Context-outcome associations mediate context-switch effects in a human predictive learning task

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Abstract

Four experiments explored the role of contexts in information retrieval after different levels of acquisition training in human predictive learning. Participants were trained where cue (X) was followed by an outcome in context A while a different cue (Y) was followed by the absence of the outcome in context B. When 4 training trials with each cue were conducted, testing the stimuli in the alternative contexts decreased predictive judgments to X and increased predictive judgments to Y. These effects disappeared both when training was increased up to 18 trials (Experiments 1a and 1b), and when the outcome was presented in both contexts A and B (Experiments 2 and 4). When the outcome was presented in both contexts, the nonreinforced cue Y, trained in the presumably excitatory context B, became a conditioned inhibitor (Experiment 3). Additional experience with one of the contexts, but not with both, made the context-switch effect reappear (Experiment 4). These results suggest that irrelevant contexts may enter into direct associations with the outcome before prolonged training leads participants to discard them as predictors.

Key words: Associative learning; Attention; Context-switch effect; Human predictive learning; Training level

Context-outcome associations mediate context-switch effects in a human predictive learning task.

Within any given learning situation there are a number of stimuli that are present that may not provide information relevant to what is intended to be learned. This background stimulation is referred to as context, and it has been traditionally shown to play an important role in information retrieval. Generally, when target stimuli are tested outside the context where information about them was learned, performance associated with that information deteriorates (e.g., Baddeley, 1992; Bouton, Nelson, & Rosas, 1999; Godden & Baddeley, 1975; Tulving & Osler, 1968).

A relevant issue within the context literature is that not all information seems to be equally affected by context changes. Information characterized as a simple excitatory association, such as that acquired in classical conditioning, has been found to transfer robustly across contexts. On the other hand, information acquired during extinction, the presentation of the conditioned stimulus without the unconditioned stimulus, has been shown to be context dependent. That is, the once eliminated conditioned response recovers when the test is conducted in a context different from that in which the response was eliminated, and this recovery seems to be the rule both in human and nonhuman animals (e.g., Baker, Murphy, & Vallée-Tourangeau, 1996; Havermans, Keuker, Lataster, & Jansen, 2005; Matute & Pineño, 1998; Neumann, 2006; Peck & Bouton, 1990; Pineño & Miller, 2004; Üngör & Lachnit, 2008; Rosas, Vila, Lugo, & López, 2001). Similar results have been found in different interference paradigms such as counterconditioning, when the cue is sequentially paired with the presence of two incompatible outcomes, and in some other forms of interference (see Bouton 1993, 1994 for a review).

A key question regarding the phenomena above is “What makes the information context specific?” In his original proposal, Bouton (1993) suggests that either inhibitory or second-learned information about a cue is more context dependent than excitatory or first-learned information about the same cue. Nelson (2002) as well as Nelson and Callejas-Aguilera (2007) showed that the key was that the information was second-learned. When a cue is sequentially associated with two different meanings, the second meaning about the cue becomes more context specific, regardless of whether the meaning is characterized as inhibitory or excitatory. More recently, in rat appetitive conditioning, Nelson (2009) has shown that even first-learned information that has been suppressed by learning interfering information is context dependent when it is relearned.

One reason for why second-learned information is context specific was also suggested by Bouton (1997). According to him, giving a cue two different meanings makes the cue ambiguous. This ambiguity in the meaning of the cue leads animals to pay attention to the contexts to disambiguate the situation, and that attention makes ambiguous information context-specific.

All of these ideas focus on specific features of the information to explain context specificity –whether the information is inhibitory or excitatory, first- or second-learned, or whether it is ambiguous or not. However, there are studies in the literature that have shown that information that is neither inhibitory nor second-learned may be context dependent (e.g., Bonardi, Honey, & Hall, 1990; Hall & Honey, 1989, 1990; Rosas & Callejas-Aguilera, 2006, 2007; Rosas, García-Gutiérrez, & Callejas-Aguilera, 2006). To explain context-specificity in these situations, Rosas, Callejas-Aguilera, Ramos-Álvarez, and Abad (2006) followed Bouton's (1997) idea that ambiguity prompts attention to contexts, making ambiguous information context specific. They suggested that the essential factor determining context specificity is whether human and nonhuman animals are attending to the contexts during learning and proposed an attentional theory of context processing as an extension of Bouton's (1993) theory. According to that theory, once participants pay attention to the context all information learned within that context will become context specific, regardless of whether such information is excitatory, inhibitory, first- or second-learned, ambiguous or not.

Rosas, Callejas-Aguilera, et al. (2006) suggested five factors that should modulate attention to contextual stimuli, and thus context dependence of *all* information learned within the context. First, and along with Bouton (1997), ambiguity in the information should increase attention to the contexts (e.g., Callejas-Aguilera & Rosas, 2010; Rosas & Callejas-Aguilera, 2006; but see Nelson & Callejas-Aguilera, 2007). Second, instructions in human participants may modulate context-switch effects (Callejas-Aguilera, Cubillas, & Rosas, 2010; Eich, 1985; see also Bouton, 1993; but see Neumann, 2007). Third, attention should be affected by whether the contexts are informative in solving the task such as when they are involved in direct discriminative relationships between cues and outcomes (e.g., León, Abad, & Rosas, 2008; 2010a; Preston, Dickinson, & Mackintosh, 1986). Fourth, the relative salience of the context with respect to other more discrete stimuli should also affect attention directed to it. And fifth, the experience the organism has with irrelevant contexts is expected to play a role in the attention they control (León, Abad, & Rosas, 2010). Specifically, it is expected that attention to irrelevant contexts is high at the beginning of training, when the organism cannot discount the context as being meaningful. Increasing experience with the context and the task should give the organism the opportunity to discover that cues, and not contexts, are relevant to solving the task, and attention to context is expected to decrease under such circumstances. This idea is not new in the literature. Myers and Gluck (1994), Kruschke (2001), and Mackintosh (1975) all predict that attention to stimuli decreases as their predictive value decreases (c.f., Pearce and Hall, 1980).

Once attention is devoted to the context, associative theories such as those developed by Rescorla and Wagner (1972) and Mackintosh (1975) assume that the contexts would enter into direct associations with the outcome. However, Bouton and Swartzentruber (1986) conducted three experiments exploring the associative and occasion setting properties of contexts used in Pavlovian discrimination of conditioned suppression with rats and found no evidence of direct context-outcome associations (see also Bouton & King, 1983). They found that contexts shared several critical properties with stimuli that occasion-set stimulus-outcome relationships, suggesting that contexts control behavior through hierarchical relationships modulating cue-outcome associations.

A large number of studies is consistent with that occasion-setting interpretation (see Bouton, 1993 for a review). As a recent example, León et al. (2010b) explored the impact that experience with a task has on the context specificity of the learning that occurs. They trained participants to perform an instrumental task within a computer game in which different responses were performed in the presence of discriminative stimuli to obtain reinforcers. Performance in the presence of the target stimulus was tested after different levels of training in the same context in which the stimulus was trained, and in a different but equally familiar context. In agreement with the attentional theory of context processing, they found a deleterious effect of context change on performance when participants received 3 training trials with each cue, but not when training was increased to 5 or 8 trials (see also Hall & Honey, 1990; but see Bonardi et al., 1990). As contexts were equally paired with the outcomes in that experiment, direct context-outcome associations could not account for the context switch effects observed after short training. Rather, the effects are better explained if contexts are assumed to play the role of occasion setters (see also Hall & Honey, 1989, 1990). That is not to say that contexts cannot enter into direct associations with the outcome in some situations (e.g., Grau & Rescorla, 1984; Ibérico et al., 2008; Sansa, Artigas, & Prados, 2007; see also Abad, Ramos-Álvarez, & Rosas, 2009; Murphy, Baker, & Fouquet, 2001).

The experiments we present here were conducted with two goals. First, we wanted to test whether the attenuation of context-switch effects over training found by both León et al. (2010b) in human instrumental conditioning, and by Hall and Honey (1990) in rats' fear conditioning, can be replicated in human predictive learning. Second, we explored whether the context-switch effect after simple acquisition in human predictive learning can be explained by direct associations between the context and the outcome as associative theories like Rescorla and Wagner (1972) and Mackintosh (1975) would suggest, rather than by hierarchical relationships in which contexts modulate cue-outcome relationships as is mainly assumed within studies in the associative learning literature (e.g., Bouton, 1993, 1994; Callejas-Aguilera & Rosas, 2010; Nelson et al., 2010).

Participants were trained in a situation in which they had to predict whether different cues (food names) were followed by an outcome (diarrhea) in different contexts (restaurants) (see for example, García-Gutiérrez & Rosas, 2003; Rosas & Callejas-Aguilera, 2006). The designs of the experiments are presented in Table 1. In all the experiments, two target cues, X and Y, were trained in two different contexts. Cue X was consistently followed by the outcome in context A, while cue Y was consistently followed by the absence of the outcome in context B. Then both cues were tested in the same context of training and in the alternative context. The effects of context switch would show as a change in the participants' when tested in the context where the cue was never presented before with respect to when tested in the context within which the cue was trained. Experiments 1a and 1b explored the effect of the level of training on context switch effects upon reinforced and non-reinforced cues in human predictive learning. Experiment 2 manipulated the availability of the outcome across different contexts and its influence on context switch effects. Experiment 3 tested the possibility that non-reinforced cues become conditioned inhibitors in an excitatory context. Finally, Experiment 4 manipulated post-training experience with each of the contexts to evaluate how this experience affected context-switch effects in human predictive learning.

Experiment 1

León et al. (2010b) found a deleterious effect of context switch on performance that appeared after short training and disappeared when training was increased in human instrumental conditioning (see also Hall & Honey, 1990, Experiment 3). The goal of Experiment 1 was first, to test whether the same kind of effect could be obtained in human predictive learning (Experiment 1a), and second, to begin the exploration of the mechanisms underlying this context switch effect (Experiment 1b).

The design of Experiments 1a and 1b is presented in the top panel of Table 1. Two groups of participants received training in which a cue was followed by an outcome in context A (X+), while another cue was presented without outcome in context B (Y-). Groups 4 received four training trials with each cue, while Groups 18 received 18 training trials with each cue. Pilot experiments found that 90% of participants show a greater level of responding on Trial 4 than on Trial 1, while 95% of participants show consistent performance by trial 18 with this procedure. In a subsequent test, the reinforced cue X (Experiment 1a) and the nonreinforced cue Y (Experiment 1b) were tested in the same context in which they were trained (A for X and B for Y) and in the alternative context (B for X and A for Y). According to the results reported by León et al. (2010b) in human instrumental conditioning, the context switch effect should appear after short training (Groups 4) and disappear when training is increased (Groups 18).

In addition to extending the results of León et al. (2010b) to human predictive learning situations, the design of this experiment begins to explore the mechanism underlying the context switch effects after short training. In general terms, some attention-based approaches in the literature suggest that at the beginning of training participants pay attention to all potential predictors of the outcome, contexts included (e.g., Mackintosh, 1975; Pearce & Hall, 1980). So, contexts would gain predictive value, and the deleterious effect of context switches would appear. Then, when training increases and participants have the opportunity to learn about the actual predictors of the outcomes, contexts may be discarded as potential predictors, removing the deleterious effect of a context switch (e.g., Kruschke, 2001; Mackintosh, 1975; Rosas, Callejas-Aguilera et al., 2006).

The combined design of Experiments 1a and 1b allows for testing the explanation of context switch effects in terms of direct associations between the context and the outcome. Note that the design included one filler in context A to avoid a perfect correlation between context A and the outcome. This forced the inclusion of a different filler in context B with the goal of equating exposure to the contexts and the number of stimuli across contexts (see Table 1). Also note that the outcome was not presented in context B. This differential outcome experience across contexts was intended. If contexts play the role of direct predictors of the outcome at some early point in training, then context switch from an excitatory context (A) to a context in which the outcome has never been presented (B) should produce decreases in performance. Alternatively, taking a cue from a context in which no outcome was presented to an excitatory context should produce increases in performance. Alternatively, if contexts control performance by modulating cue-outcome associations (e.g., Bouton, 1993, 1994), context-switch effects should appear only with cue X. As cue Y is not expected to develop an association with the outcome, no detectable context-switch effects would be expected with cue Y.

Method

Participants

Ninety-six undergraduate students of the University of Jaén participated in the experiment (48 in Experiment 1a, and 48 in Experiment 1b). They were between 18 and 25 years old, and approximately 75% of them were women. They had no previous experience with the task. All participated voluntarily and gave their informed consent before starting the experiment.

Apparatus and stimuli

The experiment was conducted on 5 PCs with SuperLab Pro (Cedrus Corporation) software. Computers were located within the same room, and they were isolated from each other by mobile partitions. All stimuli and instructions were presented in Spanish. Participants interacted with the computer using the mouse.

Food names were chosen from the pool selected by García-Gutierrez & Rosas (2003). Garlic and eggs were counterbalanced as cues X and Y. The outcome (+) was a gastric problem (diarrhea) or its absence (-). Two fictitious restaurants (The Canadian Cabin and The Swiss Cow) were counterbalanced across participants as contexts A and B. Two additional cues, F1, and F2 (corn and cucumber, respectively), were used as fillers.

Each trial consisted of a cue screen and a feedback screen. On the top of the cue screen, there was a sentence that read "One person ate at restaurant… (name of the restaurant)". In the middle of the screen it was written "This person ate… (name of the food)". Below the sentence, there was a 0 to 100 scale containing 21 small green buttons. Each button had a number representing a 5-point interval on the scale. The words "None", "Little", "Quite" and "Great" appeared at the top of the scale, beginning at zero, finishing at 100, and equally separated from each other. The words were written in bold font. A button appeared in the bottom corner of the screen and read "Press here to continue…"

On the top of the feedback screen, there was a sentence that read "This person ate at restaurant… (name of the restaurant)". Below the sentence, there was another sentence that read "This person had (the outcome or the absence of it)". The outcome (diarrhea) or the absence of it (nothing) were presented in capital letters and black fonts, *diarrhea* in red and *nothing* in dark green.

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

Procedure

The experiment lasted between 10 and 20 min depending on the number of trials. Instructions were presented on four screens using a black Times New Roman 18 bold font against a white background. A yellow button with the sentence "click here to continue" was presented at the right bottom of the screen. Participants had to click with the mouse within the button to continue with the next instruction screen.

> (1st screen). "Recent developments in food technology have lead to the chemical synthesis of food. This creates a great advantage as is very low cost and easy to both store and transport. This revolution in the food industry may solve hunger in third world countries. (2nd screen). However, it has been detected that some foods produce gastric problems in some people. For this reason we are interested in selecting a group of experts to identify the foods that lead to some type of illness, and how it appears in each case. (3rd screen). You are about to receive a selection test where you will be looking at the files of persons that have ingested different foods in a specific restaurant. You will have to indicate whether gastric problems will appear. (4rd screen). To respond you should click the option that you consider appropriate, and then click on the button that appears at the bottom corner of the screen. It is very important to respect this order, given that only your first choice will be recorded. Your response will be random at the beginning, but do not worry; little by little you will become an expert".

At that point, participants were required to call the experimenter who demonstrated the instructions. The demonstration screen was identical to the screens used during training, with the exception that a new cue (pasta) was presented as predictor within a restaurant (Bully) that was not used again during the experiment. The outcome presented in the demonstration screen was the same used later during training (diarrhea).

Each trial consisted of the presentation of the cue and the feedback screens. Participants were requested to give a predictive judgment about the probability of the cue being followed by the outcome by clicking on one of the buttons on the numeric scale and then pressing the advance button (click here to continue). Immediately after this screen, and regardless of the chosen option, participants received a 1500 ms feedback screen indicating the problem the person had (diarrhea or nothing). The inter-trial interval was 1500 ms and was indicated by a screen with the sentence "Loading file of… (a randomly chosen full name)". Full names were always different to keep the impression that each file was from a different person. The design is presented in the top two panels of Table 1.

Experiments 1a and 1b were conducted in different weeks. Within each experiment, participants were randomly assigned to Group 4 or Group 18 upon their arrival to the laboratory.

Training. Each participant in Experiments 1a and 1b was trained with cue X being followed by the outcome and F1 presented alone in context A, while cues Y and F2 were presented without outcome in context B. Groups differed only in the level of training. Participants in Groups 4 received four trials with each cue in each context. Participants in Groups 18 received eighteen trials with each cue in each context.

Half of the participants in each group received training first in context A and then in context B while the other half were first trained in context B and then in context A. The distribution of trials within each context was random. Training in each context was preceded by a screen in which the sentence “Now you should analyze the files of the people that ate at restaurant… (name of the restaurant)”.

Test. The test was preceded by a screen with the sentence “Please, answer the following questions”. Test trials were identical to training trials with the only exception that no feedback was given to participants after their answer. Participants in Experiment 1a received the test with cue X in contexts A (Same) and B (Different). Participants in Experiment 1b received the test with cue Y in contexts A (Different) and B (Same). Context order at testing was counterbalanced across participants so that half of participants were tested first in context A and then in context B, and vice versa, with respect to the training order.

Dependent variable and statistical analysis

Predictive judgments were requested throughout training and testing. Acquisition data are not reported because performance in Groups 4 was misleadingly low and did not reflect the terminal levels of learning. Participants gave their judgments prior to knowing the outcome of the trial, thus judgments on trial 4 reflected performance after three trials of acquisition. Learning after four trials was only reflected on the test. Test data were analyzed using analysis of variance (ANOVA). A significance level of .05 was established for all statistical tests reported here. Effect sizes were reported using partial eta-squared (η_p^2).

Results

Experiment 1a

The top panel of Figure 1 presents mean predictive judgments given by participants in Groups 4 and 18 when cue X was tested in the same context of training (Same) or in the alternative context (Different). The context switch produced a decrease in performance in Group 4 that was not observed in Group 18. Confirming these impressions, a 2 (Group) x 2 (Test context) ANOVA found a significant Group x Test context interaction, F (1, 46) = 5.56, p = .02, η_p^2 = .10.

Subsequent analysis conducted to explore the Group x Test context interaction found a significant simple effect of Test context in Group 4, F (1, 23) = 11.23, p = .003, η_p^2 = .32, but not in Group 18, F (1, 23) = 3.19, p = .08.

Finally, the simple effect of Group in context Same was analyzed to test whether the increase in training trials produced an increase in performance. No simple effect of training level was found, F (1, 46) = 2.68, p = .10, suggesting that 4 trials of training are enough to reach an asymptotic level of performance in this situation.

Experiment 1b

The bottom panel of Figure 1 presents the mean predictive judgments given by participants in Groups 4 and 18 when cue Y was tested in the same context of training (Same) or in the alternative context (Different). The context switch produced an increase in judgments to Y in Group 4, but not in Group 18. A 2 (Group) x 2 (Test context) ANOVA found a significant Group x Test context interaction, F (1, 46) = 4.90, p = .03, η_p^2 = .09.

Subsequent analysis conducted to explore the Group x Test context interaction found a significant simple effect of Test context in Group 4, F (1, 23) = 6.84, p = .01, η_p^2 = .22, but not in Group 18, $F < 1$.

As in Experiment 1a, the simple effect of Group in context Same was analyzed to test whether the increase in training trials produced changes in performance. No effect of training level was found, $F < 1$.

Discussion

Experiments 1a and 1b were conducted with the goal of testing whether a context switch effect could be found early in training in human predictive learning and whether such an effect disappears as training progresses (e.g., Hall & Honey, 1990; León et al. 2010b). A context change conducted after 4 training trials led to a decrease in judgments to a cue that was followed by the outcome (Experiment 1a) and to an increase in judgments to a cue that was never followed by the outcome (Experiment 1b). These context switch effects were not found when training was increased to 18 trials with each cue.

The combined results of Experiments 1a and 1b extend the results of León et al. (2010b) to a human predictive learning situation by showing that the effect of a context switch upon simple acquisition appears early in training and disappears when training is increased(see also Hall & Honey, 1990; c.f., Bonardi et al., 1990) . The simplest explanation for these differential effects of context switches after short and after long training would be that cue-outcome associations after short training are weaker than cue-outcome associations after long training, regardless of whether those associations involve the presence (X) or the absence of the outcome (Y). However, this explanation is speculative and circular, given that no differences in performance based on training were found with either cue X or Y, suggesting that performance was near asymptote after 4 training trials. The only evidence of associations being weaker after short training in this experiment was that they were more susceptible to being affected by a context switch after short training than after long training.

Rescorla and Wagner's (1972) model is unable to explain these results. Note that in this design contexts are never presented by themselves, and that the number of trials was identical for each trial type. Under these conditions, Rescorla and Wagner's model predicts that both, contexts and cues will gain excitatory associative strength on reinforced trials (A:X+). On nonreinforced trials (A:F1-), the presence of the context would lead participants to expect the outcome. As this expectative is disconfirmed, F1 would acquire inhibitory associative strength. Assuming equal salience for all the cues and contexts involved in this experiment, learning would reach asymptote when the associative strength of context A is about .33, the associative strength of X is around .66 and the associative strength of F1 is around -.33. Given that no outcomes are presented in context B, the associative strength of Y, F2, and context B is expected to be zero. Accordingly, a decrease in performance to X would be expected with the context switch regardless of the level of training, depending on the excitatory associative strength accrued by context A at any given point of training. In summary, Rescorla and Wagner's (1972) theory could explain the effect of context switch on both X and Y in these experiments but has no way to explain why such a context-switch effect is affected by the level of training. Configural models such as Pearce's (1987, 1994) make the same predictions as the Rescorla and Wagner (1972) model in this situation.

An alternative explanation to these results is given by attentional theories of learning, which suggests that early in training participants pay attention to every possible predictor in the situation, including an irrelevant context. When training progresses and participants learn that cue X is the best predictor of the outcome, attention to irrelevant contexts decreases, so that context switches no longer affect performance (see Le Pelley, 2004; Mackintosh, 1975; Rosas, Callejas-Aguilera et al., 2006; c. f., Pearce & Hall, 1980).

Additionally, the combined results of these experiments suggest that the effect of a context change on simple acquisition in human predictive learning is due to a direct predictive role of the contexts early in training. Note that responding to cue X decreased when it was tested outside context A (the context in which the outcome was presented) while responding to Y increased when tested inside context A. A straightforward interpretation of these results would be that context A has become excitatory because of its association with the outcome. If so, responding to X in Group 4 would reflect the sum of an excitatory context to an excitatory cue. When cue X is tested outside the excitatory context A, responding will decrease. When a nonreinforced cue is tested inside the excitatory context, performance will increase, as was the case with cue Y. When training is increased and the role of irrelevant contexts as potential predictors is lost, prediction of the presence and the absence of the outcome would be sustained only by the cues, and context switches would have no effects.

This interpretation is in agreement with Mackintosh's (1975) attentional theory of learning, as he predicts the formation of direct associations between the context and the outcome early in training. Other attentional views of context switch effects, such as the one proposed by Rosas, Callejas-Aguilera et al. (2006), are not specific with respect to the mechanism involved in the context-switch effects, assuming that contexts may play the role of either direct predictors of the outcome (e.g., Mackintosh, 1975; Pearce, 1987; Rescorla & Wagner, 1972) or occasion setters (e.g., Bouton, 2004; Bouton & Swartzentruber, 1986). In both cases it is assumed that attention to irrelevant contexts decreases over training, decreasing their ability to control performance.

The results of Experiments 1a and 1b begin to suggest that the role of contexts early in training within this method may be associative (e.g., Mackintosh, 1975; Pearce, 1987; Rescorla & Wagner, 1972), although this conclusion is weakened by the fact that it comes from a between-experiments comparison. Additionally, these experiments confound the experience with the context and the task with the experience with the target cues, as Groups 18 received additional training with both contexts and target cues. Nevertheless, any situation that allows participants to learn that contexts are irrelevant to prediction of the outcome should suffice to decrease attention. Experiments 2, 3, and 4 were conducted to solve these issues.

Experiment 2

Experiment 2 was conducted with two goals. First, it sought to replicate the combined results of Groups 4 from Experiments 1a and 1b. Additionally, Experiment 2 tested the idea that the effect of the context switch early in training was caused by the formation of direct associations between the context and the outcome (e.g., Mackintosh, 1975; Pearce, 1987; Rescorla & Wagner, 1972). If that interpretation were correct, context switch effects should disappear when experience with the outcome is equated across contexts, as both the training and testing contexts would be equally associated with the outcome and any changes in performance to the cues caused by being tested in a context with a different associative strength from the training context should disappear.

The design of the experiment is presented in the middle panel of Table 1. Participants received four trials in which cue X was followed by the outcome in context A, and four trials in which cue Y was not followed by the outcome in context B. Two fillers were included, F1 in context A and F2 in context B. For participants in Group OA (outcome in context A), the design was identical to the one used for Groups 4 in Experiments 1a and 1b, with the outcome being presented only following cue X in context A. However, for participants in Group OAB (outcome in contexts A and B), F2 was followed by the outcome in context B, so that the outcome was present in both contexts A and B. If the context switch effect early in training found in Experiments 1a and 1b, depends on context A becoming a predictor of the outcome, then the context switch effect on X and Y should disappear when context B is made a predictor of the outcome as well. Such would be the case in Group OAB. Group OA should replicate the results of Groups 4 of Experiments 1a and 1b with a deleterious effect of context switch on performance when cue X is tested outside its supposedly excitatory training context, and an increase in responding to cue Y when it is tested outside its training context and within the context in which cue X had been paired with the outcome.

Method

Participants and apparatus

Ninety-six undergraduate students of the University of Jaén participated in the study. As in Experiments 1a and 1b, participants were between 18 and 25 years old and approximately

75% of them were women. Stimuli and the rest of experimental settings were identical to the ones used in Experiments 1a and 1b.

Procedure

Except where noted, the procedure was identical to the one used in Experiments 1a and 1b. The design of Experiment 2 is presented in the middle panel of Table 1. Participants were randomly assigned to Groups OA and OAB upon their arrival to the laboratory. All participants received 4 trials of training with each cue. The only difference between Groups OA and OAB was that in Group OAB filler F2 was followed by the outcome in context B, while in Group OA no outcome was presented in context B.

The test was within-subject because participants within each group were tested with cues X and Y in the same context in which they were trained (Same) and in the alternative context (Different). Test order of both the cues and the contexts in which the cues were encountered was fully counterbalanced.

Results and Discussion

Figure 2 presents mean predictive judgments to X and Y in the same context in which they were respectively trained (Same) and in the alternative context (Different) in groups OA and OAB. The Context switch decreased judgments to X and increased judgments to Y in Group OA. However, it had no effect in Group OAB. A 2 (Group) x 2 (Cue) x 2 (Test context) ANOVA found a Group x Cue x Test context significant interaction, F (1, 94) = 6.29, p = .01, η_p^2 = .06.

Subsequent analyses conducted to explore the three-way interaction found that the Cue x Test context interaction was significant in Group OA, F (1, 47) = 20.46, p < .001, η_p^2 = .30, but not in Group OAB, F (1, 47) = 2.66, p = .11. Simple-effect tests exploring the Cue x Test context interaction in Group OA found that the effect of Test context was significant with both cue X, F (1, 47) = 15.82, p < .001, η_p^2 = .25, and cue Y, F (1, 47) = 15.32, p < .001, η_p^2 = .24. The context change decreased predictive judgments to cue X and increased judgments to cue Y in Group OA.

In summary, the combined results of Groups 4 across Experiments 1a and 1b were replicated in Group OA. We observed a decrease in judgments to the reinforced cue (X) when it was tested outside the training context, and an increase in judgments to the nonreinforced target cue when it was tested within a context in which cue X was followed by the outcome. No effects of the context switch were found when the outcome was presented in both contexts (Group OAB).

The lack of context-switch effects in Group OAB suggests that the critical factor that determines the effect of context switch in this specific situation is the presence of the outcome in only one of the training contexts. When the outcome is presented in both contexts, the context switch effect disappears. These results are in agreement with an associative interpretation of context-switch effects after short training in human predictive learning (see for instance Mackintosh, 1975) where contexts form direct associations with outcomes.

In Group OA, the outcome was presented only in context A. An excitatory relationship between context A and the outcome was expected. This association would explain why judgments to X decreased when cue X was tested outside the excitatory context A, and why judgments to Y increased when it was tested within excitatory context A. In group OAB, there was a cue paired with the outcome within each context. Accordingly, contexts A and B could both have become excitatory and no effect of context switch would be expected.

The interpretation of the results of group OAB is compromised by an unexpected observation. The lack of context-switch effects on cue X after participants were trained with the outcome in both contexts is consistent with the idea of both contexts A and B gaining excitatory associative strength. The lack of a context-switch effect with cue Y is also in agreement with this interpretation. However, a closer inspection of the results with cue Y across groups OA and OAB shows that the lack of a context-switch effect in group OAB seems to be produced by a reduction of responding to Y in context different (A), rather than by an increase in responding to Y in context same (B). Though this difference was not statistically significant, F (1, 94) = 2.59, p = .11, this trend suggests that the lack of a context-switch effect on Y in group OAB is not due to both contexts becoming excitatory because of the presentation of the outcome within them.

Although other possibilities exist (see Matute & Pineño, 1998; Pineño & Matute, 2000), the most likely explanation for the lower responding to cue Y in both the Same and Different contexts in group OAB is that Y may have become a conditioned inhibitor. Assuming that context B becomes associated with the outcome on B:F2+ trials, the presence of B would lead participants to expect the outcome on B:Y- trials. Disconfirmation of an expected outcome is assumed to lead to conditioned inhibition that, in this case, would be accrued by Y. If that were the case, net responding to Y in both contexts would be reflecting summation between the excitatory associative strength of the context and the inhibitory associative strength of cue Y. In group OA, as the outcome was not presented in context B, Y would not have gained inhibitory strength. Experiment 3 tested this possibility.

Experiment 3

Presenting the outcome in both contexts removed the context-switch effect for both X and Y. Yet, removing the effect on Y did not take the expected form of an increase in responding to Y in the now excitatory training context, but rather a decrease in responding in both the training and test context, each of which could have been excitatory. Such a result could occur if Y had become a conditioned inhibitor. In experiment 2, Group OA received A:X+, A:F1-, B:Y- and B:F2- as in the previous experiment. Both context B and cue Y should remain neutral. Alternatively, group OAB received A:X+, A:F1-, B:Y- and B:F2+ pairings. In context B, B may become excitatory, allowing for Y to become inhibitory. The goal of Experiment 3 was to explore that possibility. The design is presented in the middle panel of Table 1. Groups OA and OAB received the same treatment as did Groups OA and OAB in Experiment 2. To evaluate whether the designs of groups OA and OAB lead to different levels of inhibition to Y, we conducted a summation test (Rescorla, 1969). Responding to cue X in context A was evaluated in compound with the potentially inhibitory cue Y. Responding to that compound was compared to a generalization-decrement control where a new, neutral, cue was used (N) in place of Y. If the treatment received by participants in group OAB leads them to establish inhibitory relationships between Y and the outcome, then Y should reduce responding when presented in compound with the excitatory cue X with respect to a neutral cue that has not been presented before.

Method

Participants, apparatus, and procedure

Sixty-four undergraduate students of similar characteristics to those participating in the preceding experiments participated in this experiment. Stimuli and the rest of experimental settings were identical to the ones used in Experiment 2, except that a new stimulus, tuna fish, was included within the pool of target stimuli (X, Y and N).

The design of the Experiment is presented in the middle panel of Table 1. The design was identical to the one used in Experiment 2, except for the test. During the test, one trial with each of two compound stimuli (XY and XN) was conducted in context A. Trial order was counterbalanced across participants.

Results and Discussion

Figure 3 presents mean predictive judgments given by participants in groups OA and OAB to the compounds XN and XY in context A during the test phase of Experiment 3. In group OAB, responding to X was lower when presented in compound with Y than when X was presented in compound with the novel stimulus N. No differences appeared in group OA. Statistical analyses confirmed these impressions. A 2 (Group) x 2(Compound) ANOVA found a significant Group x Compound interaction, F (1, 62) = 4.60, p = .03, η_p^2 = .07. Subsequent analyses conducted to explore the two-way interaction isolated the simple effect of Compound at each level of the Group variable. The simple effect of Compound was significant in group OAB, F (1, 31) = 9.38, p = .004, η_p^2 = .23, but it was not significant in group OA, F < 1.

Thus, the summation test revealed that responding to cue X was lower when X was presented in compound with cue Y than when it was presented in compound with the novel cue N in group OAB. This difference confirms that the treatment received by Y in group OAB made stimulus Y a conditioned inhibitor (e.g., Rescorla, 1969).

The combined results of Experiments 1, 2, and 3 are in agreement with the idea that contexts develop excitatory associations with the outcome announced by a cue early in training. These context-outcome associations interact with the associations between cues and outcomes, facilitating learning of inhibition about non reinforced cues. As the design of Experiments 2 and 3 were identical, except for what was tested in each experiment, it seems safe to assume that Y was also inhibitory in group OAB of Experiment 2, explaining the low responding to Y in both the same and different contexts when both contexts were supposed to develop excitatory relationships with the outcome.

Experiment 4

Results of the experiments reported so far suggest, first, that context switch effects on simple acquisition in human predictive learning may depend on the level of training, being more likely to appear early in training than when training is increased. And second, these experiments suggest that context switch effects in this situation are based on direct associations between the context and the outcome.

Experiment 4 was conducted to test this latter assumption by differentially manipulating the associative value of the contexts. The design of this experiment is presented in the bottom panel of Table 1. Three groups of participants received the same training received by group OAB in Experiments 2 and 3, with the outcome being present in both contexts A and B. Group OAB received no additional training before testing. Group OAB_B received additional experience with context B, but target cue Y was substituted by a new filler (F3). Finally, Group OAB_AB received additional experience with both contexts A and B, with cues F3 and F4 substituting for target cues

Y and X, respectively. Half of the participants in each group received a nonreinforced test with cues X and Y in the same context of training while the other half received the test with X and Y in the alternative context.

According to what was observed in Experiment 2, Group OAB should not show the context switch effect. The key to this experiment is the additional training received by Groups OAB_B and OAB_AB during Phase 2. Note that this training did not involve target cues X and Y and avoided confounding the increase in training with the cues with the increase in training with the contexts (see Experiments 1a and 1b; Hall & Honey, 1990; León et al., 2010b). If increasing the training with the contexts leads participants to stop paying attention to the contexts, as attentional theories of context change suggests (e.g., Rosas, Callejas-Aguilera et al., 2006), then increasing experience with context B in Group OAB_B should lead participants to ignore context B as potential predictor of the outcome, and context B should lose its ability to control performance (see Mackintosh, 1975). However, as context A is not additionally trained, its associative value should remain high creating a situation similar to that of Group OA in Experiment 2, with an excitatory context (context A) and a neutral context (context B). Accordingly, performance to cue X should decrease when tested outside context A, and performance to cue Y should increase when tested within context A. This effect should disappear when the predictive value of both contexts is equally undermined, as would occur when additional training is conducted with both contexts in Group OAB_AB.

Method

Participants and apparatus

Ninety-six students of the University of Jaén with similar characteristics to those participating in previous experiments participated in this experiment. Apparatus and stimuli were the same as those used in Experiments 1a and 1b, with the exception that two additional fillers were included (F3 was caviar, and F4 was tuna fish).

Procedure

Except where noted, the procedure was identical to the one used in Experiment 2. The design of the experiment is presented in the bottom panel of Table 1. Participants were randomly assigned to groups OAB, OAB_B, and OAB_AB upon their arrival to the laboratory. Half of participants within each group were randomly assigned to be tested with the cues in the same contexts in they were trained, while the other half were tested in the alternative context. The experiment was conducted in three phases:

Phase 1. All participants received the same training received by Group OAB in Experiment 2, with 4 trials each of X followed by the outcome and F1 followed by the absence of outcome in context A, and 4 trials each of Y followed by the absence of outcome and F2 followed by the outcome in context B. Trials within each context were randomly intermixed.

Phase 2. Groups differed in the training received during Phase 2. Group OAB skipped this phase and was taken directly into the test. Group OAB_B received an additional 28 randomly intermixed training trials in context B with 14 trials of F2 being followed by the outcome and 14 trials with a new filler, F3, presented without the outcome. Finally, Group OAB_AB received the same training as Group OAB_B in context B, and equivalent training with F1 without the outcome and F4 being followed by the outcome in context A. Half of participants in group OAB_AB received training in context A first, followed by training in context B, and vice versa the other half.

Test. The test was conducted between subjects, with half the participants being tested with X in context A and Y in context B (Same) and the other half being tested with X in context B and Y in context A (Different). The order of testing within each group was counterbalanced.

Results and Discussion

Figure 4 presents mean predictive judgments to cues X and Y in Groups OAB, OAB_B, and OAB_AB tested in the same context in which the cues were trained (Same), and in the alternative context (Different). A context switch effects appeared only in Group OAB_B. A 3 (Group) x 2

(Cue) x 2 (Test context) ANOVA found a significant Group x Cue x Test context interaction, F (2, 90) = 3.75, p = .02, η_p^2 = .07.

Subsequent analyses conducted to explore the three-way interaction found that the Cue x Test context interaction was significant in Group OAB_B, F (1, 30) = 12.47, p = .001, η_p^2 = .29, but not in Groups OAB and OAB_AB, *Fs* < *1*. Finally, analyses exploring the simple effect of Test context at each level of the cue factor in Group OAB_B found that the simple effect of Test context was significant with both cue X, F (1, 30) = 7.66, p = .01, η_p^2 = .20, and cue Y, F (1, 30) = 4.11, p = .05, η_p^2 = .12.

In summary, results of Group OAB replicated the results obtained with Group OAB in Experiment 2, with a context-switch effect absent in both cue X, and in cue Y. Extending training in context B led to a context-switch effect reflected as a decrease in judgments to X when tested outside context A and an increase in judgments to Y when tested outside context B. This context switch effect disappeared when additional training was conducted in both context A and context B.

Note that the test was conducted immediately after training within each group. This feature of the design introduced a slight difference among groups with respect to the time between acquisition trials for X and Y and the test, allowing for forgetting to potentially play a role in the results. However, as the interval between X and Y training and the test increased gradually between groups OAB, OAB_B and OAB_AB, and the context switch effect appeared only in group OAB_B, one is left with the unlikely assumption that forgetting only affected the intermediate retention interval (group OAB-B) and disappeared when the retention interval was increased (group OAB-AB).

The results of these three groups indicate an inverse relationship between attention participants pay to the context and the level of training (e.g., Mackintosh, 1975; Rosas, Callejas-Aguilera et al., 2006). Additionally, they also suggest that context switch effects in this situation are the result of direct associations between contexts and outcomes when participants have little experience with the contexts and the situation. The lack of a context switch effect in Group OAB could be due to both contexts being equally associated with the outcome, given the short amount of training. Increasing training within context B in Group OAB_B would reduce attention to context B, and its ability to control performance, despite its potential associations with the outcome. Consequently, on test, X would be taken from an excitatory context (A) to a non-excitatory context (B), while the contrary would be true for cue Y. When training was increased in both contexts in Group OAB_AB, participants had the opportunity to learn that both contexts were irrelevant. Accordingly, the ability of the contexts to control performance on the test would be equally compromised and thus context switch effects did not appear.

Finally, this experiment found changes in the presence or the absence of context switch effects when experience with the contexts was manipulated, leaving the experience with the cues intact. These results suggest that the essential factor leading to the presence or the absence of context switch effects in this situation is the general experience with the role of the contexts, and not the experience with the target cues.

General Discussion

This experimental series explored the role of the level of training in the context switch effect upon simple acquisition in human predictive learning, and the mechanism underlying that context switch effect. Experiments 1a and 1b found a context switch effect when training was short (4 training trials) that disappeared when training was increased to 18 training trials. This context switch effect appeared as a decrease in predictive judgments to the reinforced cue that was tested in a context in which no cue had been reinforced (Experiment 1a) and as an increase in predictive judgments to a nonreinforced cue that was tested within a context in which another cue had been reinforced (Experiment 1b). Experiment 2 found that these context switch effects depended on the outcome being presented only in one of the contexts of training, and disappeared when there was a cue followed by the outcome in both of contexts. Experiment 3 found that when the outcome was presented in both contexts, a nonreinforced cue became a conditioned inhibitor. Finally, Experiment 4 found that the context switch effect that was eliminated by training with the outcome in both contexts reappeared when additional training with different cues was conducted in one of the training contexts and disappeared again when such additional training was equated in both contexts.

Results of Experiments 1a and 1b are in accord with those reported by both Hall and Honey (1990) with rats using the conditioned emotional response procedure (see also Maes, Haverman, & Vosse, 2000; but see Bonardi et al., 1990) and with those reported by León et al. (2010b) using a human instrumental task. Thus, the effect of training upon context switch effects conducted after simple acquisition seems to generalize across different tasks and animal species.

The simplest explanation for the context switch effect would be generalization decrement, as perception of cue X may have changed outside the training context, decreasing predictive judgments. From this perspective, AX would be processed as a compound that would be associated with the outcome as a whole (see Pearce, 1987, 1994). Changing the context would imply a change in the tested compound and, according to Pearce (1987), responding would decrease because generalization from the training compound AX to the tested compound BX would be incomplete. Similarly, this model predicts an increase of responding to Y when tested in context A, given that the compound AY will receive generalized associative strength from the trained compound AX. However, it is not clear why such generalization decrement should disappear when training is increased. In fact, once an asymptotic level of performance is reached, Pearce's (1987) model predicts the same context switch effects regardless of how much training is increased. As stated in the discussion of Experiment 1, elemental models such as Rescorla and Wagner's (1972) lead to similar predictions and are equally unable to account for the deleterious effect of the level of training on context-switch effects after simple acquisition. These results are not accommodated well by Bouton's (1993) theory which predicts that contexts control performance with ambiguous cues (see Bouton, 1997). In these experiments, contexts affect performance with cues that are not ambiguous in the sense that the cues were consistently followed by the same outcome.

Attentional views such as the one proposed by Rosas, Callejas-Aguilera et al. (2006) predict that the context-switch effect will disappear with training. From their perspective, the effect of context switches depends on participants paying attention to the context, and it is assumed that attention to irrelevant contexts decreases as training increases. A similar point of view is present in some attentional theories of learning such as Mackintosh's (1975). He suggests that the associability of cues that are relatively poor predictors of the outcome decreases over training. Specifically, at the beginning of training any potential cue would be processed according to its salience, but, as training increases, associability of cues that are good predictors of the outcome would increase, and associability of cues that are relatively poor predictors of the outcome would decrease (see also Kruschke, 2001). In our experiments, contexts were irrelevant to solving the task. In fact, context A was a worse predictor of the outcome than cue X, and context B was an equally poor predictor of the outcome as cue Y. In both cases, Mackintosh (1975) suggests that associability of the contexts should decrease .That decrease would not imply a decrease in any associative strength that the context could have gained while participants were paying attention early in training, but rather a decrease in the probability of this associative strength being translated into performance (Mackintosh, 1975; p. 288).

An important question about context switch effects relates to the mechanism underlying them. Rosas, Callejas-Aguilera et al. (2006) proposal is not specific about the mechanism underlying context switch effects. However, as stated above, Mackintosh's (1975) attentional theory of learning assumes that contexts would enter into direct associations with the outcomes (see for instance Sansa, Artigas, & Prados, 2007). Alternatively, contexts may play the role of occasion setters, modulating the learning that occurred within them (e.g., Bouton, 2004; Bouton & Swartzentruber, 1986). In fact, the results obtained by León et al. (2010b) in human instrumental learning are better explained by this latter approach, as in that experiment context-switch effects appear in situations in which the contexts involved in the experiment are equally associated with the outcomes, precluding the interpretation of context-switch effects in terms of direct context-outcome relationships.

Contrary to the occasion-setting mechanism suggested by León et al. (2010b), in this series of experiments context-switch effects disappeared when the outcome was presented in both context A and context B, suggesting that contexts do not play the role of occasion setters in human predictive learning when simple acquisition is involved. Rather, they seem to enter into direct associations with the outcome as Mackintosh (1975) suggested. Additional support for this hypothesis comes from the fact that responding to the non-reinforced cue (Y) increased when it was tested in the context in which another cue was followed by the outcome, and that Y became inhibitory when trained in an excitatory context. The fact that manipulation of experience with the context after target training increases or decreases the context switch effect depending on whether such context experience is given with one of the contexts involved, or with both of them, respectively, is also in agreement with Mackintosh’s (1975) proposals.

The kind of control exerted by the contexts in this situation prompts the question of whether the stimuli used within this experimental series, and others using the same methods (i.e., Callejas-Aguilera & Rosas, 2010; Nelson & Callejas-Aguilera, 2007; Rosas & Callejas-Aguilera, 2006), may be considered true contexts or whether they have the same status as the target cues. In other words, if contexts enter into direct associations with the outcome, what is the difference between contexts and target cues? This is an important question that, as far as we know, has not been resolved in the literature. Contexts have received different definitions that are difficult to integrate in a simple, straightforward definition that would go further than what we offer here. The “context” for any stimulus is every perceptible event other than the stimulus itself. Thus, a cue is a cue surrounded by a context and is itself part of the context for other cues.

Context should not be defined by its mechanism of action. The same contextual cues that in these experiments entered into direct associations with the outcome, in other experimental series have controlled behavior by modulating cue-outcome associations (e.g., Callejas-Aguilera & Rosas, 2010). For example, context-outcome associations in these experiments are inferred from the asymmetric context-switch effect on performance, with a decrease in ratings to X and an increase of ratings to Y (tested outside and inside the allegedly excitatory context, respectively). However, Callejas-Aguilera and Rosas (2010), using the same contexts that we have used here, reported a symmetrical effect of context-switches on two cues that were trained within contexts that were equally paired with the presence and the absence of the outcome, a result that would be difficult to explain by direct context-outcome associations. Finding dual mechanisms of contextual control is not exclusive to human predictive learning. León, Callejas-Aguilera, and Rosas (2010) have found that the contexts that seem to control expression of extinction of conditioned taste aversion through a modulatory mechanism (e.g., Rosas & Bouton, 1998; Rosas, García-Gutiérrez, Callejas-Aguilera, 2007) control simple acquisition of conditioned taste aversion through direct associations with the outcome when both contexts are new at the time of conditioning.

In summary, contexts have been shown to play roles similar to those played by target cues, either entering into direct associations with outcomes, as any other conditioned stimulus, or modulating cue-outcome relationships by playing a role akin to that played by occasion setters (e.g., Holland, 1992). These differing results with respect to the mechanism through which contexts exert their control on behavior have two direct implications. First, the mechanism involved within a context-switch situation cannot be taken for granted. Appropriate tests are necessary before being able to conclude which mechanism underlies a context-switch effect within any specific situation. Such an assessment is seldom conducted, particularly in the case of human research (see Nelson et al., 2010 for discussion). Second, because the same contexts may play different roles depending on the specific conditions of the experimental situation, a key issue for research on context-switch effects in the coming years will be to establish which of those specific conditions leads to contextual control through each of these mechanisms.

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Table 1

Experimental designs

Experiment	Group	Training		Test
		Phase 1	Phase 2	
1a	4	A: **X+**, F1- / B: Y-, F2-		A: X / B: X
	18	A: **X+**, F1- / B: Y-, F2-		A: X / B: X
1b	4	A: X+, F1- / B: **Y-**, F2-		A: Y / B: Y
	18	A: X+, F1- / B: **Y-**, F2-		A: Y / B: Y
2	OA	4A: X+, F1- / 4B: Y-, **F2-**		A: X / B: X
				A: Y / B: Y
	OAB	4A: X+, F1- / 4B: Y-, **F2+**		A: X / B: X
				A: Y / B: Y
3	OA	4A: X+, F1- / 4B: Y-, **F2-**		A: XN, XY
	OAB	4A: X+, F1- / 4B: Y-, **F2+**		A: XN, XY
4	OAB	4A: X+, F1- / 4B: Y-, F2+		A: X / B: Y
		4A: X+, F1- / 4B: Y-, F2+		A: Y / B: X
	OAB_B	4A: X+, F1- / 4B: Y-, F2+	**14B:** F2+, F3-	A: X / B: Y
		4A: X+, F1- / 4B: Y-, F2+	**14B:** F2+, F3-	A: Y / B: X
	OAB_AB	4A: X+, F1- / 4B: Y-, F2+	**14A:** F4+, F1- / **14B:** F2+, F3-	A: X / B: Y
		4A: X+, F1- / 4B: Y-, F2+	**14A:** F4+, F1- / **14B:** F2+, F3-	A: Y / B: X

Note. Garlic, eggs and tuna fish were counterbalanced as target cues X, Y, and N where appropriate. Fillers F1, F2, F3, and F4 were corn, cucumber, caviar, and tuna fish, respectively. “+” and “-” represent the presence and the absence of the outcome (diarrhoea), respectively. Restaurant names “The Canadian cabin” and “The Swiss cow” were counterbalanced as contexts A and B. Numbers before contexts indicate the number of trials with each cue within that specific context. Group names represent the number of trials with each cue (4 or 18), the context in which the outcome is present (OA: Outcome in context A; OAB: Outcome in contexts A and B), or the context that received additional training (_B: Additional training with context B; _AB: Additional training with contexts A and B). Key treatments in each experiment are presented in bold.

Figure captions

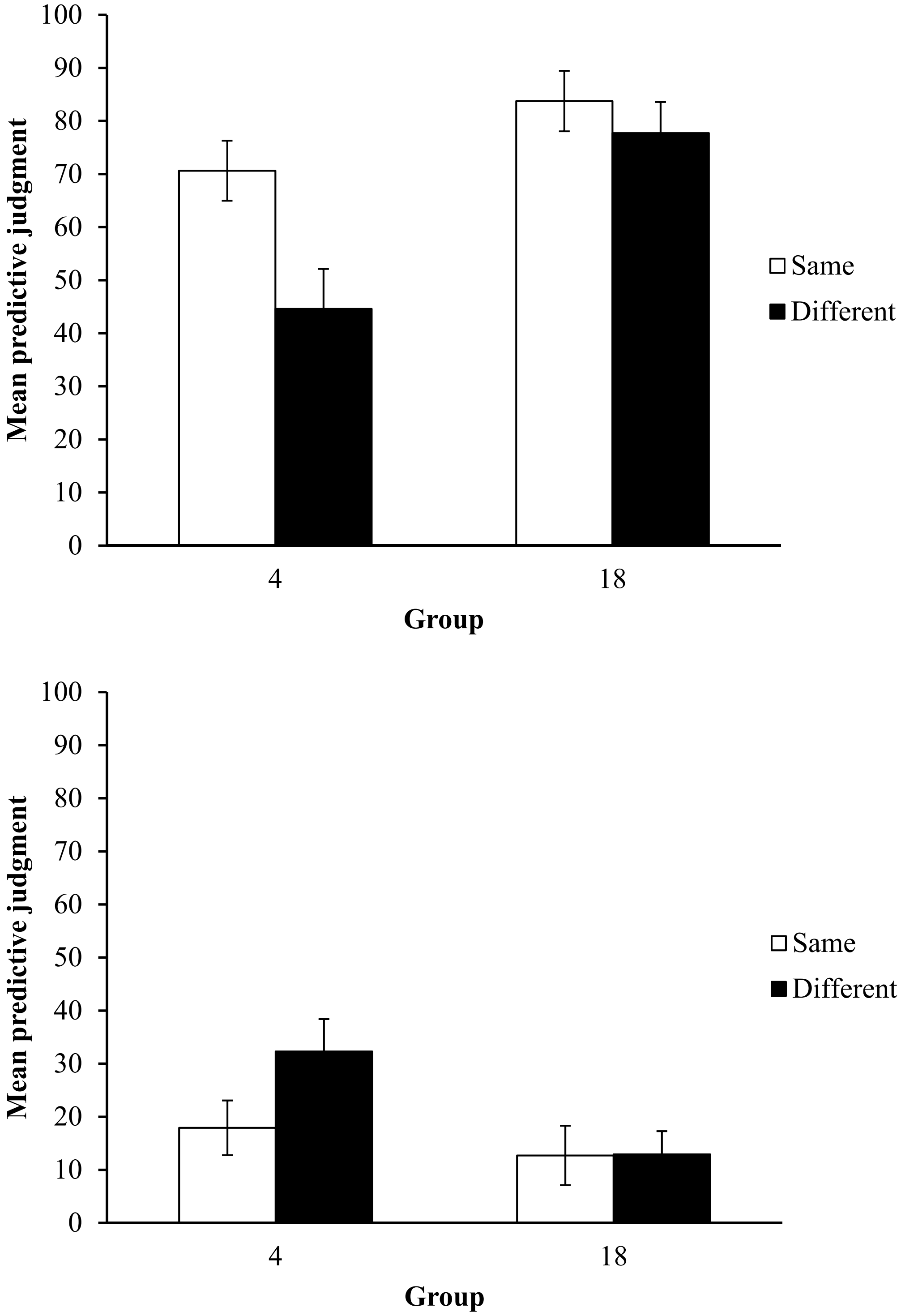
Figure 1. Mean predictive judgments given by participants in Groups 4 and 18 when cues X (top panel) and Y (bottom panel) were tested in the same context of training (Same) or in the alternative context (Different) in Experiments 1a (top panel) and 1b (bottom panel). Error bars denote standard errors of the mean.

Figure 2. Mean predictive judgments given by participants to cues X and Y in the same context in which they were respectively trained (Same) and in the alternative context (Different) in groups OA (Outcome only in context A) and OAB (Outcome in contexts A and B). Error bars denote standard errors of the mean.

Figure 3. Mean predictive judgments given by participants in groups OA and OAB to the compounds XN and XY in context A during the test phase of Experiment 3. Error bars denote standard errors of the mean.

Figure 4. Mean predictive judgments to cues X and Y in Groups OAB, OAB_B, and OAB_AB for participants tested in the same context in which cues were trained (Same), and for participants tested in the alternative context (Different). Error bars denote standard errors of the mean.

Figure 1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Mean predictive judgment
4
18
Group
Same
Different
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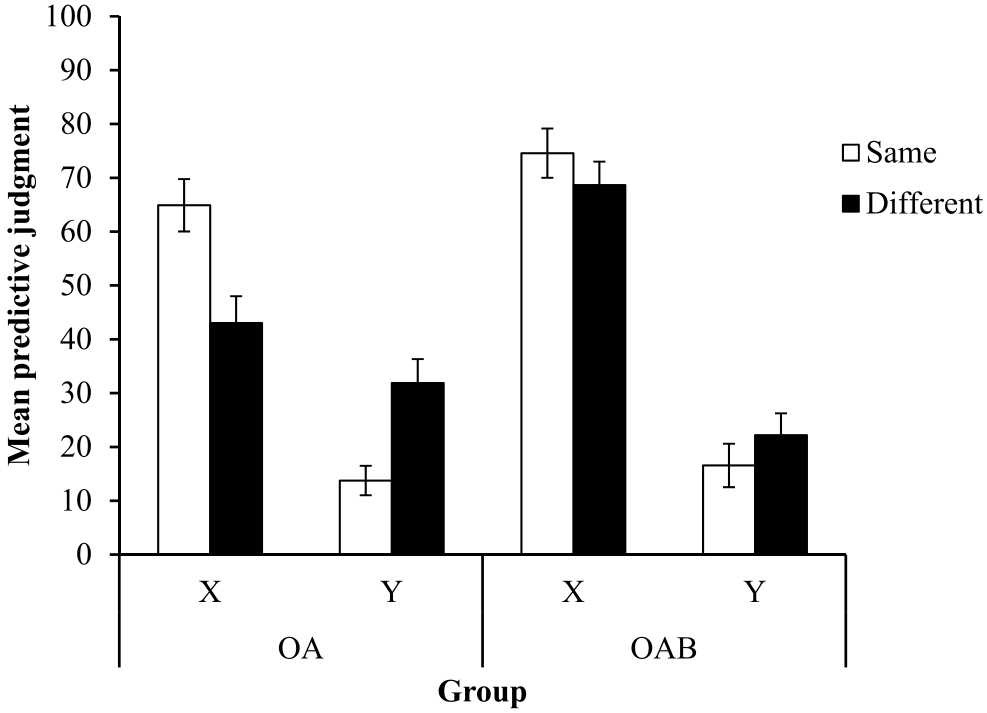
Mean predictive judgment
4
18
Group
Same
Different

Figure 2


Mean predictive judgment
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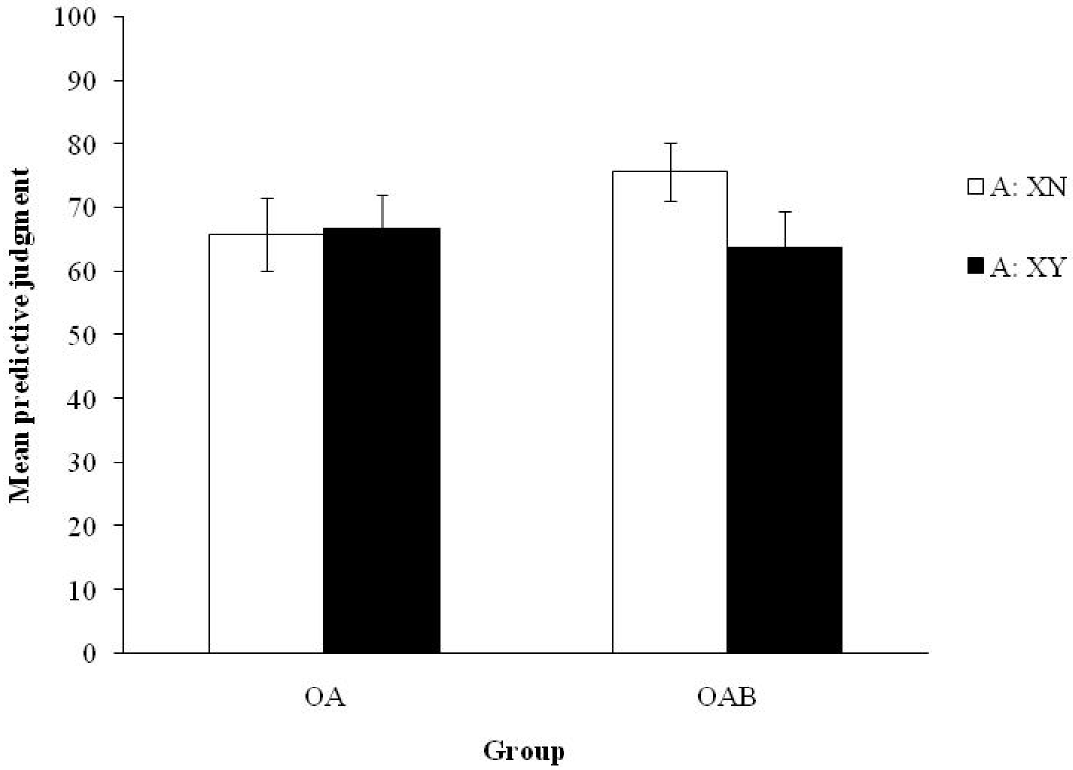
X
Y
X
Y
OA
OAB
Group
Same
Different

Figure 3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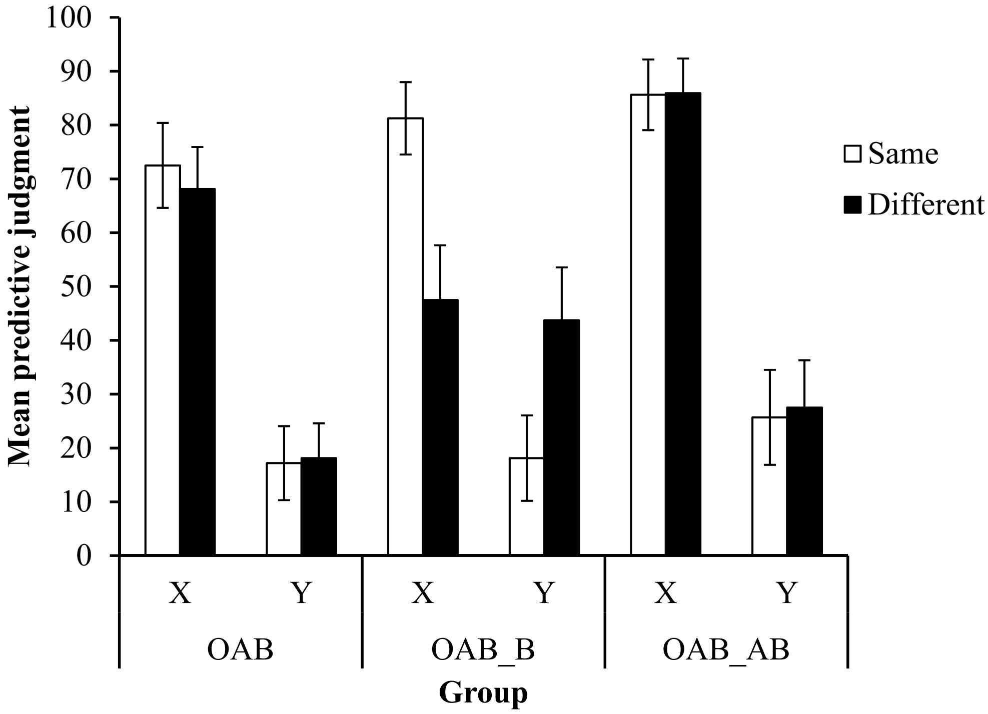
Mean predictive judgment
OA
OAB
Group
A: XN
A: XY

Figure 4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Mean predictive judgment
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OAB_B
OAB_AB
Group
Same
Different