple effect of cue was significant in Context same, $F(2, 35) = 10.82$ ($MS_e = 1397.03$) with greater judgments to Y and Z than to X, $Fs(1, 35) = 16.55$ and 15.89 ($MS_e =$

1397.03), respectively. The simple effect of cue was not significant in Context different, $F < 1$.

Table 3. Judged relationships between Cues X, Y and Z and outcomes O1 and O2 separately during the final test of Experiment 2.

		Stimuli		
Outcomes	Contexts	X	Y	Z
O1	Same	24.58	86.67	85.42
	Different	42.90	52.10	45.00
O2	Same	58.75	1.67	4.58
	Different	38.80	13.30	27.50

Judgments to X-O2 decreased in Context different, while judgments to Y-O2 and Z-O2 slightly increased. A 2 (context) x 3 (cue) ANOVA found a significant main effect of cue, $F(2,22) = 6.45$ ($MS_e = 1764.17$). The main effect of context was not significant, $F < 1$. However, there was a significant context by cue interaction, $F(2, 22) = 4.43$ ($MS_e = 607.04$). Subsequent analysis conducted to explore the context by cue interaction found that the simple effect of context was statistically significant in Z, $F(1, 32) = 5,29$ ($MS_e = 596.05$), fell just short of significance in X, $F(1, 32) = 4.03$ ($MS_e = 596.05$), $p = .053$, and it was not significant in Y, $F(1, 32) = 1.37$ ($MS_e = 596.05$). The simple effect of cue was statistically significant in Context same, $F(2, 36) = 10.19$ ($MS_e = 1217.11$) with judgments ascribed to Y-O2 and Z-O2 being lower than judgments ascribed to X-O2, $Fs(1, 36) = 16.06$ and 14.46 ($MS_e = 1217.11$), respectively. The simple effect of cue was not significant in Context different, $F(2, 36) = 1.60$ ($MS_e = 1297.11$).

In summary, the results showed that the context change led to a change in performance. The cue that was sequentially trained with two outcomes (X) showed less negative differences that were caused by a nonsignificant increase in the judgments to the X-O1 relationship combined with a decrease in the judgments to X-O2 relationship. Cues trained with a single outcome (Y and Z) showed a decrease in the differences mainly caused by a decrease in the judged relationship with O1.

DISCUSSION

Experiment 2 found a context switch effect in all the tested cues. With respect to the cue that received sequential training with two different outcomes this context switch reduced the difference between the ratings given to the relationship between Cue X and each of the outcomes, caused by a non significant increase in retrieval of the first-learned relationship (X-O1) combined with a marginally significant increase en performance according to the relationship learned during the retroactive interference training (X-O2). This is an imperfect replication of the well-known AAB renewal effect, the one that occurs when acquisition and interference are conducted in the same context, and the test is conducted in a different context (e.g., Bouton & Ricker, 1994; García-Gutiérrez & Rosas, 2003c; Rosas et al., 2001).

Most interesting are the results related to the context change effect on the cues that received training with a single outcome. The deleterious effect of context change upon performance found in Experiment 1 was replicated with respect to the cue trained in the context were Cue X received the interference training (Context A). This result extends and qualifies the idea proposed by Bouton (1993) of how context change effects work. As it was stated above, retrieval theory suggested that retrieval of either inhibitory or second-learned information was negatively affected by a context change. The result of this experiment strongly suggests that context change impairs retrieval of any information that is learned in a context where the meaning of one of the cues became ambiguous. Following Bouton (1997), we suggest that ambiguity led participants to pay attention to the context during the interference phase. Our suggestion takes this idea further, proposing that once there is something in the situation that makes participants to pay attention to the context, they code all the information as context specific.

The results obtained with Cue Z extend this proposal even further. Cue Z was trained in a context where only consistent information was presented. In fact, the test conducted after Phase 1 did not find a context change effect suggesting that the learning about the relationship between a cue and a single outcome transfers quite well between different contexts, a result that has been largely replicated in the literature (e.g., García-Gutiérrez & Rosas, 2003c; see Bouton, 1993 for a review). Somewhat surprisingly, the test conducted after X received the interference treatment in a *different* context made Z-O1 relationship context dependent, even though Z was consistently paired with O1 throughout the phases, and this relationship was coded independently of the context before the interference treatment begun (see Test 1). This result strongly suggests that once participants begin to pay attention to one specific context they generalize the attention paid to a different contexts, at least within the present task.

GENERAL DISCUSSION

The main aim of the experiments presented in this paper was to test the context switch effects upon a cue that has been paired with a single outcome. Experiment 1 found that performance was disrupted by the context change when the target cue was trained in a context where a different cue had been sequentially paired with two different outcomes. Experiment 2 replicated this result. Additionally, it found that the context change also disrupted performance on a cue that had been concurrently trained with a single outcome in a context where no ambiguous information had been presented. Finally, Experiment 2 replicated the well-known effect of context switch upon interfering information (renewal, i.e. García-Gutiérrez & Rosas, 2003c).

Retrieval theory of forgetting has explained the differential effects that context switch have upon different types of information by assuming certain asymmetry on the susceptibility of information to the context switch. It has been proposed that either or both, inhibitory and second-learned information about a cue are context dependent, while excitatory information is not (e.g., Bouton, 1993). Recent results suggest that it is second-learned, interfering information, what it is context dependent (Nelson, 2002). It is assumed that when a cue changes its outcome becoming ambiguous, the subject looks in the environment for something that allows for a disambiguation of the meaning of the cue. As a result of this search, that it is assumed to be automatic, the context where the information is acquired is coded, and information becomes context dependent (Bouton, 1993, 1997). Note that this approach suggests that making a cue ambiguous leads participants to pay attention to the context.

The results of the experiments presented in this paper qualify the assumptions of retrieval theory (Bouton, 1993). According to the results obtained here, unambiguous first-learned excitatory information can become context specific. Taking the explanation of context specificity proposed by retrieval theory to the end, the change in the meaning of a cue would make participants to pay attention to the context, and that should make all the information presented in that context specific to it. Following this explanation, first-learned information would become context-specific when it is learned in a context where another cue has received an ambiguous treatment. This explanation would fit the results of Experiment 1. However, to explain context-specificity of a cue that received consistent training in a context where only consistent cue-outcome relationships were established (Experiment 2), this explanation needs an extension. This result is particularly interesting, given that the same cue did not show context-specificity when it was tested before the interference training took place in an alternate context. Thus, it seems that interference training led participants to pay attention to all the contexts used in the task, making all the information context specific regardless of the type of information (first or second-learned) or the place where that information was acquired (a context where the ambiguous information was presented, or a different context).

In summary, these results go against the interpretation of context-switch effects given by retrieval theory (e.g., Bouton, 1993). According to the results obtained in these experiments, there is not a specific type of information that it is more easily affected by a context change, but a specific feature of the situation that makes participants to pay attention to the context. Once participants begin to pay attention to contexts, this attention transferred to different contexts from the one where ambiguity took place, making all information context-dependent.

The interpretation of these results should be qualified though. Note that the context switch effect on Cue Z in Experiment 2 appeared when this cue was taken to a context where ambiguity was presented. One could claim that to find a context switch effect upon unambiguous information it is necessary to take the cue either out from, or to a context were ambiguous information is presented. Though the design of these experiments does not allow us to reject this interpretation, recent results in our laboratory suggest that such interpretation is unlikely. With the same task used here, but with an extinction procedure as the interference treatment, we have found that once interference takes place, context specificity of first-learned information appears in a completely different task with quite different contexts (Callejas-Aguilera, García-Gutiérrez, & Rosas, 2004). These recent results additionally support the thesis proposed in this paper, suggesting that the reason for context specificity of information is that there is something in the procedure that makes participants to pay attention to the context, and subsequently all the information that they learned becomes context specific.

RESUMEN

Efecto del cambio de contexto sobre la recuperación de la información aprendida en primer y segundo lugar en aprendizaje predictivo humano. Se presentan dos experimentos que evalúan el efecto del cambio de contexto sobre la recuperación de la información acerca de una relación clave-consecuencia en aprendizaje predictivo humano. Los resultados encontrados replican el bien conocido efecto de renovación de la relación clave-consecuencia por el cambio de contexto después del tratamiento de interferencia retroactiva, así como el efecto nulo del cambio de contexto sobre la adquisición antes de que la interferencia tenga lugar (Experimento 2). No obstante, la asociación simple clave-consecuencia se vio negativamente afectada por el cambio de contexto cuando esta asociación fue establecida en un contexto donde otra clave había sufrido un tratamiento de interferencia (Experimentos 1 y 2). Cuando los participantes reciben el tratamiento de interferencia en un contexto, la relación simple clave-consecuencia aprendida en un contexto distinto también se convierte en específica del contexto. Se discuten las implicaciones de estos resultados para la teoría de la recuperación de la información.

REFERENCES

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

Bouton, M. E. (1994). Context, ambiguity, and classical conditioning. *Current Directions in Psychological Science*, *3*, 49-53.

Bouton, M. E. (1997). Signals for whether versus when an event will occur. In M.S. Fanselow & M.E. Bouton (Eds.), *Learning, motivation, and cognition: The functional behaviorism of Robert C. Bolles* (pp.385-409). Washington, DC: American Psychological Association.

Bouton, M. E. & Brooks, D. C. (1993). Time and context effects on performance in a Pavlovian discrimination reversal. *Journal of Experimental Psychology: Animal Behavior Processes*, *19* , 165- 179.

Bouton, M. E. & Ricker, S. T. (1994). Renewal of extinguished responding in a second context. *Animal Learning & Behavior*, *22*, 317-324.

Callejas-Aguilera, J. E., García-Gutiérrez, A., & Rosas, J. M. (2004, september). Context effects upon human performance: A hint on what makes information context specific. *Paper presented at the 16th Congress of the Spanish Society for Comparative Psychology*, Oviedo, Spain.

García-Gutiérrez, A. & Rosas, J. M. (2003a). Context change as the mechanism of reinstatement in causal learning. *Journal of Experimental Psychology: Animal Behavior Processes, 29,* 292-310.

García-Gutiérrez, A. & Rosas, J. M. (2003b). Empirical and theoretical implications of additivity between renewal and reinstatement after interference in human causal learning. *Behavioural Processes, 63,* 21-31.

García-Gutiérrez, A. & Rosas, J. M. (2003c). Recuperación de la relación clave-consecuencia por el cambio de contexto después de la interferencia en aprendizaje causal. *Psicológica, 24,* 243-269.

García-Gutiérrez, A. & Rosas, J. M. (2003d). The role of number of cues on retroactive interference in causal learning. *Psicológica, 24,* 271-285.

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

Hull, C. L. (1943). *Principles of behavior*. New York: Appleton-Century-Crofts

Nelson, J. B. (2002). Context specificity of excitation and inhibition in ambiguous stimuli. *Learning and Motivation*, *33* , 284-310.

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

Pavlov, I. P. (1927). *Conditioned reflexes*. (G. V. Anrep, trans.). London: Oxford University Press.

Rosas, J. M. & Bouton, M. E. (1997). Additivity of the effects of retention interval and context change on latent inhibition: Toward resolution of the context forgetting paradox. *Journal of Experimental Psychology: Animal Behavior Processes*, *23*, 283-294.

Rosas, J. M. & Bouton, M. E. (1998). Context change and retention interval have additive, rather than interactive, effects after taste aversion extinction. *Psychonomic Bulletin & Review*, *5*, 79-83.

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

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