Prior extinction increases acquisition context specificity in human predictive learning

Pedro M. Ogallar[a,*], Juan M. Rosas[a], Manuel M. Ramos-Álvarez[a], José A. Alcalá[b],
James B. Nelson[c], Manuel Aranzubia[c], José E. Callejas-Aguilera[a,*]

[a] *Universidad de Jaén, Spain*
[b] *University of Leicester, United Kingdom*
[c] *University of the Basque Country/Euskal Herriko Unibertsitatea, Spain*

ABSTRACT

One experiment evaluated the effect of extinction on the context dependence of non-extinguished information in a situation in which physical (images), rather than predominantly verbal, contexts were used in human predictive learning. Participants received training in which different foods (Cues) were associated with the presence or the absence of gastric illness (outcome) in customers of different restaurants (contexts). One cue was associated with the gastric illness while a different cue was either extinguished or not between groups. A change in the context at test led to a general decrease in both predictive judgments and the speed of responding to the non-extinguished cue. However, these decreases were greater when training was conducted during extinction of the different cue demonstrating the extinction makes acquisition context-specific (EMACS) effect. Results are contrasted with failures to find the effect in other reports and discussed in terms of extinction leading to an allocation of attentional resources to the context, facilitating the context dependence of information.

1. Introduction

The general definition of context in the literature (for a review see Bouton, 2010) involves different forms of what Smith (2007) defines as "that which surrounds", including all kinds of external and internal events such as physical (e.g., Bouton, 1994), temporal (e.g., Rosas and Bouton, 1997, 1998), emotional (e.g., Eich, 1995) and cognitive stimuli (e.g., García-Gutiérrez and Rosas, 2003). These contexts have been found to play an important role in performance, affecting both the acquisition and retrieval of information. Explaining the mechanisms that underlie contextual control has been a focus of many learning and memory theories for decades (e.g., Bouton, 1993; Nelson, 2002; Rosas et al., 2006a, 2013; Todd, 2013).

One of the most influential theories regarding the role of context in associative learning is that formulated by Bouton (1993, 1994, 1997) to explain context-switch and retention interval effects within associative interference paradigms. This theory assumes that the main role contexts play is to retrieve associative learning to resolve the ambiguity of the situation. It is assumed that when the information an organism receives from a cue or signal is unambiguous (e.g., during simple acquisition of cue-outcome associations), background stimuli are ignored, and the role of context in retrieval of information is negligible. However, when

the meaning of the cue is thought to become ambiguous, such as when an interference treatment changes a cue's established meaning by associating the cue with the absence of the outcome (extinction) or with a different outcome, the new information about the cue is assumed to be coded together with the context where that new information is acquired. Then, retrieval of conflicting information will depend on whether the test is conducted in the same context where ambiguity appeared or in a different one (see also Bouton, 1997; Nelson, 2002, 2009).

Bouton's (1993) theory has remarkable success explaining key context-switch phenomena such as the different types of renewal, a phenomenon in which an extinguished response is renewed when the test is conducted outside the extinction context (e.g., ABA, Bouton and Bolles, 1979; AAB, Bouton and Ricker, 1994; or ABC renewal, e.g., Thomas et al., 2003, where the letters represent the contexts where acquisition, extinction and testing take place). The same idea has been applied to reinstatement, a phenomenon in which the presentation of the outcome without the cue leads to a recovery of the conditioned response or the predictive judgment through what it is assumed to be a change in the associative context where the test is conducted (e.g., García Gutiérrez and Rosas, 2003; García-Gutiérrez et al., 2005; Rescorla and Heth, 1975). Likewise, in spontaneous recovery an

---

extinghished response is recovered with the simple passage of time (e.g., Pavlov, 1927; Robbins, 1990; Rosas and Bouton, 1996). The effect is assumed to occur because of a change in the temporal context where extinction takes place (e.g., Bouton, 1993). Observations of the additive effects of spontaneous recovery and renewal (Rosas and Bouton, 1997, 1998; Rosas et al., 2001; Vila et al., 2002; for a review see Bouton et al., 1999) lend support to the idea that these recovery-from-interference phenomena share a common mechanism.

However, observations of context dependence with first-learned, non-interfered information, many of which have appeared during the last decade (e.g., Nelson, 2002, 2009; Rosas and Callejas-Aguilera, 2006) suggest that Bouton's (1993) theory needs updating. While Bouton (1993) does not claim that simple first-learned information is totally unaffected by contexts, his theory has difficulties explaining context-switch effects with simple first-learned information that are facilitated after interference training with other cues (e.g., León et al., 2010; Lucke et al., 2013; Rosas and Callejas-Aguilera, 2006). For instance, Rosas and Callejas-Aguilera (2006), using a human predictive learning paradigm, trained a cue-outcome relationship either during, or after, the extinction of a different cue-outcome relationship. The extinction treatment appeared to make performance to cue-outcome relationships that were not part of the interference treatment context-specific. Performance based on a simple cue-outcome relationship was deteriorated when the test was conducted outside the context where the simple relationship was learned, in what it has been called the Extinction Makes Acquisition Context Specific (EMACS) effect (see also Bernal-Gamboa et al., 2018; Rosas and Callejas-Aguilera, 2007; Rosas et al., 2006a; but see Nelson and Lamoureux, 2015; Nelson et al., 2011).

The seminal finding of EMACS effect, motivated Rosas and his colleagues to propose the Attentional Theory of Context Processing (ATCP), extending Bouton's (1993) theory of information retrieval to situations in which contexts play a role in retrieval with cues that have not undergone an interference treatment (Ogallar et al., 2017; Rosas et al., 2006a; see also Gawronski et al., 2010). The ATCP assumes that the main factor determining context-dependence is whether the organism is paying attention to the context at the time of acquisition and testing. Whenever the organism is paying attention to the context during training, performance to a given cue is assumed to depend on whether the cue is tested in the acquisition context or in a different one (for related approaches see also Bouton, 1997; Jiang and Leung, 2005; Larrauri and Schmajuk, 2008).

In recent approaches of ATCP, it is assumed that attention to the context is modulated by two main factors. The first is the subjective relevance of the context which is assumed to be modulated by contexts' informative value (e.g., León et al., 2008, 2010; León et al., 2012; Lucke et al., 2013, 2014; Uengoer et al., 2018), by attentional instructions in human participants (e.g., Callejas-Aguilera et al., 2019; but see, Neumann, 2007), and by the relative salience of the context with respect to the cues (see Abad et al., 2009).

The second factor is situational ambiguity. Situational ambiguity is assumed to be high at the beginning of training, when the organism does not yet know the role the different stimuli play (e.g., León et al., 2011). It should also be high when the organism is exposed to contradictory information (e.g., Bernal-Gamboa et al., 2015; Callejas-Aguilera and Rosas, 2010; Nelson et al., 2013; Rosas and Callejas-Aguilera, 2006, 2007; Rosas et al., 2006b; see also Bernal-Gamboa et al., 2014).

The role of ambiguity in context depencence of information has been shown across different species and procedures (see a review in Ogallar et al., 2017). In rats, the EMACS effect has been observed after both, extinction (Bernal-Gamboa et al., 2015; Rosas and Callejas-Aguilera, 2007) and pre-exposure in conditioned taste aversion (Bernal-Gamboa et al., 2018). Moreover, the influence of the experience of interference has been found to persist across different tasks. For instance, Bernal-Gamboa et al. (2014) found that extinction of runway running made subsequent taste aversion learning context-dependent, and vice versa (see also Rosas and Callejas-Aguilera, 2006, Experiment

4). In humans, contextual dependence has been found when ambiguity has been produced by training non-target cues in a pseudodiscrimination (Callejas-Aguilera and Rosas, 2010) or in counterconditioning (see Rosas et al., 2006b). These results all seem to suggest that consistent acquisition becomes context dependent in ambiguous situations, regardless the way in which this ambiguity is generated (e.g. extinction, pre-exposure, pseudo discrimination or counterconditioning). Interestingly, attitudes are often context specific, and the contextualization of attitude formation generally forms under conditions predicted by ATCP, which has been adopted to account for those specific phenomena (Gawronski et al., 2010)

However, the literature also shows some failures to obtain the EMACS effect, suggesting that this effect may not be as ubiquitous as ATCP proposes (see Nelson and Lamoureux, 2015; Nelson et al., 2011). For instance, Nelson et al. (2011) failed to find this effect in appetitive conditioning with rats and suggested that the effect reported by Rosas and Callejas-Aguilera might have been an artifact of the use of an unpaired control group producing a restricted range of conditioning with the target CS, rather than the experience of extinction favoring context dependence of the information. Within these lines, Bernal-Gamboa et al. (2018), recently reported an EMACS effect in rats' conditioned taste aversion using no-extinction and no-conditioning controls, and with tests conducted outside the context where the interference treatment was conducted, suggesting that this effect is not due to the artifact suggested by Nelson's et al. (2011), at least within the conditioned taste aversion domain.

Nelson and Lamoureux (2015) also reported a failure to find an EMACS effect in human participants using a behavioral task in a situation where attention was clearly being maintained to contexts, casting doubts as to whether the EMACS effect could be restricted to the specific features of the task used by Rosas and Callejas-Aguilera (2006). To our knowledge, the EMACS effect in humans has been found only using predictive learning within what it has been called the Restaurant Task (see related results in automatic evaluation in Gawronski et al., 2010). In this task, participants learn relationships between the ingestion of different types of food cues (e.g., eggs, tuna, garlic, etc.) and the presence of a gastric illness outcomes in customers of imaginary restaurants that play the role of contexts.

The type of task used by Nelson and Lamoureux (2015) differed from the task used by Rosas and Callejas-Aguilera (2006) in many aspects. First, it was behavioral were a variable-ratio schedule between pressing a mouse button and earning points by shooting a spaceship produced a high rate of responding mouse clicking. Participants had been informed that the spaceship would attack them, and that the attack would drain their power leaving them unable to play while their power re-charged. Thus, they should avoid shooting at the spaceship to conserve power when they expected to be attacked. Colored sensors predicted that the spaceship would attack and participants rapidly learned to suppress their responding during these sensors. Different contexts were provided by different space-galaxy backgrounds where the gameplay would take place. In the game, context switches were initated with a message that the participant and the enemy spaceship were being transported to a different named galaxy for further testing.

In the game one CS (X) was conditioned and extinguished, or not, and then a second CS (T) was conditioned. Responding to T was assessed in the context where it was trained or in a different, but familiar, context. Extinction of X appeared to have no effect on responding to T. Responding to T in a new context was somewhat less than in its training context, and prior extinction with X provided no enhancement of that effect. The extinguished X underwent renewal when tested in a different context demonstrating that the contexts were discriminated and strong contextual control of some type of learning (extinction in this case) was achieved.

Apart from the more behavioral nature of the task, one relevant difference is that restaurant task of Rosas and Callejas-Aguilera (2006) simply used names of restaurants as contexts, while the task of Nelson

and Lamoureux (2015) also used background images of physical stimuli (e.g., stars, nebulae). There are any number of differences between these two ways of representing context that might, in some way, account for the differences in their results. For instance, the physical salience of the contexts in the Nelson and Lamoureux (2015) task might have been greater than in the restaurant task, and inherently command more attention. Such a situation would limit the effect of any further attempt to enhance attention. Also, pictures have been shown to access semantic information (e.g., which context is present) faster than words (e.g., Smith and Magee, 1980). This potential differential cognitive load in recognizing contexts between the tasks could have produced unintended, and presenty unspecified, differences in the way in which attention is allocated to them.

Whatever the value of such explanations for the divergent results reported by Rosas and Callejas-Aguilera (2006, 2007) and Nelson and Lamoureux (2015) and Nelson et al. (2011), these conflicting results reported in the literature require additional research on the EMACS effect. The experiment reported here was conducted with two specific goals. The first goal was to evaluate whether the EMACS effect can be replicated using the same task used by Rosas and Callejas-Aguilera (2006, Experiment 1), but employing physical contexts where the backgrounds were pictures of restaurants rather than simple verbal labels. The design also used within-subject testing.

The second goal was to test the interpretation of the EMACS effect given by Rosas and Callejas-Aguilera (2006) that context-switch effects depend on the attention participants pay to the contexts (see Ogallar et al., 2017; Rosas et al., 2006a; Rosas and Nelson, 2019). To this end, response speed was recorded throughout the experiment under the assumption that changes in attention to contexts and cues may potentially affect the speed of responding (e.g., Cobos et al., 2013). Greater attention is assumed to involve more processing and slower response speed. Aristizabal et al. (2017), found that when familiar cues and contexts were arranged in a novel fashion where the cue was tested within a context where that cue was not presented before, there was an increase in the relative time participants spent looking at the context. If that additional time is being used to process the contexts to facilitate some type of outcome retrieval, then it should take more time to decide of how to respond when the cue is presented outside the training context. Detection of differences between response speed would be particularly favored by the design used in this experiment as, contrary to the design used by Aristizabal et al. (2017) in which the duration of the presentation of the cue was fixed at 3 s, the cue was only presented until the participant gave the response.

The design is presented in Table 1. Two groups of participants were first trained with Cue X followed by the outcome (O). During Phase 2, all participants were trained with target Cue P1 followed by O in Context A, before being tested in both Context A and Context B. The difference between groups came from the treatment received by X during Phase 2. Participants in Group E (extinction) were trained with P1 while Cue X was extinguished, while participants in Group NE (no extinction) did not have the experience of extinction with X while being trained with the target cue.

Predictive judgments to the target Cue P1 were expected to be lower in Context B (Different) than in Context A (Same, acquisition context)

Table 1
Experimental sesign.

Group	Phase 1	Phase 2	Test
E	A: **X-O**, F1-	A: **X-**, **P1-O**	A: P1
	B: F2-O, F1-	B: F2-O, F1-	B: P1
NE		A: F1-, **P1-O**	A: P1
		B: F2-O, F1-	B: P1

Note: A and B: Two physically different restaurants, counterbalanced between subjects. X and P1: Cucumber and Garlic, counterbalanced; F1 and F2: fillers. F1 and F2: eggs and tuna fish, respectively. O: gastric illness.

only in the group that had the extinction experience, E (see Rosas and Callejas-Aguilera, 2006). Additionally, we expected participants in Group E to show slower response speed when tested in Context B than when tested in Context A, a difference that should not appear in Group NE (for related results see Aristizabal et al., 2017; c.f., Nelson and Lamoureux, 2015).

Finally, we conducted the experiment with a large sample from two different laboratories, the one at the Universidad de Jaén (where the effect was first reported), and the one at the Universidad del País Vasco (where failures to detect the effect have been reported). Conducting the experiment in two different laboratories allowed us to ensure that the effect did not depend on nonspecific factors related to the sample used or laboratory conditions and procedures. Increasing the size of the sample also increased the statistical power. Assuming a correlation of 0.5 between the repeated measures, the study has a power of 0.79 to detect small effects ($\eta^2 = 0.01$) such as the potentially subtle effects of context switches in performance after simple acquisition that could have gone unnoticed in previous reports in the literature (e.g., León et al., 2011; Paredes-Olay and Rosas, 1999; Rosas and Bouton, 1997; Rosas and Callejas-Aguilera, 2006; Rosas et al., 2007, Experiment 2).

2. Material and methods

2.1. Participants

Ninety-six students from the Universidad de Jaén and ninety-six student from the Universidad del País Vasco participated in this experiment. They had an average age of 20.46 years and 87% of them self-identified as female. Participants had no previous experience with the task. Participants were randomly assigned to Groups E and NE upon arrival to the laboratory.

2.2. Apparatus

Participants performed the experiment individually in adjacent cubicles. Each booth had a desktop computer where the task was presented. The procedure was implemented with SuperLab Pro 4 software (Cedrus Corporation). The instructions were presented in Spanish. Monitors were 22" and set to a resolution of 1920 by 1080.

Cues were the same as those used by Rosas and Callejas-Aguilera (2006) with the exception that verbal information was substituted by a picture of the food taken from a repository of royalty-free images. *Cucumber* and *garlic* were counterbalanced as Cues X and P1. Cues F2 and F1 were *eggs* and *tuna fish*, respectively. *Diarrhea* was used as O. Contexts A and B were the images of two fictitious restaurants counterbalanced across participants. One of the images presented a terrace in front of a lake, with natural scenery and typical terrace furniture, while the other presented an old European city patio with typical bistro tables covered with elegant tablecloths (see the two top images in Fig. 1).

Two types of screens were used, cue presentation and feedback. On the cue presentation screen, an image of a restaurant (1347 × 758 pixels) was presented, centered in the screen. In the center of that image a 328 × 218-pixel picture of the food was presented. In the lower part of the screen, below the picture of the restaurant, appeared a scale from 0 to 100 divided into 21 small green 58 × 38-pixels buttons. Each button had a number representing an interval of 5 points in the scale. On top of the scale, beginning at 0 and ending at 100, and equally separated from each other, the words *none, little, some,* and *much* were presented. The feedback screen presented the same information as in the previous screen except that the scale was substituted by the presentation of the outcome (either *s/he had diarrhea* written in red font, or *s/he had no diarrhea* written in blue font. The remainder area in all screens was white. The demonstration restaurant used was a third restaurant different from the ones counterbalanced as contexts A and B and the cue used was pasta (see the bottom image in Fig. 1).

Restaurant 1
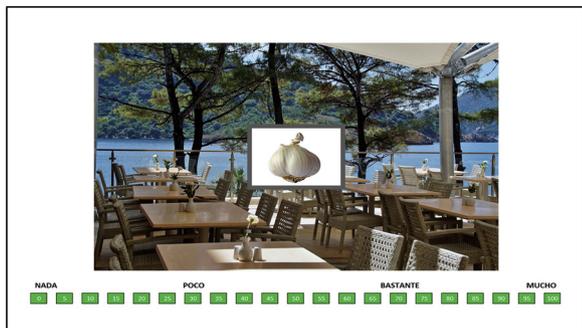
Restaurant 2

Demonstration Restaurant

Fig. 1. Pictures of restaurants and foods used as contexts and cues during the experiment (top two images), and during the demonstration trial (bottom image).

2.3. Procedure

Procedures used in this study were approved by the relevant human ethics committees at the two universities. Informed consent was obtained from participants before beginning the experiment. Participants sat in front of the computer. The instructions (listed below) were presented in successive screens. Instructions were presented using a black Times New Roman 18-point bold font against a white background. A grey button with the sentence *Click here to continue* was presented at the right bottom of the screen. Participants used the mouse to click within the button to continue with the next instructions screen. Instruction screens were sequentially presented immediately afterwards.

First screen: *Recent developments in food technology have led to the chemical synthesis of food. This process has great advantages because 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.*

Second 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.

Third 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 the degree to which you think that a gastric problem will appear. To respond you should click the option that you consider appropriate. Your response will be random at the beginning, but do not worry, little by little you will become an expert.*

At this point participants had to call the experimenter who continued the instructions by demonstration. The demonstration screen was identical to the screens used during training, with the exception that an irrelevant cue (pasta image) was presented without the outcome in a restaurant different from those used for A and B (see botton picture of Fig. 1). The experimenter showed participants how to respond on this screen.

A trial consisted of the presentation screen followed by the feedback screen. Participants were requested to make a probability judgment about the relationship between the cue and the outcome by clicking on the button of the scale they considered appropriate during the presentation screen. Thus, contrary to the procedure used by Aristizabal et al. (2017) the duration of the cue presentation was not fixed at 3,000-ms, but depended on the time taken by each participant to respond. Immediately after this screen, and independent of the chosen option, participants received a 1500-ms feedback screen indicating the problem the person had (if any). The intertrial interval was 1000 ms, and it was indicated by a screen with the sentence: *Loading the file of* [a randomly chosen full name]. Full names were always different to keep the impression that each file was from a different person. Before the beginning of the experiment, participants were randomly assigned to one of two groups: extinction (E) and no-extinction control (NE). The experiment was conducted in two phases. The design of the Experiment is presented in Table 1.

2.3.1. Phase 1

Participants in both groups received 24 trials in each context, separated in 3 blocks. In each block of trials, all participants received 4 trials of each combination X−O and F1− in Context A, or 4 trials of each combination F2–O and F1− in Context B. Trials in each block were randomly intermixed. Thus, experience with cues, outcome, and contexts was equated throughout the acquisition phase within and between groups. Each block of trials within a context was preceded by a screen with the sentence: *Now you are going to analyze the files of the people who ate at this restaurant* [restaurant's image]. The order in which blocks of trials (and contexts) were presented was counterbalanced within and between participants (ABBAAB or BAABBA).

2.3.2. Phase 2

Phase 2 was identical to Phase 1, except for the following. In both groups, a new cue was presented related to the outcome (P1–O) in Context A. The outcome of X was changed in the extinction group (E). X was not presented in the No-Extinction control group (NE). To equate the experience with the contexts, F1 was presented without outcome in this group.

2.3.3. Test phase

A test requesting predictive judgments about the relationship between P1 and O in Context B and Context A was conducted after Phase 2 with 4 presentations of P1 in each context. The transition between training and test phases was not signaled. Test trials were identical to training trials, except that the feedback screen was white, so that no feedback was provided to participants during the test trials. The order in which contexts were presented was counterbalanced between participants (ABABABAB or BABABABA). The transition between contexts was conducted as described in Phase 1.

2.4. Dependent variables and statistical analysis

Predictive judgments and latency to respond to the cues were recorded throughout training. Response speed was calculated as the inverse of the latency (Spence, 1954) between the presentation of the cue and the response on the judgments scale (inverse of the latency or reaction time —1/RT). The use of response speed rather than RT was intended with two goals: 1) to normalize the data, and 2) facilitate interpreting the graphs across dependent variables, as both, response speed and context processing measured through predictive judgments were *a priori* assumed to behave similarly. At any rate, conclusions and analyses were the same when using the latency measure.

To simplify the presentation of the results, only results of the target Cues P1 and X are reported, as responding to fillers proceeded as would be expected based on their relationships with the outcome. Predictive ratings and speeds were evaluated with mixed-factorial analysis of variance (ANOVA). Subsequent analyses were conducted with ANOVAs. Error terms and degrees of freedom were appropriately derived from the overall analyses according to methods discussed by Howell (1987, pp. 431–443). Probabilities are reported, although a general rejection criterion of p < .05 was adopted throughout. Additionally, 95% confidence intervals for the effect sizes are reported and were calculated using software available in Nelson (2016).

3. Results

3.1. Predictive judgments

The analysis involving Laboratory condition showed no interactions with Group (Phase I and Test Phase) or target cues (X vs P1 on Phase II). Thus, the laboratory condition was removed for the analysis of the data for the sake of simplicity.

Fig. 2 presents mean predictive judgments given Cues X and P1 in Groups E and NE during training Phases 1 (left panel) and 2 (right panel). Learning about X and P1 proceeded similarly in Groups E and NE. Extinction of X proceeded uneventfully in Group E. A 2 (Group) x 12 (Trial) ANOVA conducted with predictive judgments to X during Phase 1 found a significant main effect of Trial, $F(11, 2090) = 169.19$, MSe $= 325.07$, $p < .001$, $\eta_p^2 = .47$, 95% CI [.44, .49]. The main effect of Group was not significant, $F(1, 190) = 1.35$, MSe $= 3452.31$, $p = .25$. Finally the Group x Trial interaction was significant, $F(11, 2090) = 2.54$, MSe $= 325.07$, $p = .003$, $\eta_p^2 = .01$, 95% CI [.00, .02]. Subsequent analyses of the Group x Trial interaction found that the simple effect of Group was significant only in two trials at the initial

stages of training [$F(1, 717) = 6.27$, MSe $= 585.68$, $p = .01$, $\eta_p^2 = .03$, 95% CI [.004, .08] and $F(1, 717) = 5.20$, MSe $= 585.68$, $p = .02$, $\eta_p^2 = .03$, 95% CI [.002, .07], for Trials 1 and 5 respectively].

During Phase 2, a 2 (Group) x 12 (Trial) ANOVA conducted with the target Cue P1 found a significant main effect of Trial, $F(11, 2090) = 205.47$, MSe $= 171.97$, $p < .001$, $\eta_p^2 = .52$, 95% CI [.49, .54]. The main effect of Group, $F(1, 190) = 2.03$, MSe $= 3394.07$, $p = .16$, and the Group x Trial interaction were not significant, $Fs < 1$.

A complementary 2 (Cue, P1 and X) x 12 (Trial) ANOVA conducted within Group E to test the effect of extinction upon X found significant main effects of Cue, $F(1, 95) = 947.21$, MSe $= 2800.66$, $p < .001$, $\eta_p^2 = .91$, 95% CI [.87, .93], and Trial, $F(11, 1045) = 28.15$, MSe $= 305.80$, $p < .001$, $\eta_p^2 = .23$, 95% CI [.18, .26]. The Cue x Trial interaction was also significant, $F(11, 1045) = 177.19$, MSe $= 388.87$, $p < .001$, $\eta_p^2 = .65$, 95% CI [.62, .67]. Subsequent analyses of the Cue x Trial Interaction found that the simple effect of Cue was significant in all the trials, $Fs(1, 501) \geq 634.96$, MSe $= 589.85$, $ps < .001$, $\eta_p^2 \geq .87$ 95% CI [.83, .89], for the largest p (Trial 12). The value of the cues was reversed between the two first trials, indicating that extinction proceeded as expected.

Fig. 3 presents mean predictive judgments given to Cue P1 by participants in Groups E (left panel) and NE (right panel) during the 4 test trials in Context A (the training context) and in Context B (the alternative but equally familiar context). In general, predictive judgments to P1 were higher in the context where they were trained than in the alternative context, with this difference was larger in Group E than in Group NE.

Statistical analyses confirmed these impressions. A 2 (Group) x 2 (Context) x 4 (Trial) found a significant main effect of Context, $F(1, 190) = 49.29$, MSe $= 1208.35$, $p < .001$, $\eta_p^2 = .21$, 95% CI [.11, .30]. The Context x Trial interaction was also significant, $F(3, 570) = 3.25$, MSe $= 192.28$, $p = .02$, $\eta_p^2 = .02$, 95% CI [.00, .04]. Of most relevance for the goals of the study, there was a significant Group x Context interaction, $F(1, 190) = 8.73$, MSe $= 1208.35$, $p = .004$, $\eta_p^2 = .04$, 95% CI [.005, .11]. Subsequent analyses of the Group x Context Interaction found that the simple effect of context was significant in both, Group E, $F(1, 190) = 49.75$, MSe $= 302.09$, $p < .001$, $\eta_p^2 = .35$, 95% CI [.22, .50], and Group NE, $F(1, 190) = 8.27$, MSe $= 302.09$, $p = .004$, $\eta_p^2 = .08$, 95% CI [.01 .18]. Nevertheless, the simple effect of Group was significant in Context B, with lower judgments in Group E than in Group NE, $F(1, 319) = 4.89$, MSe $= 536,803$, $p = .03$, $\eta_p^2 = .02$, 95% CI [.001, .07], while they did not differ in Context A, $F < 1$. Taken together, the analyses show that the context change had a deleterious effect on retrieval that was
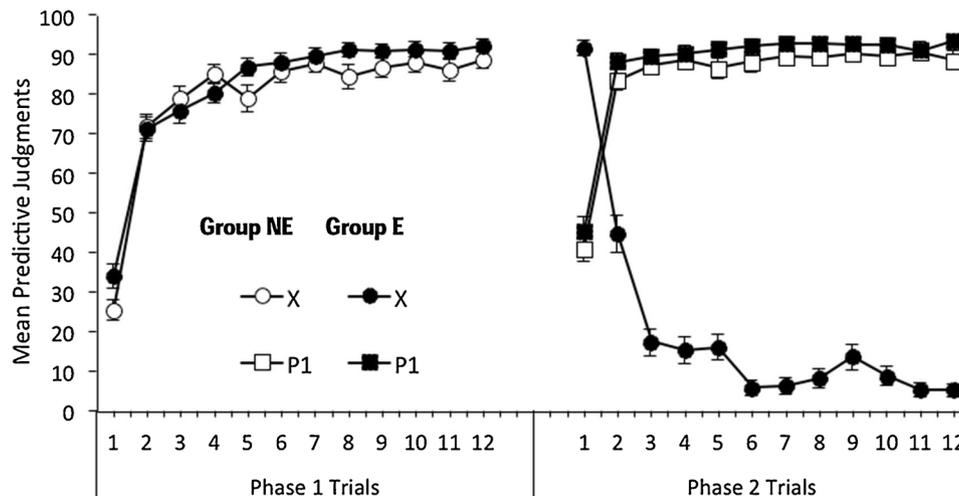
Fig. 2. Mean predictive judgments to target Cues X and P1 in Groups E and NE during the 12 Trials of Phase 1 (left) and Phase 2 (right). Error bars denote standard errors of the mean.
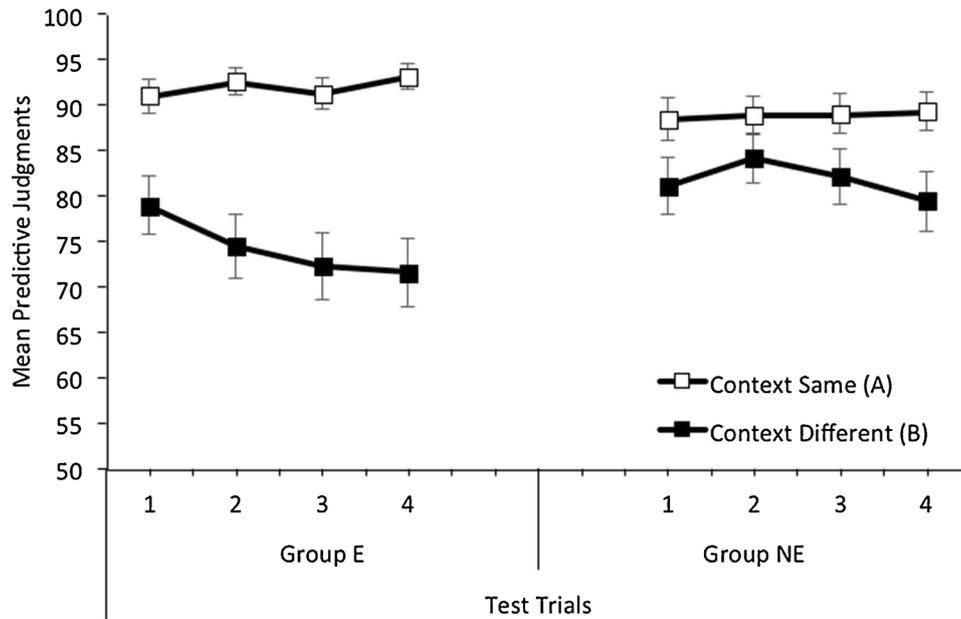
Fig. 3. Mean predictive judgments given to Cue P1 by participants in Groups E (left panel) and NE (right panel) during the 4 test trials in Context A (the training context) and in Context B (the alternative context). Error bars denote standard errors of the mean.

boosted by the extinction experience.

3.2. Response speed (1/RT)

As with the predictive judgment analysis, the analysis for response Speed involved Laboratory condition showed no interactions with Group (Phase I and Test Phase) or target cue (X vs P1 on Phase II). The laboratory condition was removed for the analysis of the data for the sake of simplicity.

Fig. 4 presents mean response speed to Cues X and P1 in Groups E and NE along the 12 training trials of Phases 1 (left panel) and 2 (right panel). Speed to respond to X increased rapidly over trials during Phase 1, regardless of the group. A similar phenomenon was observed with Cue P1 in Phase 2, while responding to X in Group E did not change throughout this phase. A 2 (Group) x 12 (Trial) ANOVA conducted with response speed to X during Phase 1 only found a significant main effect of Trial, $F(11, 2090) = 75.93$, MSe $= 0.004$, $p < .001$, $\eta_p^2 = .29$, 95%

CI [.25, .31]. Neither the main effect of Group, nor the Group x Trial interaction were significant, $Fs < 1$.

During Phase 2, a 2 (Group) x 12 (Trial) ANOVA conducted with the target Cue P1 found a significant main effect of Trial, $F(11, 2090) = 63.72$, MSe $= .004$, $p < .001$, $\eta_p^2 = .25$, 95% CI [.22, .28]. Neither the main effect of Group, nor the Group x Trial interaction were significant, $Fs < 1$. A complementary 2 (Cue, P1 and X) x 12 (Trial) ANOVA conducted within Group E to test the effect of extinction upon Cue X found significant main effects of Trial, $F(11, 1045) = 19.74$, MSe $= .004$, $p < .001$, $\eta_p^2 = .17$, 95% CI [.13 .20], and a Cue x Trial interaction, $F(11, 1045) = 12.34$, MSe $= .004$, $p < .001$, $\eta_p^2 = .12$, 95% CI [.07, .14]. The main effect of Cue was not significant, $F < 1$. Subsequent analyses of the Cue x Trial Interaction found that the simple effect of Cue was significant in the first and third trials, $Fs(1, 1132) \geq 7.15$, MSe $= .004$, $p \leq .008$, $\eta_p^2 \geq .07$, 95% CI [.01, .17], in Trial 3. Thus, response speed to the new Cue P1 was lower than to the extinguished Cue X in Group E in Trial 1, with differences slightly
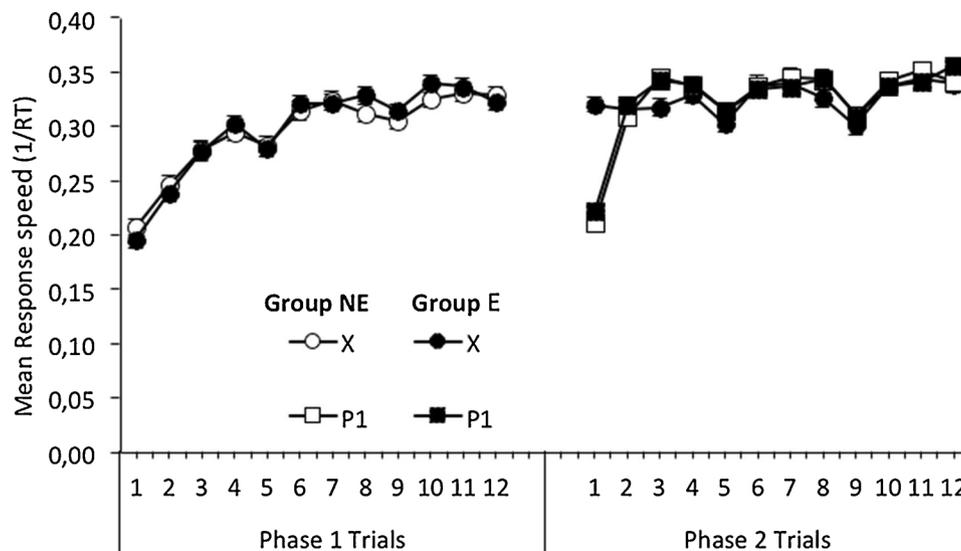

Fig. 4. Mean response speed (1/RT) to Cues X and P1 in Groups E and NE during the 12 Trials of Phases 1 (left) and 2 (right). Error bars denote standard errors of the mean.
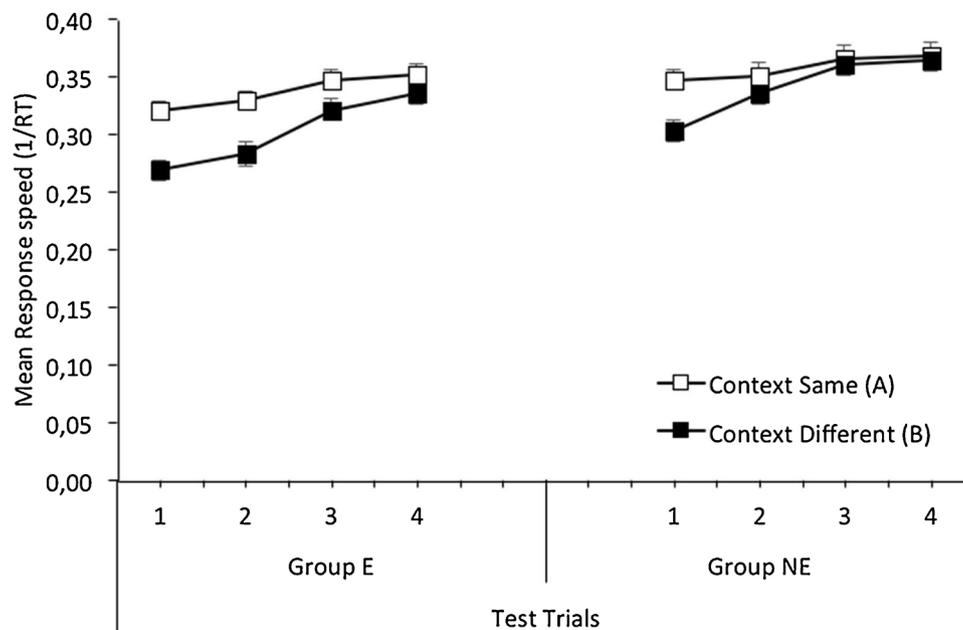
Fig. 5. Mean response speed (1/RT) given to Cue P1 by participants in Groups E (left panel) and NE (right panel) during the four test trials in Context A (the training context) and in Context B (the alternative context). Error bars denote standard errors of the mean.

reversing before disappearing afterwards. Thus, it seems like the introduction of extinction did not have major effects in response speed within this design.

Fig. 5 presents mean response speed (1/RT) given to Cue P1 by participants in Groups E (left panel) and NE (right panel) during the 4 test trials conducted in Context A (the training context) and the 4 test trials conducted in Context B (the alternative context). In general, response speed to P1 was lower in Context B (different) than in Context A (same), though these differences were greater in Group E than in Group NE. Statistical analyses confirmed these impressions. A 2 (Group) x 2 (Context) x 4 (Trial) found significant main effects of Group, $F(1, 190) = 13.27$, MSe = .026, $p < .001$, $\eta_p^2 = .07$, 95% CI [.01, .14], Context, $F(1, 190) = 69.12$, MSe = .004, $p < .001$, $\eta_p^2 = .27$, 95% CI [.17, .36], Trial, $F(3, 570) = 31.46$, MSe = .005, $p < .001$, $\eta_p^2 = .14$, 95% CI [.21, .32], and a Context x Trial interaction, $F(3, 570) = 8.34$, MSe = .003, $p < .001$, $\eta_p^2 = .04$, 95% CI [.01, .07]. Most important for the goals of this study, there was a significant Group x Context interaction, $F(1, 190) = 8.55$, MSe = .004, $p = .004$, $\eta_p^2 = .04$, 95% CI [.005, .11].

Subsequent analyses conducted to explore the Group x Context interaction found that the simple effect of Context was significant in both, Group E, $F(1, 190) = 63.13$, MSe = .001, $p < .001$, $\eta_p^2 = .41$, 95% CI [.28, .51], and Group NE, $F(1, 190) = 14.53$, MSe = .001, $p < .001$, $\eta_p^2 = .14$, 95% CI [.04, .25], indicating that the context-switch led to a decrease in the response speed regardless of the treatment received with X by the group. Additionally, the simple effect of Group was significant in both, Context A (the training context), $F(1, 244) = 5.55$, MSe = .004, $p = .02$, $\eta_p^2 = .03$, 95% CI [.002, .08], and in Context B (the different context), $F(1, 244) = 19.77$, MSe = .004, $p < .001$, $\eta_p^2 = .09$, 95% CI [.04, .16]. Accordingly, the Group x Context interaction was caused by a significant increase in the size of the context-switch effect between Group E and NE, that was reliably bigger in Group E than in Group NE, as shown in Fig. 5, No other interaction was significant, largest $F < 1$.

4. Discussion

This study was conducted with the main goal of further evaluating the EMACS effect in human predictive learning in light of the conflicting results that have been reported in the literature (Nelson and

Lamoureux, 2015; Nelson et al., 2011). Specifically, the first specific goal of this study was to evaluate whether the EMACS effect can be replicated using a predictive learning task similar to the one used by Rosas and Callejas-Aguilera (2006) in their original report, but alleviating the potential cognitive load of the task by using images of restaurants and food, rather than verbal labels. This change to physical backgrounds from verbal contexts made the nature of the contexts more similar to those used by Nelson and Lamoureux (2015), where they reported a failure to find an EMACS effect. Additionally, the second goal of the study was to explore whether evidence of attentional changes could be obtained along with the context-switch effect.

In general, the results of this study are consistent with the predictions made by ATCP (Ogallar et al., 2017; Rosas et al., 2006a). The experience with extinction in Group E led to greater context dependence of Cue P1 in Group E than in Group NE. This dependence was accompanied by slower response speeds. Response speeds were slower following extinction both when tested in the context where P1 was trained, and in the different context, with the difference being greater in the latter case.

That result is consistent with the idea that an arousal of attention to contexts accompanies extinction (Aristizabal et al., 2017). Note that this effect was not obtained at the beginning of Phase 2, where differences in the speed of responding to X only differed slightly from the speed of responding to P1, and no differences in responding to P1 were found across groups. That result is not surprising. The first time X was presented in Phase 2 there was no reason for expecting any changes in processing of X by participants, as it was presented in the same context where it was presented before, and they had no way to know that its meaning had changed. It was only after feedback was provided that prediction error arose, and attention could have changed to the context (e.g., Bouton, 1997). The fact that the procedure allows for this processing to occur during the feedback presentation is likely to diminish the possibility of detecting its effects online during training, making the procedure used in this study more adequate to detect differences at testing (as it was intended to) than during training.

This experiment also brought a somewhat unexpected result. Beside the substantial contextual dependence of P1 by the experience of extinction of X, there was also a small deleterious effect of switching the context on P1 in the absence of extinction in Group NE (see related results in human predictive learning, Üngör and Lachnit, 2006). This

result seems apparently to be in conflict with many of the results reported in the literature, as it is usually reported that simple acquisition is rarely affected by context-switches (for reviews see Bouton, 1993; Ogallar et al., 2017; Rosas et al., 2013). However, as noted in the introduction, it is not unusual to find a numerically lower performance in context different than in context same when the test is conducted after acquisition, though often such a difference is not statistically significant (e.g., Rosas & Bouton, 1997; Rosas and Callejas-Aguilera, 2006, Experiment 4). That observation was one of the reasons for using an intentionally high number of participants (192 in a within-subjects comparison), compared to what it is commonly used in the literature (between 16 and 32 participants per group). The greater power of this experiment perhaps allowed us to detect subtle trends that might have gone unnoticed in previous reports with this task (see for instance, Rosas and Callejas-Aguilera, 2006). The effect may have also been enhanced by the type of context used. The added visual complexity could support more attention. The small effect observed on P1, in the absence of extinction, is consistent with reports that suggest that contextual cues are always processed at the beginning of the task, when participants do not yet know the role played by the different elements of the task (e.g., Aristizabal et al., 2017; León et al., 2011; see also Aristizabal et al., 2016).

The different results reported by Rosas and Callejas-Aguilera (2006) and those reported by Nelson and Lamoureux (2015) do not seem to be based in the type of context used in each case. We were able to replicate Rosas and Callejas-Aguilera's (2006) results in this study using physical contexts that better parallel the procedures used by Nelson and Lamoureux (2015) who complemented the use of verbal labels with actual changes in the physical contexts. As did the current experiment, Nelson and Lamoureux showed a context-switch effect in both groups. That is, the switch effect was observed in an NE condition, in the absence of extinction of any other stimulus. Unlike the current results, the loss in the E condition observed by Nelson and Lamoureux was not greater than in their Group NE. The loss observed in their NE condition would restrict the range with which to observe an effect in the E conditions, making the effect difficult to detect except in powerful designs.

Finally, the design used in this experiment involved differential treatment of cue F1 in Context A in Groups E and NE that could leave room for an alternative interpretation of the results. Note that cue F1 was presented without outcome in Contexts A and B during Phase 1 in both groups, so that participants were perhaps explicitly trained that context change does not necessarily alter a cue's predictive value. During Phase 2, Group NE continued the same treatment, while cue F1 was absent in Context A in Group E. As ATPC suggest, contextual relevance is a factor that modulates the contextual dependency of the information, and in this case, this different training could have made the context an irrelevant source of information during Phase 1, that could have been reversed in group E by the differential treatment received by X (e.g., León et al., 2010). Notably, the design used by the studies in which EMACS effect was not reported (Nelson and Lamoureux, 2015; Nelson et al., 2011) did not include a cue that kept its meaning across contexts. Thus, contexts did not receive explicit irrelevance training in those studies. This difference allows for interpreting the EMACS effect as a decrease in context dependency in Group NE, because of the possible explicit context irrelevance training, rather than an increase in attention to the contexts by the extinction treatment. This interpretation is unlikely, as both groups whould have received explicit context irrelevance training during Phase 1, and attention to the contexts seem to decrease as training progresses even in the absence of explicit context irrelevance training (e.g., Aristizabal et al., 2016; León et al., 2010). So, the presence of a greater context change effect in group E seems to be more likely interpreted as the experience of extinction raising attention to the contexts during Phase 2, than in terms of context irrelevance training reducing context-switch effects in Group NE, though this alternative interpretation cannot be fully discarded with the present data.

In summary, the results reported in this study found the EMACS effect in human predictive learning with a mixed design, using more traditional physical contexts, and it was accompanied with a decrease in the response speed at the time of testing that is consistent with the idea of context-switch effects being based in a reallocation of attentional resources from the cue to the context after interference (e.g., Bouton, 1997; Rosas et al., 2006a; see also Aristizabal et al., 2017). However, as far as we know, with humans the EMACS effect has been reported with predictive learning (Rosas and Callejas-Aguilera, 2006) and automatic evaluation (see Gawronski et al., 2015) tasks; tasks which are very similar. In animals, it has appeared in conditioned taste aversion (Bernal-Gamboa et al., 2018; Rosas and Callejas-Aguilera, 2007; but see Bernal-Gamboa et al., 2014) with rats. Thus, before firmly concluding that the EMACS effect is a general learning effect, it will be necessary to show whether it can be replicated in behavioral tasks, with the goal of pinpointing the scope and the boundaries of this effect.

Acknowledgements

References

Abad, M.J., Ramos-Álvarez, M.M., Rosas, J.M., 2009. Partial reinforcement and context switch effects in human predictive learning. Q. J. Exp. Psychol. 62, 174–188. https://doi.org/10.1080/17470210701855561.

Aristizabal, J.A., Ramos-Álvarez, M.M., Callejas-Aguilera, J.E., Rosas, J.M., 2016. Attention to irrelevant contexts decreases as training increases: evidence from eye-fixations in a human predictive learning task. Behav. Processes 124, 66–73. https://doi.org/10.1016/j.beproc.2015.12.008.

Aristizabal, J.A., Ramos-Álvarez, M.M., Callejas-Aguilera, J.E., Rosas, J.M., 2017. Testing a cue outside the training context increases attention to the contexts and impairs performance in human predictive learning. Behav. Processes 145, 31–36. https://doi.org/10.1016/j.beproc.2017.10.001.

Bernal-Gamboa, R., Nieto, J., Rosas, J.M., 2015. Context specificity of taste aversion is boosted by pre-exposure and conditioning with a different taste. Behav. Processes 120, 111–115. https://doi.org/10.1016/j.beproc.2015.09.008.

Bernal-Gamboa, R., Rosas, J.M., Callejas-Aguilera, J.E., 2014. Experiencing extinction within a task makes nonextinguished information learned within a different task context-dependent. Psychon. Bull. Rev. 21, 803–808. https://doi.org/10.3758/s13423-013-0558-1.

Bernal-Gamboa, R., Rosas, J.M., Nieto, J., 2018. Extinction makes acquisition context-specific in conditioned taste aversion regardless of the context where acquisition and testing take place. J. Exp. Psychol. Anim. Learn. Cogn. 44, 385–395. https://doi.org/10.1037/xan0000183.

Bouton, M.E., 1993. Context, time, and memory retrieval in the interference paradigms of Pavlovian learning. Psychol. Bull. 114, 80–99. https://doi.org/10.1037/0033-2909.114.1.80.

Bouton, M.E., 1994. Context, ambiguity, and classical conditioning. Curr. Dir. Psychol. Sci. 3, 49–53. https://doi.org/10.1111/1467-8721.ep10769943.

Bouton, M.E., 1997. Signals for whether versus when an event will occur. In: Fanselow, M.S., Bouton, M.E. (Eds.), Learning, Motivation, and Cognition: The Functional Behaviorism of Robert C. Bolles. American Psychological Association, Washington, DC, pp. 385–409.

Bouton, M.E., 2010. The multiple forms of "context" in associative learning theory. In: Mesquita, B., Feldman-Barrett, L., Smith, E.R. (Eds.), The Mind in Context. Guilford Press, New York, NY, pp. 233–258.

Bouton, M.E., Bolles, R.C., 1979. Contextual control of the extinction of conditioned fear. Learn. Motiv. 10, 445–466. https://doi.org/10.1016/0023-9690(79)90057-2.

Bouton, M.E., Nelson, J.B., Rosas, J.M., 1999. Stimulus generalization, context change, and forgetting. Psychol. Bull. 125, 171–186. https://doi.org/10.1037/0033-2909.125.2.171.

Bouton, M.E., Ricker, S.T., 1994. Renewal of extinguished responding in a second context. Anim. Learn. Behav. 22, 317–324. https://doi.org/10.3758/BF03209840.

Callejas-Aguilera, J.E., Cubillas, C.P., Rosas, J.M., 2019. Attentional instructions

modulate differential context-switch effects after short and long training in human predictive learning. J. Exp. Psychol. Anim. Learn. Cogn. https://doi.org/10.1037/xan0000214. Advance online publication.

Callejas-Aguilera, J.E., Rosas, J.M., 2010. Ambiguity and context processing in human predictive learning. J. Exp. Psychol. Anim. Behav. Process. 36, 482–494. https://doi.org/10.1037/a0018527.

Cobos, P.L., González-Martín, E., Varona-Moya, S., López, F.J., 2013. Renewal effects in interference between outcomes as measured by a cued response reaction time task: further evidence for associative retrieval models. J. Exp. Psychol. Anim. Behav. Process. 39, 299–310. https://doi.org/10.1037/a0033528.

Eich, E., 1995. Mood as a mediator of place dependent memory. J. Exp. Psychol. Gen. 124, 293–308. https://doi.org/10.1037/0096-3445.124.3.293.

García-Gutiérrez, A., Rosas, J.M., 2003. Context change as the mechanism of reinstatement in causal learning. J. Exp. Psychol. Anim. Behav. Process. 29, 292–310. https://doi.org/10.1037/0097-7403.29.4.292.

García-Gutiérrez, A., Rosas, J.M., Nelson, J.B., 2005. Extensive interference attenuates reinstatement in human predictive judgments. Int. J. Comp. Psychol. 18, 240–248. Retrieved from. https://escholarship.org/uc/item/96b647tm.

Gawronski, B., Hu, X., Rydell, R.J., Vervliet, B., De Houwer, J., 2015. Generalization versus contextualization in automatic evaluation revisited: a meta-analysis of successful and failed replications. J. Exp. Psychol. Gen. 144, e50–e64. https://doi.org/10.1037/xge0000079.

Gawronski, B., Rydell, R.J., Vervliet, B., De Houwer, J., 2010. Generalization versus contextualization in automatic evaluation. J. Exp. Psychol. Gen. 139, 683–701. https://doi.org/10.1037/a0020315.

Howell, D.C., 1987. Statistical Methods for Psychology. Duxbury Press, Boston.

Jiang, Y., Leung, A.W., 2005. Implicit learning of ignored visual context. Psychon. Bull. Rev. 12, 100–106. https://doi.org/10.3758/BF03196353.

Larrauri, J.A., Schmajuk, N.A., 2008. Attentional, associative, and configural mechanisms in extinction. Psychol. Rev. 115, 640–676. https://doi.org/10.1037/0033-295X.115.3.640.

León, S.P., Abad, M.J., Rosas, J.M., 2008. Retrieval of simple cue-outcome relationships is context-specific within informative contexts. Escritos de Psicología-Psychological Writings 2, 65–73. Retrieved from. https://www.redalyc.org/pdf/2710/271020194008.pdf.

León, S.P., Abad, M.J., Rosas, J.M., 2010. The effect of context change on simple acquisition disappears with increased training. Psicologica 31, 49–63. Retrieved from. https://www.redalyc.org/pdf/169/16912881003.pdf.

León, S.P., Abad, M.J., Rosas, J.M., 2011. Context–outcome associations mediate context-switch effects in a human predictive learning task. Learn. Motiv. 42, 84–98. https://doi.org/10.1016/j.lmot.2010.10.001.

León, S.P., Gámez, A.M., Rosas, J.M., 2012. Mechanisms of contextual control when contexts are informative to solve the task. Span. J. Psychol. 15, 10–19. https://doi.org/10.5209/revsjop.2012.v15.n1.37279.

Lucke, S., Lachnit, H., Koenig, S., Uengoer, M., 2013. The informational value of contexts affects context-dependent learning. Learn. Behav. 41, 285–297. https://doi.org/10.3758/s13420-013-0104-z.

Lucke, S., Lachnit, H., Stüttgen, M.C., Uengoer, M., 2014. The impact of context relevance during extinction learning. Learn. Behav. 42, 256–269. https://doi.org/10.3758/s13420-014-0143-0.

Nelson, J.B., 2002. Context specificity of excitation and inhibition in ambiguous stimuli. Learn. Motiv. 33, 284–310. https://doi.org/10.1006/lmot.2001.1112.

Nelson, J.B., 2009. Contextual control of first-and second-learned excitation and inhibition in equally ambiguous stimuli. Learn. Behav. 37, 95–106. https://doi.org/10.3758/LB.37.1.95.

Nelson, J.B., 2016. A robust function to return the cumulative density of non-central F distributions in Microsoft Office Excel. Psicológica 37, 61–83. Retrieved from. https://www.uv.es/psicologica/articulos1.16/4NELSON.pdf.

Nelson, J.B., Lamoureux, J.A., 2015. Contextual control of conditioning is not affected by extinction in a behavioral task with humans. Learn. Behav. 43, 163–178. https://doi.org/10.3758/s13420-015-0170-5.

Nelson, J.B., Lamoureux, J.A., León, S.P., 2013. Extinction arouses attention to the context in a behavioral suppression method with humans. J. Exp. Psychol. Anim. Behav. Process. 39, 99–105. https://doi.org/10.1037/a0030759.

Nelson, J.B., Lombas, S., León, S.P., 2011. Concurrent extinction does not render appetitive conditioning context specific. Learn. Behav. 39, 87–94. https://doi.org/10.3758/s13420-011-0023-9.

Neumann, D.L., 2007. The resistance of renewal to instructions that devalue the role of contextual cues in a conditioned suppression task with humans. Learn. Motiv. 38, 105–127. https://doi.org/10.1016/j.lmot.2006.11.002.

Ogallar, P.M., Ramos-Alvarez, M.M., Alcalá, J.A., Moreno-Fernández, M.M., Rosas, J.M., 2017. Attentional perspectives on context-dependence of information retrieval. Int. J. Psychol. Psychol. Ther. 17, 121–136. Retrieved from. https://www.ijpsy.com/volumen17/num1/462/attentional-perspectives-on-context-dependence-EN.pdf.

Paredes-Olay, M.C., Rosas, J.M., 1999. Within-subjects extinction and renewal in predictive judgments. Psicológica 20, 195–210. Retrieved from. https://www.uv.es/revispsi/articulos3.99/paredes.pdf.

Pavlov, I.P., 1927. Conditioned reflexes: An Investigation of the Physiological Activity of the Cerebral Cortex. Oxford. University Press, London.

Rescorla, R.A., Heth, C.D., 1975. Reinstatement of fear to an extinguished conditioned stimulus. J. Exp. Psychol. Anim. Behav. Process. 1, 88–96. https://doi.org/10.1037/0097-7403.1.1.88.

Robbins, S.J., 1990. Mechanisms underlying spontaneous recovery in autoshaping. J. Exp. Psychol. Anim. Behav. Process. 16, 235–249. https://doi.org/10.1037/0097-7403.16.3.235.

Rosas, J.M., Bouton, M.E., 1996. Spontaneous recovery after extinction of a conditioned taste aversion. Anim. Learn. Behav. 24, 341–348. https://doi.org/10.3758/bf03198982.

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. J. Exp. Psychol. Anim. Behav. Process. 23, 283–294. https://doi.org/10.1037/0097-7403.23.3.283.

Rosas, J.M., Bouton, M.E., 1998. Context change and retention interval can have additive, rather than interactive, effects after taste aversion extinction. Psychon. Bull. Rev. 5, 79–83. https://doi.org/10.3758/bf03209459.

Rosas, J.M., Callejas-Aguilera, J.E., 2006. Context switch effects on acquisition and extinction in human predictive learning. J. Exp. Psychol. Learn. Mem. Cogn. 32, 461–474. https://doi.org/10.1037/0278-7393.32.3.461.

Rosas, J.M., Callejas-Aguilera, J.E., 2007. Acquisition of a conditioned taste aversion becomes context dependent when it is learned after extinction. Q. J. Exp. Psychol. 60, 9–15. https://doi.org/10.1080/17470210600971519.

Rosas, J.M., Callejas Aguilera, J.E., Ramos Álvarez, M.M., Fernández Abad, M.J., 2006a. Revision of retrieval theory of forgetting: what does make information context-specific? Int. J. Psychol. Psychol. Ther. 6, 147–166. Retrieved from. https://www.ijpsy.com/volumen6/num2/136/revision-of-retrieval-theory-of-forgetting-EN.pdf.

Rosas, J.M., García-Gutiérrez, A., Callejas-Aguilera, J.E., 2006b. Effects of context change upon retrieval of first and second-learned information in human predictive learning. Psicologica 27, 35–56. Retrieved from. https://www.uv.es/psicologica/articulos1.06/2ROSAS.pdf.

Rosas, J.M., García-Gutiérrez, A., Callejas-Aguilera, J.E., 2007. AAB and ABA renewal as a function of the number of extinction trials in conditioned taste aversion. Psicologica 28, 129–150. Retrieved from. https://www.uv.es/psicologica/articulos2.07/2ROSAS.pdf.

Rosas, J.M., Nelson, J.B., 2019. Context dependency as a function of prediction error-based attention. Psicológica 40, 34–45. https://doi.org/10.2478/psicolj-2019-0003.

Rosas, J.M., Todd, T.P., Bouton, M.E., 2013. Context change and associative learning. Wiley Interdiscip. Rev. Cogn. Sci. 4, 237–244. https://doi.org/10.1002/wcs.1225.

Rosas, J.M., Vila, N.J., Lugo, M., López, L., 2001. Combined effect of context change and retention interval on interference in causality judgments. J. Exp. Psychol. Anim. Behav. Process. 27, 153–164. https://doi.org/10.1037//0097-7403.27.2.153.

Smith, M.C., Magee, L.E., 1980. Tracing the time course of picture–word processing. J. Exp. Psychol. Gen. 109 (4), 373–392. https://doi.org/10.1037/0096-3445.109.4.373.

Smith, S.M., 2007. Context: a reference for focal experience. In: Roedinger, H.L., Dudai, Y., S. M, Fitzpatrick (Eds.), Science of Memory: Concepts. Oxford University Press, New York, pp. 111–114.

Spence, K.W., 1954. The relation of response latency and speed to the intervening variables and N in S-R theory. Psychol. Rev. 61, 209–216. https://doi.org/10.1037/h0058746.

Thomas, B.L., Larsen, N., Ayres, J.J., 2003. Role of context similarity in ABA, ABC, and AAB renewal paradigms: implications for theories of renewal and for treating human phobias. Learn. Motiv. 34, 410–436. https://doi.org/10.1016/s0023-9690(03)00037-7.

Todd, T.P., 2013. Mechanisms of renewal after the extinction of instrumental behavior. J. Exp. Psychol. Anim. Behav. Process. 39, 193–207. https://doi.org/10.1037/a0032236.

Uengoer, M., Pearce, J.M., Lachnit, H., Koenig, S., 2018. Context modulation of learned attention deployment. Learn. Behav. 46, 23–37. https://doi.org/10.3758/s13420-017-0277-y.

Üngör, M., Lachnit, H., 2006. Contextual control in discrimination reversal learning. J. Exp. Psychol. Anim. Behav. Process. 32, 441–453. https://doi.org/10.1037/0097-7403.32.4.441.

Vila, J., Romero, M., Rosas, J.M., 2002. Retroactive interference after discrimination reversal decreases following temporal and physical context changes in human subjects. Behav. Processes 59, 47–54. https://doi.org/10.1016/s0376-6357(02)00063-3.