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# RENEWAL AND SPONTANEOUS RECOVERY AFTER EXTINCTION IN A CAUSAL-LEARNING TASK[1]

## RENOVACIÓN Y RECUPERACIÓN ESPONTÁNEA DESPUÉS DE LA EXTINCIÓN EN UNA TAREA DE APRENDIZAJE DE CAUSALIDAD

**N. JAVIER VILA**[2]
UNAM
**JUAN M. ROSAS**[3]
UNIVERSIDAD DE JAÉN

**ABSTRACT**

Three experiments were conducted with the aim of studying extinction, and extinction related phenomena using a causal-learning task in human beings. Experiment 1 found that the excitatory association between a fictitious medicine and an illness can be extinguished by repeated exposure to the medicine without the illness. Experiment 2 found spontaneous recovery of that association when the test was conducted 48-hr after the end of the extinction. Experiment 3 found renewal of the association when the test was conducted in the acquisition context after receiving extinction in a different context. This pattern of results is adequately explained by the retrieval theory proposed by Bouton (1993), suggesting a generality of extinction learning across species and tasks.

*Key words*: Extinction, causal learning, humans, spontaneous recovery, renewal.

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2. Universidad Nacional Autónoma de México, Campus Iztacala, Tlalnepantla, México.
3. Universidad de Jaén, Jaén, España.

**RESUMEN**

Se realizaron tres experimentos para el estudio de la extinción y algunos fenómenos relacionados empleando una tarea de aprendizaje de causalidad con humanos. En el Experimento 1 se encontró que una asociación excitatoria entre una medicina y una enfermedad ficticia puede ser extinguida por la presentación repetida de la medicina sin la consecuencia. El Experimento 2 demostró la recuperación espontánea de la asociación medicina-enfermedad a las 48 h de la extinción. Finalmente en el Experimento 3 se observó el efecto de renovación de la asociación, cuando la prueba de la extinción se realizaba en el contexto de original de la adquisición después de recibir la extinción en un segundo contexto. Estos resultados pueden ser explicados por la teoría de la recuperación propuesta por Bouton (1993), y sugieren una generalidad de los efectos de la extinción entre especies y tareas.

*Palabras clave*: Extinción, aprendizaje causal, humanos, recuperación espontánea, renovación.

Pavlovian extinction occurs when a conditioned stimulus (CS) that has been previously paired with an unconditioned stimulus (US) or outcome is presented alone. The stimulus-outcome pairing leads to the developing of a conditioned response (CR) that gradually disappears when the CS is presented alone during the extinction (Pavlov, 1927). Given that the development of the CR during acquisition is assumed to indicate the formation of a stimulus-outcome association, one could assume that the gradual loss of the CR that occurs during extinction implies unlearning. This assumption can be found in some learning theories, like the well-known Rescorla-Wagner model (Rescorla & Wagner, 1972; Wagner & Rescorla, 1972). However, Pavlov (1927) previously showed that extinction does not eliminate the association between the CS and the outcome. When performance is tested some time after extinction, the CR usually reappears. This phenomenon was called spontaneous recovery by Pavlov, and it has been replicated repeatedly using different procedures on different animal species (e.g., Brooks & Bouton, 1993; Pavlov, 1927; Robbins, 1990; Rosas & Bouton, 1996), including humans (v.g., Beaulieu, 1966; De Leon, 1964; Ellson, 1938; Grant, Hunter, & Patel, 1958).

Another set of data that indicates that extinction does not imply unlearning of the stimulus-outcome association formed during acquisition comes from studies that manipulate the context between extinction and testing. When this manipulation is done, acquisition performance recovers, independently of whether the context change after extinction implies a return to the acquisition context (e.g., Bouton & King, 1993), or going to a completely different context (e.g., Bouton & Ricker, 1994; Bouton & Swartzentruber, 1986). This result is known as renewal, and, together with spontaneous recovery it suggests that extinction does not imply unlearning of the stimulus-outcome association, but rather the acquisition of new

information about the stimulus-outcome relationship that will be stored in memory without eliminating the information learned during acquisition (see Bouton, 1993 for a review).

Studies conducted with human subjects, however, have paid little attention to these phenomena. Over the last two decades, the study of human learning using causal-learning tasks has become very common in the literature, revealing similar results to those found in classical and instrumental conditioning (v.g., Dickinson & Burke, 1996; Perales, Catena, Ramos, & Maldonado, 1999; Shanks, Holyoak, & Medin, 1996). Given this parallel between animal conditioning and human causal learning results it seems somewhat surprising that so little attention has been devoted to the study of extinction and extinction-related phenomena. As far as we know, there are not studies directly conducted to evaluate spontaneous recovery from extinction in human causal learning. Rosas, Vila, Lugo, and Lopez (2001) reported recovery from retroactive interference over time in human causal learning, a result that may be considered akin to spontaneous recovery from extinction. However, spontaneous recovery following extinction has not been directly evaluated.

The renewal effect has received comparatively much more attention in human causal learning literature. The first evidence of renewal in humans was found in a pilot experiment reported by Baker, Murphy and Vallée-Tourangeau (1996), and in an experiment conducted by Paredes-Olay and Rosas (1999) using a predictive-judgments preparation. A similar effect was reported by Rosas et al. (2001) in a retroactive interference preparation. Finally, Matute and Piñeno (1998) reported a renewal like effect in a situation where training of a cue with an outcome interfered with performance to a different cue that had been previously trained with the same outcome.

The results of these studies, taken together, suggest that both spontaneous recovery and renewal may be found in a causal-learning preparation. Our aim here was to test whether such spontaneous recovery and renewal after extinction indeed can be found in a causal-learning task.

In this series, several fictitious medicines were presented related or unrelated to an illness, and then the subjects were asked to judge the relation between the medicines and the illness at different points of the experiment. Experiment 1 was a control experiment to test our extinction procedure. Experiment 2 evaluated spontaneous recovery following extinction by testing judgments either 0 or 48-hrs after extinction. Finally, Experiment 3 tested whether the return to the acquisition context after receiving extinction in a different, but equally familiar context would renew the judged causality of the medicine producing the illness.

## EXPERIMENT 1

The aim of this experiment was to test whether we can get acquisition and extinction of the positive relation previously established between a Cue (a fictitious medicine) and an Outcome (illness) using a causal-judgments task.

## METHOD

### *Participants*

Thirty students from the Universidad Nacional Autónoma de México participated in the experiment. 23 of the students were women, and 7 were men. They were between 17 and 25 years old, had no previous experience with this task. They participated in the experiment voluntarily, without any specific reward.

### *Apparatus and experimental situation*

The experiment took place in a 3 x 5 m room. On the only desk there was an IBM compatible personal computer that was used to present the stimuli. The procedure was implemented using the Power Point 7 program (Microsoft corporation). Stimuli used as Medicines A and B were Batim and Zacpron, counterbalanced across subjects. The place (top or bottom) where medicines A and B appeared on the screen was counterbalanced across trials.

### *Procedure*

Several of the procedures in Experiment 1 were used in Experiments 2 and 3. These common features were as follows.

The subject entered the room and sat in front of the computer. At that point, the following instructions appeared at the computer screen (the actual instructions were presented in Spanish):

> Welcome. In this game we are going to pretend that you are a healthcare inspector, and that you are in charge of the investigation of the following problem: Some people have complained about getting stomach aches after taking some new medicines bought in importation pharmacies. Your work will consist of observing two sets of patients and the medicines that they ingested; you should identify the medicines that caused the illness in each patient. After finishing each set of patients, you will be asked for the probability of illness after ingesting each medicine. Pay attention to every single patient as each case contains information about the ingested medicines. When a medicine produced illness a dot appears to its left.

After making sure the subject had understood the instructions, the experiments started with the sentence "1st set of files" centered on the screen. Hitting the space bar took the subjects into the first phase. In each trial a patient number, and the two medicines that the patient had taken were presented against a blue background. There was a red square in the top right corner of the screen where the words "red pharmacy" were written in black. Depending on the phase of the experiment a dot would appear to the left of one of the medicines indicating that the symptoms had appeared in that patient. Once the subject had observed the screen, hitting the space bar would take him or her into the next trial. A screen with the sentence indicating the set of files the subject was dealing with (2nd, 3rd, etc.) signaled the transition between phases. Not signaling the transition between phases could have led the subjects to consider the joint cue-outcome probabilities for the two phases as if they were just one (Catena, Maldonado, & Cándido, 1998), preventing detection of extinction. The experiments was conducted in four phases:

Acquisition: A screen was presented with the sentence "1st set of files". After that, all subjects received 12 acquisition trials in which Medicines A and B were presented concurrently, that is, they appeared on the screen at the same time; A was described as followed by illness in 75% of the cases, while B was never described as followed by illness.

Test 1: Immediately after this training ended a screen appeared asking the subjects to evaluate the probability of illness after taking the medicines A and B. The instructions were as follows:

> EVALUATION: Now, based in what you have observed, you have to assign any value between 0 and 100 to each of the medicines. A value of 0 corresponds to a medicine that DOES NOT cause the illness, while a value of 100 corresponds to a medicine that ALWAYS causes the illness. (Press the space bar to go to the pharmacy).

When the subject pressed the space bar a new screen appeared where Medicines A and B were presented concurrently in extinction within the pharmacy where they were bought. A hard copy of the screen was given to the subjects at that time so that they could write down their judgment about the relation between each medicine and the illness. A single test trial was used.

Extinction: Following this test a new screen was presented with the sentence "Second set of files." After this screen, each subject received 12 trials in which two medicines were presented concurrently on the computer screen.

Test 2: Immediately after extinction subjects received a test identical to the one given after the acquisition phase, being asked to emit their judgment about whether A and B caused the illness.

The procedures specific to Experiment 1 were as follows: three groups of subjects designated as Groups A-, A+, and C were trained in the situation described above, where a medicine (A) was followed by an imaginary illness,

while another medicine was not (B). We expected that this training would lead to an association between Medicine A and the illness, so that by the end of the phase the subjects would judge the medicine as the cause of the illness. During the subsequent extinction phase, neither Medicine A nor Medicine B were followed by illness in Group A-. Group A+ received the same medicine-illness relations that had received in the previous phase (A was followed by illness in the 75% of the trials, while B was not). In Group C-, a new Medicine C, was substituted for Medicine A such that Medicine C now was concurrently presented with Medicine B. Neither B nor C was followed by illness. In this group Medicine A was not presented during this phase. After finishing extinction all subjects were asked to judge the probability of illness providing that the patient has taken Medicines A or B. Extinction would be shown as the report of a lower probability of illness after Medicine A in Group A- than in the other groups.

*Statistical analyses*

Causal judgments in both tests were evaluated by an analysis of variance (ANOVA). Planned comparisons were made using the methods discussed by Howell (1987, pp. 431-443). The rejection criterion was set at $p$ 0.05.

## RESULTS AND DISCUSSION

Subjects judged a high relation between Medicine A and illness at the end of acquisition. After extinction, A-illness relation was judged low only in the Group where Medicine A was described as causing illness with a probability of 0.

Figure 1 presents the mean judgment (total judgments value/10) for illness after ingesting Medicine A by the subjects in Groups A-, A+, and C- in the tests conducted after the acquisition (left panel) and extinction (right panel). The judgment of whether Medicine A causes the illness was high and similar in all three groups after acquisition. However, after extinction, the probability of illness given the ingestion of Medicine A was judged low by subjects in Group A-, while it continued to be judged high by subjects in Groups A+ and C-. Statistical analyses confirmed these observations. A 3 (Group) x 2 (Test) ANOVA found significant main effects of Group [$F(2, 27) = 91.77$] and Test [$F(1, 27) = 61.79$]. Most important, the Group by Test interaction was significant [$F(2, 27) = 53.74$].

Subsequent analyses of the Group by Test interaction found that the simple effect of Group, which was not significant after acquisition [$F(2, 66) = 1.27$], was significant after extinction [$F(2, 66) = 82.62$], reflecting a lower judgment of Medicine A causing the illness in Group A- than in the other Groups [$Fs(1, 66) = 71.58$). Moreover, subjects in Group A- were the only ones that show a change in the judgments for Medicine A between acquisition and extinction [$F(1, 66) = 75.24$], for Group A-, and Fs 1, for groups A+ and C-].

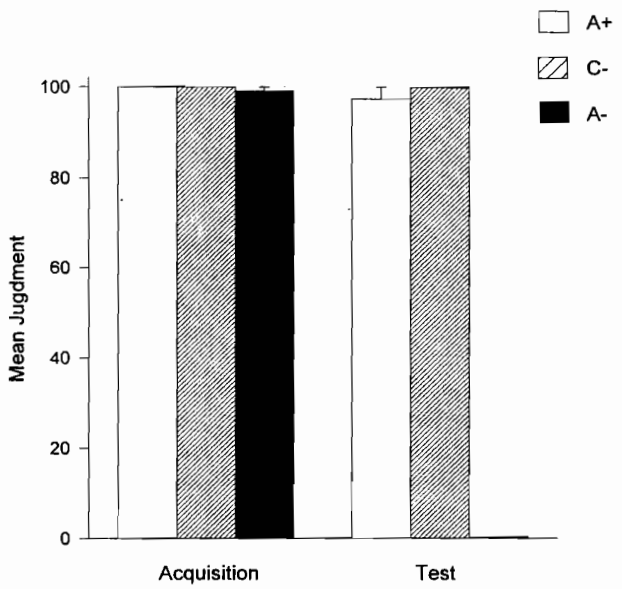


*Figure 1. Mean judgments for illness after ingesting medicine A judged by subjects in groups A-, A+, and C- in the tests run after the acquisition (left panel) and extinction (right panel). Groups are named according to the treatment that they received during extinction.*

Finally, mean judged probability of Medicine B causing the illness was 0 for all groups in both tests, reflecting that Medicine A treatment did not generalize to Medicine B. In other words, the judged relation between the medicine and illness depended on their being related.

This experiment shows that the procedure produced acquisition and extinction of the judged association between a medicine and the illness. Acquisition was specific to the medicine correlated with the illness, and extinction was confined to the unreinforced presentation of the specific medicine-stimulus that had been trained previously. The unreinforced presentation of a different stimulus (Medicine C) did not affect judgments about the relation between the originally trained stimulus (Medicine A) and the illness. Thus, it seems like that this procedure can be used to study the effects of different variables upon extinction in humans.

## EXPERIMENT 2

The fact that the passage of time causes a recovery of the extinguished response is a well-known phenomenon, first reported by Pavlov (1927). The purpose of the

second experiment was to examine spontaneous recovery in humans using the causal-learning task developed in Experiment 1.

## METHOD

### *Subjects and apparatus*

Twenty students similar to those who participated in Experiment 1 served as subjects. The apparatus was as in Experiment 1.

### *Procedure*

The procedure was identical to that in Experiment 1, except as follows. Subjects were randomly assigned to two different groups. All of them were trained in a simulated situation where the ingestion of Medicine (A) was followed by illness 75% of the time, while Medicine B was not followed by illness. After that, they received exposure to Medicine A in extinction and Medicine B continued not to be associated with illness. Finally a test was given immediately after training for one group, Group 0, and 48-hr later for a second group, Group 48. Spontaneous recovery should appear as a higher judged probability of Medicine A causing illness 48-hrs after extinction.

## RESULTS AND DISCUSSION

Subjects acquired the relation between Medicine A and the illness as in Experiment 1. Figure 2 presents the mean judgments, calculated as described in Experiment 1 for illness after ingesting medicine A as judged by subjects in Groups 0 and 48 in the tests run after acquisition (left panel) and extinction (right panel). Causality between Medicine A and illness was judged similarly high in both groups after conditioning. After extinction, causality was judged low by subjects in Group 0, but much higher by subjects in Group 48. Statistical analyses confirmed these observations. A 2 (retention interval) x 2 (test) ANOVA found significant main effects of retention interval [$F(1, 18) = 13.39$] and test [$F(1, 18) = 81.94$]. Most important, the retention interval by test interaction was also significant, [$F(1, 18) = 20.48$].

Subsequent analyses conducted to explore the Retention Interval by Test interaction found that the simple effect of retention interval was not significant in the test conducted after conditioning [$F$ 1], but it was significant after extinction [$F(1, 55) = 18.61$], reflecting a higher judgments for Medicine A causing the illness when the test was conducted 48 hrs after extinction than when it was conducted immediately.

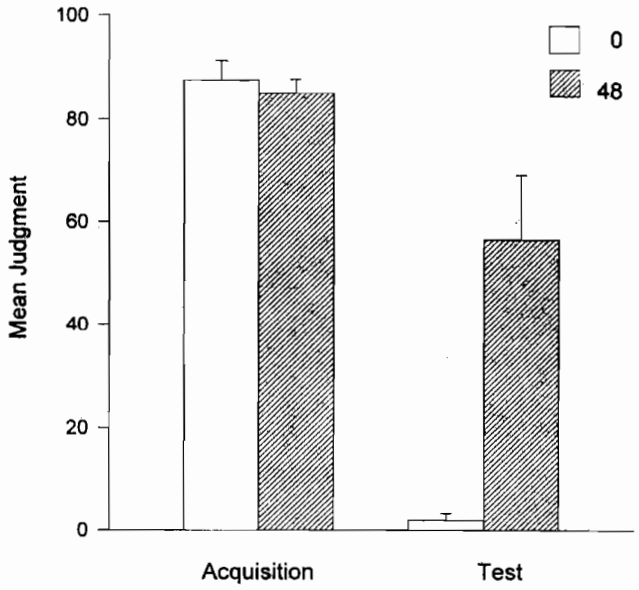


*Figure 2. Mean judgments for illness after ingesting medicine A judged by subjects in groups 0 and 48 in the tests run after acquisition (left panel) and extinction (right panel).*

Mean judged probability of Medicine B causing the illness was 0 for both groups and tests, indicating that Medicine A treatment did not generalized to B. Both acquisition and spontaneous recovery depended on the medicine being explicitly related to the illness.

This experiment demonstrates spontaneous recovery of the relation between a medicine and an illness when the test was conducted 48 hours after extinguishing this relation. It should be noted that the level of extinction at the end of extinction phase was not measured in Group 48, leaving open the possibility that the results may be related to different levels of extinction for Groups 48 and 0. We consider this interpretation unlikely. Experiment 1, together with a number of experiments conducted in our laboratory with the same parameters, show consistent extinction (see for instance the middle panel of Figure 3, Experiment 3). Although these results from other experiments cannot completely rule out the alternative explanation of our results, they make the interpretation unlikely.

These results replicate the results previously found in animals (i.e., Pavlov, 1927; Robbins, 1990; Rosas & Bouton, 1996), and humans (i.e., Ellson, 1938) using a variety of conditioning tasks, suggesting that extinction does not eliminate previously-learned stimulus-outcome associations.

## EXPERIMENT 3

Time has been considered part of the context that modulates recovery of the information by the subject (e.g., Bouton, 1993; Spear, 1973). From that point of view, the effect of time upon retrieval of any information should be mirrored by an effect of a physical context change. This effect has been found repeatedly in the animal literature. Time effects upon extinction are similar to context change effects (e.g., Bouton, 1993), and they can summate (Rosas & Bouton, 1997, 1998). The purpose of this third experiment was to test whether the same effects occur with humans. The experiment was conducted to examine whether the detrimental effect of time upon extinction would occur if, instead of manipulating the retention interval between extinction and testing, the places where conditioning, extinction, and testing occur were manipulated. That is, our interest was to determine whether extinction transfers to a context different from where it took place.

## METHOD

### *Subjects and apparatus*

Thirty-two students at the Universidad Nacional Autónoma de México participated in this experiment. They were similar to those participating in Experiment 1. The apparatus was as in Experiment 1.

### *Procedure*

The procedure was as in Experiment 1, except for the following. All subjects received 12 acquisition trials where Medicine A was presented followed by illness 75% of the times in Context X. After a judgment test, as in Experiment 1, the subjects received 12 extinction trials where Medicine A was not followed by illness. Group X received extinction in Context X, the same where acquisition took place. Group Y received extinction in Context Y, a context different from the acquisition context. Contexts X and Y were two different backgrounds representing two different pharmacies. One of the contexts was represented by a yellow square labeled "yellow pharmacy", while the other was represented by a red square labeled "red pharmacy". Both squares were presented against a blue background. "Pharmacies" were counterbalanced as Contexts X and Y such that for half of the subjects in each group Context X was the "yellow pharmacy", and Context Y was the "red pharmacy" while the reverse was true for the other subjects.

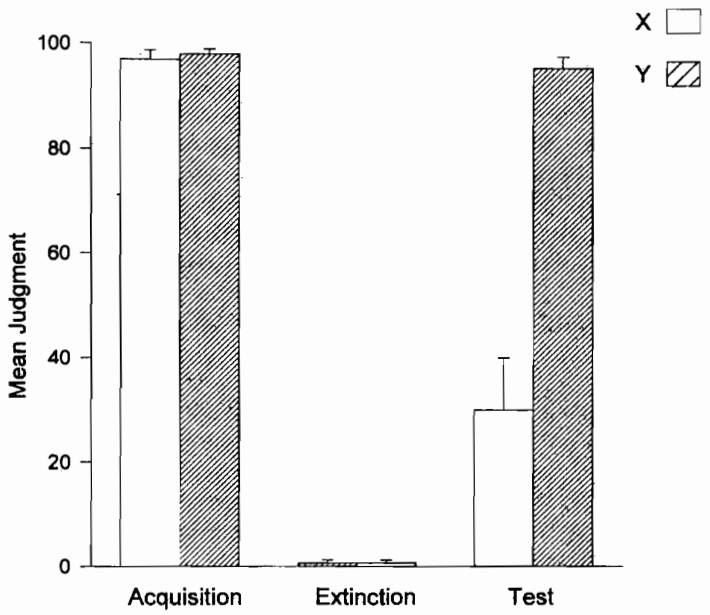


*Figure 3. Mean judgments for illness after ingesting medicine A judged by subjects in groups X and Y in the tests run in Context X after acquisition (left panel), in Contexts X and Y respectively after extinction (center panel) and again in Context X after extinction (left panel). Groups are named according to the context where they received extinction.*

Subjects received 12 additional trials in each phase in which they were exposed to the alternate context to the one where either acquisition or extinction took place. Those trials were identical to the acquisition and extinction trials except that neither Medicines nor outcomes appeared on the screen. These trials were presented randomly intermixed with the acquisition or extinction trials. This manipulation ensured that every subject received equivalent exposure to both contexts, so that they were equally familiar with each context before each test.

During acquisition and extinction Medicine B was presented concurrently with Medicine A, but it was never followed by illness. At end of the extinction, both groups received a judgment test about Medicines A and B in the same contexts where extinction had taken place (context X in Group X, and Y in Group Y).

Finally subjects received another test where their estimates of the probability of Medicines A and B causing the illness in Context X was evaluated. Thus, there was a context change between extinction and testing in Group Y, while there was not such a change in Group X.

## RESULTS AND DISCUSSION

Acquisition and extinction proceeded as in Experiments 1 and 2. Figure 3 presents the mean judgments for illness after ingesting Medicine A by subjects in Groups X and Y in the tests conducted in Context X after acquisition (left panel), in Contexts X and Y respectively after extinction (center panel) and again in Context X after extinction (right panel). Causality between A and the illness was judged similarly high after conditioning and low after extinction in both groups. However, the final test shows that the judgments for illness was considerably higher when the test was conducted in the acquisition context after being extinguished in a different one (Group Y). Statistical analyses confirmed these observations. A 2 (Group) x 3 (Test) ANOVA found significant main effects of Group [$F(1, 30) = 40.17$], and Test [$F(2, 60) = 259.54$]. Most important, the Group by Test interaction also was significant, [$F(2, 60) = 37.88$].

Subsequent analyses of the Group by Test interaction found that the simple effect of Group was not significant in the acquisition and extinction tests [$F$s 1], but was significant in the final test [$F(1, 76) = 1, 76$], reflecting a higher judgment of Medicine A causing the illness when the test involved a return to the conditioning context after extinction in an alternate context than when the final test took place in the same context as extinction.

The repetition of the test in the same context (Group X) produced an unexpected increase in the judgment of Medicine A causing the illness without any contextual change [$F(1, 42) = 22.25$]. The reason for this increase is unclear. One possible explanation of this effect is that the delay necessary to apply the post-extinction test gave enough room for some spontaneous recovery to appear. Although we cannot rule out this explanation, it is worth noting that the length of the delay was under 3 min. It seems more reasonable to suppose that the application of the first post-extinction test distracted the subjects, and that this distraction had a greater effect on the information acquired during extinction than to the information acquired during acquisition. The data from this experiment do not allow selection between these possible explanations. However, whatever the explanation of such increase in judgments may be, we should note that increase was larger in the group with a context change between extinction and testing, showing that renewal can be found in humans with this procedure.

Mean judgement of Stimulus B causing the illness was 0 for both groups and tests, reflecting that Medicine A treatment was not generalized to Medicine B. Both acquisition or renewal depended on the medicine being related to the illness.

To label the context change effect after extinction as a true renewal effect requires that the context change should not affect acquisition performance; that is, extinction should take place at the same rate independently of whether it is conducted in the acquisition context or in a different one. The procedure used in this experiment only allows for evaluation of the final performance at the end of each phase (see also Baker et al. 1996; Matute & Piñeno, 1998). This precluded

the possibility of evaluating whether extinction developed differently depending on the context where it took place, and allows for alternative explanations for the context change effect found after extinction. For instance, if extinction had been more rapid with the context change after acquisition, one could argue that part of what subjects learned during acquisition was a compound of the context and the medicine. Because the original compound is not presented during extinction in the alternate context, it could not be extinguished, and the recovery of the causal judgments during the final test would simply reflect the unextinguished response to the original compound. The procedure used in this experiment does not allow this alternative explanation of the results to be ruled out.

It is true that most of the animal literature on renewal presents a lack of context change effects upon acquisition (see Bouton, 1993 for a review; see also Rosas, Vila, Lugo, & López, in press, for a lack of context change effect upon acquisition in a causality-judgments preparation). However, because context change has been shown to disrupt acquisition also (e.g., Bonardi, Honey & Hall, 1990; Sjödén & Archer, 1989), we are cautious in concluding that an unequivocal renewal effect has been found in this experiment. Rather, the results of this experiment should be taken as an indication that renewal can be found in humans using a causal-judgment test. Before reaching a definitive conclusion about the basis for the renewal effect, however, additional data are needed from a procedure that allows registration of the data trial by trial.

## GENERAL DISCUSSION

These experiments were conducted to explore extinction of causal judgments in humans. The results of Experiment 1 show that the acquired relation between a medicine and an illness can be extinguished by the presentation of the medicine alone, and that this extinction depends on the presentation of the specific medicine that was originally related to the illness. Those of Experiment 2 show that a 48-hr period after extinction produced spontaneous recovery of the association between the medicine and the illness. Finally, in Experiment 3 changing the context after extinction renewed the association between the medicine and the illness.

Overall, these results are consistent with the view that extinction results in new learning that is stored in memory without eliminating the information learned during acquisition (i.e., Bouton, 1993). According to this view, subjects' performance at any point of the experiment would depend on the relative strength of the recovery of the different kinds of information stored in memory about the same stimulus. At the end of acquisition, only information about the positive relation between the medicine and the illness is stored in memory, and thus the causal relation between the two events is judged high by the subjects. However, by the end of extinction, the information about the positive relation between the medicine

and the illness shares memory space with the information about a negative relation between the medicine and the illness. Retrieval of one or the other will depend on a number of factors. At the end of extinction, the most recent information (medicine no illness) is the one recovered. However, when either time or context are manipulated the retrieval of extinction information is lowered, and that causes a recovery or renewal of acquisition performance.

It is worth noting that extinction learning seems to be more context and time dependent than acquisition learning. This result is consistent with the results of a number of studies conducted with animals (v.g., Bouton & King, 1993; Bouton & Ricker, 1994; Bouton & Swartzentruber, 1986). Information learned subsequently is more context and time dependent than first- learned information (see Bouton, 1993 for a review). Bouton (1993; 1994) has proposed that subjects may use the context to resolve a situation where the meaning of a stimulus is ambiguous. His view assumes that the subject does not attend to the context when the meaning of the stimulus is unique —during acquisition, in our case. However, when this meaning changes the subject then attends to the context, looking for something that reveals the current meaning of the stimulus. This theoretical interpretation fits with the data that suggest that first learned information about one stimulus is less affected by the change of the context than second learned information about the same stimulus.

This theoretical interpretation, which we can label retrieval theory, takes from memory theory the idea that time is a context (Bouton, 1993; Spear, 1971). Although this assumption has been questioned in the literature (e.g., Riccio, Rabinobitz & Axelrod, 1994; Riccio, Richardson & Ebner, 1984), there is now enough evidence to suggest that context change and time effects are based in the same underlying process (see Bouton, Nelson y Rosas, 1999a; 1999b): information affected by context change is similarly affected by time, and, conversely, information not affected by one is not affected by the other (see Bouton, 1993; and Bouton et al. 1999a for a review), and both effects add to each other (Rosas & Bouton, 1997, 1998; Rosas et al., in press). The assumption that time is a context allows retrieval theory to explain spontaneous recovery in the same terms that it explains renewal. This theory assumes that response to a stimulus with two different meanings will depend on the relative availability of each meaning in memory. Context and time manipulations enhance the retrieval of the information about acquisition by lowering the judgments of the information about extinction to be retrieved.

Note that the approach we have taken to explain these data does not imply a specific learning mechanism. Traditionally, findings in the causal-learning literature have been explained by the learning of a rule that determines the relation between the cue and the outcome (v.g., Allan, 1980; Cheng & Novic, 1992; Cheng, 1997). More recently, an alternative account to causal learning has been assumed the establishment of an association between the cause and the effect. This approach has been based on the similarity between causal-judgment re-

search results and results from the animal conditioning literature (e.g., Dickinson & Burke, 1996; Shanks, 1993; Shanks & Dickinson, 1987). Although the results presented in this paper also are similar to results from the animal literature, these experiments do not allow us to decide between these two theoretical approaches to causal learning. The learning mechanism may be either associative or statistical; the only requirement of retrieval theory is that information about acquisition and extinction should be independently stored in memory, an assumption that seems justified given the results of the experiments reported in this paper, and in other experiments in the literature (see Bouton, 1993).

In summary, the experiments presented in this paper present a useful technique for studying extinction and extinction-related effects in human beings. Though additional research is necessary before reaching a definitive conclusion about the mechanisms of the extinction-related phenomena in humans presented here, the results obtained in these experiments suggest that extinction in human beings may be affected by the same factors that affect it in other animals. The present results can be adequately explained by the retrieval theory of learning, a theory that has been developed mainly through animal research. Thus, these experiments can be considered additional evidence of the existence of general learning processes that are shared by different animal species, including humans.

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