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DOCTORAL DISSERTATION / TESIS DOCTORAL

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Analysis of the mechanisms of contextual control of information retrieval

The role of interference in context dependence of acquisition and extinction

Análisis de los mecanismos de control contextual de la recuperación de la información

El papel de la interferencia en la dependencia contextual de la adquisición y la extinción

PRESENTADA POR:
Pedro Manuel Ogallar Ruiz

DIRIGIDA POR:
Juan Manuel Rosas Santos
José Enrique Callejas Aguilera
Manuel Miguel Ramos Álvarez

JAÉN, 4 de noviembre de 2019

Autorización

Juan Manuel Rosas Santos, Catedrático de Psicología Básica de la Universidad de Jaén, José Enrique Callejas Aguilera, Profesor Titular de Psicología Básica de la Universidad de Jaén, y Manuel Miguel Ramos Álvarez, Profesor Titular de Metodología de las Ciencias del Comportamiento de la Universidad de Jaén,

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Fdo.: Manuel Miguel Ramos Álvarez

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La verdadera fuerza de una idea está, no en lo que vale, sino en la atención que se le presta.

Concepción Arenal

The true strength of an idea lies not in what it is worth, but in the attention given to it.

Concepción Arenal

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En la vastedad del espacio y en la inmensidad del tiempo, mi alegría es compartir un planeta y una época con ella
Carl Sagan

La inspiración existe, pero tiene que encontrarte trabajando
Pablo Picasso

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Abstract

The general goal of this doctoral thesis was to analyze the conditions and mechanisms that underlie the coding of information as context dependent. With this aim, we have developed different studies to evaluate the conditions and mechanisms that underlie the EMACS (Extinction Makes Acquisition Context Specific) effect, as well as to assess whether the effect of changing the context on information retrieval is a particular case of a generalized increase in the attention generated by ambiguity, and that entails paying attention to the entire learning situation, including contexts.

The dissertation starts with a review of the main attention theories of learning and their role in explaining information retrieval, with special emphasis on the *Attentional Theory of Contextual Processing* (ATCP, Rosas, Callejas-Aguilera, Ramos-Álvarez, & Abad, 2006). Two studies were carried out that explore different conditions and mechanisms that underlie the EMACS effect, and this effect is directly compared with that of renewal under the same conditions, developed in laboratories other than those that have previously reported this effect. A third study explored whether the experience of interference that occurs within one task and in a given context facilitates learning in a completely different task and context, to assess whether the ultimate learning is affected by the mediation of the context where the interference occurred

In general, the theoretical review and the results reported in the studies suggest that extinction makes the acquisition of new information dependent on the context. Although this statement is not new, the studies carried out in this doctoral thesis reinforce this assertion, describing the conditions under which this effect appears, as well as the underlying mechanisms. Taken together, the results reported in this dissertation confirm the heuristic value of ATCP as a general explanation of the effects of the context change on the information retrieval. However, these results also suggest ATCP should be improved by incorporating the theoretical constructs of attentional exploration and exploitation at the base of the factors that assumes that modulate attention to the contexts, ambiguity and context subjective relevance, respectively.

Preface

For decades, explaining the conditions of information retrieval has been on the agenda of a good number of theories, becoming a primary topic within the field of experimental psychology (e.g., Archer & Sjödén, 1979; Capaldi & Birmingham, 1998; Churchill, Remington, & Siddle, 1987; Ebbinghaus, 1964; Estes, 1973, 1976; Lovibond, Preston, & Mackintosh, 1984; Medin & Schaffer, 1978; Smith, Glenberg, & Bjork, 1978; Tulving, 1974, 1983; Tulving & Thompson, 1973). One of the factors that has been found as essential in recovery of the information is the similarity between the context where learning occurs and the context in which that learning is recovered. From a holistic perspective, context is understood as everything that surrounds the target information (Smith, 2007), including external (e.g., Bouton, 1994), internal (e.g., Bouton, Keney & Rosengard, 1990; Eich, 1995), temporal (e.g., Bouton, 1993), and associative (e.g., García-Gutiérrez & Rosas, 2003) stimulation. A common result reported in cognitive studies on memory involves an impairment of information retrieval when the testing context differs from the context where the information is learned (e.g., Baddeley, 1982; Godden & Baddeley, 1975; Jensen, Harris, & Anderson, 1971; Tulving & Osler, 1968).

However, results showing impairment of recovery with the context change might need to be qualified. Studies conducted with both human and nonhuman animals show that the role of context on information retrieval is often minimal before an interference treatment takes place (Bouton, 1993). A large number of studies suggest that retrieval of information from simple acquisition, such as the learning about the relationship between a cue and an outcome, often transfers well across different contexts (e.g., Bouton, 1993; Bouton, Nelson & Rosas, 1999; Lovibond, et al., 1984; Rosas & Bouton, 1998; Rosas, Vila, Lugo, & López, 2001; but see, Archer, Sjödén, & Nilsson, 1985; Bonardi, Honey, & Hall , 1990; Hall & Honey, 1989; Sjödén & Archer, 1989). This line of research suggests that context changes only seems to affect recovery of the interfering information, leading Bouton (1993) to propose the *Theory of Retrieval of Information* (TRI), according to which only the inhibitory information, or the information secondly learned, is coded as context dependent. Subsequently, Nelson (2002, 2009) found that the key factor on making an information context dependent is whether the information is learned in the second place, regardless of its inhibitory or excitatory value.

The ambiguity that is generated when the meaning of a cue is modified by an interference treatment such as extinction plays a key role in TRI explanation of why retrieval of second-learned information is more context-dependent than retrieval of first-learned information (Bouton, 1997). Based on the idea of Darby and Pearce (1995), according to which attention to an irrelevant context increases as a result of a treatment that creates ambiguity, Bouton (1997) suggests that this increased attention to the context leads the organism to code the interfering information together with the context where the information is presented. Hence, the context of interference is expected to facilitate recovery of the information learned within that context, while leaving the context of interference will make retrieval of the interfering information more difficult.

Since its original proposal, TRI has been shown as one of the most influent and successful explanations on the role that contexts play on information retrieval (e.g., Nelson, 2002; Pearce & Bouton, 2001; Rosas, Todd, & Bouton, 2013; Todd, 2013). However, TRI also has difficulties to explain a number of context-related phenomena that have been reported in the literature. One of the most important difficulties for TRI comes from studies both in animal conditioning (e.g., Bernal-Gamboa, Nieto, & Rosas, 2015; Rosas & Callejas-Aguilera, 2007) and human predictive learning (e.g., Aristizabal, Ramos-Álvarez, Callejas-Aguilera, & Rosas, 2017; Callejas-Aguilera, Cubillas, & Rosas, 2019; León, Abad, & Rosas, 2010a, 2010b, 2011; Lucke, Lachnit, Koenig, & Uengoer, 2013; Nelson & Callejas-Aguilera, 2007; Rosas & Callejas-Aguilera, 2006; Rosas, García-Gutiérrez, & Callejas-Aguilera, 2006) showing that not only the ambiguous information is codified as context dependent, but also all the information that it is learned in a situation (ambiguous or not) in which the context is attended by the organism, regardless of whether this information is learned first or second, or whether the information is excitatory or inhibitory.

The *Attentional Theory of Context Processing* (ATCP; Rosas, Callejas-Aguilera, Ramos-Álvarez, & Abad, 2006) was presented with the goal of overcoming some of the TRI's limitations. ATCP is a direct heiress of the TRI, with which it shares its essential principles. However, ATCP also integrates principles of attentional theories of associative learning (e.g., Mackintosh, 1975; Pearce & Hall, 1980; Schmajuk & Larrauri, 2006) with the mechanisms of information retrieval in an attempt to explain why the information becomes context dependent. ATCP suggests that all the information learned within an attended context is coded with the context where it is presented, regardless of its excitatory or inhibitory nature, or whether it is consistent or ambiguous information (e.g., Ogallar, Ramos-Álvarez, Alcalá, Moreno-Fernández & Rosas, 2017; Rosas & Callejas- Aguilera, 2006). Thus, the key factor on explaining whether retrieval of an information becomes contexts dependent or not will be whether the context is attended at the time of learning, rather than whether the information is inhibitory or excitatory, and whether it is first- or second-learned. Although ATCP originally proposed 5 factors that lead an organism to pay attention to the context (see Rosas, Callejas-Aguilera, et al., 2006), these five factors have been recently synthesized in two: *ambiguity* and *subjective relevance of the context* (see Ogallar et al., 2017; Rosas & Nelson, 2019).

The *ambiguity* factor is derived from the original idea of Darby and Pearce (1995) that suggests that a situation that creates ambiguity in learning leads the organism to pay attention to the context. The role of this factor has been explored using different interference treatments (e.g., Nelson & Callejas-Aguilera, 2007, Experiment 2; Rosas, García-Gutiérrez, et al., 2006), although the one most studied has been the ambiguity generated by an extinction procedure. For example, Rosas and Callejas-Aguilera (2006) found that extinction of a cue led another cue associated with the outcome during the extinction treatment to be coded as context dependent. This effect has been referred to as the EMACS effect (Extinction Makes Acquisition Context Specific).

The role of ambiguity has been explored also in the absence of interference. For instance, ambiguity is also expected to appear at the beginning of a learning task, when the subject does not know which are the good predictors of the outcome (Mackintosh, 1975). Supporting that idea, León et al. (2010b, 2011) found that retrieval of a consistent relationship between a cue and an outcome is context specific early in training, while transfers well across contexts as learning progresses. More recently, Aristizabal, Ramos-Álvarez, Callejas-Aguilera, and Rosas (2016), using participants' gaze as an independent measure of attention, reported that the attention paid to contexts is greater during the first learning trials, decreasing as training increases (see also Aristizabal, et al., 2017).

Context subjective relevance of the context brings together the factors originally called *informative value of the context, relative salience* of context and cues, and *attentional instructions*. The *informative value of the context* is assumed to modulate attention in tasks in which the meaning of the cues is reversed across contexts, leading to retrieval of cues that are not part of the reversal training to become context-specific (e.g., León et al., 2010a; Lucke et al., 2013; Preston, Dickinson, & Mackintosh, 1986). Other studies have supported ATCP's predictions by showing that manipulations that are assumed to increase the salience of the context facilitate context dependence of the information learned within those contexts (e.g., Abad, Ramos-Álvarez, & Rosas, 2009; Bouton & Sunsay, 2001). Finally, instructions that lead participants to attend to the context make retrieval of information context dependent in situations in which the transfer between contexts is otherwise complete. Alternatively, instructions that lead participants not to pay attention to the context make the effect of context change that can be observed at the beginning of a task to disappear (e.g., Beesley, Hanafi, Vadillo, Shanks, & Livesey, 2018; Callejas-Aguilera et al., 2019; Cañadas, Rodríguez-Bailón, Miliken, & Lupiañez, 2013).

Since its formulation, ATCP has shown an important heuristic value as its predictions have promoted a good number of empirical studies trying to test them. However, this theory is not without limitations. Initial studies inferred the role of attention from the effects of context change, leading to a circular explanation of the role of attention in retrieval: The increase in attention was inferred from the effect of the context change in behavior, and those changes were assumed to be caused by the increase in attention. This limitation has been recently attenuated by the use of measures of attention independent of predictive judgments such as participants' gaze, though the number of studies is still scarce (e.g., Aristizabal et al., 2016, 2017; Lucke et al., 2013; Vadillo, Orgaz, Luque, & Nelson, 2016). A different problem is the one that refers to the generality of the EMACS effect, one of the main predictions of ATCP. Several studies show the difficulty of replicating this phenomenon in human tasks other than those using predictive learning (e.g., Nelson & Lamoureux, 2015). In addition, research in animal conditioning has found that the effect may be elusive to find (Nelson, Lombas, & León, 2011) beyond in conditioned taste aversion (e.g., Bernal-Gamboa et al., 2015; Rosas &

Callejas-Aguilera, 2007). As the EMACS effect is at the base of the predictions of ATCP, exploring the generality of that effect is essential for understanding the value of the theory.

Finally, recent studies raise a new fundamental question that the *Attentional Theory of Context Processing* has to face. It seems that, once ambiguity has increased organism's attention, this increase not only affects processing of the context, but also processing of all the information that is presented once attention is raised. If that is the case, the attention the organism pays to the context may be a side effect of a general increase in the organism's arousal that would affect all the stimuli involved in the learning situation, not just the context (e.g., Rosas & Nelson, 2019). Different studies suggest that the experience with interference treatments facilitate subsequent acquisition of temporal conditioning (Alcalá, Callejas-Aguilera, Lamoureux, & Rosas, 2019), spatial learning (Alcalá, Callejas-Aguilera, Nelson, & Rosas, 2019; see also Shanab & Cotton, 1970) or reversing learning about a conditioned inhibitor (González, Alcalá, Callejas-Aguilera, and Rosas, 2019). Likewise, the classic study carried out by Shanab & Cotton, (1970) can be interpreted in these lines, as they reported that extinguishing running in a straight corridor facilitated later learning in a T maze.

The studies showing that ambiguity facilitates learning in general, suggesting that the effect of context change may be interpreted as a specific case of a general facilitation of learning, suggest that ATCP might need to be reformulated. However, before jumping to that conclusion it is relevant to know that, in all of the studies listed above, the interference and new learning phases were conducted using the same or quite similar tasks and contexts. This procedural feature allows for an interpretation of the results in terms of changes in context processing, an idea that is at the base of the effects of context change in situations of uncertainty or interference (see Bouton, 1993, 1997; Rosas, Callejas-Aguilera, et al., 2006). To solve this problem, studies are needed where the experience with ambiguity and the test for facilitation of subsequent learning are conducted in different contexts and tasks. If facilitation of general learning after interference were reported under those conditions, ATCP would have to be revised, as context-switch effects would be a side effect of interference or ambiguous situations leading the organisms to a general increase in attention that facilitates any kind of learning, and not only learning about contexts.

The general goal of this doctoral thesis is to analyze the conditions and mechanisms that underlie the coding of information as context dependent. To achieve this goal, different empirical studies were developed focusing on (1) the conditions and mechanisms underlying the EMACS effect, and (2) whether the effects of context-switch on retrieval could be a special case of ambiguity leading the organism to increase attention to all the information presented afterwards, including contexts.

To reach this general goal, the main core of this dissertation has been structured in 5 Chapters (aside this preface and the required summary in Spanish). Chapter 1 discusses different attentional theories of learning and their role on explaining retrieval of the information. This chapter also includes a detailed review of the Attentional Theory of Context Processing (e.g., Rosas, Callejas-Aguilera, et al., 2006). The goals and hypotheses of the experimental studies are presented in Chapter 2. Chapter 3 includes two empirical studies conducted with the goal of exploring the conditions and mechanisms that underlie the EMACS effect by testing whether this effect could be replicated under different conditions and in different laboratories from the ones where this effect is mostly reported, and by comparing EMACS and Renewal effects under the same conditions. Chapter 4 explores whether the effect of experiencing interference in animals could be transferred to a different task that is learned within a different context from the one in which interference is trained, as a way to test whether the effects of interference upon subsequent learning can be found in a situation that cannot be context mediated. Finally, Chapter 5 presents a general discussion of the results reported in the empirical studies and their theoretical implications, ending with a presentation of the main conclusions of this research.

The dissertation incorporates four manuscripts that are at different moments in the publication process. The first one is a theoretical review, and has been already published (Ogallar et al, 2017). The other three manuscripts are empirical studies that explore different lacunas in the literature uncovered by the theoretical review. The first one is already in press (Ogallar et al., 2019), and the other two are in preparation. Although this structure may suggest that the thesis is intended to be presented as a compendium of papers, that is not exactly the case. The structure of the dissertation intends to show the strategy underlying the theoretical and empirical research conducted in this thesis, and presenting the research in a way that facilitates the reader to see not only how the logic of the work develops, but also how the work is planned to be shared with the scientific community. Using this strategy leads to treat each chapter independently, including in each one the references of the citations used in it. This approach leads to some repetitions in references and ideas across chapters, but has the advantage of allowing for an independent reading of each section, such as each has been, or will be published.

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Chapter I: Attentional Perspectives on Context-dependence of Information Retrieval

Ogallar, P. M., Ramos-Alvarez, M. M., Alcalá, J. A., Moreno-Fernández, M. M., & Rosas, J. M. (2017). Attentional Perspectives on Context-dependence of Information Retrieval. *International Journal of Psychology and Psychological Therapy*, *17*, 121-136. Retrieved from https://www.ijpsy.com/volumen17/num1/462/attentional-perspectives-on-context-dependence-EN.pdf

This chapter presents a review of the main attentional theories of associative learning by discussing their successes and limitations when it comes to explain the effects of context change on information retrieval. In addition, the chapter presents a detailed review of the *Attentional Theory of Context Processing*, the main theoretical framework of this dissertation, by discussing its main advances and limitations, some of which will be approached in the experimental section of the thesis.

SHORT TITLE: ATTENTION AND CONTEXT PROCESSING

Attentional Perspectives on Context-dependence of Information Retrieval

Pedro M. Ogallar[1], Manuel M. Ramos-Álvarez[1], José A. Alcalá[1], María M. Moreno-Fernández[2], & Juan M. Rosas[1]

[1] Universidad de Jaén

[2] University of Deusto

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Abstract

Attention has been traditionally understood as an important factor on acquiring new information. A review of the literature suggests that attention, specifically attention to the contexts, also plays a relevant role on information retrieval. It also shows that attention to the contexts is modulated by the ambiguity of the situation, and the informative value contexts have. The virtues and limitations of different attentional theories of learning applied to the explanation of the effects of context change on retrieval of the information are discussed. This analysis uncovers the weaknesses of current research on context processing that should be corrected by future research: The need of independent measures of attention to the contexts, the evaluation of the mechanisms of contextual control, and the possibility of taken an evolutionary perspective on the effects of context change.

Key-words: Attention, Context processing, Contextual control, Information retrieval, Learning, Memory

Introduction

The interpretation that we make of situations of daily life is often determined by the context in which we find ourselves. For instance, the meaning we attribute to the word "cell" will be different in the biology class and in a mobile phone store. The study of the conditions and mechanisms through which contextual information influences behavior has generated a large number of experimental works during the last decades. In many of those studies the role of context has been found to be especially relevant in situations involving interference, that is, in situations in which we have to deal with conflicting information (for a review see Bouton, 1993; Rosas, Tood & Bouton, 2013).

Let's take the study conducted by Paredes-Olay and Rosas (1999, Experiment 2) as an example. These authors explored the role of context on performance in a human predictive judgments task. Participants were to take on the role of a medical inspector who evaluated reports of patients treated in two different imaginary hospitals. In a first phase participants learned that treatment X used in hospital A made all patients sick, whereas treatment Y used in hospital B was totally safe. In a second phase, participants received treatment X in hospital B, and treatment Y in hospital A, both without outcomes. That is, both treatments changed the context where they were administered and treatment X had no longer effects. That is, treatment X received an extinction treatment. Changing the context before extinction had no effect on participants' performance: At the start of the phase, expectations that drug X would produce the disease remained high in hospital B while expectations that the disease appeared when the patient had ingested medication Y remained low in hospital A. As training progressed predictive judgments to treatment X gradually decreased until matching trials to treatment Y, both close to zero in the predictive judgments scale. In the final test, participants were asked to evaluate the probability that X could cause the disease in each hospital. Estimates depended on the hospital in which X was administered: Higher when X was presented in hospital A (where X had originally been paired with the outcome) than when it was presented in hospital B where the relationship between X and the outcome had been extinguished.

This recovery of the extinguished response with the change of context is known as a *renewal effect* and has been extensively studied in both animals and humans in the last three decades (see, among others, Bouton & Bolles, 1979, Rosas, García-Gutiérrez, & Callejas-Aguilera, 2007, Rosas, Vila, Lugo, & López, 2001). Studies have shown that the basic factor that determines the renewal effect is whether the interference treatment takes place in a context other than the context in which the test is performed, regardless of whether the test context is the one in which the acquisition took place (e.g., Bouton & Bolles, 1979; Rosas et al., 2001) or a different but equally familiar one (Bouton & Ricker 1994; Bouton & Swartzentruber, 1986, Tamai & Nakajima 2000; Thomas, Larsen, & Ayres, 2003).

The most complete explanation of the renewal effect was provided by Bouton (1993, 1994) in his theory of interference and information retrieval. This theory holds that the memory is formed by nodes that represent events of the world and that relate to each other in an excitatory or inhibitory way, so that the activation of one node excites or inhibits the activation of related nodes. Phenomena such as *spontaneous recovery* (Pavlov, 1927), *reinstatement* (Rescorla & Heth, 1975), or the effect of renewal at hand reveal that, once established, these relationships remain available until their recovery becomes necessary, so that sometimes the same stimulus may keep at the same time an excitatory and an inhibitory relationship with the same outcome. In Paredes-Olay and Rosas's (1999) experiment, A may produce the disease or not, depending on where it was administered. The information retrieval theory suggests that the context plays a modulating role in those situations, determining which information will be retrieved at a given time. To be clear, this theory suggests that retrieval of the information learned first will not be context-dependent, whereas retrieval of the conflicting information learned second (about extinction or interference) will depend on the test taking place in the context where such conflicting information was learned. In the experiment reported by Paredes-Olay and Rosas (1999) changing the context after acquisition had no effect on performance. However, once the information became ambiguous (A produced the disease and A did not produce the disease), the second information learned is only recovered when the test is conducted in the same context in which it was learned, but not when it is conducted in a different context (see Nelson, 2002).

This explanation of the renewal effect by the theory of retrieval of the information comes up against three main shortcomings. The first one stems from the fact that the theory is limited to narrow understanding of the renewal effect, leaving unexplained the role that contexts may play in other situations such as simple acquisition. The theory defines renewal as the information recovery that is produced by the context change after extinction, and that cannot be explained by direct context-outcome associations, regardless of whether these are excitatory or inhibitory (e.g., Nelson, Sanjuan, Vadillo-Ruiz, Pérez, & León, 2011). With this assumption, the theory is self-limiting, leaving out all those situations in which the context plays a role on performance through direct associations with the outcome (e.g., León, Abad, & Rosas, 2011, León, Callejas-Aguilera, & Rosas, 2012), as well as those situations in which context-switches affect retrieval of information retrieved that has not undergone extinction of any other form of interference (e.g., Hall & Honey 1990; Rosas & Callejas-Aguilera, 2006; Sjödén & Archer, 1989).

The second shortcoming arises from the evaluation of one of its unique assumptions. The theory holds that the essential factor in the renewal situation is leaving the context where interference occurs, regardless of whether this departure takes the organism to the same context where acquisition occurred or not. Thus, the theory expects the same results when the test is conducted in the original context of training than when the test takes place in a new context. However, the renewal effect has been found to be stronger when the design involves a return to the acquisition context during the test (ABA design, where the letters represent the contexts where the acquisition, extinction and test take place) than when the design involves only leaving the extinction context (AAB and ABC renewal designs; Harris, Jones, Bailey, & Westbrook, 2000; Nakajima, Tanaka, Urushihara, & Imada, 2000, Rosas, et al., 2007; Tamai & Nakajima, 2000; Thomas et al., 2003; see also García-Gutiérrez, Rosas, & Nelson, 2005).

The third shortcoming of the theory comes from its low explanatory power. Pointing out that the second information learned is context-dependent is not an actual explanation of why information becomes context dependent, but a description of the result most commonly obtained in the literature. The first attempt to break this circle is presented in the concluding comments of a chapter published by Bouton (1997) in which he states that interfering information becomes context dependent because it makes the cue ambiguous (i.e., the outcome announces the presence and the absence of the outcome). This ambiguity leads the organism to pay attention to the context where the information is presented in an attempt to disambiguate the situation. Conflicting information is then processed with the context where it is learned, and its retrieval becomes context-dependent. Leaving aside for now that this solution only applies to those situations in which the context change affects the interfering information, this approach highlights the role of attention as an explanatory factor of the effects of contextual change on information retrieval (see also Nelson, 2002; Darby & Pearce, 1995). In the following paragraphs, we will briefly present how main attentional theories of associative learning deal with context-switch effects.

Attentional theories of associative learning

In the last four decades, the study of the relationship between associative learning and attention has been dominated by two theories: Mackintosh's (1975a), which holds that attention to a given stimulus is directly related to its predictive power; and Pearce and Hall’s (1980), which holds just the opposite, that there is an inverse relationship between the attention a stimulus receives and its predictive power. Although they are by no means the only theoretical approaches in the literature, they capture the essential roles attention plays in associative learning, and are at the base of other, more complex approaches whose discussion would surpass the goals of this review.

The attentional theory of Mackintosh (1975a). This theory starts with the simple assumption that what is learned about a particular stimulus depends on the attention it receives, assuming that attention is greater the better predictor of its consequences the stimulus is (see the background of this model in Krechevsky, 1932; Sutherland & Mackintosh, 1971). Using a conditioning situation as an example, the greater the correlation between the stimulus and the outcome, the greater the attention the stimulus will receive. As the processing capacity of the attentional system is limited, the model also assumes that the attention received by any cue is inversely proportional to the attention received by the other cues present in the situation, so that those stimuli that are relatively good predictors of their consequences will receive progressively more attention; whereas those that are not, will be progressively ignored. In general terms, this model emphasizes the role of stimulus processing, assuming that the attentional changes that occur throughout the learning process are responsible for the final result. The Mackintosh model has received great empirical support, and it is especially successful in uniquely accounting for phenomena related to the competition between predictive cues (i.e., blocking), one of the cornerstones of theoretical development in the field of associative learning. Blocking is observed when, after pairing a given conditioned stimulus (CS, i.e., a noise) with an unconditioned stimulus (US, i.e., a brief electric shock on the legs of a rat), we present a stimulus compound in which the original CS is presented together to a new CS (i.e., a noise-light compound) followed by the same unconditioned stimulus originally used. When we later evaluate the response of fear to the added CS (the light in the example) we find that the conditioned response (CR) is lower in this situation than in another one in which the noise-light compound is preceded by the separated training of any of its elements. Thus, previous training with one of the stimuli in the compound blocks the learning about the relationship between the added element and the US (Kamin, 1969).

Mackintosh's theory (1975a) aptly predicts that blocking will not appear during the first compound training trial (Mackintosh, 1975b), as well as the increase in the CR when US value is reduced between the element training phase and the training phase with the compound (Dickinson, Hall, & Mackintosh, 1976; c.f., Rescorla & Wagner, 1972). The logic underlying these two predictions is simple and intuitive. The model holds that learning about a stimulus depends on the level of processing that it receives, identifying its associability with the attention that the stimulus receives. In other words, the capacity of a given stimulus to enter in association with other will depend on the attention it receives. The explanation for blocking arises from the fact that the stimulus added during the training phase of the compound is a worse predictor of the outcome than the stimulus originally trained, so it will be quickly discarded as potential predictor and will no longer receive attention. However, in a typical conditioning trial in which the CS slightly precedes the US, when the compound is first introduced the organism will pay attention to the added stimulus given that its outcome is still unknown. The model predicts that the added stimulus (the light in our previous example) will be processed in the first compound conditioning trial and, consequently, will gain predictive power by being followed by the outcome. It will be only later, in the following trials, when the stimulus becomes ignored due to its lower predictive value with respect to the partner stimulus in the compound. With the same logic, the model predicts that attention to the new stimulus will be kept high when there is a change in the value of the US between the training phase with the element and the training phase with the compound, regardless of the direction of the change. This phenomenon is known as *unblocking* and was already predicted by the reference associative learning model, Rescorla and Wagner's (1972; Wagner & Rescorla, 1972). However, this latter model predicts that the new learning about the added stimulus will correlate directly with the direction of the change in the value of the US, increasing when the intensity of the US increases across phases and decreasing in the opposite case, something that has not been confirmed in the literature (see Dickinson et al., 1976). The assumption of a positive correlation between the predictive power of stimuli and the attention they receive has been included in more recent models of learning, such as Kruschke's (2001, 2003), who developed a connectionist approach of some complexity. For the situations we deal with here, Kruschke's model presents similar properties to the original model, so it will not be developed here further.

The attentional theory of Pearce and Hall (1980). The Mackintosh model (1975a) starts from the idea that more attention is paid to stimuli that are better predictors of their outcomes; that is, relevant stimuli will be more attended than irrelevant stimuli. Pearce and Hall's (1980) model makes the opposite assumption. According to this model organisms pay attention to stimuli that are poor predictors of their outcomes, ignoring those that are good predictors of their outcomes which receive automatic processing. Thus, this theory shares with Mackintosh's theory (1975a) the idea that the attention stimuli receive changes with the experience. However, it differs from the latter by arguing that attentional changes in the associability of stimuli are inversely related to their predictive value.

We pointed out that Mackintosh's theory (1975a) received empirical support; and the same is true for the theory of Pearce and Hall (1980). In different experimental series that sought to contrast this theory directly with Mackintosh's theory (1975a), it was found that learning is hampered when a good predictor of the outcome is subsequently paired with a new (Dickinson et al., 1976) or more intense outcome (Hall & Pearce, 1979). This result, known as Hall-Pearce negative transfer effect, suggests that the organism stops paying attention to the stimulus once its predictive power is well established (c.f., Mackintosh, 1975a). In a related result, Kaye and Pearce (1984) found that conditioning was facilitated when the target stimulus had previously undergone partial reinforcement, thus being a poor predictor of the outcome. These results suggest that, at least in some circumstances, there is an inverse relationship between the predictive power of a stimulus and the attention it receives. Contrary to Mackintosh's (1975a) prediction, in some circumstances we learn more easily about stimuli that are bad predictors of its outcomes, while we learn more slowly about stimuli that are good predictors of them (Pearce & Hall, 1980).

Hybrid models (Le Pelley, 2004; Pearce & Mackintosh, 2010). The experimental endorsement received by the opposite predictions of Mackintosh’ (1975a) and Pearce and Hall’ (1980) models has encouraged developing of hybrid models integrating both approaches into a fuller explanation of the role of attention in associative learning. Among the most relevant attempts is that of Le Pelley (2004) who incorporates in his model two attentional parameters, one that follows the rules established by the model of Mackintosh (1975a), and another that changes according to the rules proposed by Pearce and Hall (1980). A similar approach has been developed by Pearce and Mackintosh (2010). To detail both theories surpasses the goals of this manuscript so we will limit to indicate that through different solutions both theories coordinate within the same learning algorithm the two attentional models described above, integrating the opposite results briefly summarized above and allowing for a more complete approximation to the role that attention plays in learning, and the role that learning plays in the attention that stimuli receive (see also Hall & Rodriguez, 2010; Le Pelley, Mitchell, Beesley, George, & Wills, 2016).

The role of context in attentional models of associative learning. The Mackintosh model (1975a) was developed as an alternative explanation to the associative learning explanation proposed by Rescorla and Wagner (1972), while the Pearce and Hall (1980) model sought to be an alternative to both. Finally, the hybrid models of Le Pelley and Pearce and Mackintosh (2010) tried to integrate the previous models in a unified version that allows to account for the conflicting results found in the literature and that seem to support one model discarding the other (for a recent review in this topic see Le Pelley et al., 2016). None of these models was developed with the goal of specifically accounting for the effects of context change on information retrieval. However, all of them may be applied to these situations. It is enough to consider that the context is an additional stimulus within the experimental situation susceptible to the same attentional processes that the rest of the stimuli present in the situation. Under this assumption, the context would enter into predictive competition with the rest of the stimuli. When this competition leads the context to gain predictive power, any subsequent change in the context in which learning takes place would lead to a deterioration in performance (see also Pearce, 1987, 1994, 2002; Rescorla & Wagner, 1972).

These models explain situations in which context change has a direct effect on retrieval of information about consistent relationships between neutral stimuli and their outcomes since they assume that the context becomes a predictor of the outcome in such a way that, when the context changes, organisms' response decreases in an effect known as a generalization decrement. However, none of these models can explain the asymmetry between the effects of context change on simple acquisition and extinction or interference that is usually found in the renewal phenomena described above.

A possible solution to this problem is proposed by Darby and Pearce (1995). These authors take as their starting point the configurational model of Pearce (1987, 1994, 2002). Contrary to the previous elementary models that assume that the stimuli are independently processed, this model assumes that the organisms have a transient sensory storage of limited capacity that is permanently full. The content of the sensory memory at a given time would play the role of a CS as a whole, including what is separately treated as context and target stimuli in elementary theories. Response during at testing will depend on the similarity between the present configuration and the one that is stored in memory as related to the outcome, that is, the proportion of elements contained in the test configuration with respect to the originally trained configuration and with respect to other configurations that may have been trained with the same organism. The result of this approach with respect to the role of the context is obvious: Being part of the configuration itself, any change in the context will mean a decrease in generalization and as such a decrease in the response given by the organism to the new situation. Up to this point, Pearce's model (1987) presents the same problems presented by the elementary models previously described when confronting the asymmetry of context-switch effects on acquisition and extinction. However, Darby and Pearce (1995) implemented an attentional analysis that allows Pearce's model to explain many of their results involving context. Essentially, they found that contextual specificity of a simple stimulus-outcome association appeared when contexts were part of conditional discrimination in which the relationship between each of two different stimuli and the outcome was reversed as a function of the context. Darby and Pearce (1995) argue that attention to irrelevant contexts rises when contexts are relevant to solving the learning task, with the result that they end up being part of what the organism eventually learns and, in the end, partially control the organism response (see also León, Abad, & Rosas, 2008, 2010a; Preston, Dickinson, & Mackintosh, 1986). Note that the same principle could be applied to all the models previously discussed. However, once it is accepted that attention to context can be modulated by the relevance of the context to solve the situation, the question that opens up is which are the factors that modulate the attention organisms pay to the contexts. This is the starting point of the Attentional Theory of Context Processing, which we will briefly describe below (Rosas, Callejas-Aguilera, Ramos-Álvarez, & Abad, 2006; see also Rosas & Callejas-Aguilera, 2006; Rosas, García-Gutiérrez, & Callejas-Aguilera, 2006).

Attentional Theory of Context Processing (ATCP)

In the previous paragraphs we have briefly presented the shortcomings of Bouton's theory of retrieval of the information (1993, 1994, 1997) and the limitations of attentional theories of associative learning (Le Pelley, 2004; Mackintosh, 1975a; Pearce & Hall, 1980, Pearce & Mackintosh, 2010) to become an integrative account for all the effects of context change that are reported in the literature. ATCP was proposed with the goal of overcoming these shortcomings by extending the theory of retrieval of the information in a way that allows for an explanation of context-switch effects outside the extinction/interference procedures, integrating attention and retrieval mechanisms, and suggesting a set of factors that modulate the attention contexts receive.

ATCP maintains four essential principles. The first two principles emanate directly from Bouton's theory of retrieval of the information (1993): It is argued that (1) there are two main sources of forgetting, interference, and context change; and that (2) learning of interfering information only affects retrieval of the information learned first, without erasing it; both, interfering and interfered information are assumed to be stored in memory, and recovery of one or the other will depend on the conditions under which the test is performed (e.g., Anderson, 1993; Mensik & Raaijmakers, 1988). Two additional principles are included with the goal of extending the theory to situations in which the theory of retrieval of the information lacks predictive power. Contrary to the idea that context change only affects retrieval of ambiguous information (Bouton, 1993, 1997), (3) ATCP holds that the effects of context change depend on the attention that the organism pays to the context during learning, so that whenever the context is attended retrieval of all the information learned within that attended context will become context-specific, regardless of whether that information is excitatory, inhibitory, ambiguous, or not (c.f., Bouton, 1997; Darby & Pearce, 1995). Finally, (4) it is assumed that attention to the contexts will be modulated by ambiguity (Bouton, 1997), context relevance (Darby & Pearce, 1995), the degree of experience with the context and the task, direct instructions in human participants, and its relative salience with respect to that of the specific cues used in the task. In the following paragraphs, we will briefly detail the results found in the literature with respect to each of the factors proposed by ATCP.

Ambiguity. Rosas and Callejas-Aguilera, using human predictive learning (2006) and rats' conditioned taste aversion (2007) tasks found that retrieval of all relationships learned within a context in which a cue has been extinguished, become dependent (i.e. receive an extinction treatment). Similar results have been reported when ambiguity is generated through a latent inhibition design in rats, in which the cue is first presented without outcome and then conditioned (Bernal-Gamboa, Nieto, & Rosas, 2015); and when retroactive interference is used as the treatment that generates ambiguity in humans (Rosas, García-Gutiérrez et al., 2006).

More recent work has reinforced these results beyond the initial confound between ambiguity and interference (see Nelson and Callejas-Aguilera, 2007). Contextual dependence of consistent predictors is also obtained when ambiguity is introduced through a pseudo-discrimination procedure, suggesting that ambiguity produces a general change in attention to the context, making context-dependent retrieval of all information learned in the situation (Callejas-Aguilera & Rosas, 2010; c.f., Nelson & Callejas-Aguilera, 2007). Additional evidence of extinction increasing attention to the contexts was provided by Nelson, Lamoureux, and León (2013) when finding that extinction enhances participants' performance in a subsequent biconditional discrimination in which contextual cues are relevant to solve the task. Even more, extinction seems to affect processing of contexts in which extinction has not taken place (e.g., Rosas & Callejas-Aguilera, 2006). The most striking results on this respect were reported by Bernal-Gamboa, Rosas, and Callejas-Aguilera (2014) when finding that the ambiguity produced by extinction in one task such as running in a runway led to greater context dependence of a different task such as taste aversion conditioning (see also Bernal-Gamboa, Callejas-Aguilera, Nieto, & Rosas, 2013; Rosas & Callejas-Aguilera, 2006).

Degree of experience with the context and the task. Theoretical proposals in the tradition of learning and conditioning suggest that the organism will have difficulties to separate relevant from irrelevant cues at the beginning of training (see, for example Kruschke, 2001; Mackintosh, 1975a; Myers & Gluck, 1994; Schmajuk, Lam, & Gray, 1996). From this idea follows that contextual control of responding will be higher at the beginning of training than when training progresses, a prediction that has been confirmed in different human (León, Abad, & Rosas, 2011, 2010b) and animal learning experiments (Hall and Honey, 1990; León et al., 2012, but see Bonardi, Honey, & Hall, 1990). Assuming that the context is codified in the initial stages of learning allows ATCP to be applied to situations of contextual dependence of simple acquisition and to advance an explanation of the differences between the ABA renewal design and the other renewal designs indicated above: If the acquisition context is processed in the early stages of training retrieval of the information learned in that context will be higher within the acquisition context than when the renewal design involves the mere abandonment of the interference context.

Direct instructions on human participants. Inspired by results such as those of Eich (1985) in memory tasks, it has been found that the changes in contextual dependence with the experience encountered by León, Abad, and Rosas (2011) can be modulated by attentional instructions: When participants were instructed explicitly to pay attention to the cues, the effect of context change after brief training disappeared. Complementarily, the effect of context change that did not appear after prolonged training emerged if participants were instructed to pay attention to the context (Callejas-Aguilera, Cubillas & Rosas, 2017; c.f. Neumann, 2007).

Informational value of the context (context relevance). Preston et al. (1986) found in animal research that retrieval of information about unambiguous cues shows contextual dependence whenever they are trained within contexts that are characterized by their high informative value (see also Darby & Pearce, 1995). Similarly, León, Abad, and Rosas (2008, 2010a) found that retrieval of relationships with consistent predictive value that were trained in the presence of other cues that varied their meaning depending on the context was context dependent in both, human predictive learning and instrumental conditioning (see also León, Gámez, & Rosas, 2012; Lucke, Lachnit, Koening, & Uengoer, 2013; Lucke, Lachnit, Stüttgen, & Uengoer, 2014).

Salience or relative preeminence of the context with respect to the cues. ATCP assumes that contextual dependence of the information is directly related to the salience or relative preeminence of the contexts with respect to the specific cues involved in the task. Although this prediction has not received a direct evaluation, Abad, Ramos-Álvarez and Rosas (2009) found that partial reinforcement of a cue made context-dependent retrieval of the information about a different cue that received continuous reinforcement. Pearce, Redhead, and Aydin (1997) suggest that partial reinforcement causes an internal state (N) associated with frustration (Amsel, 1958, 1992) or with a memory tracing of non-reinforced trials (Capaldi 1967, 1994) that may increase the relative salience of the context. The data of Abad et al. (2009) are consistent with this idea, as they are consistent with the formation of a direct association between the context and the outcome favored by the increase in the relative preeminence of the context because of the partial reinforcement treatment (see also Murphy, Baker, & Fouquet, 2001).

The five modulating factors summarized above are the ones originally set by ATCP. However, looking at them retrospectively, these factors may be reduced to two. Studies exploring context experience or relative salience of contexts and cues are actually manipulating the perceived ambiguity of the situation. Similarly, instructions in human participants may be understood as a way to manipulate the subjective relevance of the contexts. This approach would reduce to two the factors modulating attention to the context: ambiguity and contexts' relevance.

Regardless of the number of factors modulating attention to the contexts, the literature briefly summarized above suggests that ATCP has great heuristic value as a guide to research and it seems to be closer than its predecessors to become a comprehensive explanation of the context-switch effects on information retrieval found in the literature (but see Nelson & Lamoureux, 2015; Nelson, Lombas, & León, 2011). It overcomes some of the shortcomings of Bouton's (1993) theory of retrieval of the information, extending its explanation to situations that do not involve extinction, interference or even ambiguity, and it gives a response to why the effects of the context change occur in some situations and not in others. In addition, it keeps advantages with the general attentional theories summarized in the previous section focusing on the factors that regulate the attention, rather in the learning mechanisms that apply once contexts are attended. Nevertheless, ATCP also shares some of the problems of its predecessors and relays in assumptions that are not yet demonstrated. The goal of the next section will be to describe the most important shortcomings of current attentional approaches to retrieval of the information.

Attention and context: Explanatory limitations and future perspectives

We ended the previous paragraph by noting the advantages of TACP, but also advancing some of the shortcomings that this theory still has. We will conclude this review by presenting an overview of the main limitations that attentional theories applied to information retrieval have to solve in the years to come to reach a full understanding of the role of contexts and attention in retrieval of the information.

Independent measures of attention. In the experiments that support the idea that attention plays an important role in contextual processing, attention is inferred from changes in the dependent variable that is supposed to be affected by it. That is, it is assumed that attention plays a relevant role in the effect of context change because this effect appears when manipulating factors that supposedly modulate the attention participants pay to the context. It is assumed that an organism pays attention to the context whenever the context change has an effect on performance; and it is assumed that the effect of the context change is due to the organism paying attention to the context. This circularity weakens the explanatory usefulness of the attentional construct. To conclude that attention plays a relevant role in context processing it will be necessary to count with a measure of attention that it is independent of the effect of context-switch that it is trying to explain.

In studies with humans there are several approaches that may be useful in addressing this problem. Thanks to a hybrid task of predictive learning and semantic memory, Griffiths and Mitchell (2008) measured both the strength of learned associations and cue recognition. According to the authors, the more attention a cue receives during training the better it will be remembered/recognized in the test phase. It is feasible to adapt the designs used in the studies on context-switch effects in humans to this task, allowing for an independent verification of the attention received by the contexts and whether they control information retrieval in those situations in which attention to the contexts is assumed to play a role.

Alternatively, the online recording of participants' eye movements would also allow for an independent measure of attention to contexts and cues. In recent years the use of devices that allow online recording of the fixation points of the gaze has become an extended approach to measure attention (e.g., Hogarth, Dickinson, Janowski, Nikitina, & Duka, 2008; Hogarth, Dickinson, Wright, Kouvaraki, & Duka, 2007). These devices are becoming less invasive and annoying for participants, allowing for online registration of the area to which participants are paying attention at any given point in the task, a variable that has been shown to be closely related to attention (Deroost & Soetens, 2006), and that may be used to record the attention contexts and stimuli receive. In a recent study, Aristizabal, Ramos-Álvarez, Callejas-Aguilera, and Rosas (2016) have found that participants stop paying attention to irrelevant contexts as training progresses. Dwell time in the context area decreased as training progressed, reaching asymptotic values after a few training trials. This result is consistent with the fact that context-switch effects appear early, but not later on training (see also Aristizabal, Ramos-Álvarez, Callejas-Aguilera, & Rosas, 2017; Lucke et al., 2013).

From a different perspective, some researchers have begun to apply to the study of learning tests traditionally used in the field of attention, such as the "dote probe task" (Le Pelley, Vadillo, & Luque, 2013; Luque, Vadillo, Le Pelley, & Beesley, 2016). This test records the time it takes the participant to detect and respond to a point that can appear in any stimulus present in the task. Reaction times have traditionally been assumed to correlate with the attention individuals pay to the stimulus (e.g., Posner, Nissen, & Ogden, 1978). The typical result of the dot-probe task is that reaction times are lower when the dot is allocated on a predictive stimulus that when it is presented within a non-predictive one (see for example Le Pelley et al., 2013). This task has been recently used to assess attentional shifts to the context, thus Vadillo, Orgaz, Luque and Nelson (2016) found that when the learning situation becomes ambiguous, participants' attention moves from predictive cues to the cues that serve as context. Looking to the future, implementing the use of this type of tasks together with the measures provided by eye-tracking systems, will allow for furthering current knowledge about the role of attention on learning situations, while testing the theoretical predictions proposed from the ATCP.

Finally, the orientation response in animals has been used as an independent measure of attention in studies with nonhuman species (e.g., Keene & Bucci, 2007; Swan & Pearce, 1988). Although this measure may not be a very sensitive one, it is still possible to design and validate contexts with specific features that allow for estimating the attention received through orientation response. Thus, changes on light or texture patterns on specific areas of Skinner boxes may be used to register orientation responses, allowing for the assessment of the attention received by the contexts, and the effects of the context change on animals' attention.

Evaluation of the mechanisms of contextual control. In the case of information retrieval theory (Bouton, 1993), the hierarchical mechanism in which the context modulates the cue-outcome relationship, circumscribes this explanation to a particular and concrete interpretation of the effect of renewal. Models such as Rescorla and Wagner (1972), Mackintosh (1975a) or Pearce (1987) assume that the context is either treated as a specific stimulus that competes with target stimuli by predicting the outcome or it is part of the stimulus configuration that is related with the outcome as a whole, establishing in both cases a direct association with the outcome. Both approaches allow for explaining different context-switch effects in the literature, and none allows for explaining all of them. Finally, ATCP is completely ambiguous in this regard. This theory is not committed to hierarchical or direct context-outcome mechanisms, focusing on establishing under what circumstances attention to contexts appears or does not appear. Recent results from our laboratory seem to suggest that this might be a more appropriate approach to the study of context-switch effects on performance. Gámez, León and Rosas (2016) found that contexts simultaneously enter into association with the outcome, the discriminative stimulus and the instrumental response in a human instrumental learning situation, suggesting that future research in contextual control should focus on determining the conditions that lead to the expression of a specific association among the ones that are automatically established, rather than focusing on which associations involving context are developed within the learning situation.

An evolutionary perspective of the effects of context change. All models mentioned above take an evolutionary perspective suggesting that the basic mechanisms of learning and retrieval of information are shared by different animal species, including the human being. This idea is backed up by an important number of studies in the literature. However, this literature is not exempt from controversial results (i.e., García-Gutiérrez & Rosas, 2003; against Delamater, 1997 and Ostlund & Balleine, 2007; or Rosas & Callejas-Aguilera, 2007 against Nelson, Lombas et al., 2011). Since the exploration of the attentional aspects of contextual processing in nonhuman animals is rather scarce and has been performed within a very limited range of tasks, it remains to be ascertained whether these differences are due to the mechanism of contextual control that depends on the type of task used or it is due to real differences in the contextual processing among different species. Research in the coming years will need to explore the generalization of the effects of attentional manipulations on performance after changes in the context in the rat and the human being using different procedures.

Conclusions

A review of the literature on context-switch effects on information retrieval strongly suggests that attention plays an important role in context processing and contextual dependence of information. However, the confirmation of this relationship will depend on further development of independent measures of attention to the context that would allow separating the attention contexts receive from the context-switch effects on performance. From a theoretical point of view, we have found that none of the current theories on the effects of context change can fully explain the great variety of context change effects that appear in the literature. Part of the problem stems from the difficulty of determining which mechanism of contextual control mechanism will be in effect once participants are paying attention to the context. Establishing the range of conditions that give rise to direct or hierarchical associations is still pending in the literature. Finally, and in a complementary way, it will be necessary to explore the role of attention in the contextual processing of different species in order to be able to conclude whether a general theory of context processing can be established. The direction that the work should take and its guidelines seem therefore well established and these challenges should be faced from different laboratories in the following years in order to reach a comprehensive theory of the effects of the context change on information retrieval.

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Chapter II: Goals and hypotheses

As we have discussed in the previous chapter, the *Attentional Theory of Context Processing* (Rosas, Callejas-Aguilera, Ramos-Álvarez & Abad, 2006) has been characterized by its high heuristic value, to the extent that it has generated a large number of studies with the goal of testing its theoretical assumptions (see Ogallar, Ramos-Álvarez, Alcalá, Moreno-Fernández, & Rosas, 2017). Feedback from empirical research has led, since its initial formulation, to an update of ATCP with the goal of improving its explanatory scope. One of these modifications was reducing to two (ambiguity and subjective relevance of the context) the five factors originally proposed as modulators of attention to the contexts (see Ogallar et al., 2017).

Although the heuristic value of ATCP as an explanation of the context switch effects on retrieval of the information, recent research has also questioned the generality of one of the main demonstrations of the basic assumption of ATCP: the EMACS effect, showing that the information learned during or after an interference experience becomes context-dependent, regardless of whether that information is ambiguous or not. Beyond the data that confirm the EMACS effect, both in procedures with human participants (e.g., Rosas & Callejas-Aguilera, 2006) and in animal conditioning (Bernal-Gamboa, Nieto, & Rosas, 2015; Bernal-Gamboa, Rosas, & Nieto, 2018; Rosas & Callejas-Aguilera, 2007), there are systematic attempts to test the EMACS effect that have been unsuccessful in replicating it, both in human learning tasks (Nelson & Lamoureux, 2015), and in animal conditioning (Nelson, Lombas & León, 2011). Those failures to replicate the EMACS effect outside the tasks and procedures in which it was first reported questions the generalization of the effect and, thus, the generalization of the principles of ATCP. Additionally, recent research suggests that the coding of information as context dependent may be the particular manifestation of a more general effect that leads to a generalized facilitation of learning, and not only of learning about contexts (Alcalá, Callejas-Aguilera, Lamoureux, & Rosas, 2019; Alcalá, Callejas-Aguilera, Nelson, & Rosas, 2019; González, Alcalá, Callejas-Aguilera, & Rosas, 2019). However, this idea is yet under discussion, as the experimental research that supports it allows for an interpretation in terms of increasing context processing, as discussed above.

General goal and main Hypothesis

Extending the test of the validity and limitations of ATCP by exploring the conditions and mechanisms that underlie the EMACS effect, as well as testing the limitations of ATCP as an explanation of context-switch effects on retrieval on the light of recent research that suggests that context-switch effects on retrieval may be a side effect of ambiguity facilitating learning in general, and not only about contexts (e.g., Rosas & Nelson, 2019).

Main Hypothesis. As, according to ATCP, the mechanisms and conditions of renewal and EMACS effects are the same, we expected to be able to replicate the EMACS effect in different laboratories and under the same conditions that are known to produce the renewal effect. Additionally, we expected to find independent evidence of the role of attention to the contexts in the EMACS effect, as it has been reported in the literature for context-switch effects at the beginning of training (Aristizabal, Ramos-Álvarez, Callejas-Aguilera, & Rosas, 2016, 2017), and when contexts are informative for participants (Lucke, Lachnit, Koening, & Uengoer, 2013). Finally, if context switch effects can be interpreted as a side effect of ambiguity facilitating learning in general, this facilitation of learning should be found when the context and the task where facilitation of learning is tested are different from the ones in which ambiguity is developed.

Specific Goals and Hypotheses

Goal 1. One of the factors that may be responsible for the conflicting results on the EMACS effect reported in studies with human participants has been the modality of the contexts used in their experimental tasks. Studies in which this effect has been reported employed tasks in which the contexts were verbal labels (e.g., Rosas & Callejas-Aguilera, 2006; Rosas, García-Gutiérrez, & Callejas-Aguilera, 2006). In contrast, studies in which the EMACS effect was not replicated used physical contexts such as images on the computer screen (e.g., Nelson & Lamoureux, 2015). There are therefore differences between these two ways of representing the contexts that could, in some way, explain the differences reported in the literature. However, according to the principles of ATCP, the differences found between those studies cannot be due to the modality of the contexts, since regardless of their characteristics they would be attended by the ambiguity generated by an extinction treatment, and therefore the information would be coded as context dependent. Thus, the first goal of the experimental section of this dissertation was to try to discard the interpretation of the differences across studies in terms of the type of contexts used in those studies by testing whether the EMACS effect could be replicated when using the original task in which it was first reported in humans (Rosas & Callejas-Aguilera, 2006, Experiment 1), but with contexts similar to the ones used in the studies that did not replicate the EMACS effect (see Nelson & Lamoureux, 2015).

Hypothesis 1: Extinction treatment of a cue is expected to make retrieval of the acquisition of another cue context-dependent when physical, rather than semantical contexts are used, as ATCP predicts.

Goal 2. Testing the role played by attention in the coding of information requires measures of attention that are independent of the behavioral measure used to test context-switch effects (i.e., predictive judgments). A common limitation in studies with humans that suggests that attention to the contexts plays a role in context change effects is that the role played by attention is inferred from the effect of context change, which leads to a circular explanation. This limitation has been recently overcame in the literature by using measures of attention to the context that are independent from the effect of context change on the behavioral measure. For instance, eye-tracking systems have been used to test the role of attention in context-switch effects that appear after simple acquisition at the beginning of training (Aristizabal et al., 2016, 2017), or when contexts are relevant to solve the task (Lucke et al. 2013). To our knowledge, no study on the EMACS effect has incorporated an independent measure of attention to the contexts. The second goal of this dissertation was to incorporate an independent measure of attention to the context within the EMACS effect, as a way to test whether this effect could be explained by changes in attention to the context by the extinction experience, as ATCP predict. We choose the speed of response, under the assumption that changes in attention to contexts and signals would affect the speed of response (e.g., Cobos, González-Martín, Varona -Moya, & López, 2013). It is assumed that greater attention implies more processing and a slower response speed. If that additional time is being used to process the contexts to facilitate some type of information retrieval, then participants should take longer to decide how to respond when the signal is presented outside the training context.

Hypothesis 2. Treatment of extinction with a cue is expected to lead to an increase in the participants' attention to the learning situation, which should reduce the response speed when the information is tested in a different context the context of acquisition.

Goal 3. One of the main differences between TRI and ATCP is what refers to which information becomes context dependent. Unlike TRI, ATCP proposes that all information learned under an ambiguous situation is coded together with the context in which it is acquired. This information can be inhibitory, as is the case with renewal from extinction; or it can be excitatory, as in the EMACS effect. In the case of the extinguished information, a deleterious effect of a context change is observed when the test is carried out outside the context of extinction, regardless of whether the change means returning to the context of acquisition or not (ABA versus AAB and ABC renewal) or whether acquisition and extinction are conducted in the same context (AAB renewal) or in two different contexts (ABA and ABC renewal). To our knowledge, the EMACS effect has been only reported under AAB designs. According to ATCP renewal and EMACS effects are due to the same underlying mechanism: Extinction raising attention to the contexts. Thus, the third goal of this dissertation was to evaluate whether EMACS and Renewal could be concurrently found when acquisition and extinction of the ambiguous cue takes place in two different contexts (A and B, respectively), and the test is conducted either in the acquisition context (A), or in a context different from acquisition and extinction contexts (C).

Hypothesis 3. Following ATCP, we expected to find both, renewal from extinction and the EMACS effect when acquisition and extinction of the ambiguous cue takes place in two different contexts and the test with both, the extinguished cue (Renewal) and the consistently trained cue (EMACS), takes place either in the context where the extinguished cue was originally paired with the outcome, or in a familiar context different from the contexts where the acquisition and extinction treatments were conducted.

Goal 4. Recent reports in the literature show how learning a temporal conditioning is facilitated by an experience of reversal discrimination in which role played by two stimuli with respect to the outcome is reversed across phases (Alcalá, Callejas-Aguilera, Lamoreux, et al., 2019). Similarly, discrimination reversal in a Morris pool facilitates spatial learning of the location of a new platform (Alcalá, Callejas-Aguilera, Nelson, et al., 2019), and the experience of extinction of a non-target cue facilitates reversal of a conditioned inhibitor (González et al., 2019). These results suggest that the experience of interference raises the attention of the organism to everything that occurs afterwards. This general activation of the organism can somehow facilitate its learning so that the increase in context processing by the interference at the base of ATCP will be just an instance of a more general effect of interference in attention. However, all the studies conducted to test these phenomena have been conducted by testing the influence of interference on new learning in the same or very similar tasks and contexts, leaving open the possibility that the improvement in learning would be explain by increased context processing. However, if this activation facilitates learning in general, this facilitation should be observed regardless of whether the context where interference and new learning are experienced are the same or different. Thus, the fourth goal of this dissertation was to evaluate whether experiencing interference in a given task would facilitate learning in a different task and in a different context in rats.

Hypothesis 4. It is expected that a successive negative contrast treatment will increase the attention of the organisms to the learning situation and that this general activation will facilitate a learning of subsequent temporal conditioning, a totally different task and contexts.

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Chapter III: Exploring the conditions and mechanisms that underlie the EMACS effect

Chapter III aims to address specific Goals 1, 2, and 3. Two empirical studies were developed to explore the conditions and mechanisms underlying the EMACS effect. The first empirical study searched for a replication of the EMACS effect (Goal 1) with a variation of the restaurant task with which that effect was originally reported (Rosas & Callejas-Aguilera, 2006). In the study presented here contexts and cues were presented as images, rather than as semantical information, making the task more similar to the tasks in which the effect has not been found (Nelson & Lamoureux, 2015). The EMACS effect was tested by the standard changes in predictive judgments given by participants and, in addition, this study recorded the speed of participants' response as an independent (though indirect) test of the role of attention in the EMACS effect (Goal 2).

The second empirical study addressed Goal 3, testing whether the same process underlies Renewal from extinction and EMACS effects by concurrently testing Renewal and EMACS effects within the same experimental design, and using ABA and ABC renewal designs that, to our knowledge, had not been used to test the EMACS effect before.

Experimental Study I. Prior Extinction Increases Acquisition Context Specificity in Human Predictive Learning

Ogallar, P. M., Rosas, J. M., Ramos-Álvarez, M. M., Alcalá, J. A., Nelson, J. B., Aranzubia, M., & Callejas-Aguilera, J. E. (2019). Prior Extinction Increases Acquisition Context Specificity in Human Predictive Learning. *Behavioural Processes*, *169*, *in press*. doi: 10.1016/j.beproc.2019.103984

RUNNING HEAD: EMACS EFFECT IN HUMANS

Prior Extinction Increases Acquisition Context Specificity in Human Predictive Learning

Pedro M. Ogallar[1], Juan M. Rosas[1], Manuel M. Ramos-Álvarez[1], José A. Alcalá[2], James B. Nelson[3], Manuel Aranzubia[3], & José E. Callejas-Aguilera[1]

[1] Universidad de Jaén

[2] University of Leicester

[3] University of the Basque Country/Euskal Herriko Unibertsitatea

Correspondence:

Pedro M. Ogallar

Department of Psychology

Universidad de Jaén

23071 – Jaen

Spain

e-mail: pogallar@ujaen.es

Abstract

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

Keywords: Context · Extinction · Humans · Predictive Learning · Response Speed

1. Introduction

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

One of the most influential theories regarding the role of context in associative learning is that formulated by Bouton (1993, 1994, 1997) to explain context-switch and retention interval effects within associative interference paradigms. This theory assumes that the main role contexts play is to retrieve associative learning to resolve the ambiguity of the situation. It is assumed that when the information an organism receives from a cue or signal is unambiguous (e.g., during simple acquisition of cue-outcome associations), background stimuli are ignored, and the role of context in retrieval of information is negligible. However, when the meaning of the cue is thought to become ambiguous, such as when an interference treatment changes a cue's established meaning by associating the cue with the absence of the outcome (extinction) or with a different outcome, the new information about the cue is assumed to be coded together with the context where that new information is acquired. Then, retrieval of conflicting information will depend on whether the test is conducted in the same context where ambiguity appeared or in a different one (see also Bouton, 1997; Nelson, 2002, 2009).

Bouton's (1993) theory has remarkable success explaining key context-switch phenomena such as the different types of renewal, a phenomenon in which an extinguished response is renewed when the test is conducted outside the extinction context (e.g., ABA, Bouton & Bolles, 1979; AAB, Bouton & Ricker, 1994; or ABC renewal, e.g., Thomas, Larsen & Ayres, 2003, where the letters represent the contexts where acquisition, extinction and testing take place). The same idea has been applied to reinstatement, a phenomenon in which the presentation of the outcome without the cue leads to a recovery of the conditioned response or the predictive judgment through what it is assumed to be a change in the associative context where the test is conducted (e.g., García Gutiérrez & Rosas, 2003; García-Gutiérrez, Rosas, & Nelson, 2005; Rescorla & Heth, 1975). Likewise, in spontaneous recovery an extinghished response is recovered with the simple passage of time (e.g., Pavlov, 1927; Robbins, 1990; Rosas & Bouton, 1996). The effect is assumed to occur because of a change in the temporal context where extinction takes place (e.g., Bouton, 1993). Observations of the additive effects of spontaneous recovery and renewal (Rosas & Bouton, 1997, 1998; Rosas, Vila, Lugo, & López, 2001; Vila, Romero, & Rosas, 2002; for a review see Bouton, Nelson, & Rosas, 1999) lend support to the idea that these recovery-from-interference phenomena share a common mechanism.

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

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

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

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

The role of ambiguity in context depencence of information has been shown across different species and procedures (see a review in Ogallar et al., 2017). In rats, the EMACS effect has been observed after both, extinction (Bernal-Gamboa et al., 2015; Rosas & Callejas-Aguilera, 2007) and pre-exposure in conditioned taste aversion (Bernal-Gamboa et al., 2018). Moreover, the influence of the experience of interference has been found to persist across different tasks. For instance, Bernal-Gamboa et al. (2014) found that extinction of runway running made subsequent taste aversion learning context-dependent, and vice versa (see also Rosas & Callejas-Aguilera, 2006, Experiment 4). In humans, contextual dependence has been found when ambiguity has been produced by training non-target cues in a pseudodiscrimination (Callejas-Aguilera & Rosas, 2010) or in counterconditioning (see Rosas, García-Gutierrez, & Callejas-Aguilera, 2006). These results all seem to suggest that consistent acquisition becomes context dependent in ambiguous situations, regardless the way in which this ambiguity is generated (e.g., extinction, pre-exposure, pseudo discrimination or counterconditioning). Interestingly, attitudes are often context specific, and the contextualization of attitude formation generally forms under conditions predicted by ATCP, which has been adopted to account for those specific phenomena (Gawronski et al, 2010)

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

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

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

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

Apart from the more behavioral nature of the task, one relevant difference is that restaurant task of Rosas and Callejas-Aguilera (2006) simply used names of restaruants as contexts, while the task of Nelson and Lamoureux (2015) also used background images of physical stimuli (e.g., stars, nebulae). There are any number of differences between these two ways of representing context that might, in some way, account for the differences in their results. For instance, the physical salience of the contexts in the Nelson and Lamoureux (2015) task might have been greater than in the restaurant task, and inherently command more attention. Such a situation would limit the effect of any further attempt to enhance attention. Also, pictures have been shown to access semantic information (e.g., which context is present) faster than words (e.g., Smith & Magee, 1980). This potential differential cognitive load in recognizing contexts between the tasks could have produced unintended, and presenty unspecificed, differences in the way in which attention is allocated to them.

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

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

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

Table1

Experimental Design.

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

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

Predictive judgments to the target Cue P1 were expected to be lower in Context B (Different) than in Context A (Same, acquisition context) only in the group that had the extinction experience, E (see Rosas & Callejas-Aguilera, 2006). Additionally, we expected participants in Group E to show slower response speed when tested in Context B than when tested in Context A, a difference that should not appear in Group NE (for related results see Aristizabal et al., 2017; c.f., Nelson & Lamoureux, 2015).

Finally, we conducted the experiment with a large sample from two different laboratories, the one at the Universidad de Jaén (where the effect was first reported), and the one at the Universidad del País Vasco (where failures to detect the effect have been reported). Conducting the experiment in two different laboratories allowed us to ensure that the effect did not depend on nonspecific factors related to the sample used or laboratory conditions and procedures. Increasing the size of the sample also provides increased the statistical power. Assuming a correlation of .5 between the repeated measures, the study has a power of .79 to detect small effects (η^2 = 0.01) such as the potentially subtle effects of context switches in performance after simple acquisition that could have gone unnoticed in previous reports in the literature (e.g., León et al., 2011; Paredes-Olay & Rosas, 1999; Rosas & Bouton, 1997; Rosas & Callejas-Aguilera, 2006; Rosas, García-Gutiérrez, & Callejas-Aguilera, 2007, Experiment 2).

2. Material and methods

2.1 Participants

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

2.2 Apparatus

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

Cues were the same as those used by Rosas & Callejas-Aguilera (2006) with the exception that verbal information was substituted by a picture of the food taken from a repository of royalty-free images. *Cucumber* and *garlic* were counterbalanced as Cues X and P1. Cues F2 and F1 were *eggs* and *tuna fish*, respectively. *Diarrhea* was used as O.

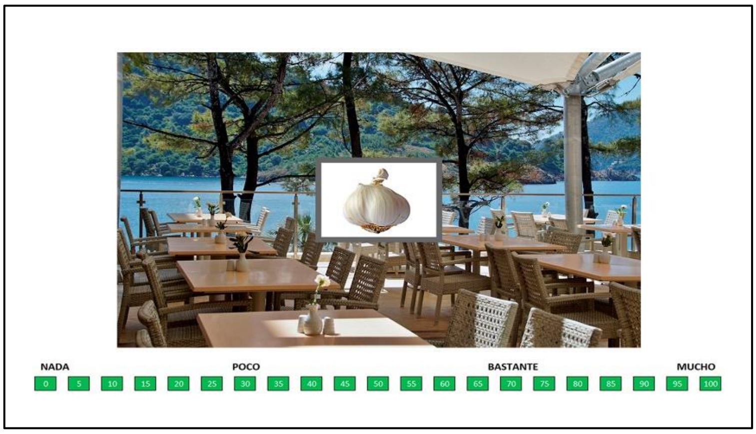
Contexts A and B were the images of two fictitious restaurants counterbalanced across participants. One of the images presented a terrace in front of a lake, with natural scenery and typical terrace furniture, while the other presented an old European city patio with typical bistro tables covered with elegant tablecloths (see the two top images in Figure 1).

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

2.3 *Procedure*

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

Restaurant 1



Restaurant 2

Demonstration Restaurant

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

First screen: *Recent developments in food technology have led to the chemical synthesis of food. This process has great advantages because its cost is very low and it is easy to store and transport. This revolution in the food industry may solve hunger in third-world countries.*

Second screen: *However, it has been detected that some foods produce gastric problems in some people. For this reason, we are interested in selecting a group of experts to identify the foods that lead to some type of illness and how it appears in each case.*

Third screen: *You are about to receive a selection test where you will be looking at the files of persons that have ingested different foods in a specific restaurant. You will have to indicate the degree to which you think that a gastric problem will appear. To respond you should click the option that you consider appropriate. Your response will be random at the beginning, but do not worry, little by little you will become an expert.*

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

A trial consisted of the presentation screen followed by the feedback screen. Participants were requested to make a probability judgment about the relationship between the cue and the outcome by clicking on the button of the scale they considered appropriate during the presentation screen. Thus, contrary to the procedure used by Aristizabal et al. (2017) the duration of the cue presentation was not fixed at 3,000-ms, but depended on the time taken by each participant to respond. Immediately after this screen, and independent of the chosen option, participants received a 1,500-ms feedback screen indicating the problem the person had (if any). The intertrial interval was 1,000 ms, and it was indicated by a screen with the sentence: *Loading the file of* [a randomly chosen full name]. Full names were always different to keep the impression that each file was from a different person. Before the beginning of the experiment, participants were randomly assigned to one of two groups: extinction (E) and no-extinction control (NE). The experiment was conducted in two phases. The design of the Experiment is presented in Table 1.

2.3.1 Phase 1

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

2.3.2 Phase 2

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

2.3.3 Test Phase

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

2.4 Dependent Variables and Statistical Analysis

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

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

3. Results

3.1 Predictive Judgments

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

Figure 2 presents mean predictive judgments given Cues X and P1 in Groups E and NE during training Phases 1 (left panel) and 2 (right panel). Learning about X and P1 proceeded similarly in Groups E and NE. Extinction of X proceeded uneventfully in Group E. A 2 (Group) x 12 (Trial) ANOVA conducted with predictive judgments to X during Phase 1 found a significant main effect of Trial, $F(11, 2090) = 169.19$, MSe = 325.07, $p < .001$, $\eta_p^2 = .47$, 95% CI [.44, .49]. The main effect of Group was not significant, $F(1, 190) = 1.35$, MSe = 3452.31, $p = .25$. Finally the Group x Trial interaction was significant, $F(11, 2090) = 2.54$, MSe = 325.07, $p = .003$, $\eta_p^2 = .01$, 95% CI [.00, .02]. Subsequent analyses of the Group x Trial interaction found that the simple effect of Group was significant only in two trials at the initial stages of training [$F(1, 717) = 6.27$, MSe = 585.68, $p = .01$, $\eta_p^2 =$

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

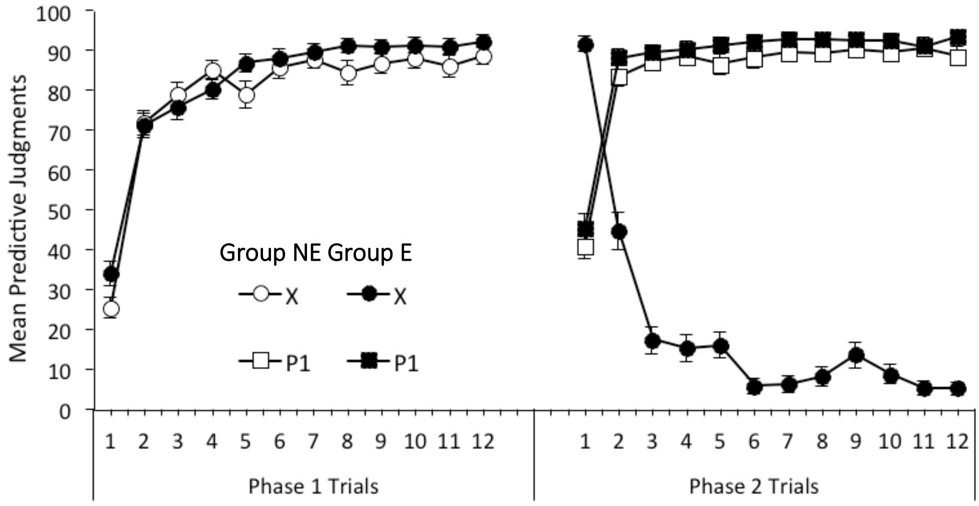


Fig. 2. Mean predictive judgments to target Cues X and P1 in Groups E and NE during the 12 Trials of Phase 1 (left) and Phase 2 (right). Error bars denote standard errors of the mean.

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

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

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

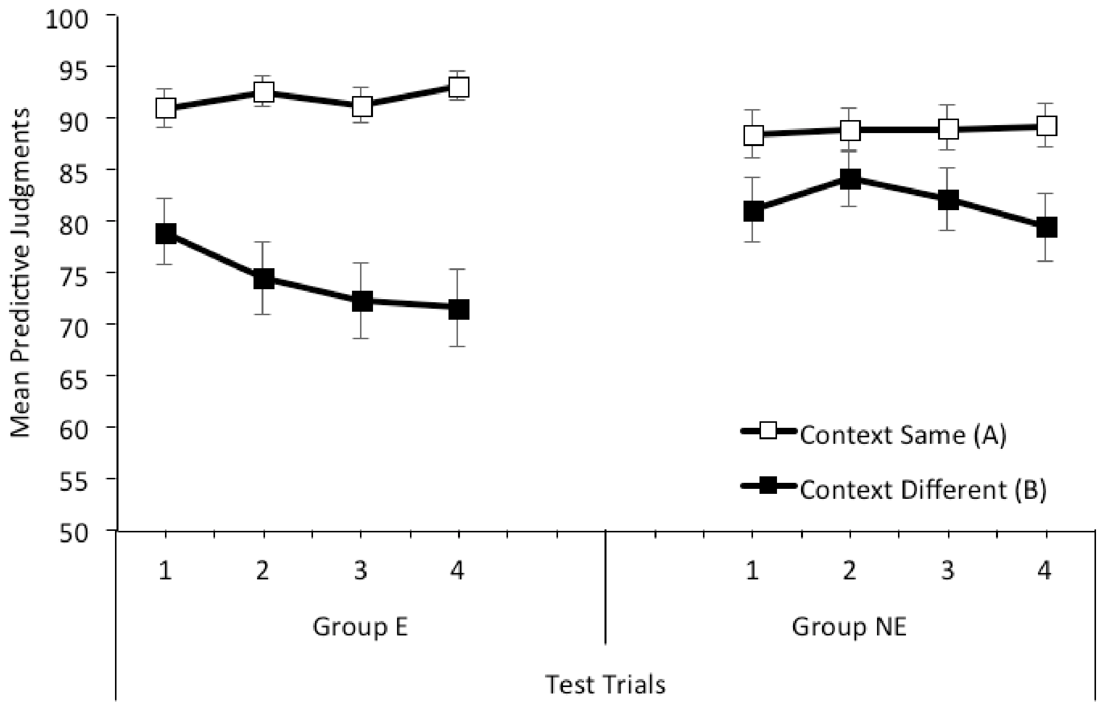


Fig. 3. Mean predictive judgments given to Cue P1 by participants in Groups E (left panel) and NE (right panel) during the 4 test trials in Context A (the training context) and in Context B (the alternative context). Error bars denote standard errors of the mean.

Statistical analyses confirmed these impressions. A 2 (Group) x 2 (Context) x 4 (Trial) found a significant main effect of Context, $F(1, 190) = 49.29$, MSe = 1208.35, $p < .001$, $\eta_p^2 = .21$, 95% CI [.11, .30]. The Context x Trial interaction was also significant, $F(3, 570) = 3.25$, MSe = 192.28, $p = .02$, $\eta_p^2 = .02$, 95% CI [.00, .04]. Of most relevance for the goals of the study, there was a significant Group x Context interaction, $F(1, 190) = 8.73$, MSe = 1208.35, $p = .004$, $\eta_p^2 = .04$, 95% CI [.005, .11]. Subsequent analyses of the Group x Context Interaction found that the simple effect of context was significant in both, Group E, $F(1, 190) = 49.75$, MSe = 302.09, $p < .001$, $\eta_p^2 = .35$, 95% CI [.22, .50], and Group NE, $F(1, 190) = 8.27$, MSe = 302.09, $p = .004$, $\eta_p^2 = .08$, 95% CI [.01 .18]. Nevertheless, the simple effect of Group was significant in Context B, with lower judgments in Group E than in Group NE, $F(1, 319) = 4.89$, MSe = 536,803, $p = .03$, $\eta_p^2 = .02$, 95% CI [.001, .07], while they did not differ in Context A, $F < 1$. Taken together, the analyses show that the context change had a deleterious effect on retrieval that was boosted by the extinction experience.

3.2 Response Speed (1/RT)

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

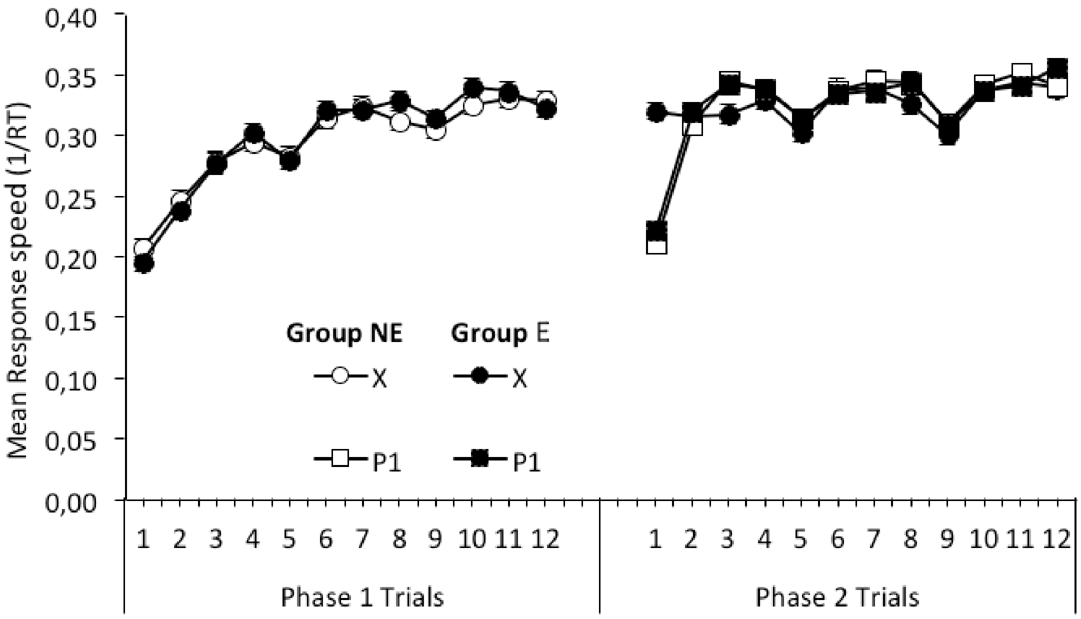


Fig. 4. Mean response speed (1/RT) to Cues X and P1 in Groups E and NE during the 12 Trials of Phases 1 (left) and 2 (right). Error bars denote standard errors of the mean.

Figure 4 presents mean response speed to Cues X and P1 in Groups E and NE along the 12 training trials of Phases 1 (left panel) and 2 (right panel). Speed to respond to X increased rapidly over trials during Phase 1, regardless of the group. A similar phenomenon was observed with Cue P1 in Phase 2, while responding to X in Group E did not change throughout this phase. A 2 (Group) x 12 (Trial) ANOVA conducted with response speed to X during Phase 1 only found a significant main effect of Trial, $F(11, 2090) = 75.93$, MSe = 0.004, $p < .001$, $\eta_p^2 = .29$, 95% CI [.25, .31]. Neither the main effect of Group, nor the Group x Trial interaction were significant, *Fs* < 1.

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

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

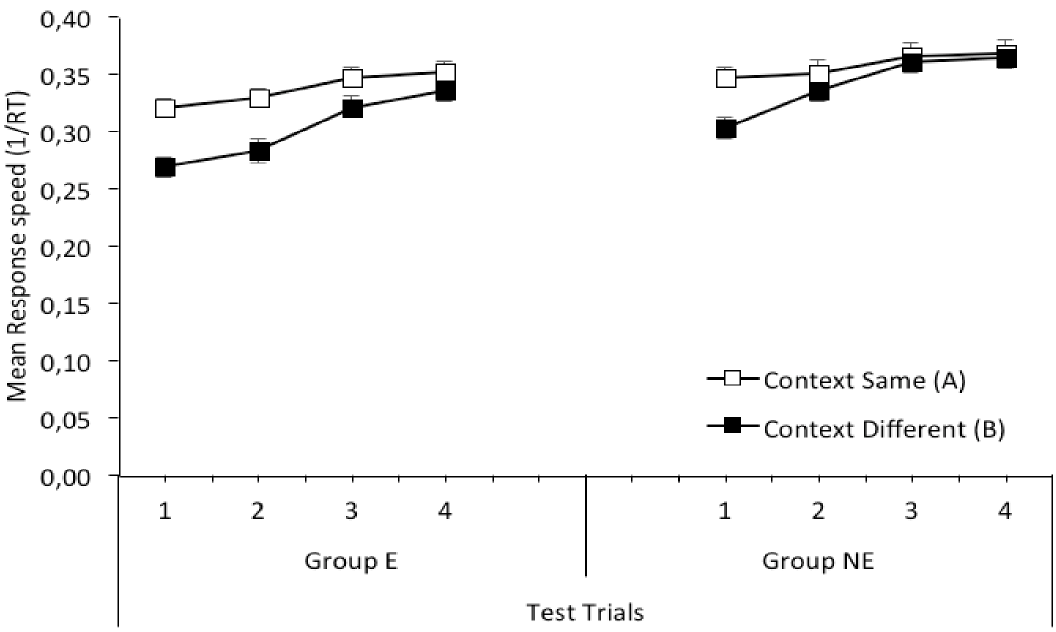


Figure 5: Mean response speed (1/RT) given to Cue P1 by participants in Groups E (left panel) and NE (right panel) during the four test trials in Context A (the training context) and in Context B (the alternative context). Error bars denote standard errors of the mean.

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

4. Discussion

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

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

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

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

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

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

In summary, the results reported in this study found the EMACS effect in human predictive learning with a mixed design, using more traditional physical contexts, and it was accompanied with a decrease in the response speed at the time of testing that is consistent with the idea of context-switch effects being based in a reallocation of attentional resources from the cue to the context after interference (e.g., Bouton, 1997; Rosas, Callejas-Aguilera et al., 2006; see also Aristizabal et al., 2017). However, as far as we know, with humans the EMACS effect has been reported with predictive learning

(Rosas & Callejas-Aguilera, 2006) and automatic evaluation (see Gawronski, Hu, Rydell, Vervliet, & De Houwer, 2015) tasks; tasks which are very similar. In animals, it has appeared in conditioned taste aversion (Bernal-Gamboa et al., 2018; Rosas & Callejas-Aguilera, 2007; but see Bernal-Gamboa et al., 2014) with rats. Thus, before firmly concluding that the EMACS effect is a general learning effect, it will be necessary to show whether it can be replicated in behavioral tasks, with the goal of pinpointing the scope and the boundaries of this effect.

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Correspondence concerning to this article may be addressed to José E. Callejas-Aguilera, jecalle@ujaen.es or Pedro Ogallar, pogallar@ujaen.es

Experimental Study II. Concurrent Evidence of Extinction Making Acquisition Context Specific (EMACS) and ABA and ABC Renewal in Human Predictive Learning

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RUNNING HEAD: CONCURRENT EVIDENCE OF EMACS AND RENEWAL

Concurrent Evidence of Extinction Making Acquisition Context Specific (EMACS) and ABA and ABC Renewal in Human Predictive Learning

Pedro M. Ogallar[1], José E. Callejas-Aguilera[1], Juan M. Rosas[1] and Jeffrey Lamoureux[2]

[1] Universidad de Jaén

[2] Boston College

Correspondence:

Pedro M. Ogallar

Department of Psychology

Universidad de Jaén

23071 – Jaen

Spain

e-mail: pogallar@ujaen.es

Abstract

Two experiments evaluated whether the experience of Extinction Makes Acquisition Context Specific and becomes context dependent itself under ABA and ABC renewal designs in a human predictive learning situation. Target cue P was trained in the same context (B) in which target cue E was extinguished after being trained in a different context (A). Testing the target cues outside the extinction/acquisition context led to an increase in responding to cue E (Renewal effect) and a decrease in responding to cue P (EMACS effect) regardless of whether the test was conducted in context A (Experiment 1), or in an alternative context C (Experiment 2). Combined results suggest that Renewal and EMACS effects may be based in the same underlying mechanism.

Keywords: Context · EMACS Effect · Extinction · Predictive Learning · Renewal

1. Introduction

One of the most representative and studied effects of context affecting information retrieval is known as renewal (Bouton & Bolles, 1979). In a standard renewal procedure, a cue is first associated with an outcome in one context (A). Subsequently, this relationship is extinguished in a different context (B), what results in the disappearance of the previously acquired response. Finally, the cue is tested back in the acquisition context A, resulting in a partial renewal of the response learned during the acquisition phase. This procedure is known as ABA renewal, in which the letters identify the contexts where acquisition, extinction and testing take place (e.g., Bouton & King, 1983; Rosas, Vila, Lugo, & López, 2001). Renewal has been reported using ABC (e.g., Thomas, Larsen, & Ayres, 2003), and AAB renewal designs (e.g., Bouton & Ricker, 1994; Rosas & Callejas-Aguilera, 2006), suggesting that the key feature of the renewal effect is that the test takes place in a context different from the extinction context. When extinction and testing contexts are the same, the extinction information is recovered. However, when the test context is different from the extinction context, retrieval of extinction is impaired, and the acquisition information is recovered, at least partially. These studies also show that contextual control preferentially affects the extinction information, since the effect of changing context on acquisition is much less common and it is not usually observed in these designs when contexts are familiar to the organism (e.g., Bouton, 1993; c.f., Hall & Honey, 1989, 1990; Sjöden & Archer, 1989).

Theory of retrieval of the information (Bouton 1993, 1994, 1997) is one of the most successful theories in explaining the effects of context change on performance and information retrieval. This theory assigns the context a key role in solving the ambiguity generated by an experience of associative interference (i.e., extinction). According to this theory, only inhibitory or second-learned information becomes context dependent (Bouton, 1993), though more recent reports show that it is retrieval of the second-learned information what becomes context dependent, regardless of whether that information is inhibitory or excitatory (Nelson, 2002, 2009).

More recent studies have shown that information about unambiguous cues may also become context dependent when they are trained during or after the interference experience (e.g., Rosas & Callejas-Aguilera, 2006, 2007; Rosas, García-Gutiérrez, & Callejas-Aguilera, 2006). These results set the grounds for the Attentional Theory of Context Processing (ATCP, Rosas, Callejas-Aguilera, Ramos-Álvarez, & Abad, 2006). ATCP suggests that information retrieval becomes context dependent in any situation in which the context is attended, regardless of whether this information is ambiguous or not, first- or second-learned (see also, Gawronski, Rydell, Vervliet, & De Houwer, 2010; Ogallar, Ramos-Álvarez, Alcalá, Moreno-Fernández, & Rosas, 2017). ATCP considers attention as the key factor in context dependence of the information. When the learning situation does not lead the organism to attend the context, contexts are assumed to be ignored, and retrieval of the information will not depend on the context where testing takes place (Jiang & Leung, 2005). However, when the learning situation leads the organism to direct its attention to the context, retrieval of all the information learned within that context will become specific. Following this idea, when the contexts are attended in an extinction situation, not only the extinguished cue would be encoded as context dependent (Bouton, 1997), but also other cues that are trained simultaneously or sequentially to the extinction treatment, even those with a consistent meaning (e.g., Rosas & Callejas-Aguilera, 2006, 2007; Rosas, García-Gutiérrez, et al., 2006; see also Bernal-Gamboa, Nieto, & Rosas, 2015; Bernal-Gamboa, Rosas, & Callejas-Aguilera, 2014; Bernal-Gamboa, Rosas, & Nieto, 2018; c.f. Bouton, 1997).

The principles of ATCP have received an important support in both, human and nonhuman animal experiments (e.g., Ogallar et al., 2017). The empirical evidence that supports the principles of ATCP with human participants comes mainly from predictive learning tasks (for a review see Rosas & Nelson, 2019; Rosas, Todd, & Bouton, 2013). In one of the most commonly used, the Restaurants' Task (e.g., Rosas & Callejas-Aguilera 2006), participants learn that costumers eating different foods (cues) in specific restaurants (contexts) may develop a stomach disease (outcome). In this task, the food-outcome association usually transfers quite well across contexts in the absence of interference or ambiguity. However, when a food-outcome association becomes ambiguous (i.e., after an extinction treatment) the transfer between contexts is altered for both, the extinguished cue and the rest of cues that did not receive the extinction treatment. For instance, Rosas and Callejas-Aguilera (2006) used a design in which participants were exposed to a cue associated with a gastric disease (E+) in the first phase. In the second phase, the cue was extinguished in group Extinction (E-) but not in group Control. Participants in both groups were trained with the target cue P followed by the disease. Finally, in the test phase, P was tested in a different, but equally familiar context. Test results found worse performance in group Extinction than in group Control, suggesting that Extinction of E Made Acquisition of P Context Specific (hereinafter referred as the EMACS effect). Evidence of this effect has been reported in humans with predictive learning (Ogallar et al., 2019; Rosas & Callejas-Aguilera, 2006; Rosas, García-Gutiérrez, et al., 2006) and automatic evaluation (Gawronski, Hu, Rydell, Vervliet, & De Houwer, 2015) tasks. In animals, EMACS effect has been found in conditioned taste aversion (Bernal-Gamboa, et al., 2015; Bernal-Gamboa, et al., 2018; Rosas & Callejas-Aguilera, 2007). Moreover, EMACS effect has been found to persist across different tasks in both, human and nonhuman animals (Bernal-Gamboa, Callejas-Aguilera, Nieto, & Rosas, 2013; Bernal-Gamboa, et al., 2014; Rosas & Callejas-Aguilera, 2006; but see Nelson & Lamoureux, 2015; Nelson, Lombas, & León, 2011 for results that qualify these findings).

ATCP assumes that the same underlying (attentional) mechanism explains Renewal from extinction and EMACS effects. Both effects would be the outcome of extinction raising the organism attention to the context, so that all the information learned within that attended context becomes context specific, regardless of whether that information is inhibitory (extinction) or excitatory (acquisition) (e,g., Rosas, Callejas-Aguilera et al., 2006). If this assumption is correct, the EMACS effect must be found under the same conditions in which the renewal effect has been reported. As stated above, renewal effect has been found in situations in which extinction is carried out in the same context of acquisition (AAB), in a different context (ABA), or when the acquisition, extinction and testing are conducted in three different contexts (ABC). However, the EMACS effect has been reported only when training of the target cue is carried out when acquisition and extinction of the ambiguous signal is carried out in the same context. The goal of this study was to test whether EMACS and Renewal effects can be concurrently found within the same situation when acquisition and extinction of the ambiguous cue take place in two different contexts (as it is the case in ABA and ABC renewal designs). With this goal, two experiments were designed in which cue E was extinguished while cue P was paired with the outcome. Experiment 1 was intended to test whether EMACS and Renewal effects appear when ambiguity is produced by training acquisition and extinction in two different contexts (AB), and the test is conducted in context A. Experiment 2 tried to test whether EMACS and Renewal effects appear when ambiguity is produced by training acquisition and extinction in two different contexts (AB), and the test is conducted in a familiar context that has not been used during the acquisition/extinction training (C), and thus is not involved in the extinction training. As stated above, the main theoretical assumption is that Renewal by extinction and EMACS effects share the same underlying (attentional) mechanism. Therefore, at testing we expected to find an attenuation of acquisition performance on cue P (EMACS effect) and an increase in acquisition performance on cue E (Renewal effect).

2. Experiment 1

Experiment 1 tested whether EMACS effect appears under the standard design used in an ABA renewal test (see top section of Table 1). In other words, the goal of Experiment 1 was to test whether a cue-outcome association becomes context-dependent when a different cue is conditioned and then extinguished in two different contexts. To pursue this goal, we chose the new version (Ogallar et al., 2019) of the predictive learning situation developed by Rosas and Callejas-Aguilera (2006) in which contexts and food were represented by actual pictures, rather than by their name. Two groups of participants were first trained with cue E followed by the outcome (O) in context A. During Phase 2, all participants were trained with target cue P followed by O in Context B. The difference between groups came from the treatment received by E during Phase 2. Participants in Group E (Extinction) were trained with P while cue E was extinguished in context B, while participants in Group NE (No Extinction) did not have the experience of extinction with E while being trained with P in context B. Finally, cues P and E were sequentially tested in Contexts A and B. Predictive judgments to target Cue P were expected to be lower in Context A (Different) than in Context B (Same, acquisition context for cue P) only in the group that had the extinction experience, group E. By contrast, predictive judgments to Cue E were expected to be higher in Context A

(Different from the context in which E was extinguished) than in Context B (Same, extinction context for cue E).

2.1. Method

2.1.1. Participants

Thirty-one students' volunteers from Boston College participated in this experiment. They had an average age of 20 years, and 81% of the participants were women. Participants were rewarded with course credit for their participation and they had no previous experience with the task. Participants gave their informed consent before starting the task, and they were randomly assigned to Groups E and NE upon arrival to the laboratory.

2.1.2. Apparatus

Participants performed the experiment individually in two adjacent cubicles. The task was implemented on laptops. Laptops had a 14" screen and were set to a resolution of 1024 by 786. The procedure was implemented using the program SuperLab Pro (Cedrus Corporation). Stimuli, materials, and instructions were always presented in English.

The cues were the same as those used in Ogallar et al. (2019). In this version of the Restaurant Task cues were the same as those used by Rosas & Callejas-Aguilera (2006), with the exception that verbal information was substituted by a picture of the food. Cucumber and garlic were counterbalanced as cues E and P. Cues F1 and F2 were tuna and eggs respectively. Diarrhea was used as the outcome (O). Contexts were the same as those used in Ogallar et al. (2019). Contexts A and B were the images of two fictitious restaurants counterbalanced across participants (see Ogallar et al., 2019 for a more detailed description).

Each trial consists of two screens, cue and feedback screens. The cue screen consists of an image of a restaurant (1348 x 760 pixels) in the center of the screen. Centered within the image of the restaurant, the cue appears with a size of 326 x 218 pixels. Under the image of the restaurant there is a scale that goes from 0 to 100 divided into 21 small buttons of 55 x 40px, each one being an interval of 5 points. The words none, little, some and much were presented on the scale, starting at 0 and ending at 100 with the same distance between them. The feedback screen presented the same information as the cue screen with the exception that scale was substituted by the presentation of the outcome (either *s/he had diarrhea* written in red letters or *s/he had no diarrhea* written in blue letters). The rest of the screen was white. The restaurant and the cue (pasta) used in the demonstration trial were different from the ones used during the task.

2.1.3. Procedure

The procedure used in this study has been approved by the Boston College human experimentation ethics committee. Upon arrival at the laboratory, a consent report was provided to the participants, after which they were invited to sit in a cabin with a laptop. Instructions for the task were presented in that computer on different screens. These instructions were shown on a white screen with 18-point Times New Roman black font. In each of the instruction screens a button appeared at the bottom right with the text *Click here to continue*. Participants used the mouse to click on this button and move on to the next instruction screen.

First screen: *Recent developments in food technology have led to the chemical synthesis of food. This process has great advantages because its cost is very low and it is easy to store and transport. This revolution in the food industry may solve hunger in third-world countries.*

Second screen: *However, it has been detected that some foods produce gastric problems in some people. For this reason, we are interested in selecting a group of experts to identify the foods that lead to some type of illness and how it appears in each case.*

Third screen: *You are about to receive a selection test where you will be looking at the files of persons that have ingested different foods in a specific restaurant. You will have to indicate the degree to which you think that a gastric problem will appear. To respond you should click the option that you consider appropriate. Your response will be random at the beginning, but do not worry, little by little you will become an expert.*

When participants finished reading this last instruction screen they called the experimenter to continue with a demonstration. The demonstration trial was identical to those used during training with the exception that an irrelevant cue (pasta) was used in a different restaurant from the ones used during the rest of the experiment.

All trials consisted of the presentation of the cue screen followed by the feedback screen. Participants were asked for a probability judgment about the relationship between the cue and the outcome by marking on the scale button that they deemed appropriate. Immediately after they marked their choice, and regardless of the option in which the participants clicked, they received the feedback screen in which they could see the outcome or the absence of outcome for 1,500ms. The intertrial interval lasted 1,000ms, and was indicated by a screen with the sentence: *Loading the file of* [a random full name]… In each of the trials a different full name was used to keep the impression that each file was from a different person. Before starting the experiment, participants were randomly assigned to each group: Extinction (E) and Non-Extinction control (NE). The experiment was carried out in three phases. The design of the experiment is presented in the top section of Table 1.

Table 1

Experimental Designs.

Experiment	Group	Pre-Phase	Phase 1	Phase 2	Test Phase *EMACS*	Test Phase *Renewal*
1	E	-	A: **E-O**, F1- B: F2-O, F1-	A: F2-O, F1- B: **E-, P-O**	A: P? B: P?	A:X? B:X?
	NE			A: F2-O, F1- B: F1-, **P-O**	A: P? B: P?	A:X? B:X?
2	E	A: F3-O, F4- B: F3-O, F4- C: F3-O, F4-	A: **E-O**, F1- B: F2-O, F1-	A: F2-O, F1- B: **E-, P-O**	C: P? B: P?	C:X? B:X?
	NE			A: F2-O, F1- B: F1-, **P-O**	C: P? B: P?	C:X? B:X?

Note: A and B (contexts): Pictures of two different fictitious restaurants, counterbalanced across participants (image of a terrace in front of a lake, with natural scenery and typical terrace furniture, while the other restaurant presented an old European city patio with typical bistro tables covered with elegant tablecloths). C, a new context used in Experiment 2 (image of a new fictitious night restaurant with colored chairs and tables and some ornaments made with wood). E and P (target cues): Pictures of different foods (cucumber and garlic) counterbalanced. F1, F2, F3 and F4 (filler cues): Pictures of different foods (eggs, tuna fish, caviar and corn, respectively). O (outcome): gastric illness.

2.1.3.1. Phase 1.

All participants in the experiment received 24 trials in each context, separated into three equal blocks. In each block of trials, participants received 4 randomized trials of each association E-O and F1- in context A, or 4 randomized trials of each association F2-O and F1- in context B. Experience with contexts, cues and the outcome was equated in this phase within and between groups. Each block of trials within a context was preceded by a screen with the image of the restaurant and the sentence: *Now you are going to analyze the files of the people who ate at this restaurant*. The order in which the contexts and blocks of trials were presented was counterbalanced within and between participants (ABBAAB or BAABBA).

2.1.3.2. Phase 2.

Phase 2 was identical to Phase 1, except for the following. In both groups a new cue was associated to the outcome (P-O) in Context B. The cue E was presented without the outcome in context B for Group E. To equate the experience with context B, F1 was presented without outcome in Group NE in Context B. Finally, cue F2 was presented followed by the outcome and cue F1 was presented in the absence of the outcome in context A in both groups.

2.1.3.3. EMACS test.

A predictive judgment test was conducted in which participants were asked about the relationship between P and O in context A and context B with 4 presentations of P in each context. The transition from Phase 2 to the testing phase was not signaled. Transition between contexts was signaled as described in Phase 1. The trials in this phase were the same as those in the previous phases with the exception that this time the participants did not receive feedback; instead it was replaced by a white screen. The order in which contexts were presented was counterbalanced within and between groups (ABABAB or BABABA).

2.1.3.3. Renewal test.

After testing cue P, participants were asked about the relationship between cue E and O. The test for E was identical to the one used for cue P. The transition between tests was not signaled.

2.1.4. Dependent variables and statistical analysis

Predictive judgments were recorded during training. To simplify the presentation of the results, only results with cues P and E are reported (the responses to the fillers was as expected based on their relationship with the outcome). Predictive judgments were evaluated with a mixed-factorial analysis of variance (ANOVA). The probabilities are reported with a general rejection criterion of p <.05. Additionally, confidence intervals for effect sizes of 95% are reported.

2.2. Results

2.2.1. Training (Phases 1 and 2)

Figure 1 presents the mean predictive judgments given by participants to cues E and P in Groups E and NE during Phase 1 (left) and Phase 2 (right). Learning about E (Phase 1) and P (Phase 2) increased over training, regardless of the groups. Extinction of E proceeded as expected in Group E. A 2 (Group) x 12 (Trial) ANOVA conducted with predictive judgments to E during Phase 1 found a significant main effect of Trial, $F(11, 319) = 32.90$, MSe = 235.87, $p < .001$, $\eta_p^2 = .532$, 95% CI [.44, .58]. The main effect of Group and the interaction Group x Trial were not significant, *Fs < 1*.

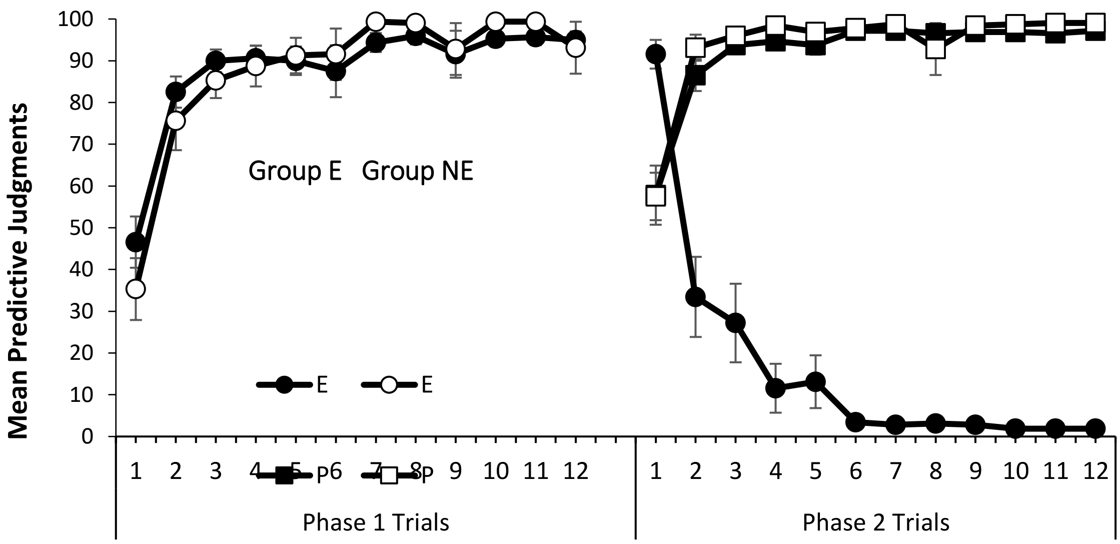

Fig. 1. Mean predictive judgments to target cues E and P in groups E and NE during the 12 Trials of Phase 1 (left) and Phase 2 (right). Error bars denote standard errors of the mean.

During Phase 2, a 2 (Group) x 12 (Trial) ANOVA conducted with target cue P found a significant main effect of Trial, $F(11, 319) = 36.02$, MSe = 109.58, $p < .001$, $\eta_p^2 = .554$, 95% CI [.47, .60]. The main effect of Group and the Group x Trial interaction were not significant, *Fs* < 1. Furthermore, responding to E decreased progressively in group E, $F(11, 165) = 36.11$, MSe = 299.51, $p < .001$, $\eta_p^2 = .707$, 95% CI [.61, .74], showing that the extinction treatment was effective on reducing responding to cue E in that group.

2.2.1. EMACS Test

The left section of Figure 2 presents the mean predictive judgments given by participants to cue P in groups NE and E during the tests conducted in context B (same) and in context A (different). There were no differences between predictive judgments to cue P in group NE. However, predictive judgments to cue P were lower in context different (A) than in context same (B) in group E. A 2 (Group) x 2 (Context) ANOVA conducted with the target cue P found a significant main effect of Group, $F(1, 29) = 11.79$, MSe = 888.65, $p = .002$, $\eta_p^2 = .289$, 95% CI [.05, .50]. The main effect of Context was also significant, $F(1, 29) = 8.23$, MSe = 1007.97, $p = .008$, $\eta_p^2 = .221$, 95% CI [.02, .44]. More important for the goals of the study, there was a significant Group x Context interaction, $F(1, 29) = 6.13$, MSe = 1007.97, $p = .019$, $\eta_p^2 = .175$, 95% CI [.00, .40]. Subsequent analyses of the Group x Context Interaction found that the simple effect of context was significant in Group E, $F(1, 15) = 7.90$, MSe = 1883.54, $p = .01$, $\eta_p^2 = .345$, 95% CI [.02, .59], but not in Group NE, $F(1, 14) = 1.08$, MSe = 69.85, $p = .32$, $\eta_p^2 = .071$. Additionally, the simple effect of Group was significant in context A, $F(1, 29) = 8.93$, MSe = 1833.68, $p = .006$, $\eta_p^2 = .235$, 95% CI [.02, .45], neither in context B, $F(1, 29) = 4.47$, MSe = 62.94, $p = .04$, $\eta_p^2 = .134$, 95% CI [.00, .36].

2.2.1. Renewal Test

The right section of Figure 2 presents the mean predictive judgments given by participants to cue E in groups NE and E during the tests conducted in context B (same) and in context A (different). No differences in responding to cue E across contexts were observed in group NE. However, responding to cue E in group E was higher in context different (A) than in context same (B). A 2 (Group) x 2 (Context) ANOVA conducted with the cue E found a significant main effect of Group, $F(1, 29) = 91.85$, MSe = 2245.96, $p < .001$, $\eta_p^2 = .760$, 95% CI [.57, .84]. The main effect of Context was also significant, *F(*1,

29) = 15.51, MSe = 2964.08, $p < .001$, $\eta_p^2 = .349$, 95% CI [.09, .55]. Of most relevance for the goals of this study, there was a significant Group x Context interaction, $F(1, 29) = 12.12$, MSe = 2964.08, $p = .002$, $\eta_p^2 = .295$, 95% CI [.05, .50]. Subsequent analyses of the Group x Context Interaction found that the simple effect of context was significant in Group E, $F(1, 15) = 15.13$, MSe = 5573.53, $p < .001$, $\eta_p^2 = .502$, 95% CI [.11, .70], but not in Group NE, $F(1, 14) = 1.79$, MSe = 168.24, $p = .20$, $\eta_p^2 = .113$. Additionally, the simple effect of Group was significant both, context A, $F(1, 29) = 10.40$, MSe = 3368.33, $p = .003$, $\eta_p^2 = .264$, 95% CI [.04, .48], and context B, $F(1, 29) = 112.55$, MSe = 18.40, $p < .001$, $\eta_p^2 = .795$, 95% CI [.63, .86], suggesting that renewal from extinction was not complete.

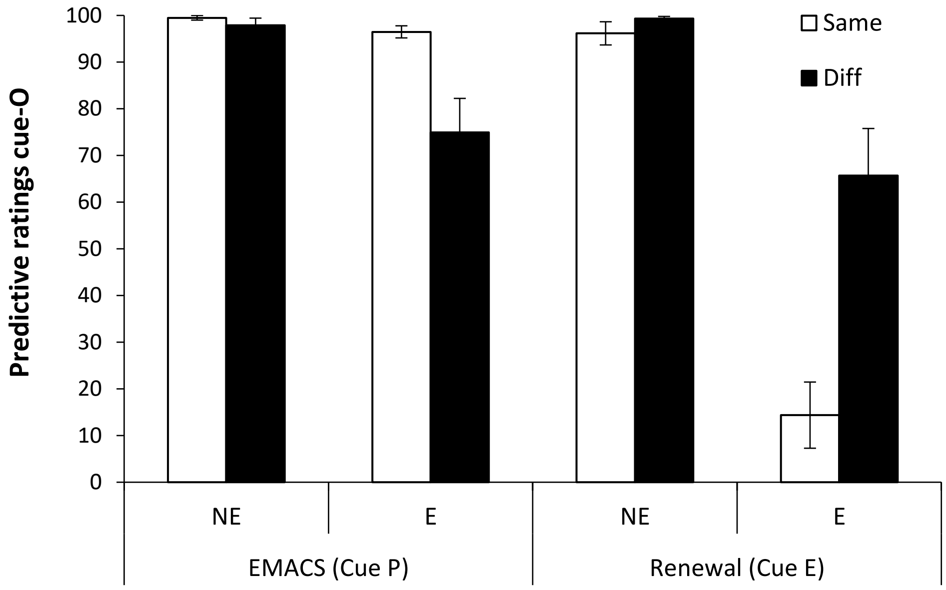

Fig. 2. Mean predictive judgments given to cues P (left) and E (right) by participants in groups E and NE during the test trials in context A (Different) and in context B (Same). Error bars denote standard errors of the mean.

In summary, Experiment 1 found that extinction of a cue (E) made context-specific retrieval of a different association (P-O) that had received consistent training at the same time that retrieval of extinction of cue E also become context specific. This result provides the first evidence of the EMACS effect in a learning situation where ambiguity is built by training sequentially acquisition and extinction of a cue (E) in two different contexts (AB), and in which the test is conducted in the context in which the extinguished cue was paired with the outcome. Furthermore, the result replicated the

ABA renewal by extinction within the same procedure. Thus, this experiment replicates the EMACS effect using a design akin to ABA renewal, adding support to the idea that both phenomena may be based in the same underlying process. Interestingly, the same context produces a loss of responding to the excitatory cue (P) and an increase of responding of the extinguished cue (E) so that the effect of context changes upon responding here cannot be explained by direct associations between the context and the outcome, as it seems the case in predictive learning experiments that find context-switch effects early on training (León, Abad & Rosas, 2010). Alternatively, context switch effects in this situation seem to be more likely explained by contexts playing the role of modulators of cue-outcome associations (e.g., Bouton, 1993).

Both, in this experiment, and in the ABA renewal designs that equate contexts' experience throughout training, the test is conducted in a context that, according to ATCP, will be also attended once extinction takes place in the alternative context. Thus, this experiment leaves unanswered the question of whether the EMACS effect can be found when the test is conducted in a context with which the participant has no experience after extinction, and thus, it is not expected to be attended during training. Experiment 2 was conducted with the goal of testing whether the EMACS effect appears when the test involves leaving an attended context and it is conducted in a context that was not part, neither presented during training with the target cues.

3. Experiment 2

The results reported in Experiment 1 suggest that the same mechanisms underlie renewal and EMACS effects under an ABA renewal design. The goal of Experiment 2 is to extend the test to an ABC renewal design. In this design the extinguished cue (E) is tested in a context different (C) from both, the acquisition context (A) and the extinction context (B). Additionally, participants were familiarized with context C before starting training with the target cues E and P. Consequently, the test was conducted in a familiar context, but this context was not part of the extinction training and thus, would not be especially attended.

The design of Experiment 2 is presented at the bottom section of Table 1. The design was identical to the design used in Experiment 1, with the exception that additional context and fillers were presented before Phase 1 so that participants had experience with the three contexts used in the experiment before starting training with the target cues E and P.

3.1. Method

3.1.1. Participants

Sixty-three students from Boston College participated in this experiment. The average age of the participants was 19 and 69% of the participants were women. Participants were assigned to different groups randomly.

3.1.2. Apparatus and procedure

Apparatus and design of Experiment 2 were identical to those used in Experiment 1 with the following exceptions: Before starting with Phase 1, all participants received 12 pre-training trials separated in 3 blocks (Pre-training phase). In each block of trials participants received 4 trials, two with a new filler F3 followed by the outcome, and two with a new filler F4 without outcome. Trials in each block were randomly intermixed. Each block of trials took place in a different context (A, B and C). This pre-training phase tried to familiarize participants with the three contexts used in the experiment, so that context C was not new at the time of testing. Caviar and corn were added to the food fillers' list. Context C was the image of a new fictitious night restaurant with colored chairs and tables and some wooden ornaments. The transition between contexts was signaled as described in Experiment 1. Training in Phases 1 and 2 was identical to the one used in Experiment 1. Finally, participants were asked about the relationship between P and O in context B (where P-O relationship was trained) and in context C (a familiar context in which neither cue E nor cue P were previously presented). After testing cue P, participants were asked about the relationship between E and O. The test for E was identical to the one used for P. The order in which contexts were presented was counterbalanced within and between groups (BCBCBC or CBCBCB).

3.2. Results

3.2.1. Training (Phases 1 and 2)

Figure 3 presents the mean predictive judgments given by participants to cues E and P during Phase 1 (left panel) and Phase 2 (right panel) in Groups E and NE. Learning about E and P increased over training, regardless of the groups. Extinction of E proceeded as expected in Group E. A 2 (Group) x 12 (Trial) ANOVA conducted with predictive judgments to E during Phase 1 only found a significant main effect of Trial, $F(11, 671) = 53.51$, MSe = 240.89, $p < .001$, $\eta_p^2 = .467$, 95% CI [.41, .51]. Neither the main effect of Group, nor the Group x Trial interaction were significant, $F(1, 61) = 1.29$, MSe = 3481.09, $p = .26$, $\eta_p^2 = .021$, for the highest p value corresponding to the main effect of Group.

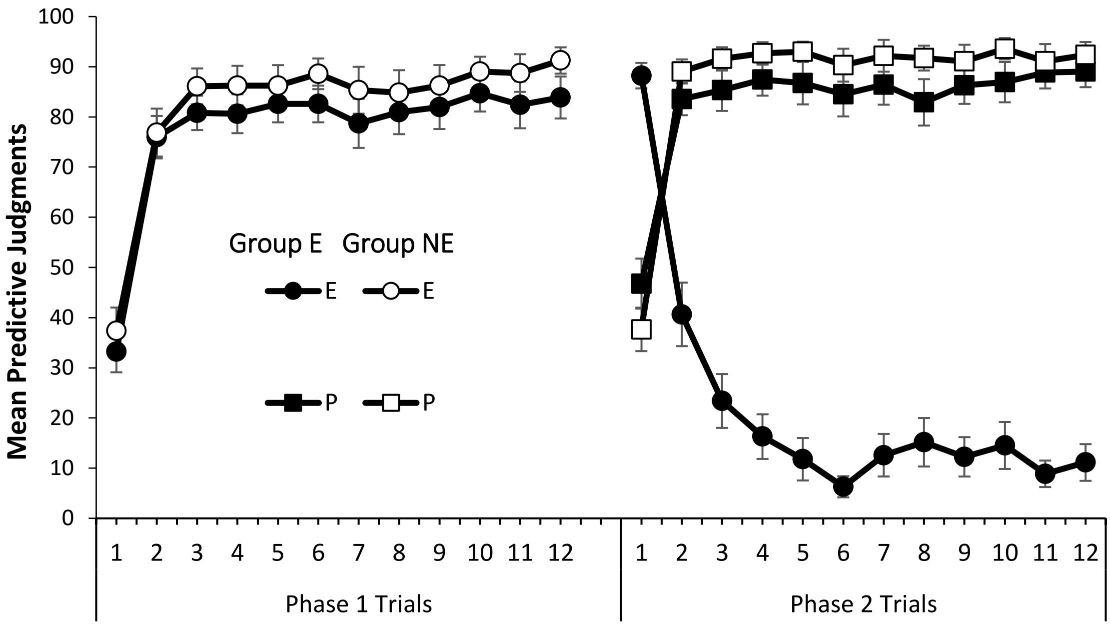

Fig. 3. Mean predictive judgments to target cues E and P in groups E and NE during the 12 Trials of Phase 1 (left) and Phase 2 (right). Error bars denote standard errors of the mean.

During Phase 2, a 2 (Group) x 12 (Trial) ANOVA conducted with the target cue P only found a significant main effect of Trial, $F(11, 671) = 64.61$, MSe = 179.16, $p < .001$, $\eta_p^2 = .514$, 95% CI [.46, .55]. Neither the main effect of Group, nor the Group x Trial interaction were significant, $F(1, 671) = 1.80$, MSe = 179.16, $p = .051$, $\eta_p^2 = .029$, for the highest p value corresponding to the interaction. As the p value of the interaction was close to significance, we decided to explore the interaction further, but the simple effect of Group was not significant in any trial, $F(1, 61) = 2.87$, MSe = 425.72, $p = 0.09$, for the highest p value corresponding to trial 8. Finally, responding to E decreased progressively in group E, $F(11, 330) = 35.08$, MSe = 457.61, $p < .001$, $\eta_p^2 = .539$, 95% CI [.45, .58], showing that the extinction treatment was effective on reducing responding to cue E in that group.

3.2.2. EMACS test

The left section of Figure 4 presents the mean predictive judgments given by participants to cue P in Groups NE and E during the tests conducted in context B (same) and in context C (Different). The response transfer between contexts seems lower in Group E than in Group NE. A 2 (Group) x 2 (Context) ANOVA found significant main effects of Group, $F(1, 61) = 6.62$ MSe = 2291.74, $p = .013$, $\eta_p^2 = .098$, 95% CI [.00, .25], and Context, $F(1, 61) = 8.69$ MSe = 411.74, $p = .005$, $\eta_p^2 = .125$, 95% CI [.01, .28]. Most important, there Group x Context interaction was also significant, $F(1, 61) = 6.11$ MSe = 411.74, $p = .016$, $\eta_p^2 = .091$, 95% CI [.00, .24].

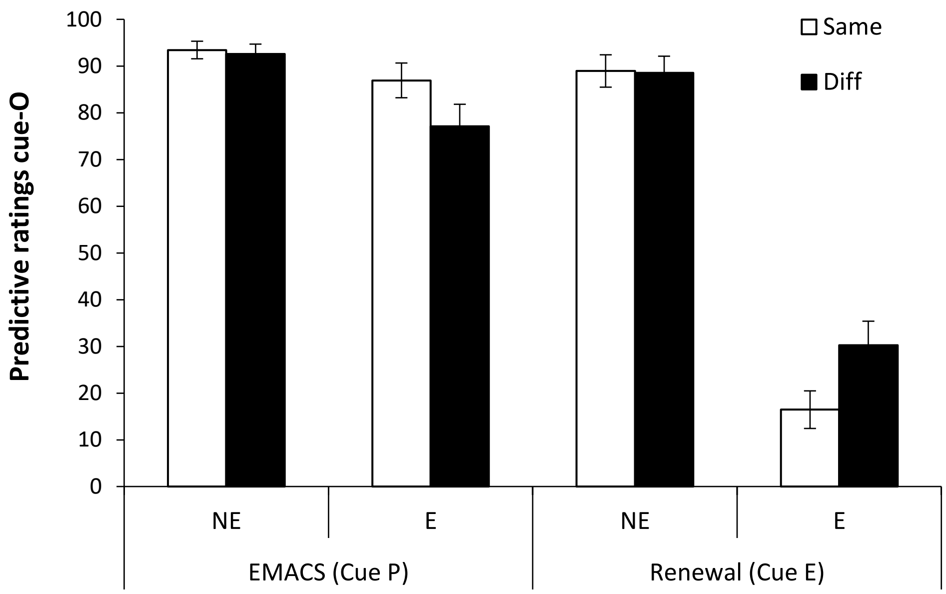

Fig. 4. Mean predictive judgments given to cues P (left) and E (right) by participants in groups E and NE during the test trials in context C (Different) and in context B (Same). Error bars denote standard errors of the mean.

Subsequent analyses conducted to explore the Group x Context Interaction found that the simple effect of context was significant in Group E, $F(1, 30) = 7.32$, MSe = 812.94, $p = .01$, $\eta_p^2 = .196$, 95% CI [.01, .41], and was no significant in Group NE, $F(1, 31) = 2.01$, MSe = 23.48, $p = .166$, $\eta_p^2 = .061$. Additionally, the simple effect of Group was no significant in context B (Same), $F(1, 61) = 2.49$, MSe = 1071.69, $p = .12$, $\eta_p^2 = .039$, but it was significant in context C (Different), $F(1, 61) = 9.20$, MSe = 1631.79, $p = .004$, $\eta_p^2 = .131$, 95% CI [.02, .29].

3.2.3. Renewal test

The right section of Figure 4 presents the mean predictive judgments given by participants to cue E in Groups NE and E during the tests conducted in context B (same) and in context C (Different). Responding to cue E was higher in context C than in context B, in what seems to be the standard ABC renewal results. Responding to cue E in group NE does not seem to differ across contexts. A 2 (Group) x 2 (Context) ANOVA found significant main effects of Group, $F(1, 61) = 159.92$, MSe = 3367.52, $p < .001$, $\eta_p^2 = .724$, 95% CI [.60, .79], and Context, $F(1, 61) = 6.58$, MSe = 854.01, $p = .01$, $\eta_p^2 = .097$, 95% CI [.00, .25]. The Group x Context interaction was also significant superseding the main effects of Group and Context, $F(1, 61) = 7.46$, MSe = 854.01, $p = .008$, $\eta_p^2 = .109$, 95% CI [.01, .26].

Subsequent analyses of the Group x Context Interaction found that the simple effect of Context was significant in Group E, $F(1, 30) = 6.95$, MSe = 1696.14, $p = .01$, $\eta_p^2 = .188$, 95% CI [.01, .41], but not in Group NE, $F < 1$. Additionally, the simple effect of Group was significant in both, context C (Different), $F(1, 61) = 87.08$, MSe = 2456.12, $p < .001$, $\eta_p^2 = .588$, 95% CI [.42, .69], and context B (Same), $F(1, 61) = 187.49$, MSe = 1765.41, $p < .001$, $\eta_p^2 = .755$, 95% CI [.64, .82], suggesting that renewal from extinction in group E was not complete as responding was far from reaching the response to E in the absence of extinction (group NE).

In summary, Experiment 2 replicated the results reported in Experiment 1 in both EMACS and Renewal effects, but when the test was conducted in a context with which the participants had not experience after extinction.

4. General Discussion

The main goal of this experimental series was evaluating whether the EMACS effect may be found under the same conditions in which renewal it is usually found. To our knowledge, EMACS has been only reported in a procedure in which acquisition and extinction of the ambiguous cue take place in the same context (AA). However, renewal has been also reported when acquisition and extinction take place in two different contexts, regardless of whether the test is conducted later in the acquisition context (ABA design) or in a different context (ABC design).

For this purpose, we conducted two experiments in which we found concurrent evidence of the EMACS and renewal effects when extinction was conducted in two different contexts, regardless of whether the test was conducted in the context where the extinguished cue was originally paired with the outcome (Experiment 1), or in a different one with which participants had no experience after the extinction treatment started (Experiment 2). Additionally, these experiments found perfect transfer of simple acquisition in the absence of extinction, both, regardless of whether the acquisition took place at the beginning of training (cue E in group NE), or closer to the test (cue P in group NE).

In addition to the similar result reported in this experimental series, the design used in each experiment allows to approach different theoretical issues. Experiment 1 used an ABA Renewal from extinction design. In many experiments conducted with this design, renewal from extinction may be explained to the return to an excitatory context. The use of context B during extinction can partially protect the CS from extinction (Rescorla & Wagner, 1972). Context B may acquire some inhibitory strength during extinction that would protect the CS from losing all of its excitatory associative strength (Rauhut, Thomas, & Ayres, 2001; Thomas & Ayres, 2004). This protection of the loss of associative strength would lead to renewal response when extinguished cue is tested in a context different from the extinction context. This interpretation needs of context A to acquire some excitatory strength during acquisition. Thus, renewal would be explained by the combination of the residual excitatory associative strength of the CS and the excitatory associative strength of context A during the test. However, such interpretation is unlikely with the results reported here. Experiment 1 tested cue P in context A, an excitatory context that should have increased responding to P rather than impairing it. Finding opposite results within the same context for cues P and E suggests that contexts do not enter into direct associations with the outcome in this situation (c.f., León, et al., 2010). Alternatively, it seems more likely to suggest that contexts control performance through a hierarchical, occasion-setting like mechanism as the one proposed by Bouton (1993).

In Experiment 2, the test in context C allowed to evaluate whether the EMACS effect can be found when the target cue (P) is tested in a context that kept a zero contingency with the outcome, but in which neither the ambiguous cue (E) nor the target cue (P) were presented before. Furthermore, the training in context C took place before ambiguity training began, which excludes an explanation in terms of excitatory or inhibitory associative strength of the contexts that could develop once participants are assumed to pay attention to the context once extinction began. Although it was not the main goal of this research, to our knowledge this is the report of ABC renewal in a predictive learning task.

The results found in these experiments expand the conditions in which the EMACS effect can be found. Most importantly, the combination in the same procedure of results showing EMACS effect and Renewal by extinction, suggest that both phenomena may be based on the same underlying process. Under the same learning situation, to leave the extinction context seems to involve both, an increase in responding when the extinguished cue is tested in a renewal procedure, and a decrease in the response when the excitatory cue is tested in an EMACS procedure. As stated above, explaining the combination of these two results found within the same procedure makes it difficult to explain any of them in terms of the excitatory or inhibitory associative strength acquired by the contexts. ATCP solves this problem by assuming an attentional mechanism that raise the attention to the context when the information become ambiguous, coding all the information learning since then as context dependent (Ogallar et al., 2017: Rosas, Callejas-Aguilera et al., 2006). This interpretation agrees with the idea that extinction would produce a general increase in attention (e.g., Schmajuk, Lam, & Gray, 1996) or in the engagement of the attentional exploratory mechanism (Le Pelley, Mitchell, Beesley, George, & Wills, 2016) with the goal of solving the ambiguity that extinction produces in the organism. According to these interpretations, the context-switch effect could be considered like a side effect of a wider phenomenon that, under an ambiguity situation, facilitates subsequent learning about contexts, as shown in this experimental series, but also about different tasks and procedures that were not part of the original learning, such as it has been recently reported in the literature (Alcalá, Callejas-Aguilera, Lamoureux, & Rosas, 2019; Alcalá, Callejas-Aguilera, Nelson, & Rosas, 2019; González, Alcalá, Callejas-Aguilera, & Rosas, 2019; see also Rosas & Nelson, 2019).

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Correspondence concerning to this article may be addressed to José E. Callejas-Aguilera, jecalle@ujaen.es

Chapter IV: Does an ambiguity experience facilitate learning across different contexts and tasks?

In the studies presented above it is suggested that the experience of extinction could produce a general increase in attention leaving open the possibility that renewal and EMACS effects, as well as other context-switch effects on retrieval, could be explained as a side effect of this general increase in attention that would raise attention to the contexts as well (e.g., Rosas & Nelson, 2019). However, as stated in the preface, the studies testing the idea that interference produces a general increase in attention conduct the interference training and the learning test with similar tasks and within similar contexts, allowing for an explanation of the results in terms of changes in context processing (Alcalá, Callejas-Aguilera, Lamoureux, & Rosas, 2019; Alcalá, Callejas-Aguilera, Nelson, & Rosas, 2019; González, Alcalá, Callejas-Aguilera, & Rosas, 2019).

Chapter IV presents an empirical study in which the effect of an interference experience upon new learning is studied within two quite different tasks and contexts, with the goal of exploring whether the experience of interference would facilitate subsequent learning when the context is not involved. Specifically, the empirical study presented here evaluated the effect of the experience with consummatory negative successive contrast in rats on acquisition of temporal conditioning that took place within a different context (Skinner Boxes) from the one where the original consummatory training was conducted (Plexiglas cages placed in a different room). We chose rats to conduct this study, as it was easier to count with two truly different standardized tasks and contexts with rats in our laboratory than with human participants. Finding facilitating learning after the conflicting experience under these conditions will strongly suggest that the experience of interference leads to a general facilitation of learning that would affect context as well, suggesting the need of a revision of the Attentional Theory of Context Processing.

Experimental Study III. Experiencing Consummatory Successive Negative Contrast Facilitates Subsequent Temporal conditioning in rats Magazine Training

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RUNNING HEAD: NEGATIVE CONTRAST AND TEMPORAL CONDITIONING

Experiencing Consummatory Successive Negative Contrast Facilitates Subsequent Temporal conditioning in rats Magazine Training

José A. Alcalá[1], Pedro M. Ogallar[2], José E. Callejas-Aguilera[2], and Juan M. Rosas[2]

[1] University of Leicester

[2] Universidad de Jaén

Correspondence:

Pedro M. Ogallar

Department of Psychology

Universidad de Jaén

23071 – Jaén

Spain

e-mail: pogallar@ujaen.es

Abstract

One experiment assessed the effect of experiencing Consummatory Successive Negative Contrast (cSNC) on acquisition of subsequent temporal discrimination in rat's appetitive conditioning. After a day of magazine training, two groups of animals received a daily session with exposure to a sucrose at either 32% or 4% dilution during ten days. In days 12-14 rats received two daily sessions, a consummatory one in which both groups received 4% sucrose, immediately followed by a temporal conditioning session in which all rats received food under a fixed time schedule of 60 seconds. Thus, sucrose concentration was reduced from 32% to 4% in group 32-4, while remained at 4% in group 4-4. Consumption in group 32-4 was reduced after the shift in the sucrose concentration below consumption in group 4-4, showing the well-known cSNC effect. Temporal conditioning developed faster in group 32-4 than in group 4-4, suggesting that the experience of cSNC facilitated subsequent learning of a temporal discrimination that takes place with a different task and within a different context. Results are discussed in terms of current associative theories of human and nonhuman conditioning and attention.

Keywords: Attention, Consummatory Successive Negative Contrast, Temporal Conditioning

1. Introduction

Learning about the regularities in the environment and updating this learning to changes in those regularities is essential for survival of the organisms. How human and non-human animals react to fluctuations of the environment has been the focus of a large number of studies since the seminal study of extinction conducted by Pavlov (1927). During extinction, a stimulus or a response that has been previously conditioned is no longer followed by the outcome. Thus, the predictive value of that stimulus changes, generating a situation of associative interference in which the new information interferes with the information previously learned, generating a sudden increase in the prediction error. Associative theories understand learning as reduction of that prediction error (e.g., Rescorla & Wagner, 1972).

One of the multiple alternatives to produce changes in the prediction error is to introduce partial, but sudden increases or decreases in the value of the reward, leading to successive contrast effects in the organism behavior (for a review see Flaherty, 1996). For instance, in the experimental procedure known as Successive Negative Contrast (SNC), after a first stage in which the animal is used to receive a given reward by performing a given behavior, the value of the reward is suddenly lowered. This reduction is assumed to generate a state of frustration that leads the animal to perform worse than an animal receiving the low reward from the beginning (e.g., Amsel, 1992). Both, in extinction and in SNC, there is a discrepancy between what the organism expects and what the organism receives. This discrepancy leads to a situation of uncertainty or ambiguity that it is gradually corrected as prediction error is reduced by new learning.

The experience of uncertainty has been assumed to produce a general activation of the organism that might facilitate subsequent learning. For instance, Anselme (2010) suggests that some degree of uncertainty is needed to activate the cognitive resources as a strategy to obtain information about the environment. Le Pelley, Mitchell, Beesley, George, and Wills (2016), suggest that when environmental conditions are not fully predictable, the organism engages the *attentional exploration mechanism* in what could be understood as an attempt to explore all the possible sources of information under the basic assumption that the goal of the organism is to predict its environment. There are a number of studies in the literature suggesting that this general idea has some value. For instance, Robinson, Anselme, Fischer, and Berridge (2014) found that rats exposed to higher levels of uncertainty shown greater explorative behaviors to non-preferred elements than rats exposed to lower degrees of uncertainty. Similar results are found when the change in the environment is produced by SNC. As illustration, Elliot (1928) found that rats displayed more entries into the unrewarded arms of the maze after experiencing the downshift. This pattern of behavior may be understood as rats searching for the previously experienced reward or alternatively looking for new sources of reward (see also Pecoraro, Timberlake, & Tinsley, 1999).

A recent study by De la Casa, Mena, Ruiz-Salas, Quintero, and Papini (2018) suggests that the effects of SNC could go further than a simple increase in the exploratory behavior. De la Casa et al. (2018), using consummatory Successive Negative Contrast (cSNC), trained animals with a dissolution of 32% sucrose before giving them access to a dissolution of 4% sucrose. Control group received access to the dissolution of 4% sucrose from the start. Downshifting the value of the reward produced the standard drop in consumption in the experimental group below consumption of the control animals. After a session of downshift, half of the animals in each group were exposed to a conditioned stimulus (CS), while the other half received equivalent exposure to the context. The retardation of conditioning that follows nonreinforced exposure to the CS was attenuated in the animals that had the cSNC experience, suggesting that experiencing cSNC somewhat preserved the associability of a pre-exposed CS. In a recent study in human predictive learning, González, Alcalá, Callejas-Aguilera, and Rosas (2019) also reported an attenuation of the retardation effect that appears when a conditioned inhibitor is paired with the outcome in participants that experienced extinction with a different stimulus.

Taking together, these results suggest that the experience of uncertainty may facilitate subsequent learning, either by facilitation of the exploratory behavior (e.g., Anselme, 2010) or by engaging the attentional exploration mechanism (e.g., Le Pelley et al., 2016). A recent report from our laboratory may serve as an illustration. Alcalá, Callejas-Aguilera, Lamoureux, and Rosas (2019) trained two groups of rats to discriminate between two different stimuli, one followed by food and the other presented alone. The relationship between the stimuli and the outcome was reversed in half of the animals, while it was kept the same in the other half. After this experience, rats received the food under a fixed time program, finding that the animals that had the reversal experience developed the temporal conditioning faster than animals that either did not have a previous learning experience, or that their experience did not involve discrimination reversal (see Nelson, Fabiano, & Lamoureux, 2018 for a similar effect in human learning). A similar pattern of results has been reported in spatial learning. Shanab and Cotton (1970) found that experiencing extinction in a runway facilitated subsequent acquisition of a T-maze discrimination and vice versa. More recently, Alcalá, Callejas-Aguilera, Nelson & Rosas (2019) reported that rats that experienced interference within a water maze learned faster a new position of the platform than rats that did not have the reversal experience.

An issue that is common to most of the studies briefly discussed above is that the learning situation in which the facilitation effects of interference have been tested is the same, or quite similar to the one in which the interference procedure is developed. Even in the study of De la Casa et al. (2018) where the effect of cSNC was tested on latent inhibition of fear conditioning, consummatory and Pavlovian procedures took place within the same operant boxes. The only exception to our knowledge is the study of Shanab & Cotton (1970), that used two different labyrinths (a runway and a T-maze), though they shared a number of similar features as well. Consequently, in previous studies the effects of the interference experience upon new learning may depend on interference facilitating general context processing (e.g., Bouton, 1993; Rosas, Callejas-Aguilera, Ramos-Álvarez, & Abad, 2006), allowing the organism to relocate its attentional resources in the relevant aspects of the new learning situation.

However, the assumption that facilitation of learning is due to changes in general arousal/attention should not depend on the new learning taking place in the same task or within a similar context to the one where the interference experience took place, as these general changes are not expected to be context-specific. The main goal of this study was to evaluate whether the facilitation effect on learning that has been reported after different interference experiences (e.g., Alcalá et al., 2019; De la Casa et al., 2018; Nelson et al., 2018) may be found when the interference experience and the new learning take place in different contexts, precluding an interpretation of the effect in terms of interference increasing context processing (Bouton, 1993; Rosas et al., 2006).

The design of the study is presented in Table 1. Two groups of animals received access to a 32% dissolution of sucrose (Group 32-4) or to a 4% dissolution of sucrose (Group 4-4) in distinctive plexiglass boxes. Once consumption was stabilized, the solution in group 32-4 was downshifted to 4%. Three sessions with the 4% solution were conducted. Immediately after each of these sessions, rats received one session of classical temporal conditioning in standard operant cages placed in a different laboratory room. Food was delivered every 60 seconds (Fixed Time, FT60). Intermixing consummatory and temporal conditioning sessions was intended to maximize the possibility of detecting the influence of the changes in the prediction error upon new learning, as prediction error is assumed to decrease as training in the new situation proceeds and the animal updates its knowledge. We expected the downshift in the reward to produce the well-known cSNC effect in Group 32-4. The key issue in this study is whether the experience of cSNC facilitates subsequent learning of a temporal discrimination in a completely different task and context, a result that is expected by the idea that changes in de prediction error affect general processing of the information, rather than only to the contexts (e.g., Alcalá et al., 2019).

2. Method

The experiment was conducted at the Laboratory of Animal Behavior and Cognition of the Centre of Animal Production and Experimentation of the Universidad de Jaén. Experimental procedures were approved by the bioethical committee of the Universidad de Jaén, reference JA-U1 2013.

2.1 Subjects

Sixteen female Wistar rats provided by Janvier Laboratories (France) were used in this experiment. They were about 5 months old with a mean free-feeding weight of 197 g (range 180-224 g) at the beginning of the experiment. Rats were individually housed in standard Plexiglas cages inside a room maintained on a 12-12 hr light-dark cycle with the light part of the cycle starting at 8 a.m. Environmental conditions were constant (21° C, 60% humidity). Rats had previous experience in an unrelated experiment in appetitive conditioning in which they had to discriminate between a tone and a light within the Skinner boxes. To avoid the potential confound of previous experience, rats were orthogonally ascribed to group 32-4 and 4-4 based in the previous experimental treatments they received. Following the procedure described in De la Casa et al. (2018), the ad libitum weight of each rat was registered one day before the start of the experiment. After that, food was restricted and animals were feeding with 5–10 g per day. Following this restriction animals' weight was approximately at their 85% of the ad libitum weight at the end of experiment.

2.2 Apparatus

The experiment was conducted in two adjacent rooms. Consummatory procedures were conducted in Room 1, while Pavlovian training was conducted in Room 2.

Consummatory procedures took place in 8 transparent Plexiglass cages (14 x 23 x 23 cm) with the outside of the walls covered with a squared pattern paper (red and white squares, 7 mm side). Fluids were administered in 150-ml bottles with a standard spout.

Magazine and temporal conditioning training took place in eight operant chambers, each housed in its own sound attenuating enclosure. Ventilation fans provided background noise of 60 dB. Chambers were lit with a 2-W LED fluorescent tube mounted to the ceiling of the sound attenuating enclosure. All chambers had the same 25 x 25 x 25 cm cubic design (Panlab S.L., Barcelona). Front and rear walls were made of aluminum whereas the side walls were made of methacrylate (clear for the door access in the left side, and black for the right side). The ceiling was made of aluminum except for a circular opening 11.5 cm in diameter covered by clear methacrylate that allowed the houselight to illuminate the operant chamber. The floor was made of stainless-steel grids (0.2 cm in diameter, spaced 1.7 cm apart) that were mounted parallel to the front wall. Each head entry into the food cup was recorded by breaking an infrared photobeam and recorded as a response. A computer located within the same room controlled the apparatus, including the presentation of stimuli and the recording of behavior, using Packwin V 2.03 software (Panlab, S.L. Barcelona, Spain).

2.3 Procedure

The design of the study is presented in Table 1.

Table 1

Experiment design

	Days 2-11 (Training)	Days 12-14 (Test)	
Group	Consummatory	Consummatory	Temporal Conditioning
32-4	32%	4%	FT60
4-4	4%	4%	FT60

Note: The experiment started with a day of magazine training for all rats. 32% and 4% indicate the concentration of sucrose in a dissolution of water. FT60: Fixed Time 60 seconds reinforcement schedule. In days 12, 13 and 14, rats received two sessions a day, one in the consummatory cages immediately followed by a temporal conditioning session in the operant boxes.

Magazine Training (Day 1). All rats received one session of 20-min in which food (two pellets per presentation) was delivered on a 60s variable time (VT60) schedule.

Consummatory training (Days 2-11). Ten 5-min sessions of consummatory training were conducted. Half of the rats (Group 32-4) received access to 32% sucrose while the other half (Group 4-4) received access to 4% sucrose.

Consummatory and temporal conditioning test (Days 12-14). Three days of test were conducted. Each test day consisted of a consummatory session immediately followed by a temporal conditioning session. The consummatory session was identical to the ones conducted during training, with the only exception that all rats received 5-min access to the 4% sucrose dilution. Immediately after this session was finished, rats were moved to the operant boxes. Each temporal conditioning session lasted for 42 minutes. The first two minutes were used as an acclimation period and no food was presented. The first reinforcer was presented in minute 3, and every 60s from them on, reaching forty-trials of temporal conditioning in each session.

2.4 Dependent Variable

*Consummatory***.** Dissolution consumption was recorded by weighing the bottles before and after the 5-min consummatory sessions.

Temporal Conditioning. Temporal discrimination was determined by the number of magazines entries that occurred in successive 1-s bins pooled with all the trials of the session. The resultant distributions were smoothed by taking an average over successive 5-s bins (i.e., bins 1–5, 2–6, and so on) in order to reduce the influence of transient variations in responding (see Bonardi, Brilot, & Jennings, 2016). Thus, 56 bins were used in each session of training. These rates were then normalized (divided by the total number of responses for that rat) and multiplied by 100 to give the percentage of total responses in each bin for each rat (see Jennings, Bonardi, & Kirkpatrick, 2007). This way each animal contributed equally to the shape of the functions regardless of its response rate. With the goal of reducing the confound between magazine entries while eating the pellets and magazine entries while expecting the pellets, the first post-food five-bin interval was excluded from all the analyses involving time discrimination (see Alcalá, Callejas-Aguilera, Lamoureux et al. 2019). This first bin is not excluded from the graph to give the reader the complete idea of the general performance of the animals. Following the procedure used by Bonardi et al. (2016) a linear function was fitted to each normalized response function, computing the slope from the best-fitting linear curve for each rat. A high slope score, relative to a low or negative score, indicates that a greater proportion of an individual's head-entry responses are distributed toward the end of the CS, consistent with temporally accurate anticipation of US delivery; thus, slope was used as an estimation of temporal control (Kirkpatrick & Church, 2000).

3. Results

Consummatory training

Mean consumption of groups 32-4 and 4-4 across the 10 days of the consummatory training is presented in the left section of the graph presented in the top section of Figure 1. Consumption increased during consummatory training regardless of the group. A 2 (Group: 32-4 vs. 4-4) x 10 (Day) ANOVA only found a significant main effect of Day, $F(9,126) = 41.85$, $p < .001$, $\eta^2_p = .75$, 95% CIs [.65, .78]. Neither the main effect of Group, nor the Group x Day interaction were statistically significant, largest $F(1,14) = 2.20$, $p = .16$, for the main effect of Group.

The right section of the graph presented in the top section of Figure 1 shows performance during the 3 sessions of consummatory testing. Consumption in group 32-4 dropped below consumption in group 4-4, a difference that was attenuated over days.

A 2 (Group: 32-4 vs. 4-4) x 3 (Day) ANOVA found a significant Group x Day interaction, $F(2,28) = 20.01$, $p <.001$, $\eta^2_p = .58$, 95% CIs [.30, .71] superseding the main effects of Group and Day. Exploration of the interaction found that the simple effect of Group was significant in the three days, smallest $F(1,14) = 17.66$, $p = .001$, $\eta^2_p = .56$, 95% CIs [.15, .73], in Day 3. The simple effect of Day was significant only in group 32-4, $F(2,14) = 38.1$, $p < .001$, $\eta^2_p = .84$, 95% CIs [.58, .90], but it was not significant in group 4-4, $F < 1$.

Temporal Conditioning

The bottom section of Figure 1 presents temporal performance in groups 32-4 and 4-4 throughout the 3 sessions of the temporal conditioning test (Days 12-14). Panels a), b), and c) present the relative rate of responding across the 3 40-trial days of the temporal conditioning test as a percentage of the total response across the 51 bins included in the 60-sec fixed duration period. Panel d) presents the mean slope of the behavioral functions of each group across the 3 days of testing. Group 32-4 seems to develop temporal conditioning faster than group 4-4. A 2 (Group: 32-4 vs. 4-4) x 3 (Day) x 51 (Bin) conducted with the data from the behavioral functions (excluding the 5-sec post-food interval) found a significant 3-way interaction, $F(100, 1400) = 1.61$, $p <.001$, $\eta^2_p = .10$, 95% CIs [.02, .11], superseding all other effects and interactions. Subsequent analyses focused in evaluating the Group x Bin interaction in each day of temporal conditioning, found that the Group x Bin interaction was significant in the three days, smallest $F(50, 700) = 1.42$, $p = .03$, $\eta^2_p = .09$, 95% CIs [>.01, .10] in Day 14.

Inspection of the slope of the behavioral functions presented in panel d) of the bottom section of Figure 1 allows for a simpler comparison of the evolution of temporal conditioning across groups and test days. A 2 (Group: 32-4 vs. 4-4) x 3 (Day) found a significant Group x Day interaction, $F(2, 28) = 3.91$, $p = .03$, $\eta^2_p = .22$, 95% CIs [>.01, .41] that superseded the main effects of Group and Day. Subsequent analysis of this interaction found that the simple effect of Group was significant only in Day 12, $F(1, 14) = 5.93$, $p =.03$, $\eta^2_p = .30$, 95% CIs [>.01, .56], and it was not significant in Days 13 and 14, largest *F* $F(1,14) = 2.78$, $p = .12$, in Day 13, showing that group 32-4 acquired the temporal conditioning faster than group 4-4, and that differences were reduced as training progressed.

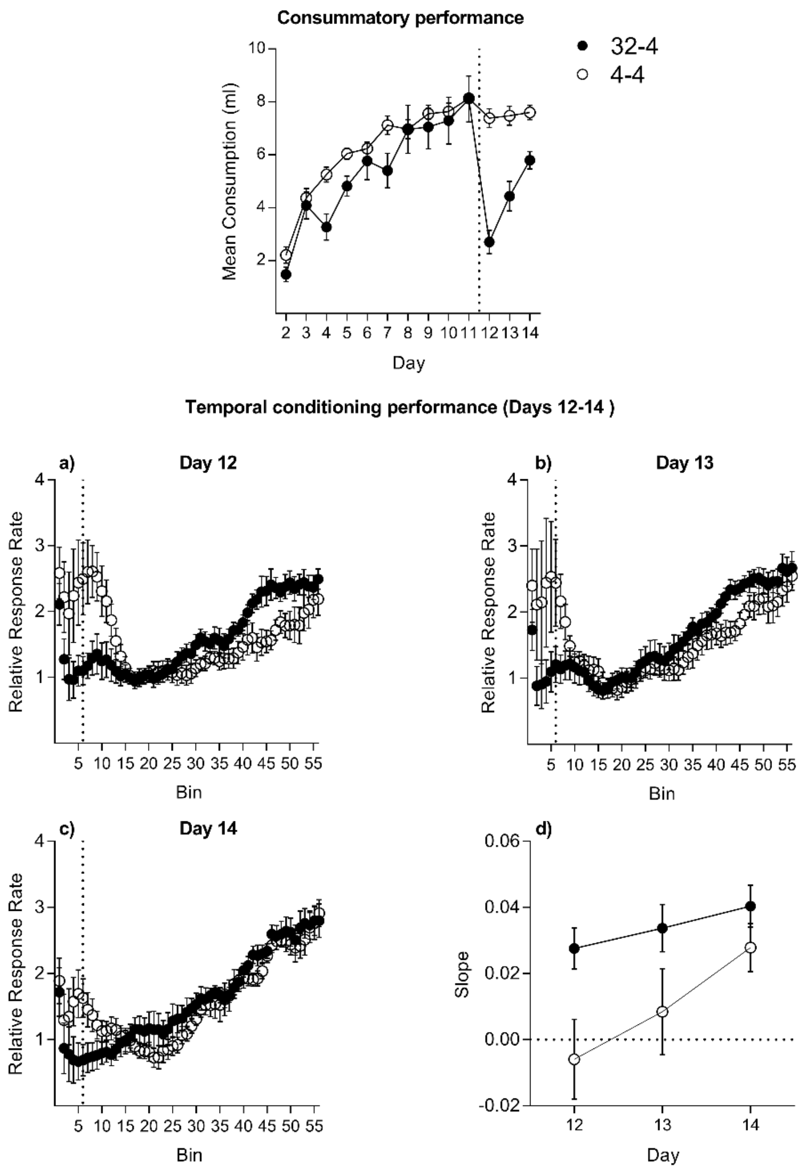

Fig. 1. *Consummatory performance*: Mean consumption in ml of the sucrose dilution during consummatory training (Days 2-11) and testing (Days 12-14) in groups 32-4 and 4-4 (name of the groups identify % of sucrose rats received in each phase). *Temporal conditioning performance*: Panels a-c) present the relative rate of responding across the 3 40-Trial sessions of testing as a percentage of the total responses across the 51 bins included in the 60-sec fixed duration period in groups 32-4 and 4-4. The dashed line separates the 5-s post-food interval from the rest of the trial. Panel d) presents the mean slope of the behavioral functions of groups 32-4 and 4-4 across the 3 40-trial sessions of testing. Error bars denote standard errors of the mean.

A complementary analysis of the first 4-trials of Day 12 was conducted in order to discard potential spurious differences between groups at the beginning of the test phase. A 2 (Group: 32-4 vs. 4-4) x 51 (Bin) ANOVA found no significant main effects or interaction between them, *Fs < 1*. The slope of the functions did not differ either, *F* < 1, showing that differences in temporal conditioning only appeared once training developed, suggesting that they actually reveal a differential acquisition of temporal conditioning in Groups 32-4 and 4-4.

5. Discussion

One experiment tested whether the experience of devaluation of an expected reward may facilitate subsequent temporal discrimination that takes place within a different task and context from which the reward devaluation took place. Two groups of rats received consummatory training with two different sucrose concentrations (32% and 4%) before being tested with the same sucrose concentration (4%). Rats experiencing the downshift in the reward showed the well-known cSNC effect, lowering their post-shift consumption of the solution below rats that were trained and tested with the 4% sucrose concentration. At the same time, rats that experienced cSNC developed temporal conditioning faster than control rats, a result that shows that the experience of cSNC facilitates learning of temporal discriminations in appetitive conditioning that takes place in a different context.

The pattern of result is similar to those reported using reversal discrimination (Alcalá, Callejas-Aguilera, Lamoureux et al., 2019) or extinction (Nelson et al., 2018) rather than cSNC as a source of interference. In all these cases, organisms experiencing unexpected events acquired subsequent temporal conditioning faster than organisms exposed to consistent learning environment. Those studies tend to explain this pattern of results by assuming that the experience of uncertainty leads the organism either to engage the attentional exploration mechanism (Le Pelley et al., 2016) or to activation of cognitive resources (see Anselme, 2010). This mechanism is assumed to prompt an unspecific increase in the arousal of the animals, leading them to engage an exploration pattern of behavior. As we noted in the introduction, animals subject to SNC exhibit more locomotion behavior than control animals (e.g., Pecoraro et al., 1999). Results reported here suggest that this greater exploration may lead to faster adaptation to the new environment conditions, facilitating temporal conditioning in this case (see also Alcalá, Callejas-Aguilera, Lamoureux et al., 2019).

Previous research in this issue has conducted the interference and new learning phases using either the same or quite similar tasks and contexts. The use of similar tasks or contexts allows for explaining the improvement of learning after interference reported in previous studies in terms of changes in context processing, an idea that has been claimed to be at the base of context-switch effects in interference or uncertainty situations (see Bouton, 1993, 1997; Rosas et al., 2006). A key feature of our study is that the experience of cSNC takes place in a context and involves procedures completely different from the ones used during the acquisition of temporal conditioning. This feature precludes an interpretation of the facilitation of new learning after the interference experience in terms of specific changes in context processing, strongly suggesting that the facilitation mechanism is not attained to the task and contexts where the interference takes place. Let’s take the study conducted by Bernal-Gamboa, Callejas-Aguilera, and Rosas (2014) as an illustration. Using a taste aversion procedure, and a straight alley, they found that the experience of extinction in one task prompted context-dependence of non-extinguished information learned within a different task. Bernal-Gamboa et al. (2014) explained their results by assuming that the experience of extinction facilitates context-processing, regardless of whether it was the extinction context or a different one.

Alternatively, the results obtained here suggest that this facilitation may be caused by a general increase in processing the information prompted by the interference experience that may facilitate context processing, but also the processing any other regularities in the environment (see Anselme, 2010; Le Pelley et al., 2016).

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Chapter V: General Discussion and Conclusions

In the following pages, the main results obtained in this dissertation, and their relevance for the *Attentional Theory of Context Processing (ATCP,* Ogallar, Ramos-Álvarez, Alcalá, Moreno-Fernández, & Rosas, 2017; Rosas, Callejas-Aguilera, Ramos-Álvarez, & Abad, 2006*)*, the theoretical framework that guided this work, will be discussed. The chapter finishes by listing the main empirical and theoretical conclusions reached in this dissertation.

General Discussion

In this section, we will enter into the analysis and discussion of the results of each of the studies presented in relation to the specific goals set out in this doctoral thesis. The results of these studies will be jointly discussed in light of ATCP predictions, discussing its value as an explanatory theory of the different effects of context change in human predictive learning.

The first specific goal pursued with this dissertation was to find out whether the EMACS effect first reported by Rosas & Callejas-Aguilera (2006; see also Rosas, García-Gutiérrez, & Callejas-Aguilera, 2006) may be replicated when physical, rather than conceptual contexts are used, as this was one of the factors that differentiate successes and failures to find the EMACS effect in the literature (Nelson & Lamoureux, 2015). ATCP predictions are the same regardless of the type of context used. This theory uses a broad definition of contexts, such as the one given by Smith (2007) when suggesting that context is everything that surrounds the target information. Thus, context involves external (Bouton, 1994), internal (Bouton, Keney & Rosengard, 1990; Eich, 1995), temporary (Bouton, 1993), and associative stimulation (García-Gutiérrez & Rosas, 2003). In fact, previous explanations of context-switch effects on retrieval such as TRI (e.g., Bouton, 1993) do no differ in their predictions based in the nature of the context either. Thus, for ATCP to have value to explain the effects of changing contexts, its predictions should be demonstrated by tests conducted with different tasks and with different type of contexts.

The study conducted to test whether the EMACS effect could be replicated when contexts are physical, rather than conceptual, modified the restaurants' task used by Rosas & Callejas-Aguilera (2006) with which the EMACS effect was first reported. The restaurants' task is a predictive judgments task that was developed by García-Gutiérrez & Rosas (2003), in which different foods (cues) are followed, or not, by gastric discomfort (outcome) in different restaurants (contexts). In the most used version of this task, cues and contexts are the name of the food and the restaurant displayed on a computer screen. The dependent variable used in this task is the predictive judgment given by participants in a scale in which they have to indicate the expected relationship between the cue and the outcome in a specific context (e.g., Abad, Ramos-Álvarez, & Rosas, 2009; Callejas-Aguilera & Rosas, 2010; Rosas & Callejas-Aguilera, 2006). The task used to test the first three goals of this dissertation introduced, as the only change, the use of real images of restaurants and food as contexts and cues, respectively. This change was intended to use contexts akin to those used by Nelson and Lamoureux (2015), in which they reported a failure to find the EMACS effect.

In this first empirical study, two groups of participants (E and NE) were first trained with a cue (X) being followed by the outcome in a given context A. During the second phase of the study, all participants were trained with a new cue (P1) consistently followed by the outcome in context A. Finally, cue P1 was tested for all participants in context A and in a different, but equally familiar context (B). The only difference between the two groups is that group E received extinction of cue X in context A during the second phase of the experiment, while group NE did not. According to ATCP predictions, the experience of interference (extinction with cue X) in group E should lead to an increase in context processing that will be reflected as a greater context dependence of all the cues presented in an attended context. So, a greater impairment on performance to the non-extinguished cue (P1) with the context change was expected in group E with respect to group NE, replicating the EMACS effect (Rosas & Callejas-Aguilera, 2006) in a situation in which contexts and cues did not require semantic processing (see Nelson & Lamoureux, 2015).

The results confirmed the hypothesis, replicating the EMACS effect in predictive learning by using pictures as contexts, with lower responding to the target cue P1 in context different in group E than in group NE at testing. Interestingly, the effect of context change was also found (though to a lower extent) in the group that had no extinction experience (group NE). In view of the obtained results, it seems reasonable to conclude that the differences found between the studies of Rosas and Callejas-Aguilera (2006) and Nelson and Lamoureux (2015), are not due to the type of context used in those studies. Alternatively, the difference may lie in the type of task used since those authors used a behavioral task. In short, these results replicate and extend those found in Rosas and Callejas-Aguilera (2006), supporting the predictions made by ATPC about the effects of context change.

Finding a context switch effect on simple acquisition in the absence of interference is an unusual result, in the sense that many of the studies conducted to test context-switch effects upon retrieval, particularly those conducted to evaluate renewal effects, report perfect transfer across contexts from excitatory associations trained before extinction (e.g., Bouton, 1993, 1994, 1997; Pearce & Bouton, 2001). However, there is converging evidence in the literature of contexts being processed in the absence of interference. For instance, León, Abad, and Rosas (2010) report retrieval of simple acquisition to be context specific at the beginning of training (see also Aristizabal, Ramos-Álvarez, Callejas-Aguilera, & Rosas, 2017). In similar lines, renewal from extinction is usually greater in ABA designs, than in AAB or ABC designs, suggesting that returning to the acquisition context facilitates recovery of the cue-outcome associations learned within that context (Harris, Jones, Bailey, & Westbrook, 2000; Nakajima, Tanaka, Urushihara, & Imada, 2000, Rosas, García-Gutiérrez & Callejas-Aguilera, 2007; Tamai & Nakajima, 2000; Thomas, Larsen, & Ayres, 2003; see also García-Gutiérrez, Rosas, & Nelson, 2005). Finally, in predictive learning studies with designs similar to the ones used here it is not unusual to observe a non-significant trend towards lower response in the different context in the group that does not undergo interference (e.g., Rosas & Callejas-Aguilera, 2006). Taking these results together, it seems that simple acquisition is context-specific in the absence of extinction, a feature that often goes unnoticed because the number of participants in most of the experiments in the literature might not be enough to find relatively subtle differences in performance. Finding a context-switch effect in the absence of the interference experience is in conflict with Bouton's (1993, 1997) idea that contexts are not processed until the experience of interference appears. However, this result fits the general idea of ATCP that context-switch effects will appear whenever the information is acquired within an attended context, and contexts are assumed to be processed in ambiguous situations, such as at the initial stages of training, as it may be the case when P1 is presented for the first time at the beginning of the second phase.

The second goal of this dissertation was to search for additional evidence on the theoretical approach that suggests that the EMACS effect in predictive learning depends on the increased attention to the context generated by an extinction treatment. One of the greatest weaknesses of the empirical studies conducted to test ATCP was the scarce use of either direct or independent attention measures of attention to the contexts, which is usually inferred from the same result that it tries to explain (the behavioral context-switch effect). It was assumed that an increase in attention to the learning situation when the test is conducted in a context different from the acquisition context would lead to a decrease in the speed of responding. Previous studies have taken the speed of response as an indirect measure of attention, under the assumption that changes in the attention given to cues and contexts affect the participants' speed of response (e.g., Cobos, González-Martín, Varona-Moya, & López, 2013). The first empirical study gathered in this dissertation recorded the speed of responding concurrently with predictive judgments, finding that the speed of responding was lower when the test was conducted outside the acquisition context, and that this difference was greater in group E than in group NE. This result mimics the result obtained with predictive judgments and suggests that the EMACS effect is based on an increase in attention to the context with the extinction experience, such as ATCP suggests.

The third goal of this dissertation was to test whether the EMACS effect occurs when the acquisition and extinction of the ambiguous cue take place in two different contexts and the test is carried out either in the acquisition context or in a context different from those of acquisition and extinction. That is, the third goal of this dissertation was to test whether the EMACS effect appears in the same situations in which renewal from extinction is usually found, searching for a convergent replication of renewal and EMACS effects as a direct prediction of the common explanation given by ATCP to both phenomena. Unlike the classic attentional theories of learning (e.g., Mackintosh, 1975; Pearce & Hall, 1980), and TRI (Bouton, 1993, 1994, 1997), ATCP suggests that all the information learned under an interference situation is coded as dependent on the context in which it is acquired, regardless of whether that information is excitatory or inhibitory. Attention to the context is assumed to be the key factor on explaining context-switch effects, regardless of whether this context-switch effect is renewal from extinction, EMACS, or any other detrimental effect of switching the context on retrieval of any type of information. The literature has shown that extinction is coded as context dependent in a variety of situations (see Bouton, 1993). Renewal from extinction appears when acquisition and extinction are carried out in two different contexts and the test is conducted in the acquisition context (ABA renewal, Bouton & King, 1983), when acquisition and extinction are carried out in the same context and the test takes place in a different one (AAB renewal, Bouton & Ricker, 1994), and also when acquisition, extinction and testing are carried out in three different contexts (ABC renewal, Thomas, et al., 2003). According to ATCP, the EMACS effect should be found under the same conditions in which renewal is reported. However, to our knowledge, the EMACS effect only has been informed with designs where acquisition and extinction with the alternative cue take place in the same context (AA) and the test is carried out in a different one (B).

The second empirical study presented in this dissertation addressed the issue of whether the EMACS and renewal from extinction effects can be concurrently found within the same task, regardless of whether the context change involves a return to the context of acquisition of the extinguished cue or being tested in a context different from those of acquisition and extinction. The results obtained in that empirical study confirm that EMACS is found under the same conditions as renewal from extinction (ABA and ABC designs), complementing previous reports in the literature showing concurrent renewal and EMACS effects using an AAB design (Rosas & Callejas-Aguilera, 2006), and adding support to the idea that both phenomena may be based in the same underlying mechanism, as ATCP sustains.

Finding renewal from extinction and EMACS effects under the same design and within the same situation is a particularly strong result as support of ATCP explanation of context-switch. As stated above, EMACS and renewal from extinction effects appear as opposite behavioral outcomes of the context change, with an increase in responding in the case of renewal, and a decrease on responding in the case of EMACS. These opposite results cannot be explained by assuming that the context enters into direct associations with the cue and the outcome, suggesting that EMACS and Renewal effects in predictive learning are both instances of contexts controlling behavior through hierarchical, occasion-setting like, associations. This is not to say that contexts always control retrieval of the information by a hierarchical mechanism. León et al. (2010), using a task similar to the one used here, found that early on training contexts control performance by direct associations with the outcome. ATCP has no trouble in integrating these results, as this theory assumes that contexts will control behavior by establishing different types of associations with different types of stimuli, depending on the situation (Ogallar, et al., 2017; Rosas, Callejas-Aguilera, et al., 2006).

Taking together the results reported so far, ATCP appears as the most solid candidate to explain the different types of context-switch effects that are reported in the literature. An increasing number of empirical studies seem to fit with the idea that context-switch effects depend on attention received by the contexts, and that such attention is modulated by (1) the experience of ambiguity and (2) the informative value of the context.

Nevertheless, there is an issue that needs to be discussed before taking ATCP as a complete explanation for all the context-switch effects in the literature. The role of the informative value of the contexts in the attention they receive suggested by ATCP seems quite clear. However, the role of ambiguity on raising attention to contexts admits a different interpretation in the sense that attention to the contexts may be just an instance of a more general effect in which increases in prediction error may activate a mechanism that leads to an unspecific increase on attention (Beesley, Nguyen, Pearson, & LePelley, 2015) rather than to the specific increase on attention to the contexts suggested by ATCP (Rosas, Callejas-Aguilera, et al., 2006).

Recent studies have described two types of attention that affect the organism in a learning situation (eg, Beesley et al., 2015; George & Kruschke, 2012; Le Pelley, 2004; Le Pelley, Haselgrove, & Esber, 2012; Pearce & Mackintosh, 2010; for a review see Le Pelley, Mitchel, Beesley, George, & Wills, 2016). When there are good predictors of the outcomes, the organism is assumed to activate the *attentional exploitation* mechanism, sol that it can achieve the greatest possible benefits by eliminating irrelevant information (according to the model of Mackintosh, 1975). This type of mechanism is similar to the one that is assumed to be activated by increases in the subjective predictive value of the context, in ATCP terms (e.g., Ogallar et al., 2017). However, when the organism faces uncertain results, either because it faces new learning or because it does not count with reliable predictors of the outcome (such as in ambiguous situations), an *attentional exploration* mechanism will be activated in order to identify new contingencies and resources that would allow the organism to explain relevant aspects of its environment (following Pearce & Hall, 1980, attentional model of associative learning). This latest mechanism does not quite fit with the original approach taken by ATCP, as ATCP assumes that ambiguity specifically raises attention to the contexts (e.g., Ogallar et al., 2017; Rosas, Callejas-Aguilera, et al., 2006) rather than leading to unspecific increases in attention that would have an increase on attention to the context as a side effect. Recent results in the literature seem to show that the increases in attention caused by interference are not specific to the context. Quite at the contrary, interference has been claimed to increase the general arousal of the organism so that a previous experience of interference facilitates subsequent learning about time (Alcalá, Callejas-Aguilera, Lamoreux, & Rosas, 2019), and space (Alcalá, Callejas-Aguilera, Nelson, & Rosas, 2019; Shanab & Cotton, 1970) in nonhuman animals, and reversal of a conditioned inhibitor in humans (González, Alcalá, Callejas-Aguilera & Rosas, 2019). These data have been claimed to show that interference activates the *attentional exploration* mechanism, which would facilitate learning new contingencies in the environment. However, as the experience of interference and the new learning in all studies that report this effect take place in the same context or using very similar tasks, the results reported could be alternatively explained by variations in contextual processing that would fit the current formulation of ATCP.

The third empirical study presented in this dissertation aimed to assess whether the ambiguity generated on an organism in a given task would facilitate learning in completely different task that is conducted in a totally different context. This study found that receiving a consummatory successive negative contrast treatment in Plexiglas cages facilitated a subsequent learning of temporal conditioning in Skinner boxes in rats. Animals, rather than humans, were used in this study with the goal of better controlling the difference between tasks and contexts in our laboratory. The use of animals may be understood as a limitation that does not allows for a direct translation of these results to human participants. Though this is true, and advise caution, it should be noted that all the results obtained in this line of research have been replicated in rats and human participants in our laboratory, including the result of ambiguity facilitating subsequent learning (González et al., 2019).

Thus, in light of the results of the last empirical study of this dissertation, it seems reasonable to suggests that ATCP should update its principles by incorporating the two different types of attentional mechanisms that have been recently proposed in the literature: *Attentional exploration* and *attentional exploitation* mechanisms (e.g., Beesley et al., 2015). The two factors that modulate attention to the context proposed by ATCP fit quite well with the two types of attention described above. Increasing the subjective predictive value of the contexts is expected to activate the *attentional exploitation* mechanism, leading the organism to pay attention to relevant contexts. Alternatively, ambiguity caused by a prediction error would activate the *attentional exploration* mechanism leading to an increase on context processing, and in any other information that is presented in the situation. Future theoretical and empirical developments should test the value of these ideas as a potential opportunity for ATCP to gain specificity in its theoretical proposal.

Conclusions

1. The Extinction Makes Acquisition Context Specific (EMACS) effect is replicated in predictive learning when physical, rather than conceptual contexts, are used (see Nelson & Lamoureux, 2015).

2. The EMACS effect seems to be caused by extinction leading participants to an increase in the attention paid to the contexts, as suggested by the substantial decrease in the speed of responding outside the training context that is differentially observed in participants that had the extinction experience. This result is consistent with the explanation of the EMACS effect in terms of extinction raising participants' attention to the context given by the *Attentional Theory of Context Processing* (ATCP) (Rosas, Callejas-Aguilera, et al., 2006).

3. EMACS and Renewal from extinction effects in predictive learning are found under the same conditions, suggesting that both effects are based in the same underlying mechanism (interference raising attention to the contexts), such as ATCP suggests.

4. A conflicting experience (consummatory negative contrast) in rats is found to facilitate subsequent learning of temporal conditioning in a completely different task and context, extending recent results in the literature that suggest that the increase on attention to the context after the interference experience suggested by ATCP may be only a specific instance of a general increase in attention effect of ambiguity.

5. Taking together, the results reported in this dissertation confirm the heuristic value of ATCP as a general explanation of the effects of context change on retrieval of the information. However, they also suggest that the explanatory power of ATCP would be increased if the attentional exploration and exploitation mechanisms (Beesley et al., 2015) are incorporated to the factors that are assumed to modulate context changes (ambiguity and context subjective relevance, respectively).

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Capítulo VI: Resumen extendido

1 Introducción

Durante décadas, la importancia atribuida al estudio de la *recuperación de la información* ha suscitado un gran número de investigaciones y de teorías, lo que ha convertido este tema en primordial dentro de la psicología experimental (e.g., Archer y Sjödén, 1979; Capaldi y Birmingham, 1998; Churchill, Remington, y Siddle, 1987; Ebbinghaus, 1964; Estes, 1973, 1976; Lovibond, Preston, y Mackintosh, 1984; Medin y Schaffer, 1978; Smith, Glenberg, y Bjork, 1978; Tulving, 1974, 1983; Tulving y Thompson, 1973). Un factor identificado como determinante en la recuperación de la información aprendida es la similitud entre el contexto de aprendizaje y el contexto de recuperación. Desde un punto de vista holístico, se entiendo por contexto todo aquello que rodea a la información objetivo (Smith, 2007), incluida la estimulación externa (e.g., Bouton, 1994), interna (e.g., Bouton, Keney, y Rosengard, 1990; Eich, 1995), temporal (e.g., Bouton, 1993), y asociativa (e.g., García-Gutiérrez y Rosas, 2003). El resultado común informado en estudios cognitivos sobre la memoria es un decaimiento del aprendizaje cuando el contexto de recuperación difiere del contexto de adquisición (e.g., Baddeley, 1982; Godden y Baddeley, 1975; Jensen, Harris, y Anderson, 1971; Tulving y Osler, 1968).

Esta afirmación, no obstante, debe ser matizada. Estudios posteriores han mostrado que el papel del contexto en la recuperación de la información es mínimo en ausencia de un tratamiento de interferencia (e.g., Bouton, 1993). Además, un importante número de estudios sugieren una transferencia completa entre contextos de la información que se adquiere en condiciones normales, como por ejemplo una asociación clave-consecuencia (Bouton, Nelson y Rosas, 1999; Lovibond, et al., 1984; Rosas y Bouton, 1998; Rosas, Vila, Lugo, y López, 2001; c.f., Archer, Sjödén, y Nilsson, 1985; Bonardi, Honey, y Hall, 1990; Hall y Honey, 1989; Sjödén y Archer, 1989). Estos resultados motivaron la Teoría de la Recuperación de la Información (TRI, Bouton, 1993), según la cual la información inhibitoria, o la aprendida en segundo lugar, se codifica como dependiente del contexto. Con posterioridad, Bouton (1997) se basa en la idea original sobre la ambigüedad de Darby y Pearce (1995), y propone el mecanismo que lleva a que la información interferente se codifique como dependiente del contexto, a partir del incremento de la atención al contexto que genera dicha ambigüedad. De este modo, el contexto de interferencia facilitará la recuperación de la información aprendida en él, mientras que la salida de ese contexto dificultará la recuperación de la información interferente aprendida en él. Unos años después, Nelson (2002, 2009) encuentra que es la información aprendida en segundo lugar la que se convierte en dependiente del contexto, independientemente de su valor inhibitorio o excitatorio.

Desde su propuesta original, la TRI se ha confirmado como una de las teorías más relevantes sobre el papel que desempeña el contexto en el aprendizaje en situaciones de ambigüedad (e.g., Nelson, 2002; Pearce y Bouton, 2001; Rosas, Todd, y Bouton, 2013; Todd, 2013). Sin embargo, la TRI no está exenta de problemas; uno de los más importantes procede de estudios tanto en condicionamiento animal (e.g., Bernal-gamboa, Nieto, y Rosas, 2015; Rosas y Callejas-Aguilera, 2007), como en aprendizaje predictivo humano (e.g., Aristizabal, Ramos-Álvarez, Callejas-Aguilera, y Rosas, 2017; Callejas-Aguilera, Cubillas, y Rosas, 2019; León, Abad, y Rosas, 2010b; Lucke, Lachnit, Koenig, y Uengoer, 2013; Nelson y Callejas-Aguilera, 2007; Rosas y Callejas-Aguilera, 2006; Rosas, García-Gutiérrez, y Callejas-Aguilera, 2006), en los que se demuestra que no sólo la información ambigua se codifica como dependiente del contexto, sino que ante una situación (ambigua o no) en la que el contexto es atendido, toda la información aprendida se convierte en dependiente del contexto, independientemente de que se trate de información aprendida en primer o en segundo lugar, o del carácter excitatorio o inhibitorio de dicha información.

La Teoría Atencional del Procesamiento Contextual (TAPC*;* Rosas, Callejas-Aguilera, Ramos-Álvarez, y Abad 2006) se propuso con el objetivo de explicar los fenómenos predichos por la TRI, así como superar las limitaciones con las que ésta tropezó. La TAPC es heredera directa de la TRI, con la que comparte sus principios fundamentales. Asimismo, integra principios de otras teorías atencionales del aprendizaje asociativo (Mackintosh, 1975) con los mecanismos de recuperación de la información, en un intento de explicar por qué la información se convierte en dependiente del contexto.

La TAPC propone que la información que se aprende en un contexto atendido se codifica como dependiente del mismo, independientemente de su carácter excitatorio o inhibitorio, o de que se trate de información consistente o ambigua (Ogallar, Ramos-Álvarez, Alcalá, Moreno-Fernández, y Rosas, 2017; Rosas, Callejas-Aguilera, et al., 2006).

Originalmente, la TAPC propuso 5 factores que llevan a un organismo a prestar atención al contexto (véase Rosas, Callejas-Aguilera, et al., 2006), finalmente agrupados en solo dos factores: la *ambigüedad* y la *relevancia subjetiva del contexto* (véase Ogallar et al., 2017; Rosas y Nelson, 2019).

El factor *ambigüedad* proviene de la idea original de Darby y Pearce (1995), que sugiere que la ambigüedad en una situación de aprendizaje lleva a que un organismo preste atención al contexto. El papel de este factor ha sido estudiado con distintos tratamientos de interferencia (e.g., Nelson y Callejas-Aguilera, 2007, Experimento 2; Rosas, García-Gutiérrez, et al., 2006), si bien el más estudiado ha sido la ambigüedad generada mediante un procedimiento de extinción. Por ejemplo, Rosas y Callejas-Aguilera (2006) comprobaron que la extinción de una clave llevó a la codificación de otra clave, entrenada de forma consistente con la consecuencia durante la fase de extinción, como dependiente del contexto. Este efecto ha sido denominado como EMACS (Extinction Makes Acquisition Context Specific). En ausencia de interferencia también se ha informado de ambigüedad al inicio de una tarea de aprendizaje, cuando todavía no existen buenos predictores de la consecuencia (Mackingosh, 1975). En este sentido existen datos que apoyan las predicciones de la TAPC, que informan de la codificación de la información como dependiente del contexto al inicio del entrenamiento, hasta que se establecen buenos predictores de la consecuencia (e.g., León et al., 2010b).

Por otro lado, la *relevancia subjetiva del contexto* agrupa los factores *valor informativo* del contexto, *saliencia relativa* de los contextos, e *instrucciones atencionales*. El *valor informativo* del contexto modula la atención en tareas en las que el contexto resulta esencial para el aprendizaje de una discriminación simple, en la que el significado de las claves varía en función del contexto en el que se presentan (e.g., León, Abad, y Rosas, 2010a; Lucke et al., 2013; Preston, Dickinson, y Mackintosh, 1986). Otros estudios han corroborado las predicciones de la TAPC al mostrar la relación directa entre la saliencia del contexto y la atención que se le presta (e.g., Abad, Ramos-Álvarez, y Rosas, 2009; Bouton y Sunsay, 2001). Por último, también se ha demostrado el papel que pueden desempeñar las instrucciones, por ejemplo, haciendo desaparecer el efecto de cambio de contexto que se observa al inicio del aprendizaje o, por el contrario, dificultando la transferencia entre contextos cuando el aprendizaje es prolongado (e.g., Beesley, Hanafi, Vadillo, Shanks, y Livesey, 2018; Callejas-Aguilera, et al., 2019; Cañadas, Rodríguez-Bailón, Miliken, y Lupiañez, 2013).

Desde su formulación, la TAPC ha demostrado un importante valor heurístico en la medida que sus predicciones han generado un gran número de estudios empíricos. No obstante, esta teoría tampoco está exenta de problemas. Los estudios iniciales inferían el papel de la atención a partir del cambio de contexto registrado con una medida conductual (juicios predictivos) incurriendo en una explicación circular; se infería el incremento de la atención a partir del efecto de cambio de contexto informado en los juicios predictivos. El registro en los últimos años de medidas indirectas de la atención mediante el uso de instrumentos que registran el seguimiento de la mirada (e.g., Aristizabal, Ramos-Álvarez, Callejas-Aguilera, y Rosas, 2016, 2017; Lucke, et al., 2013; Vadillo, Orgaz, Luque y Nelson, 2016), y que son independientes de los juicios predictivos, ha supuesto un avance importante en la resolución de esta limitación. Un problema distinto es el que se refiere a la generalidad del efecto EMACS. Diversos estudios muestran la dificultad de replicar dicho efecto con humanos en tareas distintas a las de aprendizaje predictivo (e.g., Nelson y Lamoureux, 2015). Asimismo, en condicionamiento animal el efecto se ha mostrado esquivo (Nelson, Lombas, y León, 2011) más allá de los resultados que informan del efecto en aversión condicionada al sabor (e.g., Bernal-Gamboa, et al., 2015; Rosas y Callejas-Aguilera, 2007).

Por otro lado, resultados informados en estudios recientes plantean que la relación entre la atención y el contexto podría tratarse de la manifestación particular de un efecto más general, lo que supone un nuevo reto para la TAPC. Diferentes estudios sugieren que la experiencia con un tratamiento de interferencia facilita el aprendizaje posterior en otra tarea, como por ejemplo, la adquisición en una tarea de condicionamiento temporal (Alcalá, Callejas-Aguilera, Lamoureux, y Rosas, 2019), el aprendizaje espacial (Alcalá, Callejas-Aguilera, Nelson, y Rosas, 2019; véase también Shannab y Cotton, 1970), o el aprendizaje posterior clave-consecuencia de un inhibidor condicionado (González, Alcalá, Callejas-Aguilera, y Rosas, 2019). Los resultados de estos estudios muestran que la ambigüedad facilita el aprendizaje, y sugieren que el efecto de cambio de contexto puede ser interpretado como un caso específico de esta facilitación, lo que sugiere la cecisidad de reformulación de la TAPC. No obstante, esta afirmación no está exenta de problemas. Los estudios en los que se basa emplearon tareas y contextos muy similares, por lo que no excluyen la interpretación de estos resultados en términos de cambios en el procesamiento del contexto, esta idea se sitúa a la base de los efectos de cambio de contexto en situaciones de incertidumbre o interferencia (e.g., Bouton, 1993, 1997; Rosas, Callejas-Aguilera, et al., 2006). Resolver este problema requiere de la realización de estudios en los que los distintos aprendizajes sean muy distintos, al mismo tiempo que cada uno de ellos transcurran en contextos muy diferentes.

El objetivo general de esta tesis doctoral es analizar las condiciones y los mecanismos que subyacen a la codificación de la información como dependiente del contexto. Con este objetivo hemos desarrollado distintos estudios para evaluar las condiciones y los mecanismos que subyacen al efecto EMACS, así como para evaluar si el efecto de cambio de contexto sobre la recuperación de la información es un caso particular de un incremento generalizado de la atención generado por la ambigüedad, y que conlleva prestar atención a toda la situación de aprendizaje, incluidos los contextos.

Para la consecución de estos objetivos, esta tesis doctoral se ha estructurado en 5 capítulos. En el Capítulo 1 se revisan las principales teorías atencionales del aprendizaje y su papel en la explicación de la recuperación de la información. También incluye una revisión detallada de la Teoría Atencional del Procesamiento Contextual. En el Capítulo 2 se detallan los objetivos y la hipótesis de los estudios experimentales que conforman esta tesis doctoral. El Capítulo 3 incluye dos estudios experimentales, desarrollados en laboratorios distintos de los que han informado con anterioridad este efecto. En estos estudios se exploran distintas condiciones y mecanismos que subyacen al efecto EMACS, y se compara directamente este efecto con el de renovación bajo las mismas condiciones. El Capítulo 4 explora si el efecto de la interferencia que ocurre en el aprendizaje con una tarea y en un contexto determinado, facilita el aprendizaje en otra tarea y contexto completamente diferentes, para evaluar si el aprendizaje último se encuentra afectado por la mediación del contexto donde ocurrió la interferencia. Por último, el Capítulo 5 plantea una discusión general de los resultados informados en los estudios empíricos, y de sus implicaciones teóricas, para finalizar con la presentación de las conclusiones principales de este trabajo de investigación.

2 Resumen de los estudios empíricos de la tesis

Estudio 1. La extinción previa aumenta la especificidad del contexto de adquisición en el aprendizaje predictivo humano

Objetivo 1: Replicar el efecto EMACS utilizando la tarea de los restaurantes (Rosas y Callejas-Aguilera, 2006, Experimento 1), pero empleando contextos físicos a partir de imágenes visuales, en lugar de contextos conceptuales a partir de etiquetas verbales.

Hipótesis 1: El tratamiento de extinción sobre una clave convertirá la adquisición de otra clave en dependiente del contexto en una tarea de aprendizaje predictivo humano en la que se utilizan contextos físicos a partir de imágenes reales en lugar de contextos conceptuales.

Objetivo 2: Buscar evidencia adicional a la aproximación teórica que sugiere que el efecto EMACS en aprendizaje predictivo depende del incremento de la atención al contexto que se genera por un tratamiento de extinción.

Hipótesis 2: El tratamiento de extinción incrementará la atención de los participantes a la situación de aprendizaje, lo que reducirá la velocidad de respuesta cuando se prueba la información en un contexto diferente al de adquisición.

Con estos objetivos se realizó un experimento de aprendizaje predictivo humano, en el que se utilizaron contextos físicos a partir de imágenes reales, y en el que se registró, además de los juicios predictivos, la velocidad de respuesta con la que fueron emitidos. Los participantes en este estudio fueron asignados aleatoriamente a uno de dos grupos. En la primera fase todos los participantes fueron entrenados con una clave, E, seguida de la consecuencia. En la segunda fase se procedió a la extinción de E en el grupo Extinción. Además, de manera concurrente todos los participantes fueron entrenados con una nueva clave, P, seguida de la consecuencia. Los resultados en la variable juicios predictivos mostraron efecto de cambio de contexto sobre P en los dos grupos, sensiblemente más acentuado en el grupo Extinción. Asimismo, en el grupo Extinción la velocidad de respuesta fue menor cuando la clave P fue probada en el contexto diferente al de adquisición. Estos resultados extienden el efecto EMACS informado en tareas de aprendizaje humano con contextos conceptuales (mediante la utilización de etiquetas verbales) a contextos físicos (a partir de imágenes reales). Además, la simetría entre los juicios predictivos y la velocidad de respuesta sugiere que el efecto EMACS se basa en el incremento de la atención a los contextos que genera el tratamiento de extinción, como predice la TAPC.

Estudio 2. Evidencia de la concurrencia del efecto EMACS y del efecto de renovación ABA y ABC en aprendizaje predictivo humano

Objetivo: Estudiar si el efecto EMACS y el efecto de renovación aparecen de manera concurrente en la misma tarea, cuando la adquisición y la extinción de una clave ambigua tiene lugar en dos contextos diferentes, y la prueba se realiza bien en el contexto de adquisición, o bien en un contexto diferente a los de adquisición y de extinción.

Hipótesis: Si el efecto EMACS y el efecto de renovación se encuentran afectados por las mismas condiciones, y por los mismos mecanismos de aprendizaje como predice la TAPC, entonces ambos aparecerán de manera concurrente en la misma tarea.

Con este objetivo realizamos dos experimentos. En cada uno de ellos, dos grupos de participantes recibieron entrenamiento con una clave seguida de la consecuencia en el contexto A (A: E-O). Durante la segunda fase recibieron entrenamiento con una nueva clave en el contexto B (B: P-O). Además, de manera concurrente se procedió a la extinción de E en el grupo Extinción (B: E-). Por último, ambas claves (E y P) fueron probadas en los contextos A y B (Experimento 1), y en los contextos A y C (Experimento 2). En ambos experimentos se obtuvieron los efectos EMACS y de renovación, independientemente de que la prueba se realizara en el contexto en el que la clave extinguida fue inicialmente asociada con la consecuencia (Experimento 1), o en un contexto diferente, con el que los participantes no tuvieron experiencia una vez iniciado el tratamiento de extinción (Experimento 2). El patrón de resultados opuestos informado en estos experimentos en la fase de prueba, que supone una disminución en la respuesta de la clave condicionada P, y un incremento en la respuesta de la clave extinguida E, dificulta su explicación en términos de la fuerza asociativa (excitatoria o inhibitoria) adquirida por los contextos, al mismo tiempo que apoya una explicación basada en un mecanismo de asociación jerárquica tipo occasion-setting (Bouton, 1993), que convierte en dependiente del contexto toda la información aprendida (E y P), y no sólo la información ambigua, tal y como propone la TAPC (Rosas, Callejas-Aguilera, et al., 2006)

Estudio 3. La experiencia en Contraste Sucesivo Negativo Consumatorio facilita el condicionamiento temporal en una tarea de entrada en el comedero con ratas

Objetivo: Estudiar si la mejora en el aprendizaje que se observa después de un tratamiento de interferencia, también ocurre cuando el aprendizaje posterior en otra tarea, y el contexto donde transcurre, son muy diferentes.

Hipótesis: La experiencia contradictoria que genera un tratamiento de contraste sucesivo negativo consumatorio, tendrá un efecto facilitador sobre el aprendizaje posterior en una tarea de condicionamiento temporal con ratas.

Con este objetivo diseñamos un estudio en que la mitad de las ratas recibieron un tratamiento de contraste sucesivo negativo consumatorio (CSNc), a partir de la diminución de la concentración de azúcar en una disolución con agua entre las fases de precambio y de postcambio. Para la otra mitad se mantuvo la misma concentración en las dos fases. Esta tarea tuvo lugar en cajas de plexiglás. Posteriormente, en una segunda tarea, todos los animales recibieron un entrenamiento de condicionamiento temporal en cajas de Skinner, muy distintas a las cajas empleadas en la primera tarea, tanto por su tamaño, como por su aspecto, como por los materiales de las que estaban hechas, así como por su ubicación (cada tarea tuvo lugar en un módulo distinto del laboratorio). Los animales en el grupo de CSNc aprendieron la discriminación temporal de manera más rápida que los animales del grupo Control, lo que sugiere que la facilitación en el aprendizaje de una segunda tarea no está mediada por la similitud de los aprendizajes previo y posterior a la incertidumbre, así como tampoco por la similitud entre los contextos donde transcurren dichos aprendizajes.

3 Conclusiones

De manera general, la revisión teórica y los resultados informados en los estudios que conforman esta tesis doctoral sugieren que la extinción convierte la adquisición de nueva información en dependiente del contexto. Pese a que esta afirmación no es novedosa, los estudios realizados en esta tesis doctoral refuerzan esta aseveración, al describir las condiciones bajo las qué aparece este efecto, así como los mecanismos que subyacen. Además, confirma el papel fundamental de la atención para que la información se codifique y se recupere como dependiente del contexto.

Esta conclusión general puede ser descrita en los términos de las siguientes conclusiones específicas:

1. Se replica el efecto de la extinción que convierte la nueva información adquirida en específica del contexto (EMACS), en una tarea de aprendizaje predictivo cuando se emplean contextos físicos en lugar de contextos conceptuales (véase Nelson y Lamoureux, 2015).

2. El efecto EMACS parece estar causado por la extinción que lleva a un incremento en la atención de los participantes a los contextos, tal y como sugiere el descenso observado en los participantes del grupo extinción, en la velocidad de respuesta cuando se presenta la información fuera del contexto de entrenamiento. Este resultado es consistente con la explicación que da la Teoría Atencional del Procesamiento Contextual del efecto EMACS (Rosas, Callejas-Aguilera, et al., 2006).

3. La demostración en una misma tarea de aprendizaje predictivo, de los efectos EMACS y de renovación por extinción, sugiere que ambos efectos son debidos a mecanismo subyacente común, tal y como sugiere la TAPC.

4. La experiencia contradictoria en ratas (inducida por un tratamiento de contraste sucesivo negativo), facilita el posterior aprendizaje de condicionamiento temporal, en una tarea y contexto completamente diferentes, lo que extiende los resultados recientes en la literatura, y refuerza la afirmación que sugiere que el incremento de la atención al contexto, después de una experiencia de interferencia, puede ser solo un caso específico de un incremento general de la atención generado por la ambigüedad.

5. Tomados de manera conjunta los resultados informados en esta tesis doctoral, confirman el valor heurístico de la TAPC como una explicación general de los efectos del cambio de contexto sobre la recuperación de la información. Sin embargo, estos resultados también sugieren que el poder explicativo de la TAPC sería mayor si sumara los mecanismos de atención exploratoria y de explotación (Beesley, Nguyen, Pearson, and LePelley, 2015), a los que ya asume como moduladores del cambio de contexto (ambigüedad y relevancia subjetiva de los contextos, respectivamente).

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