The effect of context change on simple acquisition disappears with increased training

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The goal of this experiment was to assess the impact that experience with a task has on the context specificity of the learning that occurs. Participants performed an instrumental task within a computer game where different responses were performed in the presence of discriminative stimuli to obtain reinforcers. The number of training trials (3, 5, or 8) with each discriminative stimulus varied between participants. A single test trial was conducted in the context where training occurred or in a different but equally familiar context. The change in context attenuated performance in participants that received 3 training trials, but not in the others, suggesting that the influence of context on performance decreases when training increases.

Learning about stimuli and responses never occurs in a vacuum. Rather, there is always a set of stimuli in the background, largely incidental to the task, that provide a context. Although incidental to the task, changes in that background have been found to cause losses of learned performance across a variety of different tasks and animal species (e.g., Paredes-Olay & Rosas, 1999; Pineño & Miller, 2004; Rosas, García-Gutiérrez, & Callejas-Aguilera, 2007; Rosas, Vila, Lugo & López, 2001; see Bouton, 1993 for a review). This apparent failure of learning to transfer across contexts suggests that in some situations learned information may be coded with the context and be context dependent.

Bouton (1993, 1994, 1997) suggested that contexts may come to control the retrieval of learned information depending on the nature of the

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information that is learned.   He suggested that inhibition is a type of information that might inherently be contextually dependent, and that any information acquired as a second-meaning attached to a stimulus might also be contextually dependent.   These two situations, learning of inhibition or attaching a second meaning to some stimulus, might encourage the coding of the contextual information. Subsequent work (Bouton & Nelson, 1994; Nelson & Bouton, 1997; Nelson, 2002) has failed to demonstrate that information which can be characterized as inhibitory is inherently context dependent. Nelson (2002) as well as Nelson and Callejas-Aguilera (2007), have demonstrated that the meaning of cues becomes especially context dependent when those meanings are the second meanings attached to a stimulus, and interfere with ones learned earlier. For example, Nelson (2002) found that excitatory conditioned responding to a tone that had been paired with food, which ordinarily transfers robustly across contexts (Bouton & Nelson, 1994; Nelson & Bouton, 1997; Brooks & Bouton, 1993), was attenuated when the tone had previously been a signal for the absence of food.

Approaches that focus on the specific features of information (i.e., inhibitory or second-learned) and situations in which those features are acquired as determinants of contextual control confront difficulty in explaining situations in which information that is neither inhibitory nor second-learned has been found to be context dependent (e.g., Bonardi, Honey, & Hall, 1990; Hall & Honey, 1989, 1990; Rosas & Callejas-Aguilera, 2006, 2007). Rosas and Callejas-Aguilera (2006) suggested that the situations where second-learned information is acquired are situations that might serve to arouse attention to the context. Such features of the situation could encourage participant's attention to contextual stimuli leading those stimuli to be processed at the time of learning about discrete stimuli, resulting in context dependency of that learning.

To illustrate, Rosas and Callejas-Aguilera (2006) used a symptom-disease type paradigm where participants learned, in a fictitious situation, that some clients in a restaurant suffered diarrhea after eating garlic. This type of simple first-learned information transferred perfectly across experimental contexts (restaurants). Later, they learned that eating garlic did not produced diarrhea anymore. This second–learned information was highly context dependent. They only treated garlic as if it would be a safe food in the context where that information was learned. Of interest, while they were learning new information about the garlic, they were also learning that cucumbers produced diarrhea. This was a simple type of first learned information, yet it was being learned while something new about

the garlic was being learned, and it was likewise context dependent. It is as if the situation created by learning something new about garlic led participants to attend to the contexts resulting in even simple unambiguous first-learned information being context dependent (see also Rosas, García-Gutiérrez, & Callejas-Aguilera, 2006; Rosas & Callejas-Aguilera, 2007).

Rosas and Callejas-Aguilera (2006) directly suggested that learning new information about a cue would lead participants to attend to the context. Along with that, Rosas, Callejas-Aguilera, Ramos-Álvarez and Abad (2006) suggested four other factors which should modulate attention to contextual stimuli, and thus the context dependency of information learned within the context. First, experience with the context and the task should matter. According to Myers and Gluck (1994), experience will matter as attention to the contexts is supposed to decrease as the predictive value of the cue increases (see also Mackintosh, 1975). Second, instructions to human participants may affect context coding (e.g., Eich, 1985; see also Bouton, 1993). Third, attention should be affected by whether the contexts are informative in solving the task such as when they bear a direct discriminative relationship to an outcome (e.g., Preston, Dickinson, & Mackintosh, 1986), and fourth, the relative salience of the context with respect to other more discrete stimuli should affect attention directed to it.

The experiment presented here was designed to assess the role of experience with the contexts and task on the context dependency of learned information. Information that is relevant to solving a task is unknown at the beginning of training, thus participants may attend to, and code, irrelevant contextual information early in training but not later. This assumption is consistent with both Mackintosh (1975) and Kruschke (2001), who suggested that attention to irrelevant stimuli decreases over training while attention to relevant stimuli increases. Thus the effect of experience with the context and task should have an inverse relationship with the contextual control of learned information. Early in training when attention to contexts is high, more contextual dependency should be observed than later in training when attention to the context should have decreased.

Prior experiments on this exact question are contradictory. Hall and Honey (1990), using a conditioned emotional response task (Estes & Skinner, 1941) gave rats training in two contexts. In context A, stimulus X was paired with foot shock while in Context B stimulus Y was paired with foot shock. Extinction with these stimuli took place either in the context where it was trained, or in the other context. In the critical experiment (Experiment 3) rats received either one or eight training trials. Conditioned responding to the X and Y stimuli was attenuated when testing was

conducted in a different context, but only in the group that had received one training trial. Thus, these findings are in accord with our hypothesis.

Bonardi, Honey and Hall (1990) report results in a conditioned taste aversion study that appear to be contrary to the findings just discussed. Rats received pairings of salt or acid with lithium chloride induced illness in two different contexts, respectively. Then, they received extinction of these stimuli either in the context where the pairings occurred or in the different context. Despite a trend for a loss of the conditioned aversion when the flavors were tested in contexts different from where the aversion was acquired, the aversion was statistically the same in the two contexts. In a second experiment rats received five pairings of the flavors with illness, and in this case the conditioned aversions were context dependent. The aversion was statistically stronger when the flavors were tested in a different context than where the aversions were acquired. Though these overall results seem at odds with those discussed in the previous paragraph, any conclusions regarding the effect of the number of training trials is tenuous at best as it relies on a cross experiment comparison.

As we have seen in previous paragraphs, the scarce experiments that have dealt with this issue in the literature were conducted with Pavlovian conditioning procedures in animals. With the goal of extending the exploration of these phenomena to a different task and species, the experiment reported here used a human instrumental conditioning task. Participants played a computer game (Gámez & Rosas, 2005; 2007; see also Paredes-Olay, Abad, Gámez, & Rosas, 2002) where they received training with four stimuli in two contexts. In the task, they were required to defend Andalusia against invasion by shooting missiles at tanks or planes by clicking on their respective pictures (R1 and R2). Which attacker could be destroyed was signaled by a coloured sensor (discriminative stimulus) at the top of the screen (see Figure 1). Training was conducted in different contexts provided by background images of natural scenery found in Andalusia.

The design of the experiment is presented in Table 1. Participants received instrumental discriminative training in which giving a specific instrumental response (R1 or R2) in the presence of a discriminative stimulus (e.g. X) provided a reinforcer (O1 or O2) in different contexts. Responding with R1 in the presence of the target discriminative stimulus (X) was reinforced with O1 (X:R1-O1) in context A. Three additional stimuli were used to ensure that participants had equivalent experience with contexts A and B, and with the outcomes within each context (A: Y:R2-O2, and B: Z:R1-O1, R:R2-O2). The test was conducted with X in the same

Pre-Stimulus

Discriminative Stimulus (i.e., X)

Participant CLIKS on the plane (i.e., R1)

Participant DOES NOT CLICK on the plane
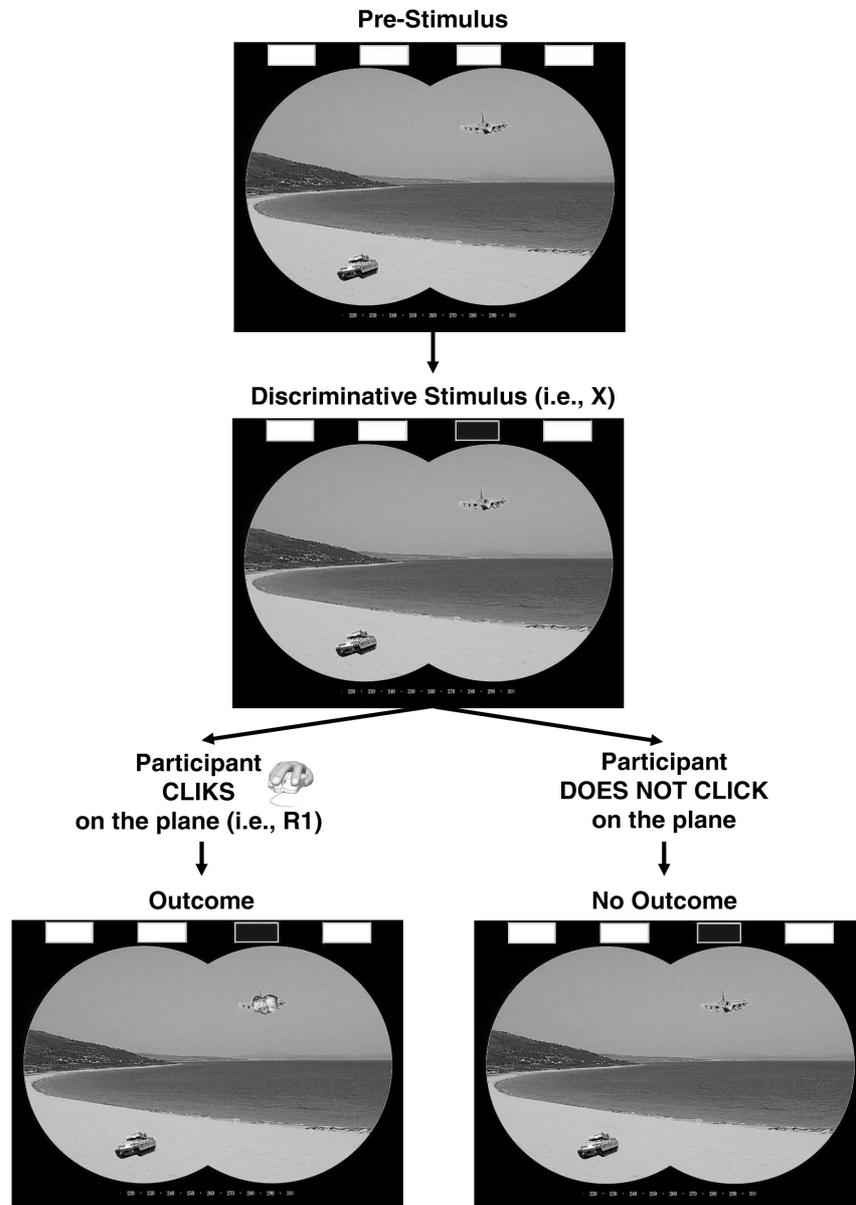
Outcome

No Outcome

Figure 1. Example of trial. The top section presents the Pre-stimulus period. Plane and tank are presented on the context (natural beach of Tarifa in this case) but no response is reinforced. The middle section presents the Stimulus period. Discriminative stimulus lights on and responding in the correct attacker produces reinforcement, while not responding or responding in the alternate attacker does not lead to reinforcement (bottom).

context in which it was trained (context A), or in a different context (context B). Groups differed in the number of training trials with each discriminative stimulus (3, 5, or 8) and in the context in which the test was conducted (Same or Different –S or D). Pilot experiments had revealed that with less than 3 training trials not enough learning was developed as to allow detecting any deleterious effect of context switch. Additionally, those experiments suggested that context-switch effects were no longer present when the number of trials was increased over 8. Given these previous results, in the experiment reported here we included a training level half way between 3 and 8 with the goal of beginning the exploration of the level of training required to eliminate the context-switch effect in this task. As the median between 3 and 8 falls between 5 and 6, we decided to use 5 training trials with the hope of maximizing the possibilities of detecting the context-switch effect.

Context dependency should be observed as a decrease in the rate of correct responses (R1) in the presence of X when it is presented in context B (Different) than when X is presented in context A (Same). According to Rosas, Callejas-Aguilera et al. (2006, se also Kruschke, 2001; Mackintosh, 1975), an inverse relationship between context dependency and the number of training trials should be observed. As the number of training trials increase, context dependency should decrease.

METHOD

Participants. Participants were 72 students from the University of Jaén (approximately 65% were women). They were between 18 and 26 years old and had no previous experience with this task.

Apparatus and stimuli. Participants were trained individually in three adjacent isolated cubicles. Each cubicle contained a Pentium PC on which the task was presented. The procedure was implemented using the SuperLab Pro (Cedrus Corporation) software.

The task was a variation of the task used by Gámez & Rosas (2005, 2007). Participants played a computer game in which they had to defend Andalusia from air and land attacks. The task is presented in Figure1. The main screen presented a black viewscreen simulating a control panel. On top of the screen there were four rectangles that could be coloured. Red, navy blue, light blue and grey colours were counterbalanced as discriminative stimuli X, Y, Z, and R. Contexts were presented within the viewing area of the viewer. Sceneries of different beaches of Andalusia,

Puerto Banús (urban beach, with tall buildings next to it) and Tarifa (natural beach, without buildings around), were counterbalanced as contexts A and B. The two attackers were a plane and a tank. The plane was presented on the sky, on the top right area of the context, while the tank was presented on the sand, in the bottom left area of the context. Both attackers could appear in one of two different positions within their respective areas on the context so that it would give the impression of movement to the participant. The instrumental response was clicking on either the plane or the tank (R1 and R2, counterbalanced). Destruction of the tank and the plane was counterbalanced as outcomes 1 and 2 (O1 and O2) across participants.

Table 1. Experimental design.

Group	Training	Test
3S	**A: 3X: R1-O1**, 3Y: R2-O2 / B: 3Z: R1-O1, 3R: R2-O2	**A: X**
3D	**A: 3X: R1-O1**, 3Y: R2-O2 / B: 3Z: R1-O1, 3R: R2-O2	**B: X**
5S	**A: 5X: R1-O1**, 5Y: R2-O2 / B: 5Z: R1-O1, 5R: R2-O2	**A: X**
5D	**A: 5X: R1-O1**, 5Y: R2-O2 / B: 5Z: R1-O1, 5R: R2-O2	**B: X**
8S	**A: 8X: R1-O1**, 8Y: R2-O2 / B: 8Z: R1-O1, 8R: R2-O2	**A: X**
8D	**A: 8X: R1-O1**, 8Y: R2-O2 / B: 8Z: R1-O1, 8R: R2-O2	**B: X**

Note. Groups' name shows the number of trials of training with each discriminative stimulus (3, 5 or 8) and whether the test was conducted in the same context of training (S) or in a different context (D). Red, Navy blue, light blue and grey sensors were counterbalanced as discriminative stimuli X, Y, Z and R. O1 and O2 represent the two outcomes (Plane or Tank destruction, counterbalanced). Contexts A and B were sceneries of different beaches of Andalucía (Puerto Banús and Tarifa), counterbalanced. R1 and R2: Clicking on the plane or the tank, counterbalanced. Target treatments are presented in bold.

Procedure. All participants gave their informed consent to participate in the experiment. The instructions and all necessary information were presented on the computer screen. Participants interacted with the computer using the mouse (left button). Instructions were presented in five screens using a black Times New Roman 26 bold font against a light yellow background to emulate the appearance of an old document. To advance the instruction screens the participant had to click on a button labeled as "next" placed on right bottom of the screen. Each participant was initially asked to read the following instructions (in Spanish):

> (Screen 1) Andalusia is being attacked. Different parts of Andalusia are being assaulted by land and air. You are placed in the only bunker able to face up the attackers. Your work consists of defending Andalusia. Use the mouse to launch missiles to the targets. You should destroy the attackers before they take over Andalusia. (Screen 2). The monitor represents the bunker's viewer, and the different attackers you should face will appear on it. Your technology and weapons are older than theirs, so you will need to shoot several times to destroy them. To shoot, click with the left button of the mouse while the pointer is on top of the target. (Screen 3) On top of the viewer there are several sensors. Each of those sensors will indicate that <u>only one</u> of the attackers is within your shooting range and can be destroyed by you. If the sensors are off, none of the attackers will be within the shooting range. (Screen 4) The battle begins! Remember that you can destroy only one attacker at any given time, so you will have to discover which one is currently within the shooting range. Remember not to waste the ammunition on the attackers that are beyond the shooting range. Call the experimenter if you have any doubts. Otherwise, click with the mouse to begin. GOOD LUCK!

Participants were randomly assigned to one of the 6 experimental groups (3S, 3D, 5S, 5D, 8S or 8D; see below for details) upon their arrival to the laboratory. The experiment was conducted in two phases (see design on Table 1).

Training. Half of the participants were first trained in context A and then in context B, and vice versa for the other half. The change of contexts was announced by a screen where the sentence "Your detachment has been posted to… (name of the beach where the battle continued)". This screen was presented for 2000 msec. Each participant received X:R1-O1 and Y:R2-O2 trials in context A, and Z:R1-O1 and R:R2-O2 trials in context B. Trial order within each context was random. Each trial was divided in Pre

and Stimulus periods (see Figure 1). During the Pre period, the tank and the plane were presented without the discriminative stimulus for 4 s (see top panel of Figure 1). Responding during this period was not reinforced. During the Stimulus period, the tank and the ship were presented accompanied by the relevant discriminative stimuli, depending on the trial (see middle panel of Figure 1). Correct responses were reinforced under a VI2 reinforcement schedule in which the availability of reinforcers oscillated randomly between 1 and 3 s. Once the reinforcer was available the trial continued until the participant gave the correct response. Participants were forced to choose the correct response to end the trial. Groups 3, 5, and 8 (S and D) received 3, 5, or 8 trials with each discriminative cue in each context, respectively.

Test. All participants received a single trial with X. No reinforcement was available during the test trials. Pre and Stimulus periods lasted 4 s each. Before the test trial the screen informing about the context was presented. Half of the participants received the test in context A (Same, groups S) and the other half received the test in context B (Different, groups D).

Dependent variable and statistical analysis

Total mouse clicks on each target were recorded and transformed to percentage of correct responses, taking appropriate response to the present target as a reference. Responding was evaluated by analysis of variance (ANOVA). The rejection criterion was set at $p < .05$.

RESULTS

All participants learned the relationship between the discriminative stimuli, the responses, and the outcomes by the end of training. Percentage of correct responses in the last training trial for the target discriminative stimulus (X) were 87.74 (6.01) in Group 3S, 82.86 (6.38) in Group 3D, 91.67 (5.75) in Group 5S, 94.17 (4.34) in Group 5D, 95.83 (4.17) in Group 8S, and 95.49 (3.30) in Group 8D (SEM is presented within brackets). A 3 (Training trials) x 2(Test context) ANOVA did not find any significant main effect or interaction, largest $F(2, 66) = 2.20$ (Mse = 314.01). Thus, by the end of training participants learned to give R1 in the presence of X, regardless of the level of training or the context in which the test was going to be conducted.

The most interesting results came from the test phase. Figure 2 depicts percentage of correct responses to X in both, the context in which it was

trained (Same) and the alternate context (Different) as a function of the training trials (3, 5, or 8). Percentage of correct responses was lower on the test than at the end of training. The reason for this is, in all likelihood, because the test was in extinction and when the correct response was not reinforced, participants engaged in the alternate response. A 3 (Training trials) x 2 (Test context) ANOVA found a significant main effect of Test context, $F(1, 66) = 5.48$ (Mse = 842.06). Most important the Training trials by Test context interaction was statistically significant, $F(2, 66) = 3.20$ (Mse = 842.06). The main effect of Training trials was not significant, $F<1$.
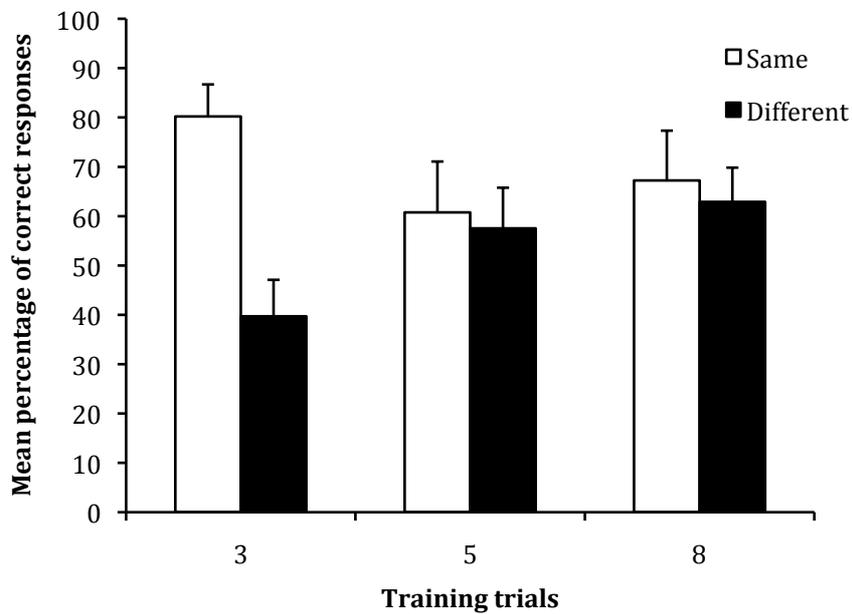

Figure 2. Percentage of correct responses in the presence of the target discriminative stimulus X during the test conducted in the same context where X was trained (Same), or in a different, but equally familiar context (Different) as a function of the training trials (3, 5, or 8). Error bars denote standard errors of the mean.

Subsequent analyses conducted to explore the two-way interaction found that the simple effect of Test context was significant only after 3 Training trials, $F(1, 22) = 17.00$ (Mse = 578.356), but it was not significant after 5 or 8 Training trials, $Fs < 1$. Thus, the deleterious effect of context

change on performance only appeared with low levels of training, disappearing when the level of training was increased.

DISCUSSION

In the present experiment we found that a change of context had a deleterious effect on responding controlled by a stimulus. That is, the apparent control of responding by the stimulus appeared context dependent. Of most importance, that context dependency was only evident after three training trials. After five or eight trials, no such dependency was observed. These results are in agreement with the results reported by Hall and Honey (1990) in rats' CER (see also Maes, Haverman, & Vosse, 2000; but see Bonardi et al. 1990), and show a remarkable parallel between human and animal data.

On the simplest approach, results could be explained as a generalization decrement. Perception of X may have changed in context B, decreasing X control over responding. As appealing as this simple explanation may be, it cannot account for the whole pattern of results. There is no reason to think that increasing training with X in context A should decrease generalization decrement. If anything, increasing training should increase X processing in context A, and generalization decrement should increase as well, rather than decrease.

Alternatively, the increase in training may have produced an increase in the differentiation between X and the context in which it appears (e.g., Gibson & Gibson, 1955). This increase in perceptual discrimination of X would make X to gain control on the target instrumental relationship. Accordingly, an inverse relationship between context dependency of learning and the amount of training given with a task would be expected. A similar conclusion, but focusing on the predictive power of the stimulus with respect to the outcome was anticipated by attentional theories of learning. Mackintosh (1975) suggests that attention to cues that are relatively poor predictors of outcomes decreases over training, making them less likely to control performance (see also Kruschke, 2001). Rosas, Callejas-Aguilera et al. (2006) applied this idea to the processing of contextual stimuli. From their perspective context dependency depends on whether participants attend to the context during training. Alternatively, context dependency should be lost when participants stop attending to the context. In the present design, the context was irrelevant to solving the task, thus initial levels of attention directed toward the context should decrease over training according to Mackintosh (1975). This decrease on attention does not imply a decrease on the associative strength (or, in more

general terms, the predictive power of the context) that would be gained by the context at the beginning of training. Increased training should affect only to α, the parameter that determines the associability of the context, decreasing it to zero. However, Mackintosh (1975) points out that decreases in α might make an stimulus to lose control over responding even when the associative strength of the stimulus is high "if a decline in α decreases the probability that this associative strength would be translated into performance" (Mackintosh, 1975; p. 288). Accordingly, context dependency should be observed early in training, but not later, as we found in the present experiment.

Though the results clearly show an inverse relationship between context dependency and training, they do not necessarily speak to the mechanism that accounts for the dependency observed early in training. Attentional theories such as that offered by Mackintosh (1975) assume that the attention would result in the contextual stimuli entering into direct associations with the outcomes (see for instance, Sansa, Artigas, & Prados, 2007). Context dependency observed would be the result of simply losing the contribution of the context to the associative activation of an outcome representation. As context were equally paired with the outcomes in the present experiment, the contexts would have been equally associated with the outcomes, thus a direct context-outcome association cannot account for the effect we observed on the test. It is also possible that the context entered into a hierarchical type of relationship with the cue and the outcome where it might modulate the learning that occurred between them. This type of hierarchical "Occasion Setting" role is a more likely explanation for the deleterious effect of a context change that we observed (e.g., Holland, 1983; applied to contexts see Bouton, 2004; Bouton & Swartzentruber, 1986). However, no definite conclusion about the underlying mechanism of the context switch effect in this situation can be established with the present data. Additional research should be conducted to clearly disentangle whether attention leads participants to use the context as a direct predictor of the outcome or as an occasion setter.

The present experiment adds to recent evidence suggesting that simple first-learned and unambiguous information can become context dependent and is consistent with the idea that attention to the context contributes to that dependency. The results indicate that context dependency is lost when the presence of other more reliable relationships lead participants to ignore the context over training, focusing on information relevant to solving a task.

RESUMEN

El efecto del cambio de contexto en la adquisición simple desaparece cuando se aumenta el entrenamiento. El objetivo de este experimento fue valorar el impacto que tiene la experiencia con una tarea en la especificidad contextual del aprendizaje. Los participantes realizaron una tarea instrumental en un juego de ordenador en el que se realizaban distintas respuestas en presencia de distintos estímulos discriminativos con el fin de obtener reforzadores. El número de ensayos de entrenamiento con cada estímulo discriminativo varió entre participantes (3, 5 u 8). Se realizó un ensayo de prueba en el mismo contexto donde había tenido lugar el entrenamiento o en un contexto distinto pero igualmente familiar. El cambio de contexto empeoró la actuación en los participantes que recibieron 3 ensayos de entrenamiento, pero no afectó al resto, sugiriendo que la influencia del contexto en la actuación decrece cuando se aumenta el entrenamiento.

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