Escritos de Psicología
2008, 2-1: 65-73

LA RECUPERACIÓN DE RELACIONES SIMPLES CLAVE-CONSECUENCIA ES ESPECÍFICA DEL CONTEXTO EN CONTEXTOS INFORMATIVOS

RETRIEVAL OF SIMPLE CUE-OUTCOME RELATIONSHIPS IS CONTEXT-SPECIFIC WITHIN INFORMATIVE CONTEXTS

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Resumen Se realizó un experimento en aprendizaje predictivo humano con el objetivo de explorar el papel del valor informativo del contexto donde se aprende la información sobre la dependencia contextual de la actuación. Tres grupos de participantes recibieron entrenamiento en una discriminación entre dos claves (X e Y) mientras otra clave (Z) siempre fue seguida de la consecuencia en el contexto A. En el contexto B la discriminación se invirtió en el grupo I (informativo). El grupo NI1 recibió la misma discriminación X-Y en el contexto B, mientras el grupo NI2 no recibió entrenamiento con X e Y en el contexto B. La extinción subsiguiente de Z fue más rápida en el contexto B que en el contexto A en el grupo I, mientras que no se encontraron diferencias entre contextos en los grupos NI1 y NI2. Estos resultados sugieren que los participantes codifican información independiente del contexto como dependiente del mismo cuando los contextos son relevantes para resolver la tarea.

Palabras clave Efectos de cambio de contexto, extinción, atención, aprendizaje predictivo humano, renovación.

Abstract An experiment in human predictive learning was conducted with the goal of exploring the role of the informative value of the context where the information is learned on context dependency of performance. Three groups of participants received training on a discrimination between two cues (X and Y) while another cue (Z) was always followed by the outcome in context A. Discrimination was reversed in context B for group I (informative). Group NI1 received the same X-Y discrimination, while Group NI2 did not receive training with X and Y in context B. Subsequent extinction of Z proceeded faster in context B than in context A in group I, while no differences across contexts were found in groups NI1 and NI2. These results suggest that participants code context-independent information as context dependent when contexts are relevant for solving the task.

Key words Context-switch effects, extinction, attention, human predictive learning, renewal.

The impairment on performance when the test context is different from the acquisition context is a well-known phenomenon within both human and animal learning literatures (e.g., Baddeley, 1992; Bouton, 1993; Tulving & Osler, 1968). One of the most studied instances of this phenomenon is the renewal effect (Bouton & Bolles, 1979). When animals are trained in a situation in which the same cue is sequentially followed by an outcome in context A (acquisition), and then by a different outcome in context B (interference), returning to the acquisition context during the test renews performance according to the acquisition phase (ABA renewal, Bouton & Bolles, 1979; Rosas & Bouton, 1998). Similar results are obtained when acquisition and interference are conducted in context A, and the test is conducted in context B (AAB renewal, Bouton & Ricker, 1994; Rosas & Callejas-Aguilera, 2006; Rosas, García-Gutiérrez, & Callejas-Aguilera, 2007), and when acquisition, extinction and testing are conduced in three different contexts (ABC renewal, e.g., Pineño & Miller, 2004; Thomas, Larsen, & Ayres, 2003). The combination of the different instances of renewal shows that performance developed during the interference phase is more context dependent than performance developed during the acquisition phase. Accordingly, Bouton (1993) gathers a large number of examples in which simple excitatory conditioning is not context dependent, while performance according to the interference treatments depends on the test conducted in the same context in which such interference treatments were conducted. Similar results may be observed in human predictive and causal learning (e.g., Paredes-Olay & Rosas, 1999; Rosas, Vila, Lugo, & López, 2001). However, simple cue-outcome positive relationships also have been reported to be context dependent in some occasions (e.g., Bonardi, Honey & Hall, 1990; Hall & Honey, 1989, 1990).

Given these mixed results, the question that needs to be answered is what makes the information context-specific in some situations, while in other situations performance is the same regardless of the test context. The original explanation given by Bouton (1993), suggesting that both, inhibitory information (preventive cues) and the second information that is learned about the same cue (see Nelson, 2002) are more context dependent than excitatory (generative cues) or first-learned information has important shortages, as it is not able to explain why excitatory information is sometimes context-dependent, and sometimes it is not. A similar problem affects Bouton (1997) idea that ambiguity leads animals to pay attention to the context where ambiguous information is learned, so that ambiguous information is coded within the context in which it is presented (see also Darby & Pearce, 1995). This idea does not allow explaining why non-ambiguous information (excitatory information) is context-specific in some situations.

On trying to solve this problem, Rosas and his colleagues took up Bouton's (1997) idea of ambiguity raising the attention animals pay to the context where ambiguous information is learned, suggesting that attention is the essential factor that makes information context-specific. According to Rosas and his colleagues, whenever participants are paying attention to the learning context, performance will be context dependent, regardless of the type of information involved (Rosas, Callejas-Aguilera, Ramos-Álvarez, & Abad, 2006; c.f. Bouton, 1993, 1997; Darby & Pearce, 1995; Nelson, 2002). Essentially, if anything in the situation leads participants to orient their senses to the context, everything within that context will become context specific.

According to Rosas, Callejas-Aguilera et al. (2006) there are at least five manipulations that would modulate the attention participants pay to the context: a) The ambiguity on the meaning of the cues prompted by interference should raise attention to the contexts (e.g., Rosas, García-Gutiérrez, & Callejas-Aguilera, 2006; Rosas & Callejas-Aguilera, 2006, 2007; but see Nelson & Callejas-Aguilera, 2007); b) An increase in the relative salience of the context with respect to the cues should favour attention to the contexts with respect to the cues (see Abad, Ramos-Alvarez, & Rosas, 2008; Bouton & Sunsay, 2001); c) Experience with the context and the task; it is assumed that irrelevant contexts will be attended at the beginning of training, when participants do not have enough information about the task as to discard the context; alternatively, attention to irrelevant contexts is assumed to decrease as training progresses and participants learn about the cue-outcome relationships (Myers & Gluck, 1994; León, Abad, & Rosas, 2009); d) Receiving instructions that draw or withdraw attention to the context is assumed to increase or decrease context specificity of the information(e.g., Eich, 1985; but see also Neumann, 2007). Finally, e) Giving the context informative value is assumed to increase context-specificity of the information.

Recent research in our laboratory has explored the influence of this later factor on context specificity of the information. Based on an experiment conducted by Preston, Dickinson, and Mackintosh (1986, Experiment 2) using an instrumental discrimination in rats, León, Abad, and Rosas (2008) conducted an experiment with the goal of assessing the impact that the informative value of the context where the information is learned has on the context specificity of performance.

Using a variation of the task developed by Gámez & Rosas (2005, 2007) participants were trained on an instrumental task within a computer game in which they had to defend different beaches of Andalucía (contexts) destroying several attackers by clicking on them (responses). Three groups of participants received training on a discrimination between two discriminative stimuli (X and Y) while responding in the presence of another discriminative stimulus (Z) was always followed by the same reinforcer in context A. Discrimination was reversed in context B for group Informative. Group Non-Informative 1 received the same X-Y discrimination in context B. Up to this point, the design of León et al. (2008) was basically the same that the design used by Preston et al. (1986). However, this design does not allow to differentiate whether the context-switch effect is prompted by the informative value given to the context in group Informative, or whether the lack of context-switch effect in group Non-Informative 1 was produced by the training of the same discrimination across contexts leading participants to ignore the contexts, reducing the context-switch effect that would have appeared were the informative value of the contexts neutral. To avoid this confound, León et al. (2008) added a third group to their design, group Non-Informative 2. In this latter group X-Y was not presented in context B, being substituted by the discrimination between two new stimuli. A single test trial with Z revealed lower response rate in context B (a familiar context where Z was never presented before) than in context A in group Informative. No differences across contexts were found in the two control groups.

The two experiments in the literature in which the role of the informational value of the contexts on context-specificity of stimuli that do not affect contexts' informative value were conducted within instrumental situations in which animals and participants had control of the reinforcer. The main goal of the experiment presented here was to extend the exploration of the role of manipulating the informative value of the context on the context-switch effect to a human predictive learning situation akin to classical conditioning in the sense that the presence of the outcome is arranged by the experimenter, and does not depend on participants' behaviour. This exploration would allow for extending the generality of the effect, not only across species, but across different tasks with different cognitive requirements.

Participants confronted a situation where they had to predict whether different cues (food names) were followed by an outcome (diarrhoea) in different contexts (restaurants) (see García-Gutiérrez & Rosas, 2003). Experimental design was similar to the one used by León et al. (2008), and it is presented in Table 1. Three groups of participants were trained on a discrimination between X and Y in context A (X+, Y-). Additionally, they received training with a cue consistently followed by the outcome in the same context (Z+). For group informative (I) meanings of X and Y were reversed in context B (X-, Y+). Two non-informative (NI) control groups were used. Group NI1 was similar to the control group in the experiment conducted by Preston et al. (1986), with X and Y receiving the same treatment in contexts A and B. Finally, for group NI2 X and Y were presented only in context A. Filler cues were presented to ensure that experience with the outcome was the same across contexts and groups. A test was conducted where Z was presented in extinction within the training context or within a different but equally familiar context. The key question in this experiment was whether context specificity of Z depended on whether the context where Z was trained was relevant to solve the task as Rosas, Callejas-Aguilera et al. (2006) suggest.

METHOD

Participants

A hundred and two undergraduates from the University of Jaén took part in this experiment in exchange for course credit. They were between 18 and 25 years old, and had no previous experience with this task. Approximately 75% were women and 25% were men. Data from 30 participants were eliminated (7 in group I, 11 in group NI1, and 12 in group NI2) because their performance did not differ between the beginning and the end of training on any of the cues that were followed by the outcome, indicating no learning (or no motivation) at all during their participation in the experiment. Participant's assignment to the groups was random.

Apparatus and stimuli

The experiment was implemented in 5 PCs with SuperLab Pro (Cedrus Corporation) software. All stimuli and instructions were presented in Spanish.

Food names were chosen from the pool selected by García-Gutierrez & Rosas (2003). Garlic, cucumber and eggs were counterbalanced as cues X, Y and Z. The outcome (+) was a gastric problem (diarrhoea) or the absence of it (-). Two fictitious restaurants (The Canadian Cabin, and The Swiss Cow) were counterbalanced

across participants as contexts A and B. Four additional cues, F1, F2, F3 and F4 (corn, caviar, tuna fish and grouper, respectively), were used as fillers with the goal of equating outcome experience across contexts.

Each trial counted with a cue screen and a feedback screen. On the top of the stimulus 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. On top of the scale, beginning on zero, finishing in 100, and equally separated from each other appeared the words "None", "Little", "Quite" and "Great", respectively, written in bold font. In the bottom corner of the screen appeared a button that 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 (diarrhoea) or the absence of it (nothing) were presented in capital letters and black fonts, diarrhoea in red colour 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 food appeared in capital letters in a cobalt blue font. The name of the restaurant "The Swiss Cow" appeared within a yellow oval. The rest of the text appeared in black fonts. Screen background was white.

Procedure

Participants were individually tested in a 40 min session. Instructions were presented in 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 instructions screen.

(1st screen). "Recent developments in food technology lead to chemical synthesis of food. This creates a great advantage as its cost is very low, and it is easy to store and transport. This revolution in the food industry may solve hunger in third world countries. (2nd screen). However, it has been detected that some foods produce gastric problems in some people. For this reason we are interested in selecting a group of experts to identify the foods that lead to some type of illness, and how it appears in each case. (3rd screen). You are about to receive a selection test where you will be looking at the files of persons that have ingested different foods in a specific restaurant. You will have to indicate whether gastric problems will appear. (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 this point, participants had to call the experimenter that continued giving the instructions by demonstration. The demonstration screen was identical to the screens used during training, with the exception that a new cue (pasta) was presented as predictor. For half of the participants, demonstration trial took place in context A, and for the other half took place in context B.

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 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 independently of the chosen option, participants received a 1500 ms feedback screen indicating the problem the person had (diarrhoea o nothing). The inter-trial interval was 1500 ms and it was indicated by a screen with the sentence "Loading file of… (a ran-

TABLA 1

EXPERIMENTAL DESIGN

GROUP	TRAINING	TEST
I	A: X+, Y-, Z+, F2 B: X-, Y+, F1+, F2-	A: Z-, F2+ or B: Z-, F2+
NI1	A: X+, Y-, Z+, F2- B: X+, Y-, F1+, F2-	A: Z-, F2+ or B: Z-, F2+
NI2	A: X+, Y-, Z+, F2- B: F3+, F4-, F1+, F2-	A: Z-, F2+ or B: Z-, F2+

Note: Relevant treatments are written in bold font. Garlic, cucumber and eggs were counterbalanced as cues X, Y, and Z. Fillers F1, F2, F3, and F4 were corn, caviar, tuna fish and grouper, 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. X and F3 played the role of S1, while Y and F4 played the role of S2. See text for details.

domly 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 Table 1.

Training

Four training blocks were conducted in each context. Four trials of each cue-outcome combination were presented in each block, leading to a total of 16 trials per block and context that were presented in random order. Each context change was preceded by the sentence "Now you should analyze the files of people that ate at restaurant… (Restaurant´s name)." This screen was presented for 3000 msec. The order in which those training blocks with each context were presented to participants was counterbalanced intra and across participants. (ABBABAAB or BAABABBA). All participants received the same treatment in context A, with X and Z being followed by the outcome, while Y and F2 were not followed by it. Groups differed on the treatment received in context B. In group I, X and Y reversed their relationship with the outcome with respect to the relationship they kept in context A. In group NI1, relationship between X and Y and the outcome was the same in context B that it was in context A. Finally, in group NI2, X and Y were not presented in context B. Cues F1, F2, F3, and F4 were included as fillers, to ensure that the two contexts were equally paired with the presence and the absence of the outcome.

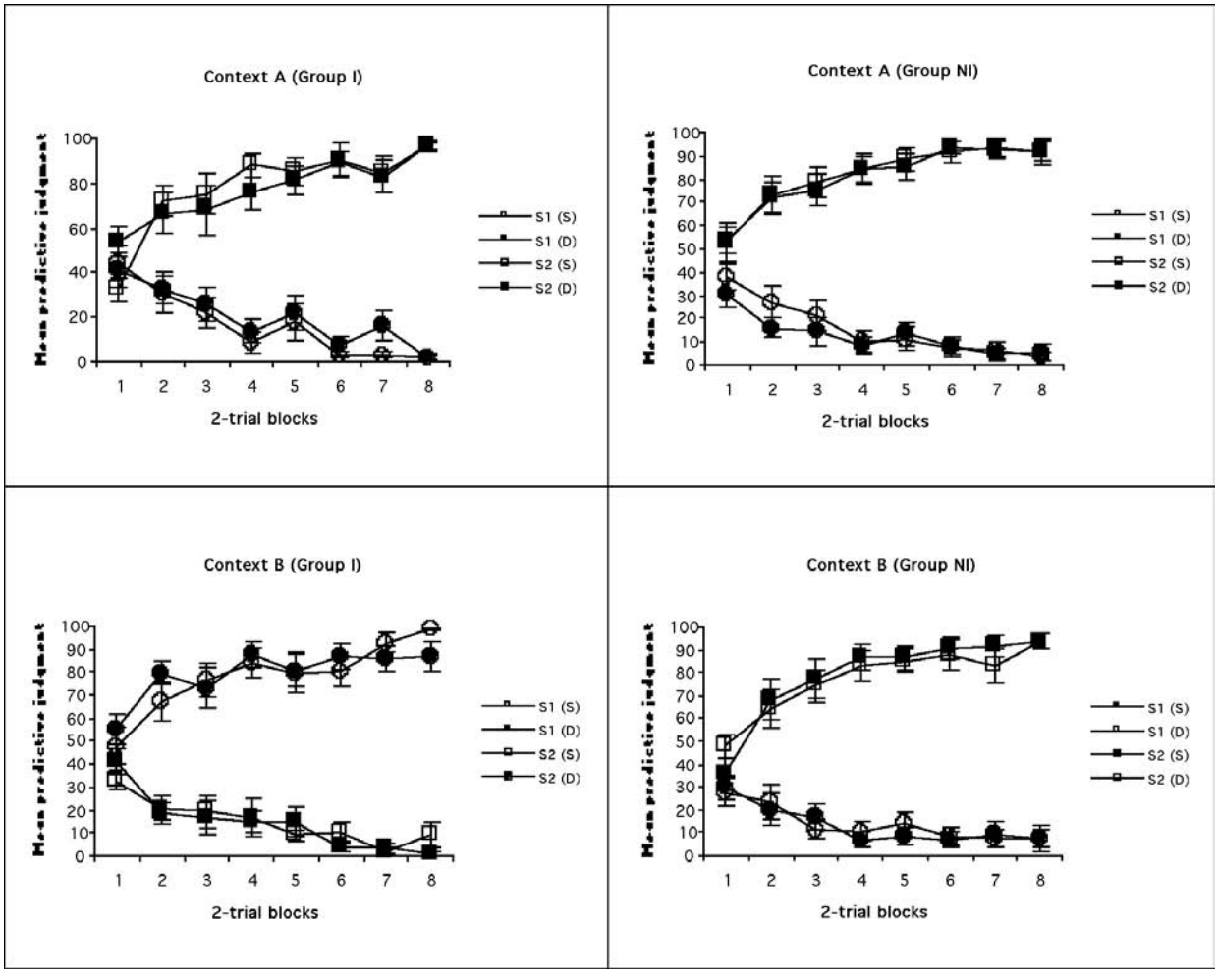

Figure 1. Mean predictive judgments given to the two target stimuli (S1 and S2) during discrimination training in contexts A (top row) and B (bottom row), in groups I (left column) and NI (right column) as a function of whether participants were going to receive the subsequent test with Z in context A (S), or in context B (D) across the 8 2-Trial blocks of training. Error bars denote standard errors of the mean.

Test

The change of phases was not signalled. Participants received 6 extinction trials with Z- and 6 trials with F2 followed by the outcome, randomly intermixed. Half of participants in each group received the test in context A (Same), and the other half in context B (Different).

Dependent variable and statistical analysis

Predictive judgments were requested throughout training and testing. A significance level of .05 was established for all statistical tests reported here.

RESULTS

To simplify the presentation of the results, preliminary analyses were conducted comparing performance of the control groups (NI1 and NI2) throughout acquisition and testing. Note that participants in group NI2 did not receive training with X and Y in context B. With the aim of comparing performance in the two groups, F3 and F4 were treated as target cues (X and Y) in that group. None of the analyses involving group as a factor revealed significant differences, largest $F(7, 308) = 1.72$ (MSe = 212.37). Accordingly, data from the two control groups were pooled in all the subsequent analysis.

Figure 1 presents the mean predictive judgments given to the two target stimuli (S1 and S2) during discrimination training in contexts A (top row) and B (bottom row), in groups I (left column) and NI (right column) as a function of whether participants were going to receive the subsequent test with Z in context A (S), or in context B (D) across the 8 2-Trial blocks of training. A 2 (Group) x 2 (Test context) x 2 (Acquisition context) x 2 (Target) x 8 (Block) found a significant 4-way interaction between Group, Acquisition context, Target and Block, $F(7, 476) = 41.65$ (MSe=283.92). No effect or interaction involving Test context was significant, largest $F(7, 476) = 1.01$ (MSe=257.71).

Subsequent analyses conducted to explore the 4-way interaction focused on the first and last block of training. The Group x Acquisition context x Target interaction was not significant at the beginning of training, in Block 1, $F<1$, but it was significant at the end, in Block 8, $F(1, 70) = 2337.45$ (MSe=56.41) revealing the influence of the training treatments. Analysis isolating the two levels of the group factor in Block 8 found that the Acquisition context x Target interaction was significant in group I, $F(1, 23) = 1473.75$ (MSe=135.60), in which the meaning of the target cues was reversed across contexts, but it was not significant in group NI, $F<1$. Finally, the simple effect of Target in group I was significant in both acquisition contexts, Smallest $F(1, 23) = 434.72$ (MSe=212.86). However, inspection of Figure 1 shows that the simple effect of Target in context A reflects high judgments for target cue S1 and low judgments for target cue S2, while the contrary is true in context B. In summary, discrimination was effective in group I by the end of training, with participants judging the specific relationship between the target cues and the outcome depending on the context of training.

Figure 2 presents the mean predictive judgments given to cue Z across the 8 2-trial blocks of training in context A in groups I and NI as a function of whether participants were going to receive the test in the same context of training (S) or in a different context (D). A 2 (Group) x 2 (Test context) x 8 (Block) ANOVA found a significant main effect of Block, $F(7, 476) = 2.32$ (MSe=238.69). No analyses involving Group as a factor were significant, largest $F(7, 476) = 1.56$ (MSe=238.69). Thus, participants learned about the relationship between Z and the outcome regardless of the group.

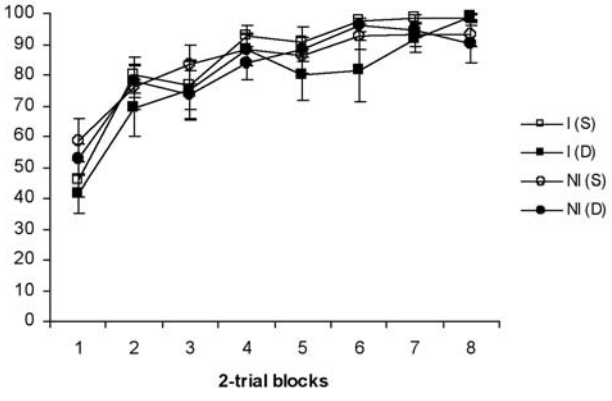

Figure 2. Mean predictive judgments given to cue Z across the 8 2-trial blocks of training in context A in groups I and NI as a function of whether participants were going to receive the test in the same context of training (S) or in a different context (D). Error bars denote standard errors of the mean.

The most interesting results of this experiment are presented in Figure 3. This figure presents the mean predictive judgments to Z during the 6 extinction trials of testing in groups I (left) and NI (right) as a function of whether the test was conducted in the same context of training (S) or in a different context (D). A 2 (Group) x 2 (Test context) x 6 (Trial) ANOVA found a significant Group x Test context x Trial interaction, $F(5, 340) = 3.52$ (MSe=585.51).

Subsequent analyses isolating I and NI groups found that the Group x Test context interaction was significant in group I, $F(5, 110) = 6.35$ (MSe=579.38), but it was not significant in group NI, $F < 1$. Within group I, this interaction appeared because the simple effect of

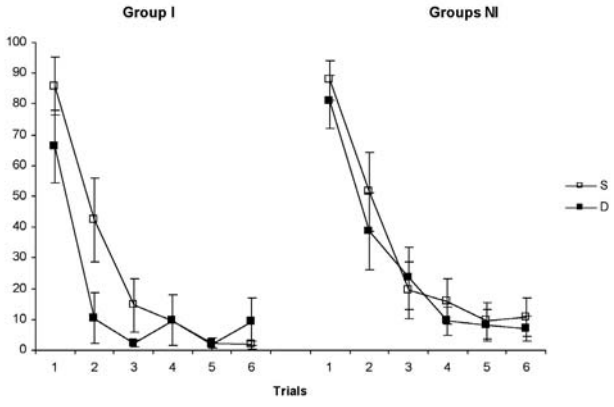

Figure 3. Mean predictive judgments given to cue Z during the 6 extinction trials of testing in groups I (left) and NI (right) as a function of whether the test was conducted in the same context of training (S) or in a different context (D). See text for details.

context was significant in test Trials 1, $F(1, 22) = 4.75$ (MSe=938.99), and 2, $F(1, 22) = 21.17$ (MSe=992.23). No context effect was detected after trial 3, largest $F(1, 22) = 2.10$ (MSe=447.54).

In summary, participants judged a lower predictive relationship between Z and the outcome when the test was conducted outside the training context in group I. No differences across contexts were found in group NI.

DISCUSSION

This experiment was conducted with the goal of exploring whether the results reported by Preston et al. (1986) and León et al. (2008) about the role of the informative value of the context where the information is learned on context dependency of performance could be extended to a situation in which the presence of the outcome would not depend on participants' behaviour. Similarly to what was reported by León et al. (2008), expression of learning about a cue that was consistently paired with the outcome was context specific when it was learned within a context that was made informative by reversing the discrimination between two different cues across contexts (group I). As in León et al. (2008), no effect of context change was detected in non-informative contexts (groups NI).

These results replicate the results reported by Preston et al. (1986) and by León et al. (2008), extending them to a non instrumental situation in which the presence of the outcome is determined by the experimenter, rather than by participant's behaviour. Additionally, previous experiments involved learning of hierarchical relationships in which solving the task implying participants learning that the relationships between responses and outcomes depended on the presence of a specific discriminative stimulus. In those tasks, contexts would play the role of modulating these hierarchical relationships. The present experiment shows that the same effect may be found when a simpler situation is used, in which contexts modulate simple cue-outcome relationships. This result points out to the generality of the influence of the informational role of the contexts on context-specificity of the information.

Results reported here are in agreement with the proposal of Rosas, Callejas-Aguilera et al. (2006). These authors suggest that context switch effects will be obtained whenever participants pay attention to the context while the target information is learned (c.f., Bouton, 1993, 1997; Nelson, 2002). Note that this experiment does not allow for a direct measure fo the attention that is supposed to be drawn by informative contexts. Attention to the context is indirectly deducted from context specificity of the information. It is presumed that such attention to the contexts increased when contexts had informational value, so that all the information learned in those contexts became context specific. Similarly, this experiment is silent with respect to the specific mechanism regulating context-specificity of the information once attention is paid to the context. As contexts are equally paired with the outcomes, it could be assumed that the most likely mechanism regulating context-switch effects in this situation is either a hierarchical one (e.g, Bouton & Swartzentruber, 1986) or a configurational one (e.g., Pearce, 1987), but nothing in these data allows for choosing between these two alternative mechanisms.

Additional research should explore the direct effects of the informative value of the contexts on the attention participants pay to them, and what is the specific mechanism involved in context-specificity of the information. At any rate, results as the one reported in this paper encourage pursuing the exploration of how different factors that increase or decrease the attention to the contexts may affect context specificity of the information.

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This research was financially supported by Junta de Andalucía, Spain, Research Grant HUM642, and by the Spanish Ministerio de Educación y Ciencia and FEDER funds (SEJ2007-67053PSIC).