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Testing a cue outside the training context increases attention to the contexts and impairs performance in human predictive learning

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ABSTRACT

One experiment in human predictive learning explored the impact of a context change on attention to contexts and predictive ratings controlled by the cue. In Context A: cue X was paired with an outcome four times, while cue Y was presented without an outcome four times in Context B:. In both contexts filler cues were presented without the outcome. During the test, target cues X and Y were presented either in the context where they were trained, or in the alternative context. With the context change expectation of the outcome X, expressed as predictive ratings, decreased in the presence of X and increased in the presence of Y. Looking at the contexts, expressed as a percentage of the overall gaze dwell time on a trial, was high across the four training trials, and increased with the context change. Results suggest that the presentation of unexpected information leads to increases in attention to contextual cues. Implications for contextual control of behavior are discussed.

1. Introduction

In the field of experimental and comparative psychology, the role played by contexts in retrieval of information has received extensive evaluation in the last few decades (e.g., Bouton, 1993; Bouton et al., 1999; Riccio et al., 1984). Bouton (1993) suggests that one function of the context, within associative learning, is to resolve the ambiguity that appears when the same predictor is associated with two different outcomes. In the absence of conflicting information, the organism is assumed to ignore the context. However, when a cue becomes ambiguous because it is sequentially followed by the presence (acquisition) and the absence (extinction) of an outcome, the organism begins to pay attention to the context (Bouton, 1997), and retrieval of the *second-learned* information about that cue becomes context specific (see Nelson, 2002, 2009; see also Darby and Pearce, 1995).

The idea that ambiguity leads to second-learned information becoming context dependent accounts for most of the results reported in the extinction and interference literatures where such context-dependency has been observed (see Bouton, 1993, 1997). However, this approach does not account for those situations in which retrieval of *unambiguous, first-and-only learned information* acquired during, or after, a separate interference treatment with different cues becomes context-specific (e.g., Rosas and Callejas-Aguilera, 2006; Rosas et al., 2006b; Starosta et al., 2016; but see Nelson and Lamoureux, 2015; Nelson et al., 2011). The effect of interference on context-dependence of unambiguous information has been found when the latter was learned outside the interference context, and even within a different task from the one in which the interference treatment took place (Bernal-Gamboa et al., 2013, 2014; Rosas and Callejas-Aguilera, 2006). Based on the results of these studies, Rosas et al. (2006a) proposed the Attentional Theory of Context Processing (ATCP). They assume that the effect of context change depends on whether the organism is paying attention to the context or not while the information is being learned. Unlike Bouton (1997), they assume that once the organism pays attention to the context, *all* information learned within that context becomes context specific, regardless of whether that information is ambiguous (c.f., Bouton, 1993, 1997).

Interference is assumed to be one of the main sources of ambiguity, but it is not the only one (e.g., Nelson and Callejas-Aguilera, 2007). In general, ambiguity can appear whenever cues are unreliable predictors of the outcomes, such as in pseudo-discrimination designs involving partial reinforcement (e.g., Callejas-Aguilera and Rosas, 2010). Ambiguity in the absence of interference is also expected to appear at the initial stages of training, when the organism has not yet been able to determine the predictive value of the different stimuli presented in the situation, or has not yet differentiated between contexts and cues. According to ATCP, in these situations contexts are assumed to be attended and, subsequently, be part of what the organisms learn (c.f., Bouton, 1993, 1997). For instance, León et al.(2011) trained participants in a human predictive learning task. Participants reviewed

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fictitious patient files to discover the causes of gastric malaise. A food name (cue X) was followed by a gastric malaise (outcome) in the context of a restaurant, (A:X+) while another cue was followed by the absence of the outcome in an alternative context (B:Y−). When training involved only 4 trials with each cue, switching contexts led to a decrease in predictive judgments with X, and an increase in predictive judgments with Y. These effects disappeared when experience with the outcome was equated in both contexts, matching the contexts' predictiveness. That latter result suggests that the context-switch effect was based on contexts' direct associations with the outcome in the initial stages of training, producing positive and negative summation with Y and X, respectively, on test. Context-switch effects also disappeared when training was increased to 18 trials, and could be modulated by manipulating participants' experience with the contexts involved in the task (see also León et al., 2010). Similar effects have been reported in nonhuman animals (e.g., Hall and Honey, 1990; see also León et al., 2012). In general, it appears that organisms attend to contexts at the beginning of training, and that attention leads contexts to play a role in controlling behavior. Behavioral control by the context disappears when training increases and redundant contexts are discarded as being useful to solve the task.

In the studies cited above, attention to the contexts is inferred from the context-switch effects that are intended to be explained by the attentional changes, leading to a useless circular explanation. Aware of this problem, researchers have focused on searching for independent recordings of the role of attention in context processing (e.g., Lucke et al., 2013; Nelson et al., 2013; Vadillo et al., 2016). A measure of attention, independent of other behavioral variables, that has been used in studies in which there was no explicit investigation of contextual stimuli involves recordings of participants' gaze (e.g., Hogarth et al., 2008; Le Pelley et al., 2011). This measure can be considered as orienting responses used as an independent measure of attention in studies with nonhuman animals (e.g., Keene and Bucci, 2007; Swan and Pearce, 1988). In a recent report, Aristizabal et al. (2016) recorded predictive responses and eye-fixations (gaze dwell time) along 48 training trials. They reported a decrease in the relative gaze dwell time to the contexts, as usually occurs with the orienting response to irrelevant stimuli (i.e., habituation, Pavlov, 1927). At the same time, attention to the cues increased and was kept high as training progressed (Mackintosh, 1975; for a recent review see Le Pelley et al., 2016).

The design used in this study mirrored the one used by Aristizabal et al. (2016) with the exception that only 4 training trials were conducted with each predictive cue, and that target cues X and Y were both tested within and outside their training context (see León et al., 2011). Restaurant signs in which pictures of food may or may not create gastric malaise were used, fitting the mental model participants have of how events operate in the world. In this mental model food is easily assumed to be the potential cause of a gastric malaise, while restaurants naturally play the role of contexts. Food and restaurant roles are not easily exchangeable – participants would have difficulties to integrate foods as contexts that modulate whether a given restaurant causes a gastric malaise. Consistent with their role as contexts, restaurants were present across multiple cues whereas the opposite was not true. According to the principles of ATCP, contexts and cues command attention at the beginning of training, when the situation is still ambiguous and the organism is still processing the contexts. In those cases, contexts have been found to enter into associations with all the elements present in the situation (i.e., stimuli, outcomes, and responses, see Gámez et al., 2016). Specifically, contextual control in this procedure has been found to develop through direct associations between the context and the outcome (see León et al., 2011). Thus, the key issue of this study is not so much to uncover the mechanisms of contextual control in this situation, but to see whether attention to the contexts is high in those situations in which those mechanisms operate.

Specifically, this study was conducted with two goals in mind. The first goal of this experiment was to determine whether attention to the contexts is high at the time context-switches have a detrimental effect on predictive judgments about the cues. The second goal of the experiment was to explore whether attention to the contexts is strengthened when the ambiguity of the situation increases by testing familiar cues in different, but equally familiar, contexts where those cues were never presented before.

2. Materials and methods

2.1. Subjects

Sixteen undergraduate students of the Universidad de Jaén, 4 men and 12 women, participated in the experiment in exchange for course credit. Participants were between 18 and 24 years old (mean = 19.5) and gave their informed consent before starting the experiment. One of the male participants was excluded from the study because of apparatus failure. The final sample involved 15 participants.

The sample size was determined from power analysis with the generic *pwr.f2.test* function of {pwr} R library, an implementation of Cohen's f^2 general linear model. The three required parameters for this function were: (a) large effect size (f^2 statistic at 0.35–equivalent to η^2 of 0.26- following the recommendations of Cohen, 1988, pp 413–414, and consistent with our previous work, Aristizabal et al., 2016, p. 69: $\eta^2 = 0.324$), (b) significance level at 0.05, and (c) desired Power at 0.8. We estimated an optimal sample size of 12 (estimated for interactions of 3 numerator df, e.g. "2 AOI × 2 Cue × 4 Trial" design) and 24 subjects (estimated for interactions of 1 numerator df, e.g. "2 AOI × 2 Cue × 2 Context" design). These estimations are based on independent samples (e.g. between-factor designs), and thus, are conservative when extrapolated to within-factor designs, as those of Aristizabal et al. (2016) or the design for this experiment. With software G*Power 3 (see Faul et al., 2007), the optimal sample size is reduced to values between 6 and 9 (for 3 and 1 df, respectively) if we add to previous parameters an estimated correlation among repeated measures of 0.41 based on Aristizabal et al. data (2016). In sum, sample size was initially set at 16 subjects so as to ensure adequate counterbalancing, because an increase in N would require another set of 16 subjects. Moreover, previous research (Aristizabal et al., 2016; León et al., 2011) with this method has shown this sample to be adequate to detect the effects of context change in attention.

2.2. Apparatus

Stimuli and responses were controlled by E-prime 2.0 (Psychology Software Tools, Pittsburgh, USA). Eye movements were recorded by a SensoMotoric Instruments (SMI) RED 250 eye tracking system placed under the screen. The screen was approximately about 80 cm away from the participant. The binocular sampling rate was set at 60 Hz and was controlled by iView X™ software (SMI, Teltow, Germany).

Labeled pictures of garlic and eggs were counterbalanced as cues X and Y. The outcome (+) was a gastric problem (diarrhea) or its absence (−). Two fictitious restaurants were counterbalanced as contexts A: and B:, represented by a yellow oval sign with the label "La Chocita Canadiense" (The Canadian Cabin) and a blue square sign with the label "La vaca Suiza" (The Swiss Cow). Two additional cues, F1 and F2 (labeled pictures of corn and cucumber, respectively), were used as fillers. F1 was included with the goal of breaking the perfect relationship that would have been otherwise established between context A: and the outcome. F2 was included to match the number of cues across contexts (see León et al., 2011). The filler cues were never paired with the outcome.

2.2.1. Stimulus screen

The context was presented in the right top corner of the screen. To the left of the context area, there was a sentence that read, "One person ate at restaurant…" Below, there was a sentence that read "This person