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**UNIVERSITY OF SOUTHAMPTON**  
**FACULTY OF MEDICINE, HEALTH AND LIFE SCIENCES**

School of Psychology

**Differences in Context Sensitivity for Second-Learned Inhibitory  
and Excitatory Stimuli in AAB and ABC designs**

by

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Thesis for the degree of Doctor of Philosophy

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## UNIVERSITY OF SOUTHAMPTON

ABSTRACT

## FACULTY OF MEDICINE, HEALTH AND LIFE SCIENCES

Doctor of PhilosophyDIFFERENCES IN CONTEXT SENSITIVITY FOR SECOND-LEARNED  
INHIBITORY AND EXCITATORY STIMULI IN AAB AND ABC DESIGNS

By Tito Elgueta

Bouton (1997) proposed a model to explain Pavlovian conditioning according to which the order of the associations (first-learned or second-learned), not the valence of the associations (inhibitory or excitatory), determines context sensitivity in AAB and ABC renewal designs. As a consequence, Bouton's model does not predict important differences in context sensitivity between AAB and ABC designs. However, evidence suggests that there are indeed differences in context sensitivity between these two designs (e.g. Üngör & Lachnit, 2008). The aim of this thesis is to explore the role of context sensitivity of second-learned associations in AAB and ABC designs. Eight experiments are presented. Experiments 1 to 3 explored the context sensitivity of second-learned excitatory associations and second-learned inhibitory associations produced by extinction in AAB and ABC designs. The results of these experiments showed strong context sensitivity in ABC designs, both in excitatory and inhibitory second-learned associations. Yet, no context sensitivity was observed in AAB designs in any condition. Experiments 4 to 6 explored the context sensitivity of second-learned inhibitory associations using a feature negative procedure to produce inhibition. No context sensitivity was found for second-learned inhibitory associations produced by this procedure. Possible reasons for this lack of effect are discussed. Experiments 7 and 8 aimed at providing an explanation for the results of Experiments 1 to 3 of this thesis. Two mechanisms to explain differences in context sensitivity between AAB and ABC designs were explored: the number and length of trials (Gallistel & Gibbon, 2000; Haselgrave & Pearce, 2003), and the comparator hypothesis (Miller & Matzel, 1988). The results of Experiments 7 and 8 were not able to explain differences in context sensitivity between AAB and ABC designs. Overall, the results of this thesis show context sensitivity in ABC designs but not in AAB designs. This thesis finishes by discussing how the difference in context sensitivity between ABC and AAB designs can be explained based on Üngör and Lachnit's (2008) argument that context is codified during the first stage.



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**Declaration of Authorship**

I certify that the thesis I have presented for examination for the PhD degree of the University of Southampton is solely my own work and has been generated by me as the results of my own original research. Parts of Experiments 1 (Group AAB) and 2 (Group ABC) of this thesis were submitted for an MSc degree in Research Methods in Psychology at the University of Southampton (2008).

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Date: December 8, 2013



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## Chapter 1: Introduction

One central phenomenon in the field of classical conditioning is extinction (for a review, see Bouton & Woods, 2008). Extinction is a learning phenomenon in which a loss in the conditioned response (CR) is observed when a stimulus has had excitatory training, followed by the presentation of the conditioned stimulus (CS) without the presence of the unconditioned stimulus (US). In this case, the acquisition is considered a first-learned association and the extinction a second-learned association. Nonetheless, experimental evidence has shown a recovery of the response following a context switch between the extinction context and the test stage context. Thus, extinction does not simply involve unlearning of the original excitatory association.

The recovery of a response after the inclusion of a second-learned association is an important topic in learning theories today (see for a review, Bouton & Woods, 2008). The recovery of a first-learned response after the acquisition of a second-learned association challenges important theoretical models that predict that second-learned associations produce an “unlearning” of the first-learned association (e.g. Rescorla-Wagner model, Rescorla & Wagner, 1972). This means that other theoretical proposals such as performance models (e.g. Miller & Matzel, 1988), configural models (e.g. Pearce & Hall, 1980) or memory retrieval models (e.g. Bouton, 1997) might acquire more importance in the explanation of such phenomenon.

These theoretical models may be differentiated by consideration of response recovery under different experimental conditions. The aim of this thesis is to examine the role of contextual sensitivity of second-learned excitatory and inhibitory associations considering two different designs: AAB and ABC. In AAB designs first- and second-learned associations take place in the same context, A, while recovery is tested in a novel context, B. In ABC designs, on the other hand, the first-learned association takes place in context A, the second-learned association takes place in context B, and recovery is tested in a novel context, C.

Two theoretical models have been most relevant to explain the contextual sensitivity of second-learned associations: the Rescorla-Wagner model and Bouton’s retrieval model (see for a review Pineño & Miller, 2005). First, the Rescorla-Wagner

model (Rescorla & Wagner, 1972) states that in a classical conditioning situation learning is a consequence of the discrepancy between the events expected to happen and the events that actually happen. This discrepancy can produce both excitatory and inhibitory conditioning depending on the presentation of the cues. To predict the response to a stimulus in a specific situation, the Recorla-Wagner model takes into account the associative strengths of all cues involved in the situation, including the context.

According to predictions based on the Rescorla-Wagner model (1972), no major differences in context sensitivity should be observed between AAB and ABC designs in an extinction procedure. In both designs there is an excitatory training during the first stage that occurs in a particular context (Context A). In the second stage extinction takes place in a novel context (B for ABC designs) or in the same context as the one presented in the first stage (A for AAB designs). A test takes place in a novel context in both designs (Context C for ABC designs and Context B for AAB designs). It should be noted that according to this model the target CS has gone through unlearning of the previous association during the second stage. Therefore, during the test phase the target CS should have almost no associative strength. Both in ABC and AAB designs the target CS has gone through excitatory training during the first stage and through inhibitory extinction training during the second stage. As a result, the associative strength of the target CS in ABC and AAB designs should be similar at the end of the experiment. That is, when the target CS is tested in a novel context there is no expectation of recovery of the response learned in the first stage for both designs. As a consequence, no context sensitivity should be expected in both AAB and ABC designs.

On the other hand, Bouton's (1997) retrieval model proposes that first-learned associations are context independent, while second-learned associations are context-dependent. Bouton's model (1997) predicts context sensitivity in both AAB and ABC designs when the test occurs in a novel context. When the test occurs in a novel context, context dependent associations will not be activated. In a typical renewal AAB and ABC experiment the second-stage association is inhibitory (extinction). Given the absence of a second-stage context in both designs, the model predicts that the second-learned association will not be activated during the test phase and the first-learned association that is independent of context will be activated. In other

words, given that the second-learned associations are context-dependent in both ABC and AAB designs, a context switch that takes place between the second and third stages would induce a recovery of the first-learned association that is independent of context in both designs. As a consequence, context sensitivity of second-learned associations are predicted for both ABC and AAB designs.

The Rescorla-Wagner (1972) and Bouton's retrieval (1997) models predict no differences in context sensitivity between AAB and ABC designs. In the case of the Rescorla-Wagner model, context sensitivity should not be observed in any of these designs, while Bouton predicts context sensitivity in both designs. Yet, several studies have shown differences in renewal effects for AAB and ABC designs (e.g. Bouton & Ricker, 1994; Goddard, 1999; Laborda, Witnauer, & Miller, 2011; Thomas, Larsen, & Ayres, 2003; Üngör & Lachnit, 2008; Yap & Richardson, 2007). Specifically, these studies suggest that renewal in ABC designs is stronger than renewal in AAB designs.

While a large number of studies have addressed AAB and ABC design differences, little research so far has examined the mechanisms that explain differences in renewal between AAB and ABC designs. This lack of research is probably due to the fact that differences between AAB and ABC designs were not even predicted by the main theoretical models (e.g. Bouton, 1997; Rescorla & Wagner, 1972) and thus no difference needed to be explained. More research needs to be conducted to understand the mechanisms by which AAB and ABC designs differ in their context sensitivity of second-learned associations.

On the other hand, Bouton (1993) proposed that inhibitory associations are context-dependent, while excitatory associations are context-independent. In 1997, Bouton argued that it is not the difference between inhibitory and excitatory associations which determines context sensitivity, but rather the order of the presentation of the associations. Yet, research on AAB and ABC designs so far has focused only on inhibitory second-learned associations (see for a review Bouton & Woods, 2008). It remains to be evaluated whether differences in AAB and ABC designs hold in excitatory associations as well.

The aim of the current thesis is to advance the understanding of the mechanisms involved in the differences in context sensitivity between AAB and ABC designs,

considering both inhibitory and excitatory second-learned associations. In particular, this thesis seeks to address the following research questions:

*Q1. Is there a difference in the context sensitivity of second-learned associations in AAB and ABC designs?*

*Q2. Are there differences in context sensitivity between inhibitory and excitatory second-learned associations?*

*Q3. Is there an interaction between design type (AAB and ABC) and the valence of the second-learned association (excitatory and inhibitory) in terms of the context sensitivity of second-learned associations?*

Based on the predictions of Bouton's retrieval model (1997) –the model which has been argued to provide the best explanation of a range of different learning phenomena so far, see Pineño and Miller (2005)-, the following hypotheses are proposed to provide an answer to the research questions of this thesis:

*H<sub>1</sub>: The contextual sensitivity of second-learned excitatory associations will be similar in AAB and ABC designs.*

*H<sub>2</sub>: The contextual sensitivity of second-learned inhibitory associations will be similar in AAB and ABC designs.*

*H<sub>3</sub>: There will be no interaction between design type (AAB and ABC) and the valence of the second-learned association (excitatory and inhibitory) in terms of the context sensitivity of second-learned associations.*

Eight experimental studies are presented in this thesis to address these research questions. Experiments 1 to 6 put to test the contextual sensitivity hypothesis in AAB and ABC designs using second-learned excitatory and inhibitory associations. These experiments start from Bouton's (1997) proposal that contextual sensitivity will occur in both AAB and ABC excitatory and inhibitory second-learned

associations. Findings of this thesis provide strong evidence on the existence of excitatory and inhibitory contextual sensitivity for ABC designs. Yet, no contextual sensitivity was found in the case of AAB designs. These findings are discussed in the light of Bouton's (1997) and Rescorla-Wagner's (1972) models. The data from these experiments were compared to simulations which applied Rescorla-Wagner's mathematical formula to the experimental designs of this thesis. The results of these experiments proved to be inconsistent with Rescorla-Wagner's (1972) model which predicts recency effects for both AAB and ABC designs. In the current studies recency effects took place only in AAB but not in ABC designs. Similarly, Bouton's (1997) model predicts contextual sensitivity in both AAB and ABC designs, while the findings of this thesis find contextual sensitivity for ABC designs only.

Two possible mechanisms are discussed to explain the findings of Experiments 1 to 6: the duration and number of trials (Gallistel & Gibbon, 2000; Haselgrave & Pearce, 2003) and predictions from the comparator hypothesis (Miller & Matzel, 1988). Two further experiments were conducted to vary the duration and number of trials (Experiment 7) and to test predictions made by the comparator hypothesis (Experiment 8). The findings of these experiments provide little evidence for the proposed mechanisms: both experiments showed absence of context sensitivity in AAB designs.

Overall, the findings of this thesis highlight a number of problems with established theories in explaining context sensitivity of second-learned associations. First, the Rescorla-Wagner model (1972) predicts no context sensitivity in both AAB and ABC designs, while Bouton's retrieval model (1997) predicts context sensitivity in both AAB and ABC designs. However, in this thesis context sensitivity was only observed in ABC designs and not in AAB designs. Second, previous theories propose that context is codified during the second stage of a typical learning situation (Bouton, 1997; Rosas, Callejas Aguilera, Ramos Álvarez, & Fernández Abad, 2006). This means that the subjects do not code the context at all during the first stage, unless some of the information provided during the first stage provides some level of ambiguity (see Bouton & Woods, 2008; Pineño & Miller, 2005). Yet, the findings of this thesis are consistent with Üngör and Lachnit's (2008) proposal that the context is codified during the first stage. That is, the difference between AAB and ABC designs could be explained due to this contextual codification in the

first stage. More research needs to be conducted to understand the mechanisms involved. This thesis finishes by discussing implications of context sensitivity for drug addiction therapies. Given the codification of context during the first stage, treatments will be more effective if they take place in the same context where the first-learned association took place (i.e. AAB designs).

### **Practical implications**

On a practical level, understanding the recovery of first-learned associations after the training of a second-learned association can provide useful information that may help prevent relapse in drug addiction therapies. Different approaches have been applied to deal with this topic. One of these is basic research, which has focused on extinction learning (which can be considered a second-learned association), and the ways in which learning can help improve treatment. According to Siegel and Ramos (2002), there is a symbiotic relationship between basic research and clinical work in the treatment of drug addiction. This relationship highlights the importance of the predictive value of learning theories. This is particularly important for extinction treatments of drug addictions, such as exposure therapies. According to Conklin and Tiffany (2002), understanding extinction theory can help to increase treatments' efficacy. One example of this is the cue-exposure addiction treatment, which is a behavioural technique that exposes subjects to conditioned cues and contexts previously associated with drug intake. This technique aims to extinguish the compensatory conditioned responses triggered by the previously associated cues. The close relationship between extinction theory and efficacy of cue-exposure addiction treatment highlights the importance of the predictions made by the different theories that explain extinction and classical conditioning.

### **Document overview**

This thesis contains 6 chapters. Chapter 2 presents and describes relevant concepts. Chapter 3 describes four theoretical models that are relevant for the current thesis: the Rescorla-Wagner model (1972), Bouton's retrieval model (1997), the Comparator Hypothesis (Miller & Matzel, 1988) and Gallistell and Gibbon's model (2000). This explanation includes a historical review of Bouton's previous theories and propositions related to the context sensitivity of first and second-learned

associations. Chapter 4 describes the current evidence on the differences between two particular types of presentations that are usually included in renewal studies: AAB and ABC designs. The chapter includes a review of some of the most important articles about this topic. Chapter 5 presents the empirical findings of this thesis. It reports eight experimental studies that have explored the differences between excitatory and inhibitory associations, AAB and ABC designs, and different types of contexts (partner cues and background contexts). Finally, Chapter 6 summarises the main findings of this thesis, discusses implications for drug therapies, and future research.



## Chapter 2: Definition of relevant concepts

### **Introduction**

The aim of Chapter 2 is to provide a basic description of the relevant concepts of this thesis. In each case, the concept is described and applications to drug addiction treatments are discussed as an example.

### **Renewal, reinstatement and spontaneous recovery**

There are different phenomena that a learning theory should be able to predict and explain satisfactorily. Among these are renewal, reinstatement and spontaneous recovery. These phenomena are crucial for extinction training, and in order to explain extinction, learning theories must be able to address all three of these phenomena.

The renewal effect involves a first-learned association followed by a second-learned association. As a result, a robust recovery of the first-learned association is observed when the CS is tested after a context switch. There are different versions of renewal. The most common version is ABA renewal (e.g. Bouton & Woods, 2008). In this procedure, the first-learned association takes place in context A, the second-learned association in context B, and finally a test takes place in the same context where the first-learned association was learned (context A). Another version is ABC renewal, which is similar to an ABA renewal but the test takes place in a novel context (context C). Finally, there is AAB renewal, where the first and second stages take place in the same context A, and the test takes place in a novel context B.

In the reinstatement effect, the first-learned response returns after the subject is exposed to the US alone (e.g. Bouton & King, 1983; Rescorla & Heth, 1975). With a typical reinstatement effect, a CS is trained in an excitatory association during the first stage. Then extinction takes place in the second stage. Finally, before the test, a presentation of the US alone takes place. When testing of the CS takes place after the exposure to the US, a recovery of the first-learned association is observed.

Finally, spontaneous recovery is a phenomenon consisting of the recovery of a CR after a sufficient passage of time following an extinction procedure (Pavlov, 1927). Even though in this phenomenon the response is recovered, there are no

further pairings of the CS with the US and no context switch. The essential manipulation is the passage of time.

Future chapters will discuss Rescorla-Wagner models' predictions (1972) on the phenomena of recovery of the response. As a summary, this model predicts that extinction learning will result in the unlearning of the excitatory association that was learned in the first stage. If such unlearning took place no recovery of the CR would be expected to happen in the experimental situations that produce renewal, reinstatement and spontaneous recovery. However, the evidence found in studies on renewal, reinstatement and spontaneous recovery challenges the predictions of the Rescorla-Wagner model (see for a review, Pineño & Miller, 2005). If unlearning took place, no recovery of the response would be observed when the test occurs in a novel context.

The phenomena of renewal, reinstatement and spontaneous recovery can be understood from the perspective of drug addiction treatments. For example, in the case of renewal, a place where a subject usually drinks alcohol can act as a context A. In this context, the subject can learn that CSs (for example, his/her friends or music) predict a drug effect (US). The therapy setting can act as context B, where the subject learns that those CSs are not followed by alcohol. It is important to look for mechanisms to avoid the renewal of the responses (withdrawal symptoms in the case of drug addiction) when the subject faces the CSs in the place where he/she used to drink (context A) or when he faces the CSs in a novel context (context C). Reinstatement, following this analogy, can be observed when a person, after treatment, receives the effect of a drug (US), and then the CRs (i.e. abstinence symptoms) appear. Finally, spontaneous recovery implies that after the treatment, passage of time could trigger abstinence symptoms. In general, the study of these phenomena has a practical importance, because it can provide useful information to prevent relapse in drug addiction therapies (for a review, see Siegel & Ramos, 2002).

### **Multiple contexts training**

Another important topic that learning theories should be able to explain is multiple contexts learning (e.g. Glautier, Elgueta, & Nelson, 2013). Specifically, multiple contexts training is relevant for the current thesis because research on the matter explores its possible role as one way of dealing with the effects of context

sensitivity of extinction. Multiple context training can provide useful information to help explain the reasons for the context sensitivity of second-learned associations and possible generalisations of second-learned associations to novel contexts.

Multiple contexts learning can take place either during the first or second stages of training. It is important to understand the effect of multiple contexts learning, either if this learning occurs during acquisition or extinction. There is no conclusive evidence about this topic. For example, Gunther, Denniston, and Miller (1998) found evidence supporting the idea that multiple contexts extinction helps avoiding the renewal effect and multiple contexts acquisition has the opposite effect. In 2006, Bouton, Garcia-Gutierrez, Zilski & Moody, replicated these experiments under the assumption that Gunther et al.'s (1998) research presented some problems (explained in Bouton, 1997). Bouton et al. (2006) found evidence supporting for the idea that multiple contexts extinction does not help to avoid the renewal effect.

The discussion of multiple contexts learning is particularly relevant for drug addiction therapies, because subjects that consume a drug (for example, alcohol), usually do this in different contexts (multiple contexts acquisition). It is very important for therapists to have conclusive information about the effect of this learning over the results of the treatments. Furthermore, therapy context can be seen as the extinction context. It is important to understand if a multiple contexts learning during extinction is more effective in helping to avoid a relapse under new contexts or in acquisition contexts. At the same time, it seems relevant to determine if different renewal designs, such as AAB, ABA and ABC, produce different effects.

### **Primacy and recency effects**

Primacy and recency effects are relevant for this thesis because the study of context sensitivity of first- and second-learned associations is directly related to results observed in extinction or in any association that involves ambiguity in training. Primacy and recency effects are typically observed in experimental situations where there is more than one stage of learning and more than one outcome (which can be either US or no US) (for a review, see Pineño & Miller, 2005). For example, in extinction training, the first stage involves the learning of a CS signalling the presence of a US. The second stage involves the presence of a CS with no US following it. Finally, a recency effect takes place if a test is performed in the

same context where both acquisition and extinction took place, and an absence of the CR is observed. The latter happens because the most recent learned association is controlling the execution of the response. Alternatively, a primacy effect takes place when the test takes place in a novel context (i.e. AAB renewal), and a recovery of the first-learned response is observed.

In the field of drug addiction, primacy effects can be observed in a situation where a subject associates alcohol with a set of specific cues in a specific context. When the cues are presented without the drug, tolerance and abstinence symptoms are produced. In a second phase, the subject can go through an extinction training of the previously associated cues. A primacy effect occurs if after the training the subject continues to present abstinence symptoms when confronted with the associated cues. On the contrary, a recency effect takes place if the associated cues do not lead to the presence of abstinence symptoms. One interpretation is that this absence of conditioned response is due to the time proximity of the extinction training.

## **Inhibition**

Inhibition refers to the ability of a CS to pass a negative summation and retardation test for conditioned inhibition (e.g. Bouton, 1993; Nelson, 2002; Williams, 1995). In general, in learning literature, an inhibitory stimulus is one that has been trained with a feature negative procedure. This procedure implies that there is alternate training of an excitor (e.g. A+) and a negative compound (e.g. AB -). This procedure generates inhibition in stimulus B. Although there is consensus in referring to those stimuli that have been trained in a feature negative procedure as inhibitory stimulus, there are authors that argue that both extinction and the presentation of a CS with no US produce particular forms of inhibition (Bouton, 1993; Williams, 1995).

Inhibition is relevant for the current thesis because this thesis explores phenomena of extinction as a second-learned inhibitory association and the effects of contextual sensitivity of second-learned inhibitory associations produced through an inhibitory feature negative procedure.

Conditioned inhibition is a relevant concept for drug addiction therapies. For example, inhibition training takes place if a subject learns that alcohol consumption

will not take place in front of a contextual cue (e.g. a person). The contextual cue signals the absence of the drug effect. Therefore, when this training is successful abstinence symptoms should decrease significantly when the contextual cue is present.

### **Latent and super-latent inhibition**

Latent and super-latent inhibition are learning phenomena observed in experiments involving the presentation of a CS with no US during a first stage (e.g. De la Casa & Lubow, 2000, 2002; Lubow & De la Casa, 2002). The CS is then paired to an US during a second stage. As a result, interference in the learning of the CS-US association is observed, due to the preexposition of the CS alone. The difference between both phenomena is that in super-latent inhibition, a time interval between the second stage and the test is added, making the interference effect stronger.

Latent and super-latent inhibition have relevant implications for drug addiction therapies. If a subject is confronted with a set of contextual cues for the duration of a given number of trials without the presence of the drug effect, then those cues will be more difficult to train as predictors of drug consumption in the future. One consequence of this observation is that young people should delay the start of drug consumption as much as possible (Betancourt, Inostroza, & Laborda, 2008). Delaying the start of drug consumption exposes them to different contexts before these are associated with drug consumption, making it more difficult to associate these contexts to drug effects in the future.



## Chapter 3: Theoretical background

### **Introduction**

There are several learning theories that aim to explain different learning phenomena. Yet, at the moment, no single theory has been successful in explaining every documented phenomenon (for a review, see Pineño & Miller, 2005). Four theoretical models will be considered in this literature review: the Rescorla-Wagner model (1972), Bouton's retrieval model (1997), the Comparator Hypothesis (Miller & Matzel, 1988) and Gallistell and Gibbon's model (2000). The Rescorla-Wagner model has been one of the most influential models in the field of associative learning (see Miller, Barnet, & Grahame, 1995). Furthermore, it provides a mathematical formula to predict the associative strengths of every involved stimulus in a given learning situation. Its main contribution is the observation that in a classical conditioning situation, learning occurs as a consequence of the discrepancy between the events expected to happen and what actually happens. At the same time, it proposes that the effect of a particular stimulus in a learning situation is influenced by other present stimuli. Most important for this thesis, based on the Rescorla-Wagner model no context sensitivity should be expected for either AAB and ABC designs.

Bouton's (1997) retrieval model is described in this section due to its importance in predicting recovery phenomena, as well as due to its relevance for the current research. Bouton's model explores the context sensitivity of first and second-learned associations. The author proposes that while first-learned associations are independent of context, second-learned associations are dependent on context. Importantly, Bouton's model does not predict important differences in the context sensitivity of AAB and ABC designs. Specifically, it predicts context sensitivity in both designs.

Pineño and Miller (2005) reviewed different learning theories and their capability of predicting primacy and recency effects in extinction and latent inhibition in classical conditioning. They came to the conclusion that Bouton's (1997) retrieval model offered the best explanation of primacy and recency effects, compared to other models (such as Rescorla & Wagner, 1972). According to this

review, Bouton's model is the best at predicting the impact of post training manipulations in classical conditioning. Other models could not provide satisfactory predictions and explanations of primacy and recency effects nor the impact of post-training manipulations without including additional assumptions. Bouton's (1997) model could explain these phenomena without the need for additional assumptions. Nevertheless, when compared to other models, Bouton's model presents the disadvantage of not including a mathematical model that can predict different conditions.

The Comparator Hypothesis and Gallistell and Gibbon's model (2000) introduce interesting predictions for this thesis. The relevant predictions are related to the effects of the manipulation of the time of exposure to the first stage context (Miller and Matzel, 1988) and the effects of the manipulation of the length and number of trials in a conditioning situation (Galisteal and Gibbon, 2000).

### **The Rescorla-Wagner model**

In 1972, Robert Rescorla and Alan Wagner proposed a model to explain associative learning: the Rescorla-Wagner model. This model aims to explain associative learning based on a mathematical formula. Given its simplicity and accuracy explaining several learning phenomena, the Rescorla-Wagner model became one of the most influential models in the associative learning field (Miller et al., 1995). Even though there are several behavioural phenomena that are successfully predicted by the model, several other studies have concluded that the Rescorla-Wagner model fails to explain some learning phenomena (see Miller et al., 1995). The failures in prediction found in this model led associative learning psychologists to gather evidence showing the failures in the model's predictions. However, outside the field of associative learning, the Rescorla-Wagner model seems to be the most recognised model to explain animal and human learning in general.

The following section is concerned with the Rescorla-Wagner model (1972) and its importance in the field of associative learning. The section starts by introducing relevant theoretical and empirical antecedents that led Robert Rescorla and Allan Wagner to propose this model. The model will then be described in detail, including an explanation of the mathematical formula that is used to predict the change in

associative strength of the cues involved in a conditioning trial. Afterwards, empirical findings will be presented, showing evidence in favour of and against the model. This section will finish with a discussion on the current relevance and accuracy of the Rescorla-Wagner model.

The predictions made by the Rescorla-Wagner model will then be applied to the experiments of this dissertation (Chapter 5). In particular, predictions about differences between AAB and ABC designs in both excitatory and inhibitory first and second-learned associations will be discussed.

**Theoretical antecedents.** In the following, relevant antecedents of the Rescorla-Wagner model will be presented and the model will then be described in more detail. Before the Rescorla-Wagner model was proposed, contiguity -defined as the co-occurrence of two events- was considered as necessary and sufficient to produce pavlovian conditioning (e.g. Hull, 1950; Spence, 1936). The main focus was the number of pairings between CS and US to make the CR appear. In general terms, the idea of contiguity was useful to explain learning phenomena described so far. However, experiments showed new data that was not easily explained by the idea of contiguity being necessary and sufficient to produce learning (see Bouton, 2004). Some of these experiments showed phenomena such as blocking (Kamin, 1968), relative validity (Wagner, Logan, Haberlandt, & Price, 1968), correlational effects (Rescorla, 1968) and conditioned inhibition (e.g. Pavlov, 1927; Rescorla, 1968).

Rescorla and Lolordo introduced in 1965 the concept of contingency as an alternative to the contiguity proposal (Rescorla & Lolordo, 1965). The authors proposed that contingency is based on the ratio between the probability that the US and the CS are presented together, compared to the probability that the US would be present in the absence of the CS. In this way, the analysis moved from an analysis of contiguity to an analysis that considered the informative value of the CS as a predictor of the US.

Kamin (1968) proposed the idea of “surprisingness” to deal with one of the new phenomena arising from experimental data: the blocking effect. He proposed surprisingness as an important factor to determine the changes of associative strength in a learning situation. In a blocking effect preparation, an excitatory CS is paired with a neutral cue, signalling the appearance of a US. Considering that the pairings

provide contiguity between this neutral cue and the US, the appearance of a CR is expected in a test of the response to this neutral cue. When the cue was tested, no CR was presented. Kamin proposed that this neutral cue did not become excitatory because there is no surprise in the occurrence of the US after the experimental subjects had been exposed to the compound of the excitatory CS and the neutral cue. If the first excitatory CS predicted the appearance of the US, then there was no surprisingness when the US occurred after the presentation of the compound. As a consequence no CR was performed after the presentation of the neutral cue alone in test trials.

From a cognitive perspective, Kamin's proposal (1968) can be understood as follows: the change in associative strength in a learning trial is directly proportional to the degree of violation of the expectations that the subject has about the occurrence of the US after the presentation of the stimuli is presented. If the experimental subject expects the occurrence of the US after the presentation of the compound, then no change in the associative strength of the stimuli involved will take place. However, if there are no expectations of the occurrence of the US after the presentation of a stimulus (or a compound of stimuli), and the US is presented, then there will be change in the associative strength of the stimuli involved in that learning trial.

Kamin's proposal advanced the understanding of blocking as a new learning phenomenon. However, changes in the strength of a stimulus were considered to depend only on the stimulus in question and to be independent from other cues involved in the trial, an assumption that other models also made (e.g. Hull, 1943). That is, previous models considered no interaction between different cues, or between cues and context. The Rescorla-Wagner model challenged this vision by proposing a mechanism in which the associative status of the cues involved in a learning situation changes when these cues are trained in the presence of other cues. The model involved a change in the general view of how CSs (including context) interact in a learning situation.

**The Rescorla-Wagner model.** The Rescorla-Wagner model (1972) appeared as a way to explain data showing that contiguity was not sufficient to produce pavlovian conditioning. The model proposed that the co-occurrence of two stimuli

produces an association when this co-occurrence is unanticipated by the experimental subject in the current state of associative strength of the cues involved. This means that if the subject does not anticipate the co-occurrence of two contiguously presented events, then there will be a difference between its expectations and what actually occurs. At the same time, this difference in expectations plays an important role in determining if there is going to be an association between the cues or not. The Rescorla-Wagner model not only proposed this prediction, but stated it in a formal way, providing a mathematical learning rule that helped understand the associative changes in all stimuli involved in a learning situation.

The Rescorla-Wagner model (1972) proposes that the effect of presenting an US or not in a learning situation does not only depend on the stimulus presented, but also on other stimuli that are present in the situation. In other words, all stimuli involved in a trial play a role in determining the outcome of that trial. In general terms, if a compound of environmental cues has a low associative strength, this compound will present a high increment in its associative strength if paired with an US on a learning trial. Similarly, if a compound of environmental cues has a high associative strength, and this compound is presented in the absence of the US that was expected to occur after it, then the level of decrement of the associative strength associated to this compound will be high. In these terms, the Rescorla-Wagner model proposes a revolutionary view of learning trials in a classical conditioning preparation.

According to Rescorla and Wagner (1972), subjects learn that an event predicts an outcome depending on the predictability of that outcome given the co-occurrence of events. In a formal way, this model states that the change in the associative strength between a CS and a US in a given trial is calculated using the following formula (Rescorla & Wagner, 1972; see for a detailed explanation Miller et al., 1995):

$$\Delta V_X^{n+1} = \alpha_X \beta_1 (\lambda_1 - V_{total}^n)$$

Where:

- $\Delta V_X^{n+1}$  is the extent to which the CS's associative strength varies as a result of the presentation of stimulus X paired with US<sub>1</sub> on a given trial (n+1). It is important to clarify that (n) and (n+1) are used in this formula to indicate the number of the trial, and does not symbolise an exponent.
- $\alpha_X$  is the associability of CS X. This associability ranges from 0 to 1 and it is broadly linked to the intensity of CS X
- $\beta_1$  is the associability of US. This associability ranges from 0 to 1 and it is broadly linked to the intensity of the US<sub>1</sub>.
- $\lambda_1$  is the associative strength that US<sub>1</sub> can support as a maximum in any single trial. Graphically it corresponds to the asymptote of learning for a specific US.
- $V_{total}^n$  sums the associative strengths of all CSs (including X) that are present on a given trial (n+1).

Once the change in the associative strength of the CS has been calculated, it is possible to obtain the associative strength of a single CS after trial (n+1) according to the following formula (Rescorla & Wagner, 1972):

$$V_X^{n+1} = V_X^n + \Delta V_X^{n+1}$$

Where:

- $V_X^{n+1}$  symbolises the associative strength of every single CS after trial (n+1)
- $V_X^n$  equals the associative strength of CS X preceding trial (n+1)
- $\Delta V_X^{n+1}$  equals the change in the associative strength of CS X as a product of trial (n+1) and is determined by equation 1

**Successes and failures of the Rescorla-Wagner model.** The aim of learning theories is to explain and predict as many learning phenomena as possible drawing on a parsimonious and simple model. From this point of view it is possible to argue that the Rescorla-Wagner model has been relatively successful: it has been used to make ordinal predictions of an important number of learning phenomena using a relatively parsimonious model. The central tenet of the model is intuitive and it holds an important heuristic value: the ways in which subjects process events depends on the event's intensity and surprisingness. In 1995, Miller, Barnet and Grahame reviewed empirical evidence evaluating different predictions made by the model. As a product of this review the authors concluded that the Rescorla-Wagner model was successful in predicting an important number of phenomena. Among these, the explained phenomena that are most relevant for this thesis are: acquisition and extinction curves; stimulus generalization; discrimination; tests for conditioned inhibition; procedures for producing conditioned inhibition; and the trial spacing effect.

Yet, Miller et al. (1995) described a number of other learning phenomena the model has not been able to explain fully. Most relevant for this thesis, the model has not been able to predict: spontaneous recovery, external disinhibition and reminder-induced recovery from extinction; facilitated and retarded reacquisition after extinction; failure to extinguish a condition inhibitor; nonreinforcement of a novel cue in the presence of a conditioned inhibitor; nonexclusiveness of conditioned excitation and conditioned inhibition; the CS-preexposure effect; and the modulation of conditioned inhibition through posttraining extinction of other cues that were present during training.

Even though Rescorla-Wagner's model has been very useful as a heuristic tool within the field of associative learning, its shortcomings make it necessary to search for other models to explain associative learning phenomena.

**Conclusion.** The Rescorla-Wagner model has been relevant in the field of learning psychology in recent decades, mainly due to its simplicity and ability to predict a number of learning phenomena. Yet, the model is not able to fully explain an important number of other phenomena (Miller et al., 1995). Most importantly for the current thesis, studies have provided evidence that phenomena such as recovery

effects produced by context change cannot be predicted drawing on the Rescorla-Wagner model (Bouton, 1997; Glautier et al., 2013; Glautier & Elgueta, 2009; Pineño & Miller, 2005). In particular, there is extensive evidence against the notion of unlearning (for a review, see Pineño & Miller, 2005).

### **Bouton's (1997) retrieval model and its importance**

**Bouton's (1993) retrieval model.** Bouton developed an early model in 1993, considering experiments in the field of extinction, counterconditioning and post training manipulations in general. In counterconditioning and extinction, a recovery means that the response to the conditioned stimuli (CS) is performed according to the first-learned association. These experiments showed that a recovery of the conditioned response can occur after those procedures. This recovery has been called the 'renewal effect'. Bouton's (1993) model offers an explanation and predicts the recovery of the first-learned response: post training manipulations produce changes in the testing context. The explanation offered by Bouton's (1993) model is that the first-learned response is independent of context because it is an excitatory association. On the other hand, the second-learned association (extinction in this case) is dependent of context because it is an inhibitory association.

Changes in context can be either physical or temporal. Considering this, there is a retroactive interference between the different outcomes involved, which produces a recovery of the response. This means that the first-learned association produces interference of the second-learned one. It is important to mention that the retroactive interference proposed by this model does not involve unlearning of the original association; other models predict unlearning in these cases (e.g. Rescorla & Wagner, 1972). Bouton's (1993) model predicts that, if the first-learned association is an excitatory one between a CS and an US, then a second learning with the same CS would lead to the formation of a new association. This second learning can be inhibitory, as in the case of extinction. Here, the new association will be an association between CS, and no US. Bouton's model proposes that retrieval of this inhibitory association will occur only in the presence of the context where this second association was trained. If the test occurs in a different context, then the second-learned association will not be retrieved. The model incorporates the general

idea that inhibitory and excitatory associations are different in terms of retrieval. The difference proposed by this model can be described as excitatory associations being independent of context, and inhibitory associations being context dependent. This means that the key factor to determine context sensitivity is the value of the association, which can be either inhibitory or excitatory.

**Bouton's (1994) functional explanation.** Bouton (1994) later proposed a functional explanation of this model. He argued that organisms evolved favouring contextual dependency of inhibitory associations and, at the same time, contextual independency of excitatory associations. The difference between inhibitory and excitatory associations is related to differences in their nature. For example, in the case of extinction training, in a first stage, a CS is paired to an US. In a second stage, the CS is extinguished by presenting it in absence of the US. After these two stages, two different performances are available: excitatory and inhibitory responding. Bouton's explanation proposes that the performance will be selected by the context present during the testing phase. Considering the independency of context of excitatory associations, these associations will generalise well across different contexts. The inhibitory association learned in the second stage will be context dependent. This means that to be retrieved, the test must take place in the same context where this second association was learned. This prediction is successful in explaining spontaneous recovery and renewal effects: both are produced because of a failure to retrieve the inhibitory learning outside the context where the inhibitory association was learned. Given that the association is independent of context, if the association is tested in a context different to the one where the extinction was trained, the response will be excitatory.

**Bouton's (1997) retrieval model.** Bouton (1997) proposed a later modification to his model. Bouton stated that there is evidence showing that what is modulated by context is not inhibition but what is learned second (Nelson & Bouton, 1997). This means that the valence of the association is not the critical factor predicting context sensitivity. According to this logic, inhibitory associations are not particularly sensitive to context, but second-learned associations (that can be either excitatory or inhibitory) are sensitive to context. The authors conducted experiments with rats

involving both serial and simultaneous learning of negative features. They observed conditioned inhibition that was resistant to a context switch during the test. At the same time, experiments of latent inhibition in rats, using a conditioned suppression task, with and without a context switch between the acquisition and extinction stages (Swartzentruber & Bouton, 1992) provided evidence of first-learned non-excitatory associations being independent of context and second-learned excitatory associations showing context dependency.

According to Pineño and Miller (2005), this modification took place because there was a learning effect that the previous version of the model could not explain properly: super latent inhibition (De la Casa & Lubow, 2002). This phenomenon is described by De la Casa and Lubow (2002) as a 'retarded performance' during a learning task, in which the stimuli acting as a target was first irrelevant. This is different from cases where the CS was not present. Latent inhibition involves presentations of CS alone in a first stage. Then, in a second stage, there are paired presentations of CS and US. Before the testing phase, there is a long retention interval. As a result of this presentation, a strong reduction in the conditioned response is observed, compared to the conditioned response to a US that has had the same treatment, but without the presentations of CS alone in the first stage. In this phenomenon we can observe that what is modulated by the context is the second-learned association, and not inhibition.

In these experiments, it can be seen that this long retention interval following the treatment has an opposite effect compared to the one observed after the extinction training. A recovery of the conditioned response is usually observed after extinction training. At the same time, after a long retention interval in a latent inhibition treatment, the opposite is observed: the response is attenuated (for examples, see De la Casa & Lubow, 2002; Lubow & De la Casa, 2002).

This super latent inhibition phenomenon was difficult to explain by Bouton's (1993) retrieval model, because the first association –this is, CS-no US- was supposedly inhibitory, and thus, context specific. If this association was context specific – which implies a change in context- then the passage of time would attenuate the association. Instead of this, passage of time had the opposite effect. It enhanced the inhibitory association, producing the super latent inhibition effect.

Considering this evidence, Bouton changed his original model that regarded excitatory associations as independent of context and inhibitory associations as context dependent, for a model that argued that second-learned associations are context dependent. This idea implies not just inhibitory associations are context dependent. Therefore, the value of the association is not the most important factor in determining context dependency. Instead, the most important factor is the order of the associations. This model proposes that first-learned associations are independent of context, while second-learned associations are context dependent. The original model proposed valence of the association as the critical factor to determine context dependency (Nelson, 2002). Valence of an association can be either excitatory or inhibitory. This model is not capable of explaining why excitatory associations become context dependent in certain situations, such as happens in the case of counter conditioning. In the case of the super-latent inhibition effect, Bouton's new proposal assumes that the first-learned association (inhibitory in this case) is independent of context. The second-learned association (excitatory in this case) is context dependent. Finally, in a test that takes place after the passage of time, the temporal context has been modified, and so the first-learned association that is independent of the context is retrieved.

Important results supporting the model of Bouton (1997) are provided by Nelson (2002). Nelson noted that different renewal designs had a common factor: the second-learned association was always inhibitory, and it was presented after a first-learned excitatory association. Nelson also showed evidence of excitatory associations becoming context dependent when they were presented as second-learned associations. These results by Nelson suggested that both excitatory and inhibitory stimulus can become context dependent. For this experiment, Nelson (2002) used three groups of rats, involving a task where signals such as a keylight, a tone, a houselight-off and an intermittent noise signalled the income or not of food. In phase one an experimental group IE (meaning inhibitor and then excitor) received inhibitory training for a stimulus T using a feature-negative discrimination procedure. This procedure was composed of excitatory presentations of D, alternated with non-reinforced presentations of TD. In this experiment, D was darkness produced by the switching off of the lights and T was a tone. In phase two, the three groups received reinforced presentations of stimulus T. This means that an excitatory

association was second-learned for group IE. Control group P (Pseudodiscrimination) received the same exposure to Stimulus T than group IE, but for this group, the compound TD was reinforced. In this group, T did not acquire inhibition. In this way, the excitatory association learned in phase two was similar to the first-learned association with stimulus T: both were excitatory. A control group received inhibitory training for an irrelevant stimulus (N) in phase one, and excitatory conditioning with stimulus T in phase 2, T being a novel stimuli for this group. The three groups received trials in a context B where a key light (K) was reinforced to ensure that every context could become familiar for the subjects (see Table 1 for design). The critical results for this experiment were related to the context switch involved during the test phase. In this phase, T showed a loss of responding in group IE. In the control groups, T did not show any loss of responding. From these results, Nelson (2002) concluded that second-learned excitatory associations after an inhibitory first-learned association can become context dependent. In this case, the excitation was attenuated when a context switch took place in the testing phase.

Table 1

*Design of Experiment 1 (Nelson, 2002).*

Group	FN Training	T+ Training	Test
IE	A: D+, TD-	A: T+	A & B: T-
	B: K+	B: K+	
P	A: D+, TD+	A: T+	A & B: T-
	B: K+	B: K+	
N	A: D+, ND-	A: T+	A & B: T-
	B: K+	B: K+	

Note. A: and B: are contexts in which the following conditioned stimuli (CS) were presented; T= tone CS; D = house light-off CS; K = key light CS; N= intermittent noise CS; + = reinforced trials; - = non reinforced trials.

These results lead to the following question: why can a second-learned association become context dependent? Bouton may have an answer for this question (see Rosas, García-Gutierrez, & Callejas-Aguilera, 2006). In his second view, -called

‘functional perspective’ - by Rosas et al., Bouton (1994) proposes that acquisition trials allow the animal to represent the world surrounding it. This information allows the animal to make inferences about the environment. When there are different outcomes predicted by one stimulus, the first-learned association with this stimulus or the first meaning of the stimulus are more likely to be retrieved in response to this stimulus in the future. If there are outcomes for the stimulus different to the first one, the animal will consider these outcomes as exceptions to the rule. This mechanism will lead to the second-learned associations becoming context dependent (Rosas, García-Gutierrez, et al., 2006).

Bouton proposed a third view in 1997. This view is an amplified version of the previous model that proposes that subjects pay attention to the context when there are different meanings available for a stimulus. If there is a second outcome for a stimulus, the subject will pay attention to the context where this second outcome is available. This second-learned association will only be retrieved in this context. This explains the context dependency of second-learned associations.

This model proposes that first-learned associations between CS and US will always be independent of context, whether they are inhibitory or excitatory. At the same time, second-learned associations -when they involve a different outcome than the first-learned association for the CS- will produce ambiguity in the meaning of the CS. This ambiguity will make the subject pay attention to the context where the second-learned association is learned. Finally, to retrieve the second-learned association, testing must take place in the context where this association was learned. If testing takes place in any other context, the first-learned association will be retrieved. Bouton (1997) argued that for ambiguous inhibitory and excitatory associations, context will be crucial in determining the retrieved association. The predictions of this model can be applied to different and relevant phenomena.

As an example of this, Gunther, et al. (1998) conducted two experiments that are important to understand the functioning of context switch in extinction training. In their first experiment, they aimed at comparing the renewal effect produced after a multiple-contexts extinction training and after a single-context extinction training. This experiment used three groups of rats receiving the same training in phase one: reinforced trials of CS in context A. In phase 2, group E3 received multiple-contexts extinction, group R1 received single-context extinction and group E0 received no

extinction trials. Testing took place in a novel context for all groups. Group E3 showed less renewal effect than the other groups. The authors concluded that the subjects receiving extinction training in multiple contexts were more likely to respond in an inhibitory way in a novel context, compared to subject receiving single-context extinction (see Table 2).

Table 2

*Design of Experiment 1 (Gunther et al., 1998)*

Group	Training	Extinction	Testing
NE	(CS-US)A	(--) B and (--)C and (--) D	(CS)E
E1	(CS-US)A	(CS)B and (--)C and (--) D	(CS)E
E3	(CS-US)A	(CS)B and (CS)C and (CS)D	(CS)E

Note. A, B, C, D and E were distinctive contexts, the CS was a white noise, US represents the footshock unconditioned stimulus, and ‘–’ represents no stimulus presentation. Groups E1 and E3 received the same total number of non-reinforced CS (extinction) trials.

Table 3

*Design of Experiment 2 (Gunther et al., 1998)*

Group	Training	Extinction	Testing
T1	(CS-US)A and (--)B and (--)C	(CS)D and (CS)E and (CS)F	(CS)G
T3	(CS-US)A and (CS-US)B and (CS-US)C	(CS)D and (CS)E and (CS)F	(CS)G

Note. A, B, C, D, E, F and G were distinctive contexts, the CS was a white noise. US represents the footshock unconditioned stimulus, and ‘–’ represents no stimulus presentation. Both groups received the same total number of CS-US pairings and the same total number of non-reinforced CS (extinction) trials.

In a second experiment, Gunther, et al. (1998) aimed to determine if acquisition in multiple-contexts produced a stronger renewal effect than single-context acquisition (see Table 3). Two groups of rats were involved in this experiment. During phase 1, group T1 received single-context acquisition training and group T3 received multiple-contexts acquisition training. During phase two, both groups received a training consisting of multiple contexts extinction trials. The testing took place in a novel context. The results indicated that group T1 showed less renewal effect than group T3. The authors concluded that multiple-contexts acquisition and multiple-contexts extinction together produce an excitatory response when tested in a neutral context.

Bouton's (1997) model was not able to predict the results of Experiment 1 of Gunther et al (1998). In this experiment groups E1 and E3 received a first-learned excitatory association and a second-learned inhibitory association. Therefore, when tested in a novel context, both groups should have shown strong renewal effects according to Bouton's model. However, in this experiment, this strong renewal effect did not appear.

At the same time, Bouton's model predicts no differences between groups T1 and T3 for Gunther et al.'s experiment 2. Group T1 received single-context acquisition training and group T3 received multiple-contexts excitatory first-learned trainings and then a single context extinction second training. According to Bouton's model, in both groups there should be a first-learned excitatory association that is independent of context. This means that testing in a novel context should show excitatory responses. However, Gunther et al.'s findings show differences in the renewal effect between groups T1 and T3.

However, it is possible to argue that the second stage does not offer enough ambiguity for the CS. According to this idea, the subjects could have learned to discriminate between contexts such that context A acts as an excitatory occasion setter, and contexts D, E and F act as inhibitory occasion setters. This means that there is not enough ambiguity to produce any context sensitivity of the second-learned association, explaining the absence of renewal. It is also difficult to check if there were any alternative phenomena such as resistance to extinction because there were no measures during the second stage.

Bouton et al. (2006) tried to replicate Gunther et al.'s (1998) experiment, running two experiments that evaluated the effects of multiple-context extinction on renewal effect in a novel context. They replicated the experiments because they found two possible problems with them. One of these problems was that these experiments did not explore the mechanism behind multiple-contexts training effect. A second problem was that Gunther et al. did not collect data during the extinction phase, which makes a comparison between responding during the extinction phase and during the renewal test impossible. In Experiment 1, Bouton et al. (2006) used a similar experimental design to the one used by Gunther et al.'s (1998) experiment. The authors used two groups of rats receiving a single-context excitatory training between a tone and a shock in context A of phase one. In phase two, group ABBBE received single-context extinction training and group ABCDE received multiple-contexts extinction training. Testing took place in a novel context. The results of this experiment were different to the ones reported by Gunther et al. (1998). In Bouton et al.'s (2006) experiment there was no reduced renewal effect in the multiple-contexts extinction group, compared to the single-context extinction one. In this experiment, the test took place in a novel context. At the same time, Bouton et al. (2006) provided evidence of a lack of reduction of renewal effect when the test occurred in the same context where the excitatory association took place. According to the authors, this means that extinction is not less vulnerable to the renewal effect after multiple-contexts extinction training, compared to the single-context extinction training group.

The results from Bouton et al. (2006) are compatible with the predictions of Bouton's (1997) model. The latter model predicts that second-learned associations are context dependent. The prediction is thus that for both groups, the inhibitory association will be context dependent. This is what the results actually showed. In the new experiment, extinction was second-learned for both groups.

Bouton et al. (2006) conducted a similar second experiment, but included one change: to produce an ABA renewal design, the testing context would not be a novel one, but the one involved in the first stage. The experiment included two groups, ABCDA and ABBBA, which differed only in the extinction phase (being ABCDA multiple contexts and ABBBA single context). The prediction from Bouton's model (1997) was that both groups would show a strong renewal effect, because testing

took place in the same context where the first-learned association was trained. Considering that the second-learned association is expected to be context specific (whether single- or multiple-contexts trained), then the second-learned response performed in the original context should be the same as the one learned in that context: an excitatory one. The results supported this prediction.

In 1995, Williams led experiments showing results that do not match Bouton's (1997) predictions. Williams compared the effects of three different inhibitory manipulations (see Table 4): feature-negative alone, a negative feature with a cue plus a negative feature with a second cue, and finally, a negative feature plus presentations of the CS with no US. The results indicated that the presentation of a negative feature + presentations of the CS with no US formed a general form of inhibition that can inhibit the response of different cues to multiple USs.

Table 4  
*Design of Experiment 1 (Williams, 1995)*

Group	Learning Stage		
	Block 1	Block 2	Test Stage
Single	P1 → outcome	P1 → outcome	C → ?
	P2 → outcome	P2 → outcome	N → ?
	PT → outcome	PT → outcome	PTC → ?
	Ø → no outcome	P1N → no outcome	PTN → ?
		P1P2 → outcome	
Double/ Compound	P1 → outcome	P1 → outcome	C → ?
	P2 → outcome	P2 → outcome	N → ?
	PT → outcome	PT → outcome	PTC → ?
	P2N → no outcome	P1N → no outcome	PTN → ?
		P1P2 → outcome	
Double/ Element	P1 → outcome	P1 → outcome	C → ?
	P2 → outcome	P2 → outcome	N → ?
	PT → outcome	PT → outcome	PTC → ?
	N → no outcome	P1N → no outcome	PTN → ?
		P1P2 → outcome	

Note. P1 = first positive cue; P2 = second positive cue; PT = transfer cue; N = negative cue; C = control cue.

On the other hand, only feature negative training produced inhibition specific to the cue. To explain his results, Williams proposed that the inhibition produced by a feature negative training results in a configural –and not in a general- form of inhibition. This configural form of inhibition is specific to the cue. Thus, the feature negative results in an inhibitory response to the compound showed during the training are specific and they are not an inhibitory response to just one of the elements of the compound.

According to Williams (1995) there is a general mechanism of inhibition that implies that the single cue predicts no outcome. This mechanism is different to the configural one, implying that the single stimulus denies the rule that a stimulus predicts the outcome. The single stimulus does not become a general inhibitor. To become one, the subject must experience double discrimination, which means that the stimulus should be involved in a feature negative training and in presentations of a stimulus with no outcome. These predictions are different from Bouton's (1997) because Bouton's model predicts that a first-learned inhibitory stimulus can be independent of context, becoming a general inhibitor. They also contradict Williams' prediction, according to which this inhibition would be only configural.

**Conclusion.** Bouton's (1997) retrieval model can be considered as an important explanation of classical conditioning phenomena. It states that first-learned associations are context independent and second-learned associations are context dependent. This context sensitivity is independent of the value of the cues (excitatory or inhibitory). However, there are still some phenomena that the model does not accurately predict. It seems important to question, for example, if different kinds of presentations of stimuli behave in a similar way, such as presentations AAB, ABA and ABC. The model does not predict any differences between these designs. It is important to determine if that lack of difference is effective when tested. The next chapter will deal with evidence on this matter.

Other important theories to understand the experiments that will be presented in this thesis are the Comparator Hypothesis (Miller & Matzel, 1988) and Gallistell and Gibbon's (2000) model.

### **The Comparator Hypothesis (Miller & Matzel, 1988)**

The comparator hypothesis (Miller & Matzel, 1988) was proposed to explain cue competition at a time when other theories were limited to predicting single US conditioning situations (Gibbon & Balsam, 1981; Rescorla & Wagner, 1972). Miller and Schachtman (1985) found that in a cue competition situation the deficits observed in one of the competing cues could be attenuated using posttraining extinction of the other cue involved in the original situation.

The comparator hypothesis understands associations as formed based on learning mechanisms that depend on two features: the salience of the stimuli involved and the contiguity between the stimuli. In a situation of cue competition, the comparator hypothesis predicts that during the acquisition phase no cue competition will occur. At the time of testing, the observed deficit in response to one of the cues is explained as a failure in the expression of the association and not as a failure in the associative mechanisms involved. In opposition to the vast majority of learning models (e.g. Bouton, 1993, 1997; Pearce & Hall, 1980; Rescorla & Wagner, 1972), the comparator hypothesis does not predict a failure in the associative acquisition to explain the results of cue competition.

The comparator hypothesis explains pavlovian conditioning considering three associations involved in the process. The first association (Link 1) is an association between the target CS involved in the learning situation and the US. In this case, the theory refers to the association as one between the CS and the directly activated US representation. A second association (Link 2) is formed between the target CS and the so-called ‘comparator stimulus’. The comparator stimulus is defined as the most salient stimulus present during the conditioning situation that is not the target CS or the US. The comparator stimulus could be the context, or in the case of cue competition, the competing cue. Finally, a third association (Link 3) is involved. This is an association between the comparator stimulus and an indirectly activated representation of the US. At the end of the process, the associative strengths of the directly activated US representation and the indirectly activated US representation take part in a comparison process. This comparison process determines the response that follows the target CS.

According to the comparator hypothesis there is a difference between AAB and ABC renewal. This difference can be explained because in an AAB design the

association between the CS and the first-stage context is reinforced in the first and second stages. On the other hand, in ABC designs this occurs only during the first stage. Applying this prediction to the comparison process, the reinforcement of the association between the target CS and the first-stage context should lead to a reinforcement of Link 2. This implies a stronger associative strength of the indirectly activated US leading to a failure in the expression of the CR. This mechanism could help explaining the differences between AAB and ABC designs that were observed in Experiments 1 to 3 of this thesis. In AAB designs the reinforcement of Link 2 (i.e. the reinforcement of the relationship between the target CS and the comparator stimulus, in this case, context) is reinforced in the first and second stages. On the contrary, in ABC designs there is a context switch in the second stage, which means that reinforcement of the relationship will occur only in the first stage.

Predictions of the comparator hypothesis and a mathematical version of the comparator hypothesis (SOCR, Stout & Miller, 2007) were tested by Laborda, Witnauer and Miller (2011) using a lick suppression task with Sprague-Dawley-descended rats. In a first experiment the authors observed differences in response recovery after extinction produced by a context switch in AAB and ABC designs. In a second experiment they tested the effect of posttraining exposure to the first-stage context after an extinction situation in both AAB and ABC designs. They observed that this posttraining manipulation produced an increase in the response to the CS only in the AAB design. Finally, in a third experiment they tested the effect of reinforcing the association between the target CS and the first-stage context in both AAB and ABC designs. Reinforcement was again carried out through a posttraining manipulation. As in Experiment 2, they observed an increase in the response to the CS only in the AAB design.

### **Gallistell and Gibbon's model (2000)**

Gallistel and Gibbon (2000) proposed a model suggesting that subjects respond in a classical conditioning presentation according to decisions. These decisions are based on decision variables. The variables grow depending of the duration of the experience that is relevant to them. According to this approach, different decision variables are related to different decisions that the subjects deal with. For example, in the case of acquisition training, the important factor to determine if the subject

will respond is a ratio. If that ratio exceeds a threshold, then the subject will respond. The mentioned ratio consists of two elements: first, the estimate of the rate of reinforcement when the CS is present, acting as a numerator. The second element is the estimate of the rate of reinforcement when the background is present. In other words, this ratio can be understood as the estimate of the similarity between the estimate of reinforcement of the CS compared to the one of the background.

In the case of extinction, different elements are involved in the decision process. The elements involved in extinction are: first, the cumulative amount of time of exposure to non-reinforced CS after the last trial of acquisition. The second element is the amount of time of CS exposure per reinforcement that is expected by the subject. This model can be useful to explain the effects of extended extinction training. For example, if the number of trials of non-reinforced CS is augmented, then the ratio between the two elements mentioned becomes smaller, making it more difficult for the final result to go above the threshold. This makes the subject less likely to respond to the CS.

Gallistel and Gibbon's (2000) model has found support in studies that suggest extinction training works faster after continuous reinforcement than after partial reinforcement. In the case of partial reinforcement, the extinction rate has a higher value than in continuous reinforcement. This means that fewer trials of extinction are needed to pass the threshold in partial reinforcement than in continuous reinforcement.



## Chapter 4: Empirical evidence of AAB and ABC designs

### Introduction

There are different predictions that are interesting to test in the light of Bouton's (1997) model (described in Chapter 3). As has been stated before, this model predicts independence of context for first-learned associations and context dependency for second-learned associations. The model does not specify differences between different types of stimulus, such as between inhibitory or excitatory ones. At the same time, it does not specify differences when there are different context arrangements, such as the ones presented in designs AAB, ABC or ABA in renewal. According to Bouton's model, the only important factor when predicting the responses of subjects is the order of the associations (first or second-learned associations). It follows that there should be no differences between ABC, AAB and ABA renewal designs at the moment of testing. Context sensitivity should appear in all cases.

The Rescorla-Wagner model (1972) was stated before renewal gained importance in the field of experimental psychology. However, predictions made based on this model (and simulations that will be presented in Chapter 5) suggest that no context sensitivity should be observed in both AAB and ABC designs. According to the model, the target CS goes through excitatory training during the first stage and inhibitory extinction training during the second stage in both designs. Therefore, at the end of the experiment, the associative strength of the target CS should be the same in ABC and AAB designs. In other words, when the target CS is tested in a novel context no expectation of recovery of the response learned in the first stage is expected in both designs. As a result, no context sensitivity should be expected in both AAB and ABC designs.

It is important to determine under which conditions the renewal effect works. To illustrate the importance of this, it is informative to compare a classical conditioning experimental design with the acquisition of drug addiction (for details, see Siegel & Ramos, 2002). In an ABC design involving a first-learned excitatory association and a second-learned inhibitory association, an analogy with drug addiction can be made by assuming that the first context was present during the acquisition of drug

addiction, and the second context was present during a therapy treatment. Finally, a third context is the place where the effects of the treatment were tested, measuring relapse or withdrawal symptoms. Given such an analogy, it is relevant to determine if a relapse can be expected from any design (ABC, AAB and ABA), or if there is one design that shows more resistance to renewal than the others.

Considering previous studies (e.g. Bouton & Ricker, 1994; Goddard, 1999; Nakajima, Tanaka, Urushihara, & Imada, 2000; Üngör & Lachnit, 2008), there seem to be reasons to believe that there is a design that shows different sensitivity to a recovery of the initial response: the AAB design. According to these studies, the recovery in this design is harder to observe than in the case of ABC and ABA designs. If this were true it would have important theoretical and practical implications. In theoretical terms, one of the most important models of associative learning -that is, Bouton's retrieval theory (1997)- should be modified to account for the difference between AAB and the rest of the renewal designs. In practical terms, drug treatments could be designed to account for these differences. For example, it would be interesting to test if treatments given in the same context where the drug addiction was acquired (AAB design) are more effective than treatments given in a different therapeutical context (ABC or ABA designs).

In the following pages, the most relevant studies comparing AAB and ABC designs are discussed.

AAB renewal using appetitive and aversive conditioning tasks in ratsBouton and Ricker (1994) and Bouton's (1994) model clearly predict that a recovery of the response to an extinguished stimulus should be observed whenever this stimulus is tested in a novel context. This includes situations where extinction has been conducted in the same context where the excitatory training took place. The authors conducted a series of experiments using tasks involving both aversive and appetitive conditioning and tested if AAB renewal occurred after extinction.

In Experiment 1, rats were first trained to press a lever, receiving food as a reward. After this, they received training of a house light paired with a foot electroshock in context A (conditioned suppression method). Extinction training of the house light then took place in context A. Finally, responses of the subjects to the CS were tested in context A and B. If AAB renewal was observed, then a recovery of

the conditioned response should be observed in context B, but not in context A. The results of this experiment showed more responding in context B than in context A, suggesting that AAB renewal can occur with conditioned suppression.

In Experiment 2 an AAB design was used to test renewal in an appetitive task. Subjects received pairings of tone and food in context A. Then, during extinction, subjects received the CS alone in context A. Finally, responses to the CS were tested both in contexts A and B. Results showed more responding in context B than in context A, that is, they showed an AAB renewal.

A third experiment extended the results of Experiment 1 by testing AAB renewal in two groups. The first group had a normal AAB renewal training. A second group had a second training presented in context B during the extinction training. This second training aimed to equalise the amount of inhibitory and excitatory trials presented during the first and second stages. The results did not show differences between groups with or without a second training during extinction training, suggesting that the results obtained before were not due to differential associations of contexts A and B with the US.

Bouton and Ricker argued that an AAB renewal could have some generality. Evidence suggested that AAB renewal can occur in aversive and appetitive conditioning. This is evidence that has been considered to support the notion that there are a number of situations in which extinction is more context-specific than excitatory performance.

As has been noted before, at this point (1994), Bouton's theory proposed that extinction was context dependent and that excitatory associations were independent of context. In this framework, the results described above were considered as evidence to increase the number of situations where extinction is more context specific than excitatory performance. Considering this, these results encouraged the point of view of renewal acting as a general mechanism that can be observed in different kinds of associations, which is what Bouton's model (1994, 1997) has proposed in its different versions.

At this point, there was no evidence to think that AAB renewal was any different from renewal observed in designs ABC and ABA. Nonetheless, results published by Goddard (1999), suggested something different.

### **ABA but not AAB renewal using an appetitive conditioning preparation in rats**

Goddard (1999) questioned the generality of AAB renewal. Four experiments using laboratory rats were conducted, involving an appetitive conditioning task with US renewal in designs AAA, ABA, AAB and ABB. US renewal is a renewal design in which a US signals the income of a greater quantity of the US. The four experiments differed in some procedural details, but in general they aimed at testing the phenomenon of US renewal across different designs, signalling the income of another US. Because of this, only Experiment 4 will be considered.

Experiment 4 used the four mentioned conditions, controlling for all the factors that were suspected to affect the results of experiments 1, 2 and 3. The exposure to contexts A and B was the same during acquisition, extinction and test stages. The question to answer here was if controlling the amount of exposure to contexts A and B, and hence controlling their associative strength, could minimise the disruption caused by a novel context. In other words, the question was if equal amounts of exposure of excitation and inhibition in contexts A and B would prevent the recovery effect that a novel context produced.

The results showed consistent renewal in group ABA through the different experiments. At the same time, no renewal was observed in group AAB. On the one hand, these results provide evidence for the argument that renewal is a general phenomenon, because they showed renewal in a new task (ABA renewal to the signal value of a US). At the same time, however, they did not support this assumption, in that renewal was not observed with AAB designs. According to Goddard, a key problem regarding this phenomenon, is that some experiments have shown a loss of the CS signal value when there is a context change, whilst other experiments have not. The author proposes a configural model as a possible explanation for these results. For an AAB model, context A and the cue acting as a CS (which in the case of his experiments was a US), form a configural cue that is associated to the second US. After extinction, the original configural cue is presented and this is why renewal is observed.

These results are important, because they show that the renewal effect is not observed in an AAB design in different conditions. Specifically, no renewal was found when a US signalled the arrival of more USs with and without control of odour cues, and similarly no renewal was found when the passage of time was used

as a contextual cue with and without control of the exposure and associative strength of the involved contexts. Due to these revelations, Goddard is considered as one of the pioneers in questioning the generality of the renewal effect through different experimental designs (see Nakajima et al., 2000; Üngör & Lachnit, 2008).

### **ABA but not AAB renewal using an operant conditioning lever pressing task in rats**

Nakajima, Tanaka, Urushihara and Imada (2000) conducted two experiments that aimed to explore renewal effects using ABA and AAB designs in operant conditioning tasks involving a lever pressing task. In Experiment 1, three groups of rats received training to press a lever in context A using a variable time (VT) 30-s schedule. This means that the food would appear if the subject performed the target behaviour within an amount of time. This amount of time varied but the average time to perform the behaviour was 30 seconds. Two groups received extinction trials in context A (groups AAA and AAB) and one group received extinction in context B (group ABA). Finally, groups AAB and ABA were given a context switch. This means that group AAB was tested in context B and group ABA was tested in context A.

The results of Experiment 1 showed a consistent ABA renewal effect. This was observed in the recovery of the pressing lever responses when subjects were tested in context A. Group AAB did not show any renewal of responding when tested in context B.

In Experiment 2, an experiment using a similar design was conducted. This time, the task involved a discriminative operant setting and it considered groups AAA, AAB and ABA. The difference from Experiment 1 was that the lever pressing behaviour was reinforced only in the presence of a light signal. If the subjects pressed the lever in the absence of the light signal, then their behaviour was not reinforced. Through this procedure, the subjects learned that the light signal indicated the availability of reinforcement if the behaviour was performed (discrimination learning).

As in Experiment 1, the results showed consistent renewal in group ABA, but not in group AAB. Nakajima et al. (2000) suggested as a possible explanation that the lack of recent exposure to context B in group AAB, led to a spontaneous

recovery or to neophobic behaviour. In other words, the lack of familiarity with context B produced a response of fear in the subjects. This response would lead the subjects to stop responding to the operant task. The authors argued that Bouton and Ricker (1994) had exposed the subjects to context B close enough to the test phase, and they still did not see a strong AAB renewal. Nakajima et al. (2000) argued that the renewal effect observed in AAB in Bouton and Ricker's experiment was weak and did not last. According to the authors, Bouton and Ricker (1994) and Goddard's (1999) results are important because they suggest that AAB renewal might be a hard to observe phenomenon.

One of the main factors that make Nakajima et al.'s (2000) studies important is that they showed an ABA renewal and a lack of AAB renewal in an operant conditioning task. This finding expands the types of tasks where a lack of renewal effect was observed in AAB designs. At the same time, the authors suggest that ABC renewal is an important design that needs to be studied, because it can give some guidance about the mechanisms involved in the differences between ABA and AAB renewal. According to the results obtained, the authors suggested that they might not have found a renewal effect in an ABC design due to the same reasons why they did not find AAB renewal. One could argue, though, that AAB and ABC renewals have an important difference: the inclusion of a context switch between the first and second stages.

### **ABA and ABC renewal, but not AAB renewal using a discrimination reversal learning task in humans**

In 2008, Üngör and Lachnit conducted an experiment in which they evaluated the recovery effects of designs ABA, ABC and AAB, using a human predictive learning task. More specifically, a discrimination reversal task was used, using names of restaurants as contexts, different foods as CSs, and food effects as USs. In this procedure, one cue was trained as a first-learned excitatory cue and a second-learned no US cue, similar to extinction. A second cue was trained as a first-learned no US cue, and a second-learned excitatory cue.

In the experiment, 72 subjects were randomly allocated to one of three groups: AAB, ABA or ABC. Group AAB received a first-learned association in context A that could be either excitatory (i.e. the food producing stomach trouble) or non-

excitatory (i.e. the food producing no stomach trouble). Next, this group received a second-learned association that was opposite to the first-learned one, in context A. This means that if the first-learned association was excitatory, then the second one was non-excitatory, and vice-versa. Finally, a test was performed in a novel context (B).

Group ABA received the same treatment. The difference was that the first-learned association took place in context A, the second-learned association took place in context B, and the testing phase took place in context A.

Group ABC received the same treatment as both previous groups. The difference was that the first-learned association took place in context A, the second-learned one in context B, and the testing phase in a novel context (C).

The results of this experiment showed strong renewal effects in groups ABA and ABC. At the same time, no renewal effect was observed in group AAB. These results indicate differences between the designs that included a context switch between the first and second stages (ABA and ABC) compared to the group that did not include a context switch (AAB). The results in groups ABA and ABC show that the performance of the subjects during the test can be affected by contextual manipulations (i.e. testing in the second stage context or in a novel context). This effect of contextual manipulations was not observed in group AAB. At the same time, all groups showed similar performances during the discrimination reversal training (second stage), which is an indicator of generalisation of the first-learned association.

In relation to Bouton's (1997) model, one can assume that there are no differences between procedures ABA, ABC and AAB related to renewal effects. At the same time, this model assumes that contextual stimuli are processed after interfering information is presented. According to Üngör and Lachnit (2007), the subjects in this experiment discriminated between an interference treatment conducted in the initial context and one conducted in a different context. This fact means that the subjects obtained information about the context in the first stage, before the introduction of interfering information.

Üngör and Lachnit's experiment (2008) presents further evidence to suggest that AAB designs work in a different way than do ABC and ABA designs. The authors proposed that these results support a theoretical view of the context being encoded

during the first stage. This encoding is showed in the differences between groups AAB and ABC. The lack of control of performance can be observed in the transfer of acquisition performance between the first and second stages, and in the similar recovery effects after reversal training in groups ABA and ABC. The first context seems to be involved during the presentation of interfering information. During this presentation, the first-learned associations seemed to be protected from unlearning. At the same time, this protection from unlearning seemed to be achieved by the coding of second-learned associations as context dependent.

This mechanism acts in a different way when the context of the first stage learning is the same as the context of the second stage. In this case, first-learned associations can be unlearned. However, as admitted by the authors, this suggestion needs further evaluation.

### **More renewal in ABA than in AAB using an aversive conditioned odour task in rats**

Yap and Richardson (2007) conducted three experiments aiming to examine the context sensitivity of extinction learning from a developmental perspective. Regarding differences between conditions, the authors argue that AAB renewal has been shown inconsistently in previous studies. Thus, an ABA condition is predicted to produce more renewal than an AAB condition. The authors do not propose any explanation for the differences between ABA and AAB conditions in producing renewal. They only state that the difference has been consistently shown by previous experiments. They performed four experiments, but only Experiments 1 and 2 were related to the differences between different types of renewal. Both experiments examined renewal in conditions ABA, AAA, ABB and AAB using an aversive conditioned odour task in rats. However, there was no inclusion of an ABC condition. Under the assumption that the capability to recognise context sensitivity is developed around 20 days post natal (PN), they tested PN23 rats in Experiment 1 and PN16 rats in Experiment 2. In Experiment 1, the only condition that produced renewal was the ABA design. According to the authors, the ABA condition showing more renewal than the AAB condition, which is consistent with previous studies. Experiment 2, as expected, produced no renewal in any condition.

### **Weaker renewal in AAB than in both ABA and ABC using a barpress conditioned suppression task in rats**

Thomas, Larsen and Ayres (2003) conducted four experiments in the field of renewal, using a barpress conditioned suppression task in rats. Their first aim was to test for ABA renewal using different kinds of context (odour, side of the room and unintended differences between boxes). In their first experiment the authors tested if there were differences between two ABA presentations: in one case, the contexts differed in terms of odour, location and physical characteristics, while in the other case only location and physical characteristics were varied. The authors found strong renewal for the experimental group that received more elements of contextual manipulation (odour, location and physical differences of the context) and no renewal in the experimental group that received fewer elements of contextual manipulation (location and physical differences). Experiment 2 extended these findings by considering three experimental groups: one where the only change was odour, a second one where odour and the box were changed, and a third one where odour, box and the location of the experiment were manipulated. Renewal was observed only for the third experimental group where odour, box and location were manipulated.

Second, they compared ABA and AAB conditions. In Experiment 3 the authors used contextual changes described in Experiment 1 that were able to produce renewal. In group 1, they used an ABA presentation, where the first-learned association took place in an A context, the second-learned association took place in a different context B and the test took place in the A context. In group 2, the first- and second-learned associations took place in the same context, A, and the test took place in a novel context B. The results showed renewal in both cases, yet the renewal when using an ABA design was stronger.

Finally, in Experiment 4 the authors aimed to compare AAB, ABC and ABA conditions in terms of the renewal produced by them. The results of this experiment showed renewal in all three conditions, yet the renewal showed in group AAB was significantly weaker.

The results of the four experiments discussed above provide evidence against the hypothesis that AAB renewal is weak due to a difference between the first stage context and the test context because such differences occurred both in groups AAB

and ABC. Therefore, the authors argue that the reason why AAB renewal is weaker than other renewal presentations is because of the fact that the first stage and second stage contexts are identical.

### **Stronger renewal in ABA than in AAB using a drug self-administration task in rats**

Crombag and Shaham (2002) compared ABA and AAB presentations in a drug self-administration task in rats. In both cases self-administration was learned during the first and second stages was considered extinction learning. The test took place in the third stage. The findings showed stronger renewal effects in ABA than in AAB designs. The authors did not focus the discussion on the difference between ABA and AAB but in the use of Bouton's (1993) idea of using the context as an occasion setter (see Chapter 2).

### **Weaker renewal in AAB than in ABC using a lick suppression task in rats**

Laborda, Witnauer and Miller (2011) used a lick suppression task with Sprague-Dawley-descended rats which involved extinction learning to test the role of CS-context and US-context associations in AAB and ABC designs. The authors tested predictions made by the extended comparator (Denniston, Savastano, & Miller, 2001) and sometimes-competing retrieval, SOCR (Stout & Miller, 2007) theories. According to these hypotheses, AAB renewal is weaker than ABC renewal because the association between the CS and the context of acquisition is stronger in AAB designs in which both acquisition and extinction take place in the same acquisition context. There are two possible representations of the US: one that is indirectly activated through the association of the CS and the first-association context, and one that is directly activated. This competition of representations produces a loss in the CS's behavioural control and is expressed as a stronger extinction. In ABC designs extinction takes place in a different context (B) than acquisition (A). Therefore, the association between the CS and context A is potentially decreased during the second stage. As a consequence, the effectiveness of the association between the CS and context A in modulating the direct representation of the US is decreased. This produces a lower decrease in behavioural control. The prediction of the model is that the difference between AAB and ABC designs should be reduced by undermining

the association between the US and context A or the association between the CS and context A. According to the model, renewal should be stronger in AAB designs.

In Experiment 1 the authors tested if strengthening the first association context enhanced the second association context. As a result of this experiment they observed lower recovery rates of the response in the AAB than in the ABC design. In Experiment 2 they tested the relationship between the first association context and the US. To achieve this they exposed the subjects to the first association context after extinction and tested if this had an effect on responding to the target CS in AAB and ABC designs. As a result of this experiment they observed an increased response to the CS in the AAB design. This result was not observed in the ABC design. In Experiment 3 the authors tested the contribution of the association between the target CS and the first association context. To achieve this during extinction they added CS and neutral stimulus trials, aiming to overshadow the association between the CS and the first association context. They observed an increase in the response to the CS in the AAB but not the ABC design. As a conclusion of these studies the paper highlighted the importance of the role of the contextual association both in extinction and renewal.

## **Conclusion**

In general, findings suggest that renewal in ABC designs is stronger than renewal in AAB designs (e.g. Bouton & Ricker, 1994; Goddard, 1999; Laborda et al., 2011; Thomas et al., 2003; Üngör & Lachnit, 2008; Yap & Richardson, 2007). However, as Laborda et al. (2011) suggest, the reasons why AAB renewal is weaker than ABC renewal has not been fully explained. According to the evidence reviewed, there are reasons to think that there are different mechanisms involved in AAB and ABC designs. It is thus important to test Bouton's (1997) retrieval model in terms of the situations in which a difference between AAB and ABC renewal can be revealed. If differences are found to be present, one important issue is if these are present with different combinations of excitatory and inhibitory stimuli. Some of these combinations are presented in the experiments reported in Chapter 5.



## Chapter 5: Empirical Evidence

### **Hypotheses and overview of Experiments 1-6**

Bouton's (1997) retrieval model predicts that first-learned associations are independent of context and second-learned associations are context dependent. It does not, however, predict a difference between AAB and ABC designs, and between excitatory and inhibitory cues. Specifically, it predicts that there will be context sensitivity in both AAB and ABC designs. On the other hand, predictions based on the Rescorla-Wagner model (1972) expect that there will be no context sensitivity in either AAB or ABC designs.

There is consistent evidence questioning the prediction that AAB and ABC do not differ in terms of context sensitivity (e.g. Goddard, 1999; Nakajima et al., 2000; Üngör & Lachnit, 2008). The aim of the experiments presented here is to extend this research by exploring the differences in context sensitivity of second-learned associations as a function of design (AAB and ABC) and valence of second-learned associations (inhibitory and excitatory). Based on the predictions of Bouton's model (1997), the following general hypotheses are proposed:

*H<sub>1</sub>: The contextual sensitivity of second-learned excitatory associations will be similar in AAB and ABC designs.*

*H<sub>2</sub>: The contextual sensitivity of second-learned inhibitory associations will be similar in AAB and ABC designs.*

*H<sub>3</sub>: There will be no interaction between design type (AAB and ABC) and the valence of the second-learned association (excitatory and inhibitory) in terms of the context sensitivity of second-learned associations.*

In order to explore these hypotheses, six experimental studies are presented here. A further two experiments seek to explain the findings of the first six experiments. The aim of Experiment 1 was to examine if second-learned excitatory associations are equally context dependent in AAB and ABC designs. In general, the

literature has focused on studying second-learned inhibitory associations (for a review, see Pineño & Miller, 2005). Bouton's model (1997) predicts that the context-dependency will be observed for both excitatory and inhibitory second-learned associations. Bouton argues that both types of second-learned associations will show context-dependency because it is the order of the association that determines the context-dependency and not the valence of the associations, as was previously believed (Bouton, 1993). The aim of Experiment 1 was to test this prediction. This study was conducted using a causal judgment task involving partner cues as a context. This means that the cue that was set as context was discrete, appearing only when other cues were present. One cue appeared on every trial, serving the role of context. This is different from other causal judgment tasks in which the context is provided by a background cue that appears continuously instead of discretely. Based on  $H_1$ , the expectation was of similar results of context sensitivity (i.e. levels of recovery) for AAB and ABC designs. Against these expectations, Experiment 1 actually found that contextual sensitivity differed between AAB and ABC designs using second-learned excitatory associations. It remains to be evaluated whether these differences can be observed in second-learned inhibitory associations as well.

Experiment 2 used the same design as Experiment 1, but extended the research design to both second-learned excitatory and inhibitory associations. Based on  $H_1$ ,  $H_2$  and  $H_3$  the expectation was of similar results of context sensitivity of second-learned inhibitory and excitatory associations for AAB and ABC designs. Consistent with the findings of Experiment 1, differences in context sensitivity between AAB and ABC designs were observed for both excitatory and inhibitory second-learned associations. This provides evidence in favour of Bouton's (1997) argument that the order of the association instead of its valence is relevant to predict contextual sensitivity of a second-learned association. Conversely, the results are not consistent with predictions based on the models of Bouton (1997) and Rescorla-Wagner (1972) that AAB and ABC designs will show similar results in context sensitivity.

The results of Experiments 1 and 2 are thus only partially consistent with Bouton's (1997) predictions. The aim of Experiment 3 was to determine whether previously found results could be explained due to the use of a discrete cue used as context. Experiment 3 replicated the design of Experiment 2 (for both inhibitory and excitatory second-learned associations) using a continuous background context

instead. As before, Bouton's (1997) retrieval model would predict contextual sensitivity for inhibitory and excitatory second-learned associations in both AAB and ABC designs. The results were consistent with the findings of Experiments 1 and 2: no differences between inhibitory and excitatory second-learned associations were found, but differences in contextual sensitivity between AAB and ABC designs were found for both excitatory and inhibitory second-learned associations.

Experiments 2 and 3 used an extinction procedure to produce second-learned inhibitory learning. It remains to be seen whether the same results could be observed using a feature negative procedure. Additionally, Experiments 1 to 3 of this thesis did not consider first and second-learned inhibitory associations. Experiments 4 aimed to explore the context sensitivity of first- and second-learned inhibitory associations producing inhibition through a feature negative procedure. Experiment 4 failed to meet the basic requirements to produce inhibition in any of the conditions. Experiment 5 was conducted to control for possible factors that may have accounted for the failure to produce inhibition in Experiment 4. One such factor was the large number of cues involved in the designs (11CSs), which may have complicated the participants' abilities to discriminate among cues. Experiment 5 replicated Experiment 4 using fewer cues, but was still unable to produce inhibition. Therefore, the method of producing inhibition in these particular experiments was questioned. Experiment 6 explored whether adding a test between the first and second stages would provide information about the first-learned inhibitory training that is presented during the experiment. Experiment 6 was able to produce inhibition, yet the results showed a lack of context sensitivity in both AAB and ABC designs.

The following section starts by describing simulations of the results that would be expected for Experiments 1 to 3 of this thesis based on the Rescorla-Wagner model (1972). General methods of the experiments are then described. Afterwards, experiments are presented in detail one by one, with any deviations from the general method being noted on an experiment by experiment basis. For each experiment, the actual results are compared to the results that would be expected according to the simulations based on the Rescorla-Wagner model (1972). Experiments 7 and 8 follow a general discussion that pulls together the results from the first six experiments.

### Simulations of the Rescorla-Wagner model's predictions

The aim of this section is to apply the Rescorla-Wagner (1972) model and formula to Experiments 1 to 3 of this thesis. Specifically, it seeks to identify predictions made by the model about the study of the recovery of conditioned responses as a product of a change in context. It considers first- and second-learned associations using excitatory and inhibitory stimuli in both cases. Rescorla and Wagner's formula was used to predict the results of Experiments 1 to 3 of this thesis, considering their number of contexts and stimuli. Experiments 1 to 3 are then presented and the simulations are compared to the actual results. Conclusions are drawn about the model's capacity for explaining the recovery of conditioned responses as a product of a change in context.

Simulations were produced for each trial using Excel. However, the figures presented display the outputs of the final test given that this test is the only one that can be compared to the results of the experiments reported in this thesis. The results reported in these simulations were obtained as the average of ten simulated participants for each experimental group. Averaging was carried out because trial order within a simulation can have an impact on the final outcome. Therefore order was randomised within stages and within blocks and the average results from the 10 simulations were taken as indicative results. Each simulation included 416 trials for each participant. 208 trials took place in the first stage and 208 trials took place in the second stage. In both simulations, relevant CSs had a salience of 0.2 ( $\alpha = 0.2$  in the Rescorla-Wagner model formula presented in Chapter 3). The context was treated as a background cue in both simulations. Specifically, its salience was 0.1. When a CS was reinforced, the reinforcement value was 1 ( $\lambda_1 = 1$  in the Rescorla-Wagner model formula presented in Chapter 3). When a CS was not reinforced, the reinforcement value was 0 ( $\lambda_1 = 0$  in the Rescorla-Wagner model formula presented in Chapter 3). Both the context and the CSs acquired associative value during the trials.

**Simulation 1.** The aim of this simulation was to calculate the predictions made by the Rescorla-Wagner model for excitatory second-learned associations in AAB and ABC designs. Specifically, this simulation aimed to determine the contextual

sensitivity of excitatory second-learned associations that follow a different first-learned excitatory association. The behaviour of four different experimental groups was simulated.

In the first stage, Groups 1 and 2 were simulated to receive excitatory training of stimulus Y producing an excitatory outcome in context A. In the second stage both groups would receive excitatory training of stimulus Y producing a different excitatory outcome in Context A. In the third stage, second-learned responses to stimulus Y would be tested for both groups. Group 1 was simulated to be tested in the original Context A, and Group 2 was simulated to be tested in a novel B context.

In the first stage, Groups 3 and 4 were simulated to receive excitatory training of stimulus Y producing an excitatory outcome in Context A. In the second stage both groups would receive excitatory training of stimulus Y producing a different excitatory outcome in a novel context B. In the third stage, second-learned responses to stimulus Y would be tested for both groups. Group 3 was simulated to be tested in the the second stage context B, and Group 4 was tested in a novel C context.

Table 5 shows an example of the associative values observed in the simulation during the first 35 stages of association. The values presented are the associative strengths that the signalled cues or contexts have with O2 in the presented trial.

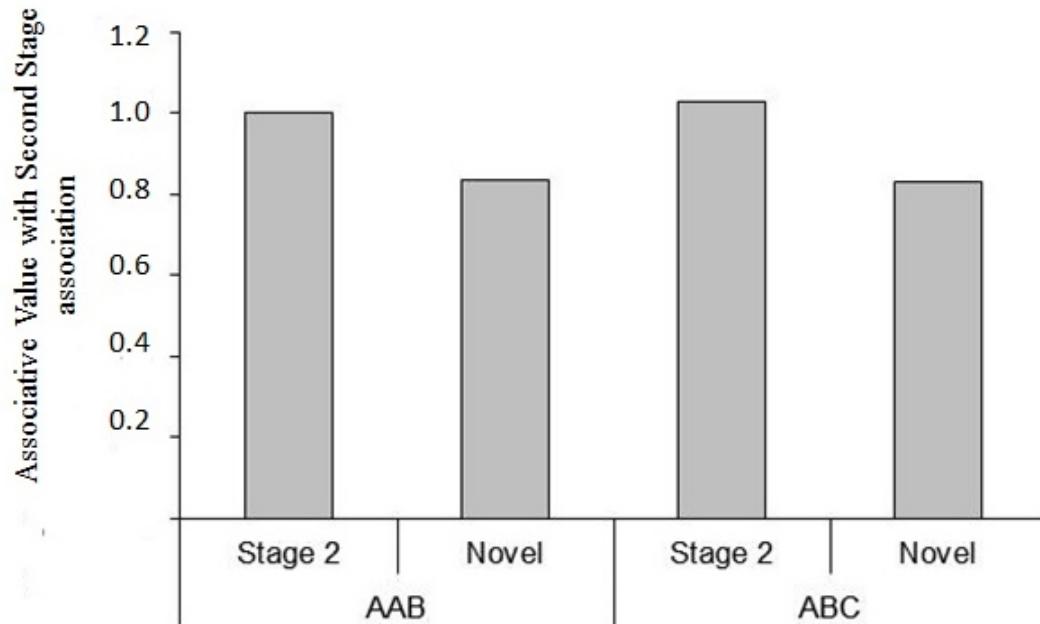
Table 5

*Example of associative values of cues involved in Simulation 1*

	Number of Trial						
	5	10	15	20	25	30	35
Context A	.17	.39	.40	.40	40	.39	.35
Cue X	.2	.44	.50	.55	.56	.57	.59
Cue Y	0	0	-.07	-.07	-.1	-.13	-.18

Figure 1 summarises the predictions made by the simulation for excitatory second-learned associations in AAB and ABC conditions. As can be seen, no major differences are predicted between the results of designs AAB and ABC. Actually, the comparison shows very similar patterns. At the same time, differences between the second stage and the novel context are similar for AAB and ABC designs. As a

result of this, no contextual sensitivity of second-learned associations is predicted using the Rescorla-Wagner model.



*Figure 1.* Predictions of the Rescorla-Wagner model for Experiment 1

**Simulation 2.** The aim of this simulation was to calculate the predictions made by the Rescorla-Wagner model for excitatory and inhibitory second-learned associations in AAB and ABC designs. Specifically, this simulation aimed to determine the contextual sensitivity of excitatory and inhibitory second-learned associations that follow a different first-learned excitatory or inhibitory association. The behaviour of eight different experimental groups was simulated.

In the first stage, Groups 1 and 2 were simulated to receive excitatory training of stimulus X producing an excitatory outcome in context A. In the second stage both groups would receive inhibitory training of stimulus X (extinction) producing no outcome in context A. In the third stage, second-learned responses to stimulus X would be tested for both groups. Group 1 was simulated to be tested in the original A context, and group 2 was simulated to be tested in a novel B context.

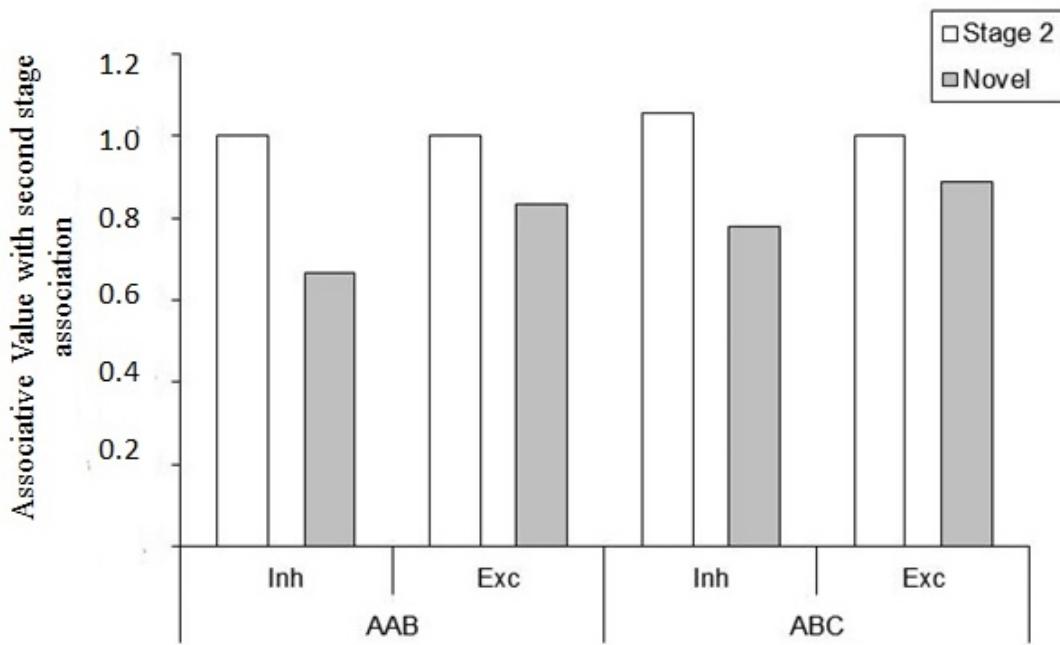
In the first stage, groups 3 and 4 were simulated to receive inhibitory training of stimulus X (preexposure) producing no outcome in Context A. In the second stage both groups would receive excitatory training of stimulus X producing an excitatory

outcome in context A. In the third stage, second-learned responses to stimulus X would be tested for both groups. Group 3 was simulated to be tested in the original A context, and Group 4 was simulated to be tested in a novel B context.

In the first stage, Groups 5 and 6 were simulated to receive excitatory training of stimulus X producing an excitatory outcome in context A. In the second stage both groups would receive inhibitory training of stimulus X (extinction) producing no outcome in a novel context B. In the third stage, second-learned responses to stimulus X would be tested for both groups. Group 5 was simulated to be tested in the the second stage context B, and Group 6 was simulated to be tested in a novel C context.

In the first stage, Groups 7 and 8 were simulated to receive inhibitory training of stimulus X (preexposition) producing no outcome in context A. In the second stage both groups would receive excitatory training of stimulus X producing an excitatory outcome in a novel context B. In the third stage, second-learned responses to stimulus X would be tested for both groups. Group 7 was simulated to be tested in the the second stage context B, and Group 8 was simulated to be tested in a novel C context.

Figure 2 summarises the predictions made by the simulation for excitatory and inhibitory second-learned associations in AAB and ABC conditions. As in Simulation 1, no major differences are predicted between the results of designs AAB and ABC. Furthermore, no major differences between excitatory and inhibitory second-learned associations are predicted. At the same time, differences between the second stage and the novel context are similar for AAB and ABC designs. As a result of this, no contextual sensitivity of second-learned associations are predicted by the Rescorla-Wagner model for either excitatory or inhibitory second-learned associations in AAB and ABC designs.



*Figure 2.* Predictions of the Rescorla-Wagner model for Experiment 2

**Conclusions.** Simulations 1 and 2 predict no differences in contextual sensitivity of second-learned inhibitory and excitatory associations for AAB and ABC designs. In fact, in both designs no context sensitivity was predicted. Meanwhile, differences between the second-stage and novel contexts are very similar for both designs.

## General Method

**Tasks.** Two versions of a learning task were used for the following experiments. Both were examples of the food-illness paradigm commonly used in studies of human learning (e.g. Rosas, García-Gutierrez, et al., 2006). All experiments approved by the School of Psychology Ethics Committee used a standard procedure for obtaining informed consent and debriefing participants (see appendices B to E). In each experiment after a general introduction and completion of consent form participants viewed a series of learning trials presented on a computer screen. Each learning trial involved the presentation of a “case” which consisted of a series of learning cues presented along with a context cue. The learning cues represented a food (or foods) that had been consumed by a person, after which the person either developed an illness or did not develop an illness. The task for the participants was to learn the extent to which the different foods produced illness. Once all the learning trials had taken place, a series of test trials were administered. In each test trial, the participants were presented with further cases, with context cues presented along with test cues, and asked to predict if that case would lead to an illness or not. In one version of the task different fruits and vegetables could produce headache or sickness. In the other version different sweets and cakes could produce stomach-ache or toothache. These tasks were identical in all respects except for the stimulus material. The purpose of using these two versions was to allow participants to be tested twice, in both versions of the task with minimal interference between tasks. With appropriate counterbalancing, repeated measures designs could be used. For example, an AAB recovery design could be run with the fruit and vegetables version and an ABC design could be run with the cakes and sweets version.

In both tasks, to ensure that any difference in response to the test cues was due to their experimental treatment, the actual images used for the different stimulus roles required by the designs were randomly selected from a set of twenty-six possibilities for each participant (e.g. images of 26 different fruits and vegetables). Thus, there was no consistent physical difference between the cues serving different stimulus roles. In addition, the assignments of outcomes to trials were counterbalanced across experimental treatments. For example, half of the

participants would have headache paired with one target cue and sickness paired with another, with these assignments reversed for the remaining half.

The order of learning trials was randomised separately within experimental blocks for each participant. During the test trials the order was also randomised for each participant subject to the constraint that tests taking place in the first stage context for participants in the ABC conditions always occurred after the second stage and novel context tests. In both conditions, half of the subjects received the tests in the second-stage context first, and the other half received tests in novel context first. For the remaining of this thesis, the fruits and vegetables task will be named “version 1” and the cakes and sweets task “version 2”.

For all experiments, in the test stage, each presentation showed in the designs was tested once.

**Outcome wording.** There were different periods of testing for subjects in the different groups of Experiment 1 and 2. Group AAB in Experiment 1 and ABC in Experiment 2 were tested in a previous time (reported in Elgueta, 2008) than groups ABC in Experiment 1 and AAB in Experiment 2. A change in the task was made during the first period after group AAB of Experiment 1 had been run. In the AAB group in Experiment 1 no illness trials ended with the word “Well”. For the remaining groups and experiments the task wording was changed so that when no illness was to occur the words “No effect” were presented. The change was made because the phrase “No effect” is a better approximation to the no-US trials used to produce extinction; “Well” can be considered a positively valenced US. In the event comparing the results of Experiment 1 with the rest of the experiments, it can be said that this difference did not produce any effect on the results of the experiment – the main features of the results of Experiment 1 (i.e. no context effect in the AAB group) were replicated using the “No effect” wording (Experiments 2 and 3).

## Experiment 1

The following experiment examined the context sensitivity of second-learned excitatory associations in AAB and ABC designs. The main aim of this experiment was to examine context sensitivity as a function of the design. Since second-learned associations have previously been found to be context dependent (Bouton, 1997), it was expected that response recovery would occur in both designs. According to the predictions of Bouton's (1997) retrieval model, since both AAB and ABC designs have the same context shift between the second stage and the test, these designs should produce equivalent response recovery. However, some authors have argued that a response recovery should be more difficult to observe in AAB designs (e.g. Üngör and Lachnit, 2008, for more details see Chapter 4).

The task presented involves the presentation of a second-learned excitatory association which is different to other experiments that work with counterconditioning. In a counterconditioning situation there is incompatibility between the outcomes that are presented during the first and second stages (Bouton & Peck, 1992). In this experiment such incompatibility is not present.

### **Method.**

**Design.** The design for Experiment 1 is presented in Table 6. A mixed design was used to investigate the principal hypothesis. In the first stage, all participants received presentations of stimulus Y (images of fruits and vegetables) in context A (provided by a partner cue), followed by an excitatory outcome (O<sub>2</sub>, headache). In the second stage all participants received presentations of Y with a different excitatory outcome (O<sub>3</sub>, sickness). The critical experimental manipulation was the context for the second-stage trials. Participants in group ABC had a context switch, experiencing all the second-stage trials in context B. On the other hand, participants in group AAB continued their second-stage trials in context A. Finally, Y was tested for both groups in the second-stage context and in a novel context. It was expected that there would be fewer second-stage appropriate responses (reports of O<sub>3</sub>) to Y in the novel context than in the second-stage context. The crucial question for the hypothesis was whether or not this difference would be the same for both groups.

As well as in the trials described above some filler trials were included. These were trials involving cue X, which was always followed by a no-US outcome ( $\Phi$ ). In group AAB the word “Well” was used to indicate no US, whereas in group ABC the words “No Effect” were used, as specified in the General Method section. The reasons to include these trials were twofold. First, these trials were included to ensure that participants actually learned to discriminate between the X and Y cues rather than simply learning that Y always produced some effect. Second, they were included to provide a degree of continuity between stages. To these ends an equal number of X and Y trials occurred in each stage. X was also tested so that it could be properly established that participants had actually learned as intended.

Table 6

*Design of Experiment 1*

Group	Stage		
	First stage	Second stage	Test
AAB	A: $X \rightarrow \Phi$ A: $Y \rightarrow O_2$	A: $X \rightarrow \Phi$ A: $Y \rightarrow O_3$	A: $X?$ A: $Y?$ B: $X?$ B: $Y?$
ABC	A: $X \rightarrow \Phi$ A: $Y \rightarrow O_2$	B: $X \rightarrow \Phi$ B: $Y \rightarrow O_3$	A: $X?$ A: $Y?$ B: $X?$ B: $Y?$ C: $X?$ C: $Y?$

Note. All the stimuli were presented on a computer. Target cues X and Y were different foods. Outcome  $\Phi$  means that the food produced a no-US outcome. Outcomes  $O_2$  and  $O_3$  were negative effects of the foods. A, B and C are different contexts provided by partner cues (i.e., other foods).

It is important to clarify that all of the trials types specified in Table 6 were replicated twice for each participant. For example, in Table 6,  $X \rightarrow \Phi$  is shorthand indicating that a participant would have experienced  $X_1 \rightarrow \Phi$  and  $X_2 \rightarrow \Phi$  trials. This means each participant had to learn four different cues – outcome associations in the first stage. Two of these remained the same in the second stage (the X trials) and two of these were changed in the second stage (the Y trials). These two replications were averaged in the analysis.

**Participants.** The participants were 96 students from the University of Southampton, recruited by advert or word of mouth. 58 participated in group AAB and 38 participated in group ABC. Participation was voluntary and participants received either £7 or psychology credits for taking part in the experiment. Their average age was 21 (ranging from 18 to 34) and they included 78 females and 18 males.

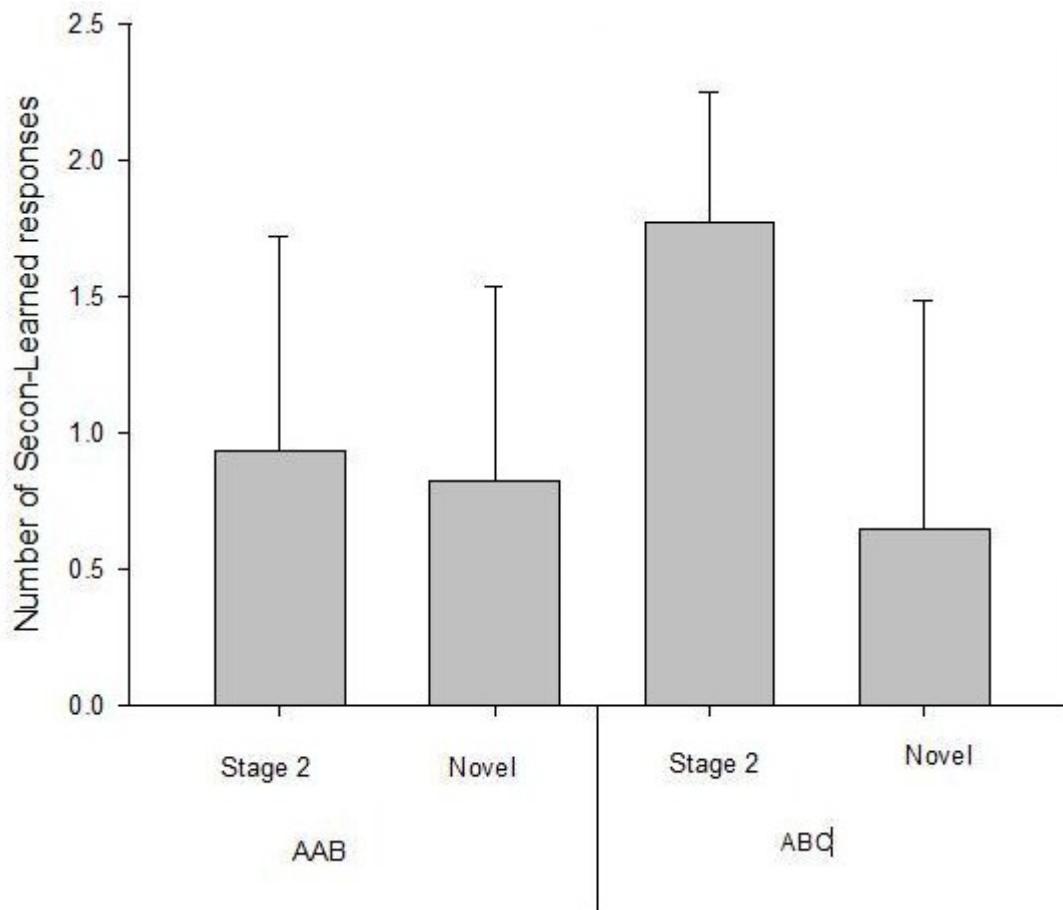
**Stimuli and apparatus.** During the experiment participants operated an IBM-compatible PC with 15-inch (43.2cm) colour monitors running in 800 (width)  $\times$  600 (height) pixel resolution. Cue and context stimuli were images of different foods represented as 100 x 100 pixel 8-bit colour bitmaps, which occupied squares of approximately 2 x 2 centimetres on the screen. There was a database of 26 such images that could be used as required by the experimental design. Outcomes were presented as text in 32 point Courier font. The computers were housed in one of three experimental cubicles in the Learning Laboratory in the School of Psychology at Southampton University.

**Procedure.** Participants completed the experiment individually. On arrival, a brief verbal description of the experiment was given. Then participants read a more detailed description of the procedures before reading and signing an informed consent form. This description and the consent form are provided in Appendix A. Participants then sat in front of the computer and were presented with instructions on the screen. These instructions gave more details on the procedure, and reiterated the information already given (see Appendix B). Once the participants understood the procedure they were invited to press the “Enter” button, after which the task began.

The task was structured as a series of learning trials followed by a series of test trials. During each learning trial, two foods were displayed onscreen for three seconds after which an outcome was shown for three seconds more. After the screen was cleared, there was an inter-trial-interval (ITI) of one second. The foods and outcomes actually displayed on each trial were dictated by the experimental design. The learning trials were divided into two stages as part of the design. Although there were context and contingency changes between the first and second stages these were not explicitly signalled to the participants as separate experimental stages. During each learning stage, there were six trials of each type. During the test stage, there was one trial of each type. During the test, subjects were asked to predict the outcome that a certain combination of food produced. Then, the participants had to type the letter signalling the outcome they predicted and press the key “ENTER”. , For sickness they had to press “S”, for toothache “T, for Headache “H”, for Stomachache “S” and for No Effect “N”. At the end of the task, participants were debriefed (Appendix F).

**Data analysis.** Second-learned responses to stimulus Y were recorded in each test. Participant responses to Y during test presentations were coded as a one if they reported O3 and zero otherwise. Thus, the maximum score was 2 if they reported O3 for both replications of the Y contingency (explained in the design section), and the minimum score was zero if they did not report O3 in either replication of the Y contingency. A 2 x 2 mixed-measures ANOVA was conducted with the number of second-learned responses as the dependent variable. Context was a within-participant factor (two levels; second stage versus novel) and Group was a between-participant factor (two levels; AAB versus ABC).

**Results.** Figure 3 shows the number of second-learned responses to Y stimuli in each context and group. For group AAB, A was the second stage context, and context B was a novel context. In the case of group ABC, B was the second stage context and C was the novel context. It can be seen that there were more second-learned responses in context B for group ABC than in any other condition and that the number of second-learned responses remained relatively constant in the other conditions.



*Figure 3.* Mean number of second-learned responses to the excitatory cue Y in second stage and novel contexts for groups AAB and ABC in Experiment 1. Error bars represent the standard error of the mean.

The mixed measures ANOVA produced significant main effects of Design (AAB versus ABC;  $F(1,100) = 10.69, p < 0.01$ ) and Context (second stage versus novel;  $F(1,100) = 34.31, p < 0.01$ ). The interaction between Design and Context was also significant ( $F(1, 92) = 19.21, p < 0.05$ ) and takes precedence in the interpretation of the results.

Student's t-tests were used to follow-up this interaction. In Group AAB there was no significant difference ( $t(55) = 0.81, p > 0.05$ ) in the mean number of second-learned responses in the second stage context ( $M = 0.94, SD = 0.79$ ) and in the novel context ( $M = 0.82, SD = 0.71$ ).

In Group ABC there was a significant difference ( $t(37) = 7.58, p < 0.05$ ) between the number of second-learned responses in second stage context ( $M = 1.78, SD = 0.48$ ) and second-learned responses in novel context ( $M = 0.65, SD = 0.83$ ).

At the same time, a significant difference ( $t(37) = 4.89, p < 0.01$ ) was observed between second-learned responses in the second-stage context between groups AAB ( $M = 0.94, SD = 0.79$ ) and ABC ( $M = 1.78, SD = 0.48$ ). A final t-test showed no significant difference ( $t(37) = 0.83, p > 0.05$ ) between second-learned responses in a novel context for group AAB ( $M = 0.82, SD = 0.71$ ) and ABC ( $M = 0.65, SD = 0.83$ ).

**Discussion.** Experiment 1 examined the context sensitivity of second-learned excitatory associations. The main question was related to the difference in context sensitivity of second-learned excitatory associations in AAB and ABC designs. The predicted result was to observe context effects in both AAB and ABC designs with some expectation that there may be greater context sensitivity in the ABC design. However, the results indicated context sensitivity only in the ABC design. As such these results are inconsistent with the predictions of Bouton's (1997) model and consistent with observations reported by Üngör and Lachnit (2008). The crucial difference between the AAB and ABC designs is the context switch between the first and second stages. The context switch between the first and second stages could only have an effect if participants somehow encoded the first-stage context. Therefore, the model of Bouton, which suggests that context is only encoded to resolve ambiguity may require some elaboration.

Additionally, no contextual sensitivity of second-learned associations were predicted for AAB and ABC designs by the simulations based on the Rescorla-Wagner model (1972) presented in this thesis. Moreover, differences between the second stage and novel context were predicted to be similar for AAB and ABC designs. These predictions are inconsistent with the findings of Experiment 1 of this thesis. The Rescorla-Wagner model predicts a high number of second-learned responses given the temporal proximity of the association. This assumption -in addition to the idea of unlearning- results in the prediction of similar results for all the mentioned conditions. In contrast, the results of Experiments 1 of this thesis

show differences between AAB and ABC designs. Specifically, in this experiments contextual sensitivity was observed in the ABC design and not in the AAB design.

However, the results of the current experiment were obtained in a procedure using excitatory associations. Since some work on context effects has been primarily focussed on context sensitivity of inhibitory associations it is of some interest to determine if the same design differences would be observed using second-learned associations that are not excitatory. Experiment 2 examines this question.

## Experiment 2

Experiment 1 showed that second-learned excitatory associations were context dependent under the conditions of an ABC design but not under the conditions of an AAB design. Experiment 2 repeated this design but added the use of inhibitory associations. The main aim was to examine context sensitivity as a function of design and the valence of second-learned association. As with Experiment 1, on the basis of Bouton's (1997) retrieval model, there was a general expectancy of response recovery. However, on the basis of the findings of Experiment 1 and the work of Üngör and Lachnit (2008), described in Chapter 4, it was now expected that the ABC design would produce stronger response recovery. At the same time, Bouton's model predicts that the key factor to produce context sensitivity is the order and not the value of the associations. According to this, we might expect no differences to be shown between excitatory and inhibitory second-learned associations. However, some authors have argued that excitatory associations should be less sensitive to context than inhibitory associations (e.g. Bouton, 1993, see Chapter 3).

**Method.** As Experiment 2 was similar to Experiment 1, only differences are described in this section.

**Design.** The design for Experiment 2 is presented in Table 7. In the first stage, all participants received presentations of X (image of cakes and sweets) followed by a no-US outcome ('no effect' message) and Y (another image of cakes and sweets) followed by an excitatory outcome (O2, toothache or stomach ache), all in Context A (partner cues). In the second stage, all participants received presentations of X followed by an excitatory outcome (O3, toothache or stomach ache) and Y followed by a no-US outcome (extinction training that aimed to produce inhibition). The critical experimental manipulation was the context for the second-stage trials. Participants in group ABC had a context switch, experiencing all second-stage trials in context B. On the other hand, participants in group AAB continued their second-stage trials in Context A. Finally, X and Y were tested for both groups in the second-stage context and in a novel context. It was expected that there would be fewer second-stage appropriate responses (reports of O3 for cue X and reports of No

Outcome for Y) to the cues in the novel context than in the second-stage context. The crucial question for the hypothesis was whether or not this difference would be the same for both groups (AAB and ABC) and whether or not there would be any differences between inhibitory and excitatory second-learned responses. No filler trials were included in this experiment, because the number of excitatory and no-US trials was balanced.

Table 7

*Design of Experiment 2*

Group	Stage		
	First stage	Second stage	Test
AAB	A: X→Φ	A: X→O3	A: X?
	A: Y→O2	A: Y→Φ	A: Y?
			B: X?
			B: Y?
ABC	A: X→Φ	B: X→O3	C: X?
	A: Y→O2	B: Y→Φ	C: Y?
			B: X?
			B: Y?
			A: X?
			A: Y?

Note. All the stimuli were presented on a computer. Target cues X and Y were different foods. Outcome Φ means that the food produced no-US. Outcomes O2 and O3 were negative effects of the foods. A, B and C are different contexts provided by partner cues (i.e., other foods).

**Participants.** The participants were 80 students from the University of Southampton, recruited by posted advert or word of mouth. Due to problems with the software, the data for 6 participants was not recorded. These participants had to be removed from the analysis leaving 74 participants. 38 participants participated in group AAB and 36 in group ABC. The participants in group ABC were tested during April 2008. Participants in group AAB were tested later, during December 2008. Participation was voluntary and participants received either £7 or psychology credits for taking part in the experiment. Their average age was 21 (ranging from 18 to 36) and they included 64 females and 16 males.

**Stimuli and apparatus.** The same stimuli and apparatus used in Experiment 1 were used in Experiment 2.

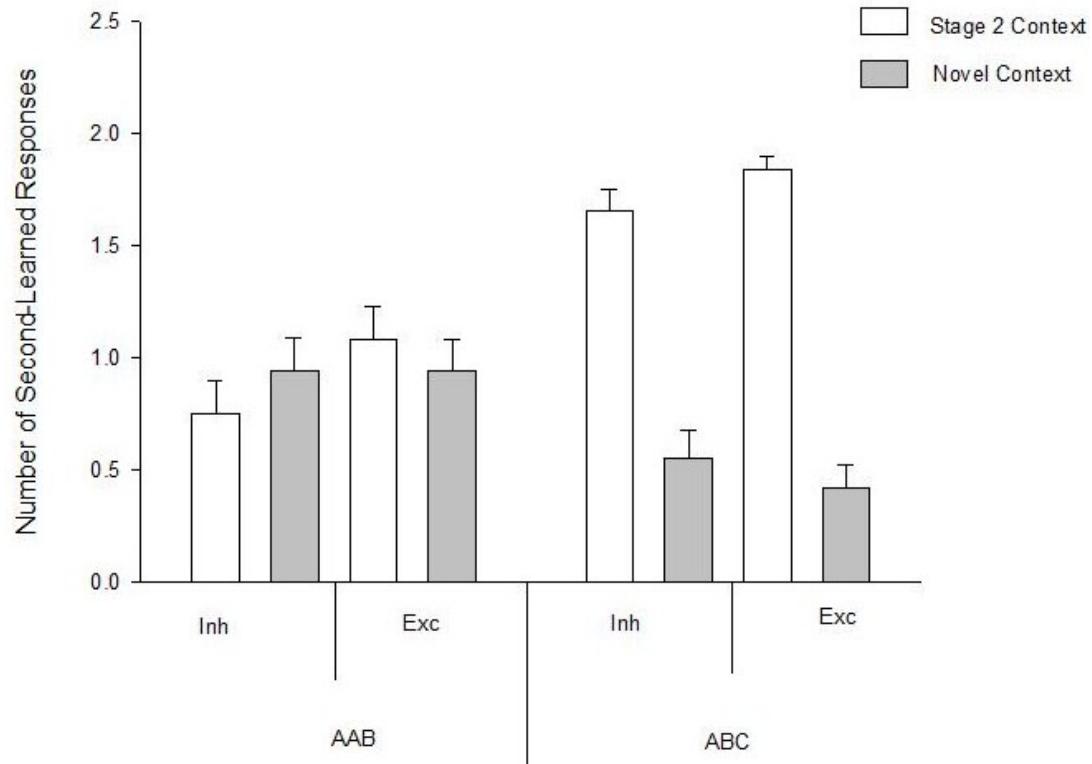
**Procedure.** The procedure was very similar to the one described in Experiment 1. This experiment involved two tasks: version 1 and version 2 (explained in the General Method section). The description of the tasks in Experiment 2 is the same as the description of the tasks in Experiment 1. The only difference is the type of images displayed. Instead of images of fruits and vegetables, the images displayed showed cakes and sweets, and the possible effects were “Toothache” and “Stomach ache”. Descriptions, consent form, instructions, structure of the task, ITI, learning stages, testing, replication of the conditions and display of the food were the same as explained for the version 1 task in Experiment 1.

**Data analysis.** Second-learned responses to stimulus Y and X were recorded in each test. Participant responses to Y during test presentations were coded as a one if they reported the no US outcome and zero otherwise. Participant responses to X during test presentations were coded as a one if they reported O3 and zero otherwise. Thus, the maximum score was 2 if they reported second-learned responses for both replications of the X and Y contingency, and the minimum score was zero if they did not report second-learned responses in either replication of the X or Y contingency. A 2x2x2 mixed measures ANOVA was conducted. The analysis had three factors, two within-participant factors - context (two levels; second-stage versus novel) and

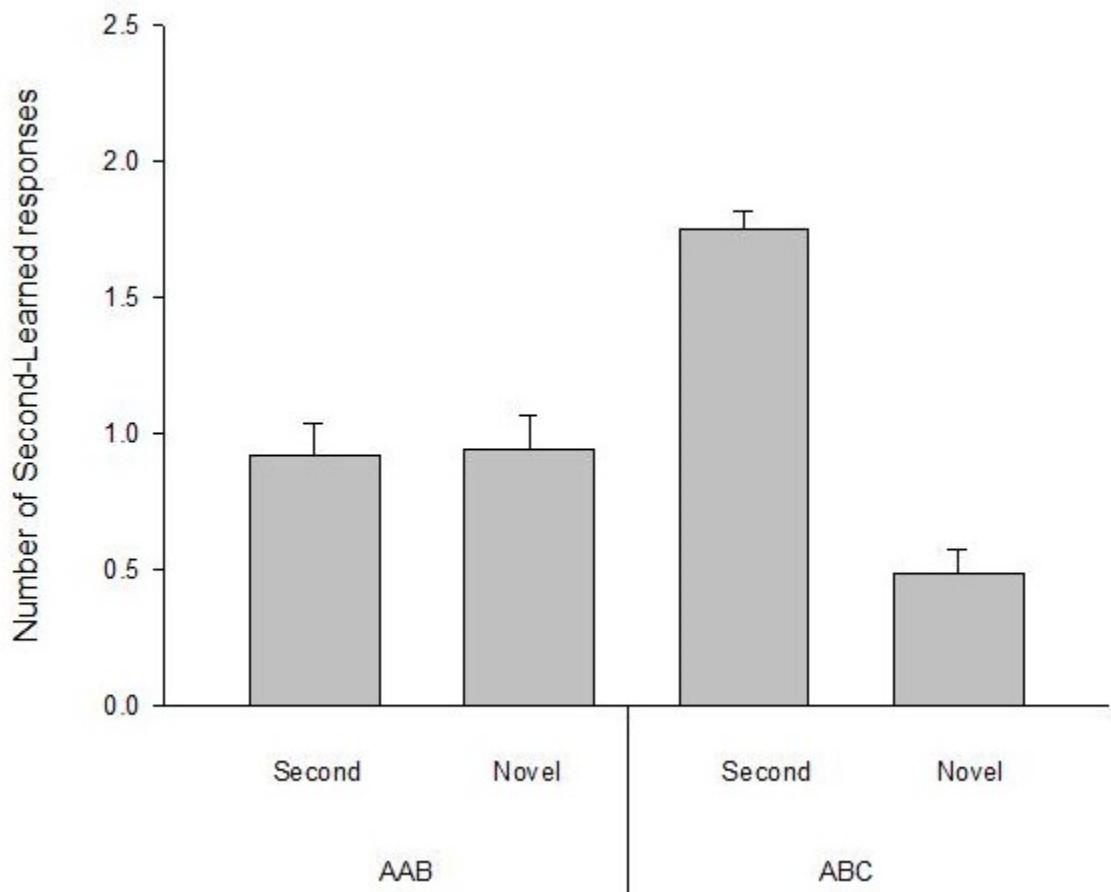
valence (two levels; inhibitory or excitatory)- and one between-participant factor - group (two levels; AAB versus ABC).

**Results.** Figure 4 shows all of the means for Experiment 2. It can be seen that the results of Experiment 1 were replicated with the largest number of second-learned responses being observed in Context B for Group ABC. This result was present whether or not the second-learned outcome was inhibitory or excitatory.

The ANOVA carried out on these data produced significant main effects of context ( $F(1,72) = 57.48, p < 0.001$ ) which was subject to an interaction with design ( $F(1,72) = 62.77, p < 0.001$ ). At the same time, there was an interaction between valence and context ( $F(1,72) = 6.36, p < 0.05$ ).

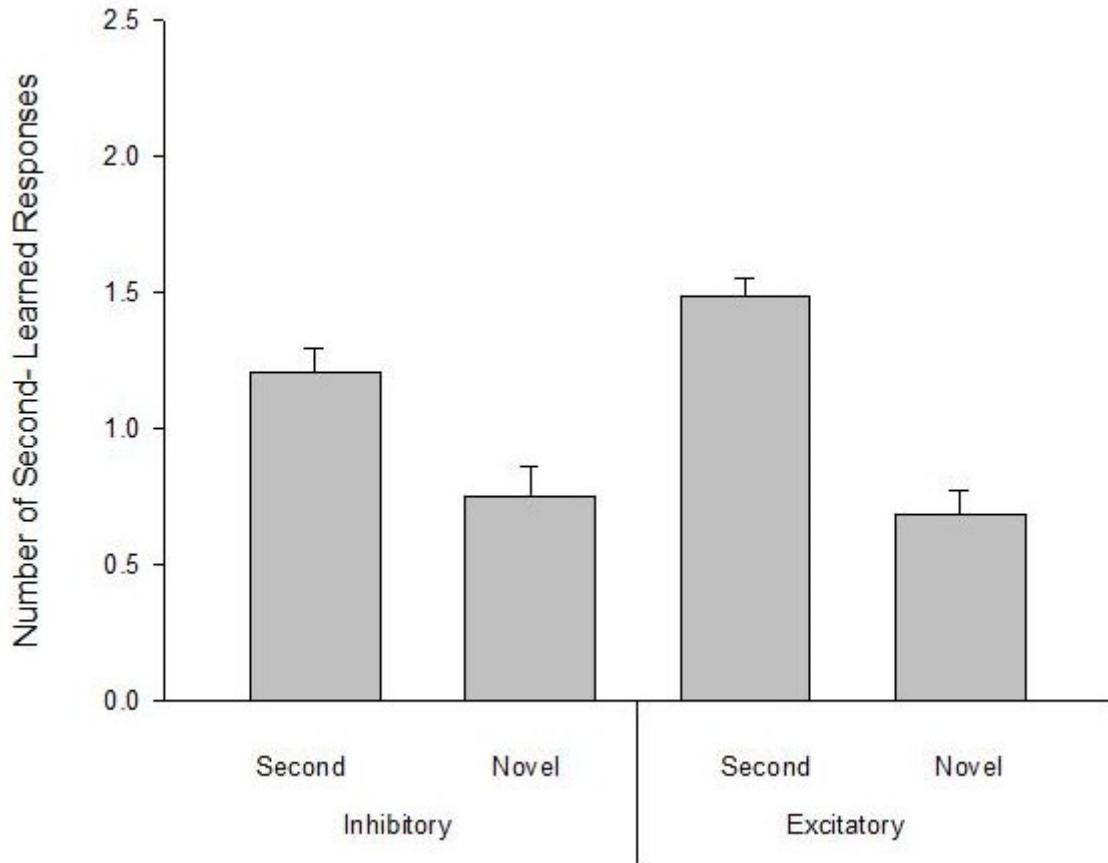


*Figure 4.* Relevant means for Experiment 2. Groups are separated by design, valence of second-learned response and context of testing. Error bars represent the standard error of the mean.



*Figure 5.* Context x Design interaction for Experiment 2. The bars indicate the number of second-learned responses in a second and a novel context in AAB and ABC designs. Error bars represent the standard error of the mean.

Figure 5 shows the interaction between context of testing (second-learned versus novel context) and the design (AAB versus ABC). There was no difference in the number of second-learned responses after a context switch in the AAB design ( $t(35) = .25, p > 0.05$ ). In group ABC there were differences in the number of second-learned responses between the different contexts of testing ( $t(37) = 10.5, p < 0.001$ ). The results showed differences between design AAB and design ABC in the number of second-learned responses in the second stage context ( $t(72) = 6.01, p < 0.001$ ). At the same time, there is a difference between designs in the number of second-learned responses in a novel context ( $t(72) = 3.07, p < 0.01$ ).



*Figure 6.* Interaction between the valence (excitatory versus inhibitory) and context (Second-learned versus novel context) in Experiment 2. Bars indicate the number of second-learned responses. Error bars represent the standard error of the mean.

Finally, Figure 6 shows the interaction between valence (excitatory versus inhibitory) and context (second-learned versus novel context). There was a fall in the number of second-learned responses between the second stage and novel contexts of testing that was significant for inhibitory ( $t(35) = 3.58, p < 0.01$ ) and excitatory ( $t(37) = 8.97, p < 0.001$ ) second-learned cues. At the same time, there were significant differences between the number of second-learned responses in second stage context produced by an excitatory second-learned cue compared to second-learned responses produced by an inhibitory second-learned cue ( $t(35) = 2.7, p < 0.01$ ). No significant differences were found between second-learned inhibitory and excitatory cues in a novel context ( $t(35) = 0.67, p > 0.05$ ).

**Discussion.** The present experiment examined the context sensitivity of second-learned excitatory and inhibitory associations in AAB and ABC designs. The main

question was related to the difference in context sensitivity as a function of design and the valence of second-learned association. The expected result, according to the results of Experiment 1, was to observe context sensitivity in the ABC design with excitatory, but also with inhibitory second-learned cues. At the same time, such context sensitivity was not expected to be observed in the AAB design. As predicted, the results indicated context sensitivity in excitatory and inhibitory second-learned associations only in the ABC design.

Considering that both designs, AAB and ABC have the same context shift between the second stage and the test, the prediction of Bouton's (1997) model was that both designs should show context sensitivity in excitatory and inhibitory associations. However, in Experiment 2 the results were consistent with the suggestion of other authors (e.g. Üngör & Lachnit, 2008), in that context sensitivity was observed only in the ABC design. At the same time, according to previous Bouton's models (e.g. Bouton, 1993), we could have expected to observe differences between inhibitory and excitatory associations (see Chapter 3 for details).

The results of Experiment 2 do not support the predictions of both of Bouton's models (Bouton, 1993 and 1997), because no context sensitivity was shown in group AAB and the same context sensitivity was observed in excitatory and inhibitory second-learned associations. In this sense, the results again support the idea proposed by Üngör and Lachnit that AAB and ABC designs differ in a context switch between the first and second stages, and the participants pay attention to that context switch even if the outcomes used in each stage do not interfere with each other.

Additionally, the expectation based on the Rescorla-Wagner (1997) model simulation presented in this thesis for excitatory and inhibitory second-learned associations was of no major differences between the results of AAB and ABC designs, as well as no major differences between excitatory and inhibitory second-learned associations. Differences between the second stage and the novel context were predicted to be similar for AAB and ABC designs.

Results of Experiment 2 are inconsistent with the predictions made based on the Rescorla-Wagner model (1997). The Rescorla-Wagner model predicts a high number of excitatory and inhibitory (depending on the experimental condition) second-learned responses given the temporal proximity of the association. According to this prediction similar results for all the mentioned conditions (excitatory and inhibitory

second-learned associations, and AAB and ABC designs) would be expected. In contrast, the results of Experiment 2 presented in this thesis show differences between AAB and ABC designs. In particular, in Experiments 2 contextual sensitivity was observed in the ABC design and not in the AAB design. However, the prediction related to the similarity of second-learned excitatory and inhibitory associations was supported by the results of the experiment.

The results of Experiments 1 and 2 have been obtained using partner cues as the context for the different stages. However, it is arguable that the most common way to present contexts in human learning tasks is the use of background contexts (Rosas et al., 2006). It is thus important to replicate the findings of Experiments 1 and 2 using a background context rather than partner cues. This is precisely what is tested in Experiment 3.

### Experiment 3

Experiments 1 and 2 showed that second-learned excitatory and no-US associations were context dependent under the conditions of an ABC design but not under the conditions of an AAB design. These results were obtained using a partner cue as a context. The following experiment examined the context sensitivity of second-learned excitatory and inhibitory associations in AAB and ABC designs, using a background cue (place, as opposed to meal context) as a context. Similar to Experiment 2, the main aim was to examine context sensitivity as a function of design and the valence of second-learned association. As with Experiments 1 and 2, on the basis of Bouton (1997), there was a general expectancy of response recovery. However, on the basis of both experiments and the work of Üngör and Lachnit (2008), described in Chapter 4, it was now expected that the ABC design would produce stronger context sensitivity of the second-learned association. Bouton's model predicts that the key factor to produce context sensitivity is the order and not the value of the associations. According to this, we might expect no differences to be shown between excitatory and inhibitory second-learned associations.

**Method.** Given that there are similar features in Experiments 1, and 2, only aspects differing from Experiment 2 will be mentioned.

**Design.** The design for Experiment 3 is presented in Table 8. It is the same design presented in Experiment 2, with the difference of the context as a background stimulus. In the first stage, all participants received presentations of X followed by a no-US outcome and Y followed by an excitatory outcome (O2), all in Context A. In the second stage, all participants then received presentations of X followed by an excitatory outcome (O3) and Y followed by a no-US outcome (extinction training that aimed to produce inhibition). The critical experimental manipulation was the context for the second stage trials. Participants in group ABC had a context switch, experiencing all second stage trials in Context B. On the other hand, participants in group AAB continued their second stage trials in Context A. Finally, X and Y were tested for both groups in the second stage context and in a novel context. It was expected that there would be fewer second stage appropriate responses (reports of

O3 for cue X and reports of No Outcome for Y) to the cues in the novel context than in the second stage context. The crucial question for the hypothesis was whether or not this difference would be the same for both groups (AAB and ABC) and whether or not there would be any differences between inhibitory and excitatory second-learned responses. No filler trials were included in this experiment, because the number of excitatory and no-US trials was balanced.

Table 8

*Design of Experiment 3*

Group	Stage		
	First stage	Second stage	Test
AAB	A: X→Φ	A: X→O3	A: X?
	A: Y→O2	A: Y→Φ	A: Y?
			B: X?
			B: Y?
ABC	A: X→Φ	B: X→O3	C: X?
	A: Y→O2	B: Y→Φ	C: Y?
			B: X?
			B: Y?
			A: X?
			A: Y?

Note. All the stimuli were presented on a computer. Target cues X and Y were different foods. Outcome Φ means that the food produced no-US. Outcomes O2 and O3 were negative effects of the foods. A, B and C are different contexts provided by the colour of the screen as a background cue.

**Participants.** The participants were 32 students from the University of Southampton, recruited by advert or word of mouth. All participants took part in both groups, AAB and ABC. Participation was voluntary and participants received either £7 or psychology credits for taking part in the experiment. Their average age was 20 (ranging from 18 to 41) and they included 25 females and 7 males.

**Stimuli and apparatus.** The same stimuli and apparatus used in Experiment 1 and 2 were used in Experiment 3. The only difference was given by the way in which the context was presented. In experiments 1 and 2, context was provided by a partner cue. In Experiment 3, context is provided by a background context.

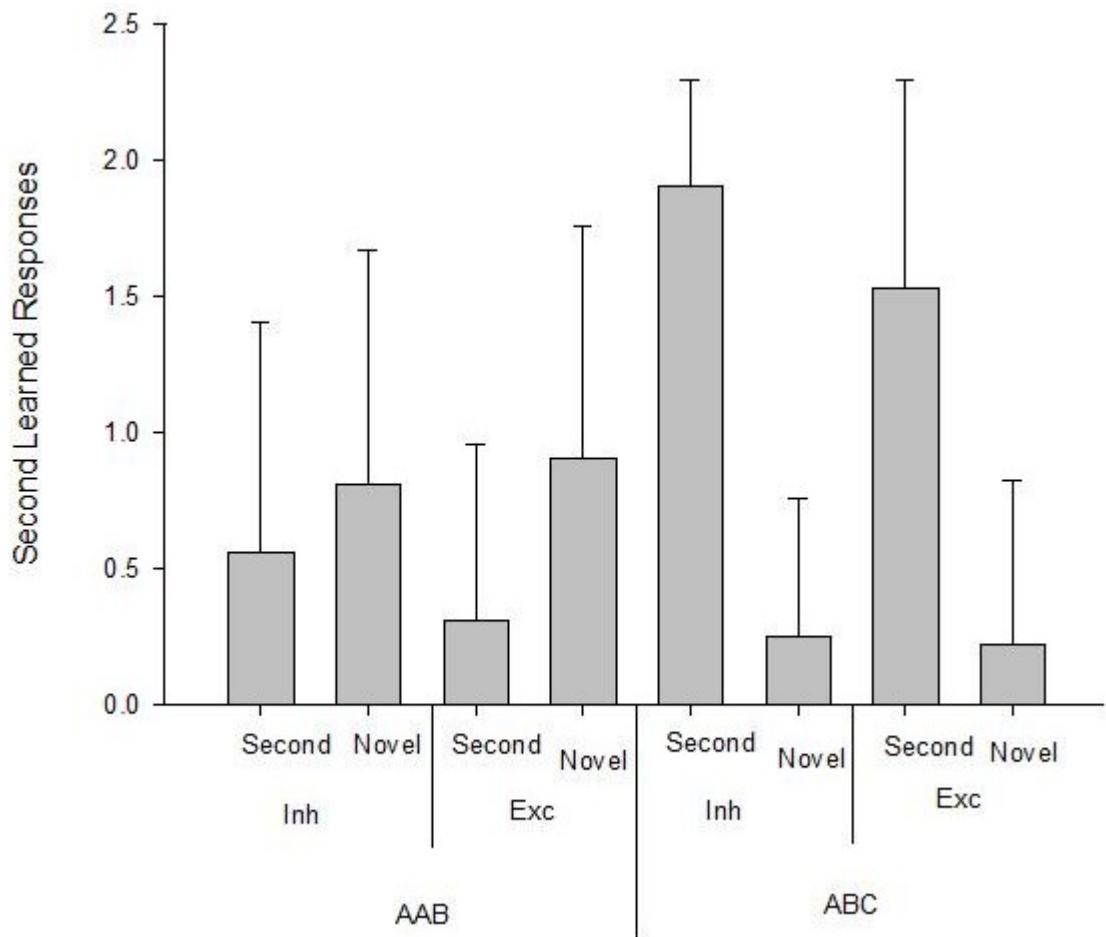
**Procedure.** Procedure was very similar to the one described in Experiment 2. This experiment involved two tasks: version 1 and version 2 (explained in the General Method section). Descriptions, consent form, instructions, structure of the task, ITI, learning stages, testing, replication of the conditions and display of the food were the same as explained for the version 1 and version 2 tasks.

**Data analysis.** The analysis was the same as was performed in Experiment 2. Second-learned responses to stimulus Y and X were recorded in each test. Participant responses to Y during test presentations were coded as a one if they reported the no-US outcome and zero otherwise. Participant responses to X during test presentations were coded as a one if they reported O3 and zero otherwise. Thus, the maximum score was 2 if they reported second-learned responses for both replications of the X and Y contingency, and the minimum score was zero if they did not report second-learned responses in either replication of the X or Y contingency. A 2x2x2 mixed measures ANOVA was conducted. The analysis had three within-participant factors, context (two levels; second stage *versus* novel), valence (two levels; inhibitory *versus* excitatory) and design (two levels; AAB *versus* ABC).

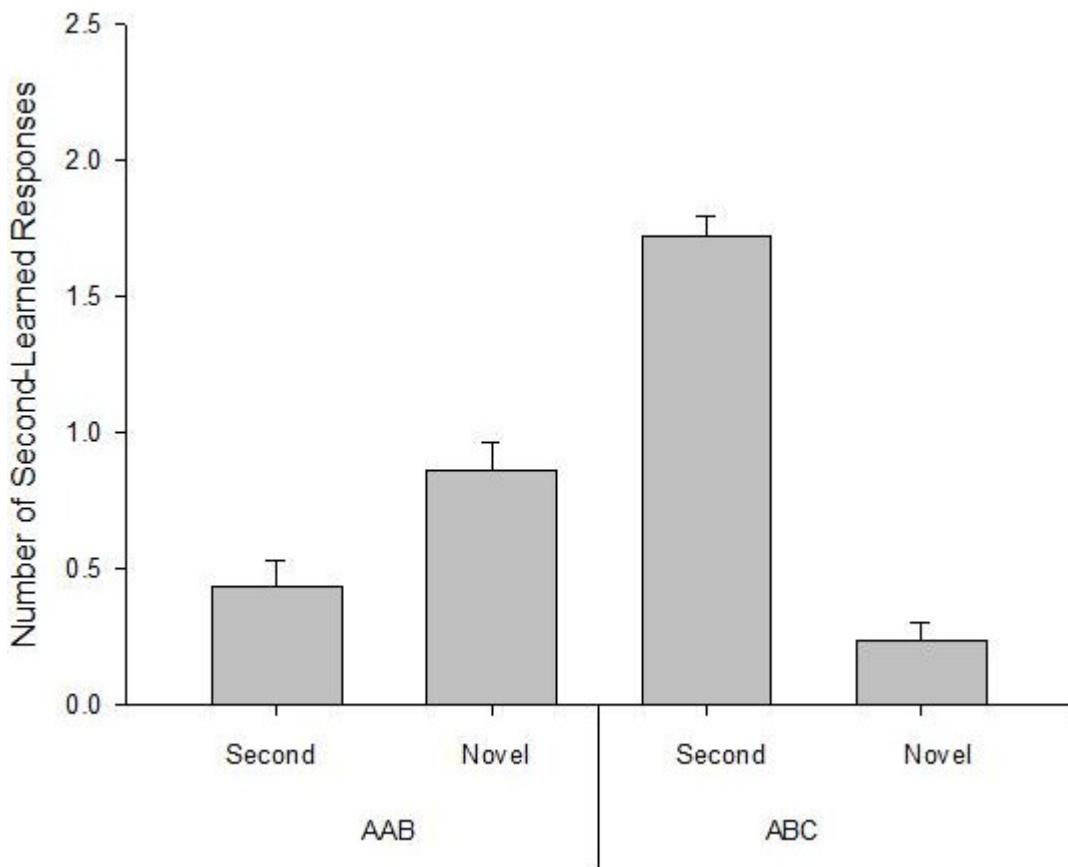
**Results.** Figure 7 shows the relevant means for Experiment 3. It can be seen that the results of Experiment 2 were replicated with the largest number of second-learned responses being observed in the second-stage context for group ABC. This

result was present whether or not the second-learned outcome was inhibitory or excitatory.

The ANOVA carried out on these data produced significant main effects of context ( $F(1,31) = 19.87, p < 0.001$ ) which was subject to an interaction with design ( $F(1,31) = 83.41, p < 0.001$ ). At the same time, there was an interaction between value and context of testing ( $F(1,31) = 7.46, p < 0.05$ ).

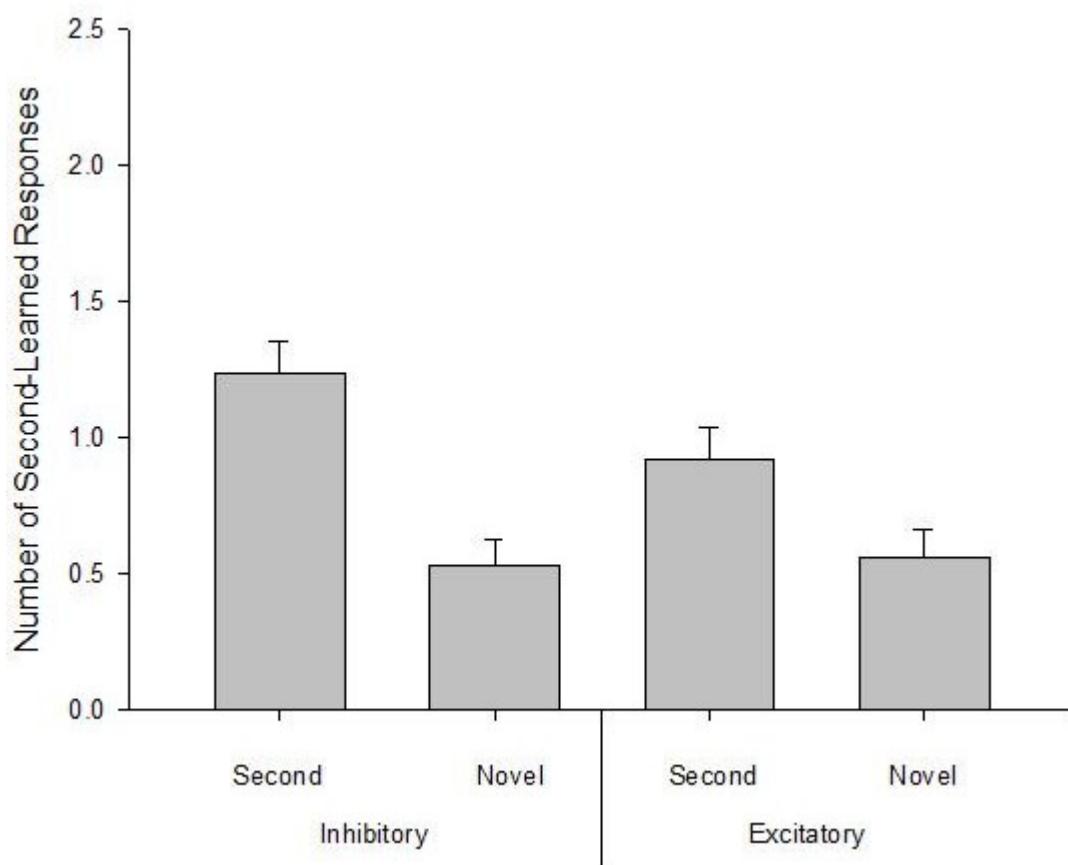


*Figure 7.* Relevant means for Experiment 3. Groups are separated by design, valence of second-learned response and context of testing. Bars indicate second-learned responses. Error bars represent the standard error of the mean.



*Figure 8.* Context x design interaction for Experiment 3. Bars indicate the number of second-learned responses. Error bars represent the standard error of the mean.

Figure 8 shows the interaction between context of testing (second-learned versus novel context) and the design (AAB versus ABC). There was a significant difference in the number of second-learned responses after a context switch in the AAB design ( $t(63) = 2.68, p < 0.01$ ). In group ABC there were differences in the number of second-learned responses between the different contexts of testing ( $t(63) = 15.29, p < 0.001$ ). The results showed differences between design AAB and design ABC in the number of second-learned responses in the second stage context ( $t(63) = 11.18, p < 0.001$ ). At the same time, there is a difference between both designs in the number of second-learned responses in a novel context ( $t(64) = 4.71, p < 0.01$ ).



*Figure 9.* Interaction between valence (excitatory versus inhibitory) and context (second-learned versus novel context) for Experiment 3. Bars indicate the number of second-learned responses. Error bars represent the standard error of the mean.

Finally, Figure 9 shows the interaction between the valence (excitatory versus inhibitory) and context (second-learned versus novel context). There was a fall in the number of second-learned responses between the second stage and novel contexts of testing that was significant in both no-US ( $t(63) = 3.84, p < 0.01$ ) and excitatory ( $t(63) = 2.13, p < 0.05$ ) conditions. At the same time, a significant difference was observed between no-US and excitatory responses in second-stage context ( $t(63) = 3.41, p < 0.01$ ). No difference was observed between no-US and excitatory responses in the novel context ( $t(63) = 0.34, p > 0.05$ ).

**Discussion.** The present experiment examined the context sensitivity of second-learned excitatory and inhibitory associations in AAB and ABC designs using a background context. The main question was related to the difference in context

sensitivity as a function of design and the valence of second-learned associations. The expected result, according to the results of Experiment 2, was to observe context sensitivity in the ABC design with excitatory and inhibitory second-learned cues. Some changes could have been expected because of the inclusion of a background context. At the same time, such context sensitivity was not expected to be observed in the AAB design. The results, as expected, indicated context sensitivity in excitatory and inhibitory second-learned associations only in the ABC design.

Considering that both designs, AAB and ABC, have the same context shift between the second stage and the test, the prediction of Bouton's (1997) model was that both designs should show context sensitivity in excitatory and inhibitory associations. However, as other authors suggest (e.g. Üngör & Lachnit, 2008), context sensitivity was observed only in the ABC design. At the same time, according to previous models of Bouton (e.g. Bouton, 1993), we could have expected to observe differences between inhibitory and excitatory associations (see Chapter 3 for details).

The results of Experiment 3 do not support the predictions of both of Bouton's models (Bouton, 1993; 1997), because no context sensitivity was shown in group AAB and the same context sensitivity was observed in excitatory and inhibitory second-learned associations. In this sense, the results again support the idea proposed by Üngör and Lachnit that AAB and ABC designs differ in a context switch between the first and second stages, and the participants pay attention to that context switch even if the outcomes used in each stage do not interfere with each other.

As in Experiment 2, the results of Experiment 3 are also inconsistent with the predictions made based on the Rescorla-Wagner model (1972) in this thesis. The Rescorla-Wagner model predicts no contextual sensitivity of second-learned associations for either excitatory or inhibitory second-learned associations in AAB and ABC designs. While Experiments 2 and 3 provide evidence that is consistent with the similarity of second-learned excitatory and inhibitory associations, they show different results for ABC and AAB designs. Specifically, contextual sensitivity was observed for the ABC design but not for the AAB design.

The definition of "inhibitory" in this experiment was related to the inhibition produced by an extinction procedure. It would be interesting to determine if the same conclusions can be applied to second-learned inhibitory associations where the

inhibition is produced by a feature-negative procedure (see Chapter 2). This question will be explored in Experiment 4.

## Experiment 4

Experiments 1, 2 and 3 showed that second-learned associations were context sensitive under the conditions of an ABC design but not under the conditions of an AAB design. The effects were the same for inhibitory and excitatory associations. In Experiments 2 and 3, the operational definition of inhibitory association was based upon an extinction procedure. CSs were trained to predict an excitatory outcome and then presented in the absence of that outcome. However, as discussed in Chapter 2, the term inhibition can refer to any reduction in associative strength, including that produced by an extinction procedure (as in Experiments 2 and 3) as well as that produced by feature negative procedures. Therefore, the main aim of Experiment 4 was to extend the examination of the context sensitivity of inhibition, this time using the feature negative procedure. For this, we compared the context sensitivity of first and second-learned inhibitory associations, both produced by feature negative training, in AAB and ABC designs. The idea of experimenting with the order of the inhibitory associations (first and second-learned) is related to the idea proposed by Bouton (1993) that inhibitory associations are particularly sensitive to the context. The aim is to explore if there are differences when the inhibitory association has been learned as either a first or a second-learned association.

This experiment tested the hypothesis that second-learned inhibitory stimuli (trained with a negative feature procedure) would show context dependency when tested in a novel context. This hypothesis, consistent with the predictions of Bouton's (1997) retrieval model, assumes that there will be no difference between second-learned inhibitory stimuli if they are tested in an AAB or an ABC design..

**Method.** Given that there are similar features in Experiments 2 and 3, only aspects differing from Experiment 2 will be mentioned.

**Design.** The design for Experiment 4 is presented in Table 9. Two fully within-participants designs were used to investigate the main hypotheses. First, it was necessary to establish that the experimental procedure produces inhibition. For this, a single repeated-measures design with three levels was used for a summation test. The response to an excitatory stimulus was compared with the response to an

excitatory plus a novel stimulus and with an excitatory plus an inhibitory stimulus. Summation is a standard method (Miller et al., 1995) to check if there is inhibition or not. The target inhibitory stimulus is presented along with an excitatory stimulus, and less excitatory response is expected compared to the presentation of the excitatory stimulus alone or the presentation of the excitatory stimulus plus a novel stimulus. Second, in line with the previous experiments, we aimed to investigate the differential effect of a context shift in AAB and ABC designs. For this we had three factors: condition (two levels; AAB vs. ABC), context (two levels; second stage vs. novel) and treatment (inhibitory meaning learned first versus inhibitory meaning learned second). An interaction between condition and context would show a different effect of transition from the second stage to test context for the AAB and ABC conditions.

In order to implement these tests, an experimental design with three stages was used. All participants were tested under two conditions (AAB and ABC using different versions of the food-illness task) and within each condition there were two stages of learning and a test as illustrated in Table 9. The inhibition tests were replicated in both conditions as shown in the inhibition rows of Table 9. During the first stage, in Context A, Y was trained as an excitatory stimulus by pairing it with O<sub>2</sub>. This training continued during the second stage, where a new excitatory stimulus, F, was introduced. Whenever F occurred in compound with G, Φ occurred. Therefore, G should become an inhibitor. This was examined in the test stage, where a summation test involving a compound with G and Y was presented. If G was truly inhibitory, there should be more inhibitory responses to a compound of GY than to Y presented alone or Y presented in a compound with a novel stimulus M and Y.

The context shift tests were also replicated in both conditions as shown in the context shift rows in Table 9. During the first stage, in Context A, X was trained as an excitatory stimulus by pairing with O<sub>2</sub>. During the second stage E, a new excitatory stimulus, was introduced paired with O<sub>2</sub>. Whenever E occurred in compound with X, Φ occurred. Therefore, X should become an inhibitor. In contrast with G, this inhibitory meaning was acquired as a second-learned association, due to the previous excitatory training that took place in the first stage. The second-stage

training took place either in the same contexts as the first stage (AAB condition) or in a novel context (ABC condition).

Table 9

*Design of Experiment 4*

Condition	First stage (Six trials)	Second stage (Six trials)	Test (One trial)
AAB			Inhibition Tests
	A: Y → O2	A: Y → O2 A: F → O2 A: FG → Φ	A: Y → ? A: YN → ? A: YG → ? A: YX → ?
	A: X → O2	A: E → O2 A: EX → Φ	Context Shift Tests B: YG → ? B: YX → ?
	A: Z → Φ A: D → Φ	A: Z → Φ A: HI → O2 A: J → Φ A: KL → O2 A: D → Φ	Filler Cues Tests B: Y → ? B: YN → ? A: E → ? A: XE → ? A: F → ? A: FG → ?
ABC	A: Y → O2	B: Y → O2 B: F → O2 B: FG → Φ	B: Y → ? B: NY → ? B: GY → ?
	A: X → O2	B: E → O2 B: EX → Φ	Context Shift Tests B: XY → ? B: GY → ? C: XY → ? C: GY → ?
	A: Z → Φ A: D → Φ	B: Z → Φ B: HI → O2 B: J → Φ B: KL → O2 B: D → Φ	Filler Cues Tests C: Y → ? C: NY → ? B: E → ? B: EX → ? B: F → ? B: FG → ?

Note. A, B and C are contexts provided by partner cues. O2 signals an excitatory outcome. Φ signals a no-US outcome. The rest of the letters signal different CSs.

The context sensitivity of these inhibitory associations as a function of condition, context and treatment (described above) was examined in Test 2, where a compound of X and Y in the second-stage context and in a novel context was compared. This comparison was also carried out for the GY compound.

As well as these critical tests, filler cues were included. They can be seen in the filling rows of Table 9. Z and D were included to balance the number of inhibitory and excitatory cues presented during the first stage. In the second stage, Z and D kept signalling a no-US outcome, with the result that at least one stimulus maintained the same meaning across different stages. HI and KL were included to balance the number of compounds signalling inhibitory and excitatory outcomes. J and D were included to balance the number of single stimuli signalling inhibitory and excitatory outcomes. During the test stage, some filler tests were included, providing information about possible differences between stages and single and compound stimuli.

**Participants.** The participants were 32 students from the University of Southampton, recruited by posted advert or word of mouth. All participants took part in both groups AAB and ABC. Participation was voluntary and participants received either £7 or psychology credits for taking part in the experiment. Their average age was 19 (ranging from 17 to 33) and they included 23 females and 9 males.

**Procedure.** Participants completed the experiment individually. All participants gave informed consent. They were given a consent form explaining that they were taking part in a learning experiment and providing basic information about the procedure. The session lasted about 40 minutes, and each participant took part in both AAB and ABC groups, using different versions of the task for each one. Participants were randomly assigned to take part in version 1 or version 2 tasks first. The number of times that each task was presented as the first task for a subject was counterbalanced.

During the first and second stages, participants were shown different trials of a couple of foods producing some effect or not. One of these foods acted as a context and it was present during all the first stage. A second food was presented as a target cue.

During the test phase, participants were asked to predict the outcome of cues either in the second-stage context (A for group AAB, B for group ABC) or a novel context (B for group AAB, C for group ABC). Each presentation was tested one time.

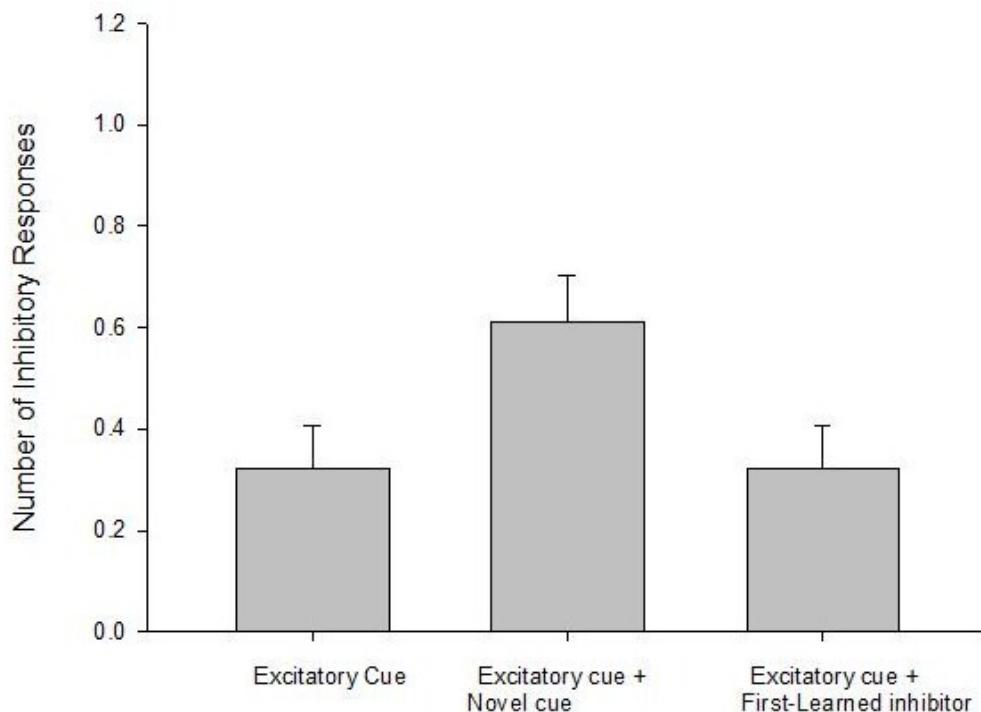
**Data analysis.** Inhibitory responses were recorded in each test. To test inhibition, a single repeated-measures ANOVA with three levels was used for a summation test. The three levels included the presentation of an excitatory cue alone (Y), an excitatory cue plus a novel stimulus (MY) and an excitatory cue plus a first-learned inhibitory cue (GY), all in the second-learned context (A for group AAB and B for group ABC).

For the context shift test, a 2x2x2 repeated-measures ANOVA was conducted. The analysis had three factors: condition (two levels; AAB vs. ABC), context (two levels; second stage vs. novel) and treatment (inhibitory meaning learned first versus inhibitory meaning learned second).

## Results.

**Inhibition.** The analysis of the data showed significant differences between a single excitatory cue ( $M = 3.23$ ,  $SD = 0.48$ ), an excitatory cue plus a novel cue ( $M = 0.61$ ,  $SD = 0.5$ ) and an excitatory cue plus a first-learned inhibitory cue ( $M = 0.32$ ,  $SD = 0.48$ ),  $F(2, 90) = 3.75$ ,  $p < 0.05$ . In this case, the number of inhibitory responses produced by the novel cue and the inhibitory cue was higher than the number produced by a first-learned inhibitory cue and an excitatory cue. This means that the inhibition test failed to prove that there was a learning of inhibition among participants. Figure 10 shows the mean responses of this inhibition test.

Considering that the inhibition test failed, the rest of the experiment can be considered invalid.



*Figure 10.* Mean inhibitory responses provided by participants for an excitatory cue alone, excitatory plus a novel cue, and excitatory plus a first-learned inhibitory cue in Experiment 4. Error bars represent the standard error of the mean.

**Discussion.** Experiment 4 failed in producing inhibition. This means that the rest of the experiment does not provide valid results, so further exploration of AAB and ABC differences in inhibitory responses in this experiment is not necessary. One possible reason for the lack of inhibition is the large number of cues that were involved in the task of Experiment 4. The number of cues might have produced confusion among participants. Experiment 5 replicates this experiment using fewer cues.

## Experiment 5

Experiment 4 explored the effects of feature negative training used to produce inhibition in AAB and ABC designs on first and second-learned inhibitory associations. However, cues trained in Experiment 4 did not pass a standard inhibition test.

It is possible that the large number of cues involved in the design of Experiment 4 produced some confusion among participants. Experiment 4 involved 11 CSs. The large number of cues might have made it harder for participants to discriminate among cues. This is why it is important to replicate these experiments using a design that uses fewer cues to make the task easier for the participants.

The main aim of Experiment 5 is further exploration of differences between first and second-learned inhibitory associations in terms of context sensitivity. This experiment tested the hypothesis that second-learned inhibitory stimuli (trained with a negative feature procedure) would show context dependency when tested in a novel context. This hypothesis is the same as the one tested in Experiment 4. The only difference is that the design involved fewer cues.

**Method.** Given that there are similar features in Experiments 4 and 5, only aspects differing from Experiment 4 will be mentioned.

**Design.** The design of Experiment 5 is presented in Table 10. Two fully between-participants designs were used to investigate the principal hypothesis. First, it was necessary to establish that the experimental procedure produced inhibition. For this, a single repeated-measures design with three levels was used for a summation test. The response to an excitatory stimulus plus a novel stimulus was compared to the response to an excitatory stimulus plus a first-learned inhibitor. At the same time, it was compared to an excitatory stimulus plus a second-learned inhibitor. This constitutes a summation test which is a standard method to check if there is inhibition or not (Miller et al., 1995). This procedure was described in detail in the design of Experiment 4.

In line with the previous experiments, Experiment 5 explored the differential effect of a context shift in AAB and ABC designs. Three factors with two conditions

each were considered for this (2x2x2) design (AAB vs. ABC), context (second stage vs. novel) and treatment (inhibitory meaning learned first vs. inhibitory meaning learned second).

Table 10

*Design of Experiment 5*

Condition	First stage	Second stage	Test
AAB			Inhibition Tests
	A: E→O2	A: E→Φ	A: XG→?
	A: EX→Φ	A: EX→O2	A: YG→?
			A: ZG→?
	A: F→Φ	A: F→O2	
	A: FY→O2	A: FY→Φ	
			Context Shift Tests
	A: G→O2	A: G→O2	B: XG→?
			B: YG→?
	A: H→Φ	A: H→Φ	B: ZG→?
ABC	A: E→O2	B: E→Φ	Inhibition Tests
	A: EX→Φ	B: EX→O2	B: XG→?
			B: YG→?
	A: F→Φ	B: F→O2	B: ZG→?
	A: FY→O2	B: FY→Φ	
			Context Shift Tests
	A: G→O2	B: G→O2	Y: XG→?
	A: H→Φ	B: H→Φ	Y: YG→?
			Y: ZG→?

In order to implement these tests, an experimental design with three stages was used. All participants were tested under two designs (AAB and ABC designs using the two different versions of the food-illness task) and within each condition there were two stages of learning and a test as illustrated in Table 10. The inhibition tests were replicated in both conditions as shown in the inhibition rows in Table 10. During the first stage, in context A, G was trained as an excitatory stimulus by

pairing it with O<sub>2</sub>. In the same stage, H was paired with no outcome. At the same time, using a feature negative procedure, X was trained as a first-learned inhibitor. Using a reverse procedure in which a cue (F) signalled no outcome when presented alone, Y was trained as a first-learned excitatory stimulus. During the second stage, groups AAB and ABC received the same treatment in different contexts. Group AAB received the treatment in context A, and group ABC received the treatment in context B. The treatment consisted of excitatory trials for cue G, no outcome trials for outcome H, a feature negative training for cue Y and an opposite feature training for cue X. According to Bouton's retrieval model (1997), in this training cue X should produce inhibition. This prediction was tested during the third stage, in which responses to an excitatory cue (G) were compared among three conditions: first, when it was presented in a compound with a novel stimulus (Z), second, when it was presented in a compound with a first-learned inhibitor (X) and third, when it was presented in a compound with a second-learned inhibitor (Y). These comparisons are summarised in the Inhibition Tests rows of Table 10.

The context shift tests were also replicated in both conditions as shown in the context shift rows in Table 10. For this test, cues Z, X and Y were tested in a compound with an excitatory cue (G) in a novel context (B in AAB and C in ABC designs).

The only filler cue included was H, presented in the first and second stages, followed by no outcome. This cue helped balancing the number of excitatory and inhibitory cues during the first and second stages.

**Participants.** The participants were 32 students from the University of Southampton, recruited by advert or word of mouth. Participation was voluntary and participants received either £7 or psychology credits for taking part in the experiment. Their average age was 21 (ranging 18 to 35) and they included 24 females and 8 males.

**Apparatus.** The same apparatus used in Experiments 1 to 4 was used in Experiment 5.

**Procedure.** Participants completed the experiment individually after giving informed consent. They were given a consent form explaining that they were taking part in a learning experiment and providing basic information about the procedure. The session lasted about 40 minutes, and each participant took part in both AAB and ABC groups, using different versions of the task for each. Participants were randomly assigned to take part in the version 1 or version 2 task first. The number of times that each task was presented as the first task for a subject was counterbalanced.

During the first and second stages, participants were shown different trials of a couple of foods producing some effect or not. One of these foods acted as a context and it was presented as a partner cue throughout the first stage. A second food was presented as a target cue. Some trials included compounds, meaning that one food acted as a context, and two foods acted as a compound CS.

During the test phase, participants were asked to predict the outcome of cues either in the second stage context, B, or a novel context, C. Each presentation was tested one time. The presentations included compounds of an excitatory cue (G) and either a novel stimulus (Z), a first-learned inhibitor (X) or a second-learned inhibitor (Y).

This training continued during the second stage in which a new excitatory stimulus, F, was introduced. Whenever F occurred in compound with G, Φ occurred. Therefore, G should become an inhibitor. This was examined in Test 2, where a summation test involving a compound with G and Y was presented. If G was truly inhibitory, there should be fewer excitatory responses to a compound of GY than to Y presented alone or Y presented in a compound with a novel compound stimulus NY.

**Data analysis.** Second-learned responses were recorded in each test. First, second-learned inhibition and second-learned excitatory tests were conducted to examine whether the experiment was successful in producing second-learned inhibitory and excitatory associations.

To test inhibition, a single repeated-measures ANOVA with four levels was used for an inhibition test, similar to a summation test. The four levels included the presentation of a second-learned excitatory cue in a novel context, a second-learned excitatory cue in the second stage context, a second-learned inhibitory cue in a novel

context, and a second-learned inhibitory cue in the second stage context. This test was conducted using subjects from the ABC design.

**Results.** Three relevant analyses were conducted. First, inhibition was tested by comparing the effect of the presented cue (second-learned excitatory cue vs second-learned inhibitory cue). Second, a context sensitivity test was performed comparing the second-learned responses of second-learned excitatory and inhibitory cues, both in a novel context and in the second stage context. Finally, differences in second-learned responses were examined between a presentation where cues were joined by an excitatory cue and a presentation where cues were joined by a pre-exposed cue.

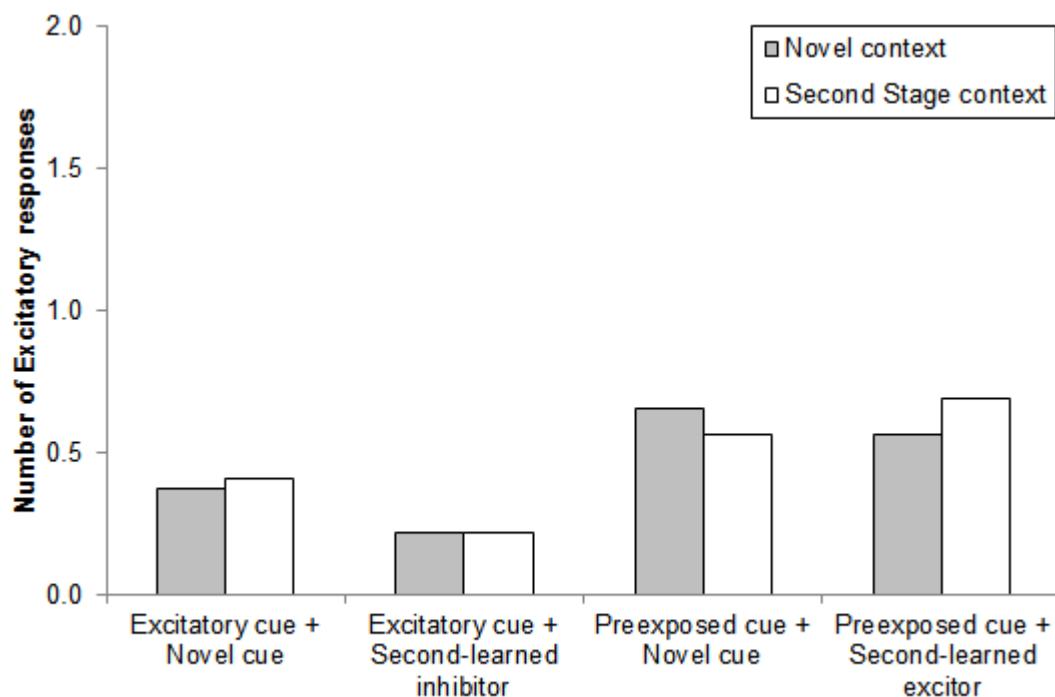


Figure 11. Mean excitatory responses provided by participants by condition in Experiment 6

**Inhibition.** The results of the analyses are presented in Figure 11. The analysis did not show significant differences between an excitatory cue plus a novel cue ( $M = 0.38, SD = 0.49$ ), and an excitatory cue plus a second-learned inhibitory cue ( $M = 0.22, SD = 0.42$ ) in a novel context, ( $t(31) = 1.54, p > 0.05$ ). There were also no

significant differences between an excitatory cue plus a novel cue ( $M = 0.41, SD = 0.50$ ), and an excitatory cue plus a second-learned inhibitory cue ( $M = 0.22, SD = 0.42$ ) in a second-learned context, ( $t(31) = 1.79, p > 0.05$ ).

Additionally, no significant differences were found between a preexposed cue plus a novel cue ( $M = 0.66, SD = 0.48$ ), and a preexposed cue plus a second-learned excitatory cue ( $M = 0.56, SD = 0.50$ ) in a novel context, ( $t(31) = 1.00, p > 0.05$ ). There were also no significant differences between a preexposed cue plus a novel cue ( $M = 0.56, SD = 0.50$ ), and a preexposed cue plus a second-learned excitatory cue ( $M = 0.69, SD = 0.47$ ) in a second-learned context, ( $t(31) = -1, p > 0.05$ ).

Finally, a 2x2 repeated measures ANOVA was conducted to test the effects of context (novel vs. second stage) and cue (second-learned excitatory cue vs. second-learned inhibitory cue). No effect of context ( $F(1,15) = 0.77, p > 0.05$ ) or cue ( $F(1,15) = 0.14, p > 0.05$ ) were observed. Finally, no interaction between context and cue was observed ( $F(1,15) = 0.78, p > 0.05$ ).

Considering that the inhibition and excitatory tests failed, the rest of the experiment can be considered invalid.

**Discussion.** As in Experiment 4, Experiment 5 failed in producing inhibition. That is, reducing the number of cues was not able to produce inhibition. This means that the rest of the experiment did not provide valid results. Thus, further exploration of AAB and ABC differences in inhibitory responses in this experiment are not necessary.

Experiment 6 aimed to explore the lack of inhibition presented at the end of the second stage in Experiments 4 and 5. To test the response to the presented stimuli at the end of the first stage, a test was included between the first and second stages.

## Experiment 6

Experiments 4 and 5 failed at producing inhibition using a feature negative training. The aim of Experiment 6 was to explore the reasons why previous experiments failed at producing inhibition. In Experiment 6 a test was included between the first and second stages to evaluate the response to the presented stimuli at the end of the first stage. The aim of this manipulation was to determine if the source of the results observed at the end of the second stage in Experiments 4 and 5 could be observed in a test at the end of the first stage. Since the number of cues did not seem to make a difference in producing inhibition, Experiment 6 used the same number of cues of Experiment 4 (11 CSs).

As in Experiments 4 and 5, Experiment 6 evaluated whether second-learned inhibitory stimulus (trained with a negative feature procedure) showed context dependency when tested in a novel context.

**Method.** Given that there are similar features in Experiments 4, 5 and 6, only aspects differing from Experiment 4 will be mentioned.

**Design.** The design for Experiment 6 is presented in Table 11. Two fully within-participants designs were used to investigate the principal hypotheses. First, it was necessary to establish that the experimental procedure produced inhibition. For this, a single repeated-measures design with three levels was used for a summation test. The response to an excitatory stimulus was compared with the response to an excitor plus a novel stimulus and with an excitor plus an inhibitory stimulus. This constitutes a summation test which is a standard method used to check if there is inhibition or not (see Miller, Barnet & Grahame, 1995). The target inhibitory stimulus is presented along with an excitatory stimulus, and less excitatory response is expected compared to the presentation of the excitatory stimulus alone or the presentation of the excitatory stimulus plus a novel stimulus. Second, in line with the previous experiments, we aimed to investigate the differential effect of a context shift in AAB and ABC designs. For this we had three factors, condition (two levels; AAB vs. ABC), context (two levels; second stage vs. novel) and treatment (inhibitory meaning learned first versus inhibitory meaning learned second). An

interaction between condition and context would show a different effect of transition from the second stage to test context for the AAB and ABC conditions.

In order to implement these tests, an experimental design with four stages was used. All participants were tested under two conditions (AAB and ABC using the two different versions of the food-illness task) and within each condition there were two stages of learning and two tests as illustrated in Table 10. The inhibition tests were replicated in both conditions as shown in the inhibition rows Table 10. During the first stage, in Context A, Y was trained as an excitatory stimulus by pairing it with O<sub>2</sub>. This training continued during the second stage, where a new excitatory stimulus, F, was introduced. Whenever F occurred in compound with G, Φ occurred. Therefore, G should become an inhibitor. This was examined in Test 2, where a summation test involving a compound with G and Y was presented. If G was truly inhibitory, there should be fewer excitatory responses to a compound of GY than to Y presented alone or Y presented in a compound with a novel compound stimulus NY.

The context shift tests were also replicated in both conditions as shown in the context shift rows in Table 10. During the first stage, in Context A, X was trained as an excitatory stimulus by pairing it with O<sub>2</sub>. During the second stage, E, a new excitatory stimulus, was introduced paired with O<sub>2</sub>. Whenever E occurred in compound with X, Φ occurred. Therefore, X should become an inhibitor. In contrast with G, this inhibitory meaning was acquired as a second-learned association, due to the previous excitatory training that took place in the first stage. The second-stage training took place either in the same contexts as the first stage (AAB condition) or in a novel context (ABC condition). The context sensitivity of these inhibitory associations as a function of condition, context and treatment (described above) was examined in Test 2, where a compound of X and Y in the second-stage context and in a novel context was compared. This comparison was also carried out for the GY compound.

Table 11

*Design of Experiment 6*

Condition	First stage	Test 1	Second stage	Test 2
AAB				Inhibition Tests
	A: Y → O2	---	A: Y → O2 A: F → O2 A: FG → Φ	A: Y → ? A: YN → ? A: YG → ? A: YX → ?
	A: X → O2		A: E → O2 A: EX → Φ	Context Shift Tests B: YG → ? B: YX → ?
	A: Z → Φ A: D → Φ	A: X → ? A: Z → ?	A: Z → Φ A: HI → O2 A: J → Φ A: KL → O2 A: D → Φ	Filler Cues Tests B: Y → ? B: YN → ? A: E → ? A: XE → ? A: F → ? A: FG → ?
ABC	A: Y → O2	---	B: Y → O2 B: F → O2 B: FG → Φ	B: Y → ? B: NY → ? B: GY → ?
	A: X → O2		B: E → O2 B: EX → Φ	Context Shift Tests B: XY → ? B: GY → ? C: XY → ? C: GY → ?
	A: Z → Φ A: D → Φ	A: X → ? A: Z → ?	B: Z → Φ B: HI → O2 B: J → Φ B: KL → O2 B: D → Φ	Filler Cues Tests C: Y → ? C: NY → ? B: E → ? B: EX → ? B: F → ? B: FG → ?

As well as these critical tests, filler cues were included. They can be seen in the filler-cue rows of Table 11. Z and D were included to balance the number of inhibitory and excitatory cues presented during the first stage. Testing X and Z between the first and second stages aimed to check if the participants had learned the basic associations presented in the first stage. In the second stage, Z and D kept

signalling a “No effect” outcome, providing additional continuity between stages. HI and KL were included to balance the number of compounds signalling inhibitory and excitatory outcomes. J and D were included to balance the number of single stimuli signalling inhibitory and excitatory outcomes. During the test stage, some filler tests were included, providing information about possible differences between stages and single and compound stimuli.

**Participants.** The participants were 32 students from the University of Southampton, recruited by advert or word of mouth. Participation was voluntary and participants received either £7 or psychology credits for taking part in the experiment. Their average age was 22 (ranging 18 to 32) and they included 23 females and 9 males.

**Apparatus.** The same apparatus used in Experiment 1, 2 and 3 were used in Experiment 6.

**Procedure.** The procedure was very similar to the one described in Experiment 4. The only difference was the inclusion of a test between the first and second stages.

In Test 1 (included between the first and second stages), participants were shown once cues X and Z in Context A, and were asked for the effect of these cues. Participants had to respond with one key. For example, for sickness they had to press “S”, for toothache “T”, for Headache “H”, for Stomachache “S” and for No Effect “N”.

In Test 2 (included between the second and third stages) participants were asked to predict the outcome of cues either in the second-stage context (A for group AAB, B for group ABC) or a novel context (B for group AAB, C for group ABC). Each presentation was tested one time.

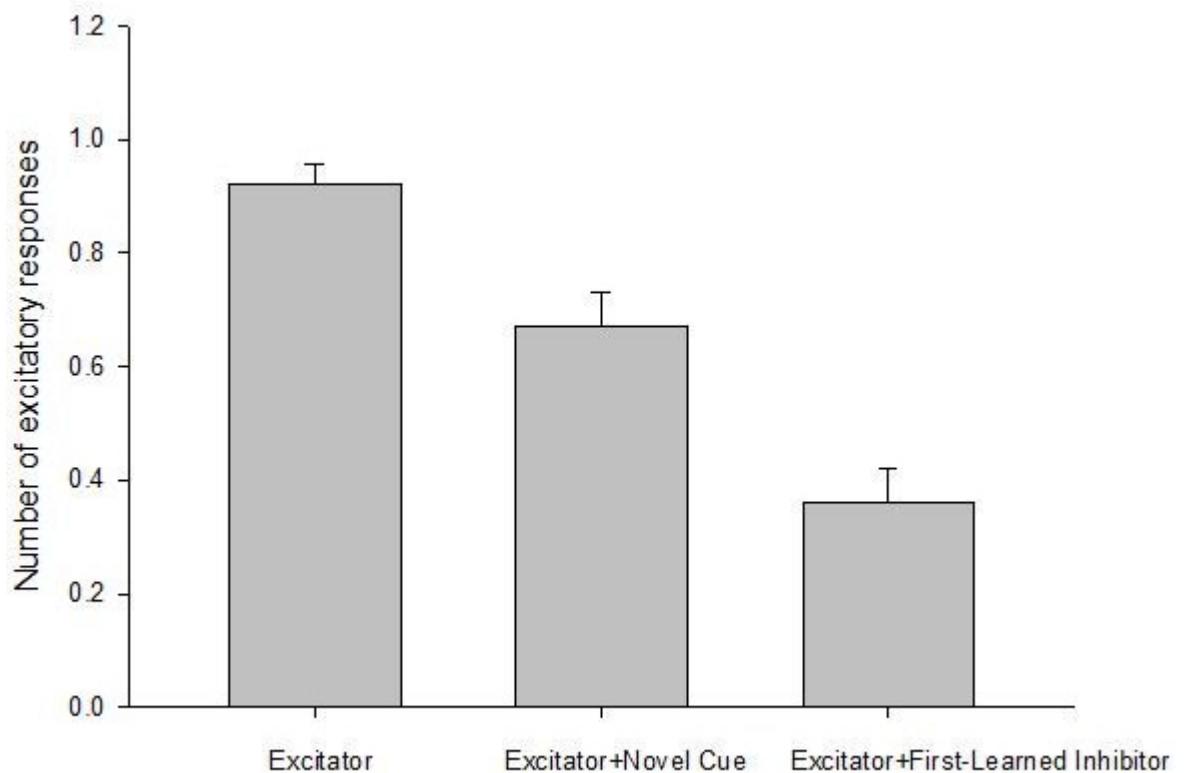
**Data analysis.** Inhibitory responses were recorded in each test. To test inhibition, a single repeated-measures ANOVA with three levels was used for a summation test. The three levels included the presentation of an excitatory cue alone (Y), excitatory cue plus a novel stimulus (NY) and excitatory cue plus a first-learned

inhibitory cue (GY), all in the second-learned context (A for group AAB and B for group ABC).

For the context shift test, a 2x2x2 repeated-measures ANOVA was conducted. The analysis had three factors, condition (two levels; AAB vs. ABC), context (two levels; second stage vs. novel) and treatment (inhibitory meaning learned first versus inhibitory meaning learned second).

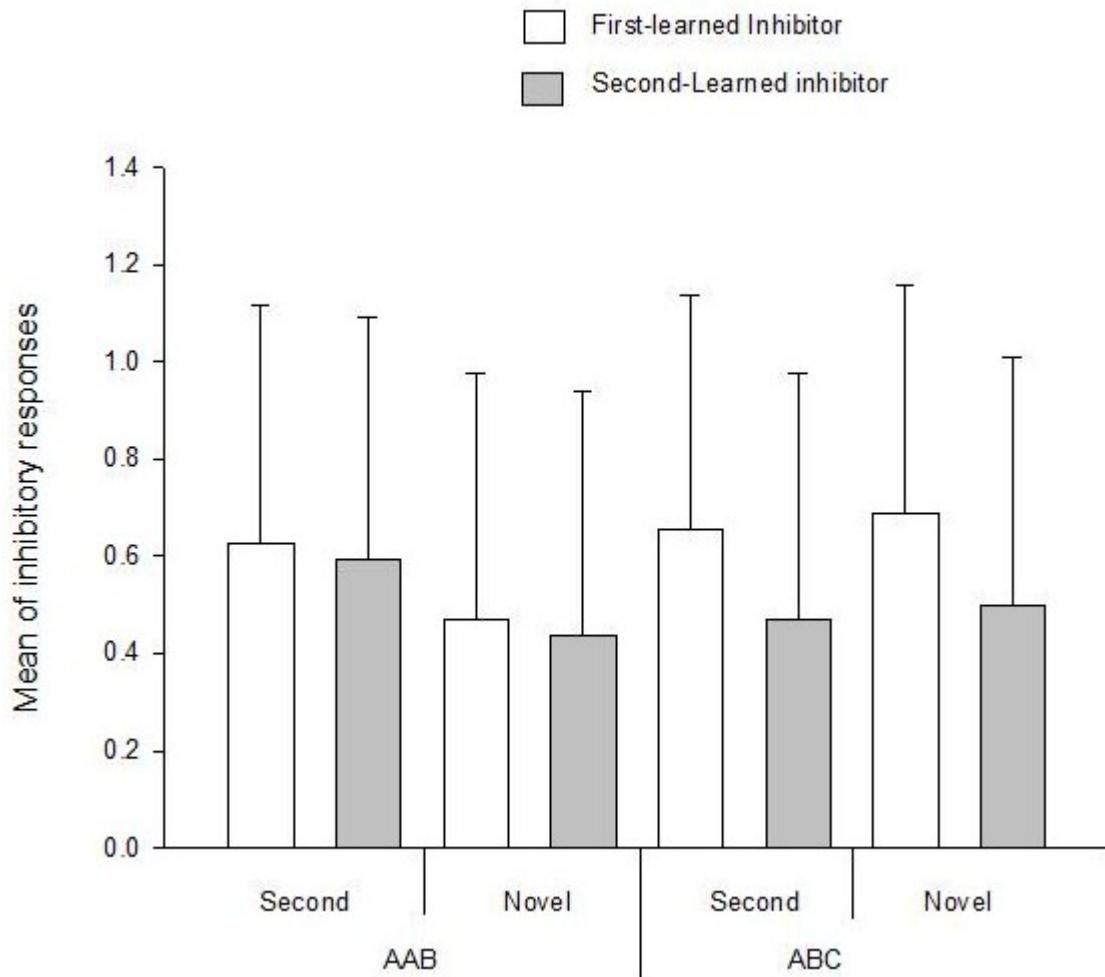
**Results.** Testing was divided into two main groups of relevant results. First, inhibition was tested by comparing the responses to an excitatory stimulus alone in compound with a novel cue, and in compound with an inhibitory cue (Table 11 cues Y, NY, and GY respectively). Second, the differences between AAB and ABC designs (context switch test) were tested using three factors: condition, context and treatment.

**Inhibition.** For this test, the number of excitatory responses was considered. The analysis of the data showed significant differences between a single excitatory cue ( $M = 0.92$ ,  $SD = 0.27$ ), an excitatory cue plus a novel cue ( $M = 0.67$ ,  $SD = 0.47$ ) and an excitatory cue plus a first-learned inhibitory cue ( $M = 0.35$ ,  $SD = 0.48$ ),  $F(1, 63) = 373.43$ ,  $p < 0.01$ . This confirms that the task produced inhibition when tested in a summation test. These results were followed by t-tests. Significant differences were observed between an excitatory cue and an excitatory cue plus novel cue ( $t(63) = 3.97$ ,  $p < 0.01$ ). At the same time, significant differences were observed between an excitatory cue and an excitatory cue plus a first-learned inhibitory cue ( $t(63) = 7.66$ ,  $p < 0.01$ ). Finally, significant differences were observed between an excitatory cue plus a novel cue and an excitatory cue plus a first-learned inhibitory cue ( $t(63) = 4.26$ ,  $p < 0.01$ ). Figure 12 shows the results of the inhibition test.



*Figure 12.* Mean excitatory responses provided by participants for an excitatory cue alone, excitatory plus a novel cue (NY), and excitatory plus a first-learned inhibitory cue (NG) in Experiment 6. Error bars represent the standard error of the mean.

**Context Switch.** Given that the procedure produced inhibition further tests to compare first and second-learned inhibitors and examine the effects of a context-switch between the first and second stages were conducted. The relevant means are shown in Figure 13. For this comparison, inhibitory responses were considered.



*Figure 13.* Mean inhibitory responses provided by participants for first or second-learned inhibitory cues, either in the second stage or a novel context, and both in AAB and ABC designs in Experiment 6. Error bars represent the standard error of the mean.

The analysis of the data showed no significant effects of condition ( $F(1,31) = 0.48, p > 0.05$ ), context ( $F(1,31) = 1.03, p > 0.05$ ) or treatment ( $F(1,31) = 3.67, p > 0.05$ ). At the same time, no interaction was shown between condition and context ( $F(1,31) = 3.07, p > 0.05$ ).

**Discussion.** In opposition to Experiments 4 and 5, Experiment 6 was able to produce inhibition at the end of the second stage. As expected, Test 1 showed excitatory responses at the end of the first stage for cue X and no excitatory

responses for cue Z. That is, the results showed the expected responses to the training that was taking place during the first stage. A lack of excitatory responses at the end of the first stage for cue X would have provided a possible explanation for the lack of inhibition in Experiments 4 and 5. However, Experiment 6 showed that the responses at the end of the first stage were the expected ones (at least in this experiment). Therefore, Experiment 6 does not provide an answer to the lack of inhibition produced in Experiments 4 and 5. These experiments provided evidence that the mechanisms to produce inhibition through feature negative procedures are not stable. At the same time, it seems to be difficult to determine the experimental parameters that are necessary to produce inhibition. For a discussion on inhibitory mechanisms and the production of consistent inhibitory conditioning, see Williams (1995).

On the other hand, the present experiment examined the context sensitivity of first- and second-learned inhibitory associations in AAB and ABC designs. The main question was related to the difference in context sensitivity as a function of design and the order of the inhibitory association (first- or second-learned). According to the results of Experiments 1, 2 and 3, the expectation was of context sensitivity in the ABC design with the second-learned inhibitory cues. At the same time, such context sensitivity was not expected in the AAB design. The results differed from those expectations indicating no context sensitivity of inhibitory associations in either AAB or ABC designs. Furthermore, an inhibitory association that was learned second did not differ from a first-learned association. These results do not therefore support the predictions of Bouton's retrieval model (1997) or those of Üngör and Lachnit (2008). Both models would predict differences between a first and a second-learned inhibitory association. However, given the inconsistent findings of experiments involving feature negative training, these results should be considered with caution.

## General Discussion of Experiments 1-6

In the present set of experiments excitatory and inhibitory second-learned associations consistently presented context sensitivity in ABC designs, but did not present context sensitivity in AAB designs (Experiments 1 to 3). These results provided evidence of context sensitivity in ABC designs using both partner cues and background as contexts.

Overall, Experiments 1 to 3 suggest that context sensitivity of second-learned associations can be observed in ABC designs, but not in AAB designs. Bouton (2004) has stated that there is more evidence showing ABC than AAB renewal. In general, different authors have found a lack of context dependency of second-learned associations in AAB designs using human prediction tasks (e.g. Rosas, García-Gutierrez, et al., 2006; Üngör & Lachnit, 2008). The present results provide further evidence of a lack of context sensitivity of second-learned associations in AAB designs and the presence of context sensitivity of second-learned associations in ABC designs in five situations. First, using partner cues in a situation involving second-learned excitatory associations following a first-learned excitatory association that was not opposite to the second one (Experiment 1). Second, using partner cues in a situation involving second-learned inhibitory (inhibition produced by extinction training) associations after a first-learned excitatory association (Experiment 2). Third, using partner cues in a situation involving second-learned excitatory associations after a first-learned inhibitory association (inhibition produced by preexposition) (Experiment 2). Fourth, using background contexts in a situation involving second-learned inhibitory (inhibition produced by extinction training) associations after a first-learned excitatory association (Experiment 3). Finally, using background contexts in a situation involving second-learned excitatory associations after a first-learned inhibitory association (inhibition produced by preexposition) (Experiment 3). In all these situations, the result was consistent: context sensitivity was observed in ABC designs, and was not observed in AAB designs.

Results of Experiments 1 to 3 are to a great extent inconsistent with the simulations made based on the Rescorla-Wagner model (1997) in this thesis. Simulations predicted no important differences between the results of AAB and ABC designs. Furthermore, they predicted a lack of context sensitivity in both

designs. Meanwhile, differences between the second-stage and novel contexts were predicted to be very similar for both types of designs. Yet, the findings of Experiments 1 to 3 of this thesis found contextual sensitivity for ABC designs and not AAB designs.

Since the main difference between AAB and ABC designs refers to a context switch between the first and second stages, these results suggest that coding of the context occurs before the introduction of ambiguity during the second stage. This suggestion is inconsistent with Bouton's (1997) retrieval model, which expects that subjects will start paying attention to the context when ambiguous information about the CS is introduced.

On the other hand, three experiments (experiments 4, 5 and 6) explored the effects of feature negative training on the context sensitivity of first and second-learned inhibitory associations. These three experiments did not show context sensitivity either in AAB nor ABC designs. Experiments 4 and 5 failed at passing the inhibition test. Experiment 6 passed a standard inhibition test, but failed to show any context sensitivity of second-learned inhibitory associations.

The results of Experiments 1 to 3 of this document suggest that with excitatory and inhibitory (produced by extinction) associations, a consistent context dependency can be observed in ABC designs. This context dependency was not observed in AAB designs. At the same time, inhibition produced by a feature negative procedure did not show any context dependency either in AAB or ABC designs. This result suggests that the feature negative training used in experiments 4, 5 and 6 is not completely reliable. More research is needed to be able to draw conclusions about the difference between AAB and ABC designs when feature negative inhibition is used.

Finally, the presented results show a pattern that can be described as a continuum in ABC designs where second-learned excitatory and inhibitory (produced by extinction) associations show more context dependency using partner cues or background cues compared to inhibitory stimuli produced by feature negative training. This continuum works only in ABC designs, because no context sensitivity could be observed in AAB designs. However, more research needs to be conducted about the idea of this continuum. For example, it is important to determine if excitatory second-learned associations following an excitatory first-

learned association (Experiment 1) show context dependency when tested in a task involving background contexts.

### **Hypotheses and overview of Experiments 7 and 8**

The results presented in Experiments 1 to 3 of this thesis are consistent in showing contextual sensitivity of second-learned associations in ABC designs. However, the results do not show this sensitivity in AAB designs. It is important to determine the mechanism underlying this difference. Different authors (e.g. Bouton & Woods, 2008; Nelson, Sanjuan, Vadillo-Ruiz, Pérez, & León, 2011) have suggested possible mechanisms underlying recovery after a context change posterior to an extinction treatment. In the results presented previously, extinction has not been the only type of second-learned association involved, but the literature in general has focused on extinction rather than on second-learned excitatory associations (see for a review, Pineño & Miller, 2005).

The final two experiments of this thesis test two possible mechanisms that might explain the results of Experiments 1 to 6: duration and number of trials (Gallistel & Gibbon, 2000; Haselgrove & Pearce, 2003) and predictions made by the comparator hypothesis (Miller & Matzel, 1988).

Experiment 7 seeks to determine whether the duration of the CS, the number of trials of the CS during the second stage and the interaction between both factors changes the results observed for AAB and ABC designs using second-learned inhibitory and excitatory cues. According to predictions made by Gallistel and Gibbon (2000) and Haselgrove and Pearce (2003) there should be differences between the results of groups that received different amount of time of exposure to the CS during the second stage. Yet, the results of Experiment 7 of this thesis did not find significant differences between the different conditions.

Experiment 8 examines whether predictions made by the comparator hypothesis (Miller & Matzel, 1988) can help explaining differences between AAB and ABC designs. Specifically, it manipulates a posttraining exposure of the first-stage context and examines if it helps producing a recovery of the first-learned response in an AAB design.

**Possible mechanism 1: Duration and number of trials.** A first option that might explain findings of Experiments 1 to 3 is the duration and number of trials. There is evidence suggesting that the amount of time that subjects are exposed to the CS during the extinction phase affects extinction (see Gallistel & Gibbon, 2000; Haselgrove & Pearce, 2003).

Experiment 2 of this thesis provides further evidence to evaluate the predictions of Gallistel and Gibbon's (2000) model, because it considered extinction in AAB and ABC design. The analysis of Experiment 2 included the same parameters for AAB and ABC designs. In the first stage, there was an acquisition training for two cues and pre-exposure training for other two cues. Given that both cues had exactly the same treatment, both will be considered in this analysis. There is a total exposure to the context of 48 seconds: four cues, each one presented six times for 2 seconds. The CS was reinforced every time it was presented, so the numerator is 1. At the same time, the background is present during the exposure to four CSs, and only half of them are reinforced. Therefore, the denominator is .5. Finally the ratio is 2, and if we assume that the threshold is 1, then the response to the CSs should be excitatory. In extinction, the first element to consider is the amount of time of exposure to non-reinforced CS after the last trial of acquisition (24 seconds in the case of Experiment 2). The second element to consider is the amount of time of CS exposure per reinforcement that the subject expects (2 seconds in the case of Experiment 2). The ratio in this case is 12.

Haselgrove and Pearce (2003) tested the hypothesis that longer CSs during extinction (compared to the CS during acquisition) produce extinction in fewer trials compared to designs in which acquisition and extinction have the same duration of the CS. This proposal is drawn from Gallistel and Gibbon's (2000) model, in which the response after extinction depends on a ratio between the time of exposure to the CS after the last presentation of the US, and the time of exposure to the CS expected between successful presentations of the US. Haselgrove and Pearce conducted five experiments testing this model. In all experiments they used rats as subjects, a clicker of different durations as CS, and food as US.

The main aim of Experiment 1 was to evaluate the effects of different durations of the CS during the extinction phase. Three groups received different durations of the CS (10s., 30s, or 270s.) with the same number of extinction trials in an appetitive

task. The results showed a small effect of the duration of the CS. In this experiment, extinction trials took place at the same time for the three groups, meaning that the interval between trials was different for different groups.

In Experiment 2, the interval between the end of a trial and the start of the following trial during extinction was the same for all the groups involved. The rest of the experiment remained the same as Experiment 1. This means that there were three groups, each one with the same number of extinction trials, and each group had a different duration for the CS during extinction (10s., 30s., or 270s.). In Experiment 1 the trials started at the same time for all the groups, producing a difference in the intervals between the end of a trial and the start of the next one. This difference was argued to possibly explain the results observed. The results of Experiment 2 were similar to the ones observed in Experiment 1. The authors suggested that the trial duration during extinction was unimportant to determine if the subjects would show a weakened response during the first ten seconds of a trial (which is the duration of the CS for a test). However, the results of the group that had 270s of CS duration during extinction showed patterns that could be interpreted as spontaneous recovery. This could be observed in the fact that the early trials presented sometimes stronger and sometimes weaker responses than the extinction phase.

The main aim of Experiment 3 was to explore the effects of presenting the CS during extinction during a fixed amount of time, but distributed in different ways for different groups. The idea is that groups with the same amount of time of CS exposure, presented in a different number of trials, would have similar responses according to the model proposed by Gallistel and Gibbon (2000). It was found that extinction progressed faster in a group exposed to one trial of extinction lasting 270 seconds compared to a group exposed to 27 exposures of 10 seconds to the CS. This means that the time of exposure to the CS during the extinction phase is not the only variable to consider at predicting when the subjects will stop responding during extinction.

Experiments 4 and 5 tested the effects of decreasing the time of exposure to extinction. Both experiments showed that decreasing the amount of time of exposure to the CS during extinction can result in a loss of responding during extinction compared to groups that had the same amount of time of exposure to the CS during acquisition and extinction. In the case of these two experiments, extinction was more

effective when using a 10s CS compared to using a 60s CS during the extinction phase. A possible explanation of these results is that repeated exposure of a short CS is more effective to produce a rapid loss of responding than the same number of presentations of a long CS. These results challenge the prediction of Gallistel and Gibbon (2000) that a longer exposure to the CS during extinction produces more rapid loss of responding.

These results suggest that either an increase (Experiments 1, 2 and 3) or a decrease (experiments 4 and 5) of the amount of time of exposure to the CS during the extinction phase can produce a loss of responding. These results challenge the proposal of Gallistel and Gibbon (2000) that stated that only increasing the amount of time of exposure to the CS during extinction, the loss of response would take place.

On the other hand, Bouton and Woods (2008) suggest that there is little support for the argument that it is the rate of reinforcement which is key in determining a decrease in responding during the extinction phase. The authors argue that the work with the Partial Reinforcement Effect (e.g. Haselgrave et al., 2004; Bouton and Woods, 2004) shows that the number of extinction trials appears to be an important factor to determine the loss of responding during extinction.

Considering these suggestions, it seems interesting to determine whether the results of group AAB in Experiments 1, 2 and 3 of this document can be explained in terms of a lack of time of exposure to the CS or a lack of trials of CS exposure during extinction. The duration and number of trials will be considered as an alternative explanation in Experiment 7. The aim of Experiment 7 is to determine if the modification of the duration of the CS, the number of trials of the CS during the second stage, and the interaction between both factors produce a change in the results presented in AAB and ABC designs using second-learned inhibitory and excitatory cues.

### **Possible mechanism 2: Predictions made by the Comparator Hypothesis.**

Based on Experiment 2 by Laborda et al. (2011) it can be hypothesised that a posttraining manipulation that exposes the subject to the first-stage context after the second stage and before the test will produce context sensitivity in a learning situation involving second-learned associations in an AAB design. To test if the

comparator hypothesis can help explaining the observed results of Experiments 1 to 3 of this thesis, Experiment 8 applies Laborda et al.'s (2011) Experiment 2 design to the experimental task used across this thesis. Experiment 8 of this thesis manipulates a posttraining exposure of the first-stage context to examine if it helps producing a recovery of the first-learned response in an AAB design. A recovery of the first-learned response when the target CS is tested in a novel context after the mentioned manipulation would provide evidence in favour of the comparator hypothesis.

## Experiment 7

Experiments 1, 2 and 3 of this thesis showed context sensitivity of second-learned inhibitory and excitatory associations in ABC designs, but not in AAB designs. Experiment 7 considers the suggestions of Gallistel and Gibbon (2000) and of Haselgrave and Pearce (2003) regarding the role of the time of exposure to a CS and the number of trials of CS exposure during the second stage. It is relevant to determine whether the results of groups in AAB designs in Experiments 1, 2 and 3 of this thesis can be explained in terms of a lack of time of exposure to the CS or a lack of trials of CS exposure during extinction. Experiment 7 considers the duration and number of trials during the second stage as possible explanations of the results of previous experiments. The aim of Experiment 7 is to determine if the modification of the duration of the CS, the number of trials of the CS during the second stage, and the interaction between both factors produces a change in the results observed for an AAB design using second-learned inhibitory and excitatory cues.

**Method.** Given that there are many similar features in Experiments 1, 2, 3 and 7, only aspects differing from experiments 2 will be mentioned.

**Design.** The design of Experiment 7 is presented in Table 12. 4 experimental groups were considered. In the first stage all participants received presentations of X followed by a no-US outcome and Y followed by an excitatory outcome (O2) in context A. During this stage the duration of the CSs presented was 3 seconds. In the second stage participants received presentations of X followed by an excitatory outcome (O3) and Y, followed by a no-US outcome. There were two experimental manipulations. The first one was given by the duration of the CSs during stage 2. Groups 1 and 2 received 3 seconds of the second-stage CS presentation. Groups 3 and 4 received 6 seconds of the second-stage CS presentation. The second experimental manipulation was given by the number of trials that took place during the second stage. Groups 1 and 3 received 12 trials of the presentations involved in the second stage. Groups 2 and 4 received 26 trials of the presentations involved in the second stage.

Table 12

*Design of Experiment 7*

Duration of CS	First stage	Second stage
3s.	12 trials	12 trials
	12 trials	26 trials
6s.	12 trials	12 trials
	12 trials	26 trials

**Participants.** The participants were 64 students from the University of Southampton, recruited by posted advert or word of mouth. Participation was voluntary and participants received either £7 or psychology credits for taking part in the experiment. Their average age was 22 (ranging 18 to 36) and they included 48 females and 16 males.

**Apparatus.** The same apparatus used in Experiments 1 to 6 was used in Experiment 7.

**Procedure.** The procedure was very similar to the one described in Experiment 2. As in Experiment 2, the experiment was completed individually. Participants were given a consent form that explained that they were taking part in a learning experiment and provided basic information about the procedure. The session lasted about 40 minutes and participants two different tasks (version 1 and 2). Participants were randomly assigned to take part in version 1 or version 2 tasks first. The number of times that each task was presented as the first task for a subject was counterbalanced.

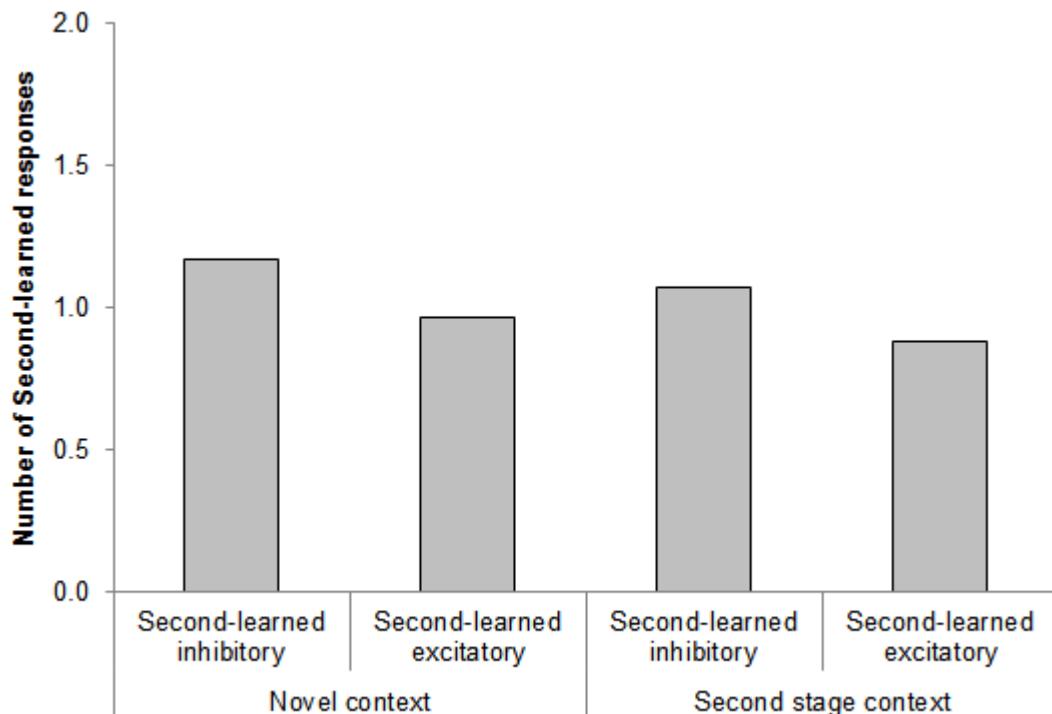
During the first and second stages, participants were shown different trials of a couple of foods producing some effect or not. One of these foods acted as a context and a second food was presented as a target cue. During the test stage, participants were shown once cues X and Z in context A, and were asked for the effect of these cues. Participants had to respond with one key. For example, for sickness they had to press “S”, for toothache “T”, for Headache “H”, for Stomachache “S” and for No

Effect “N”. Participants were asked to predict the outcome of cues either in the second stage context (A for all subjects) or a novel context (B for all the subjects). Each presentation was tested one time.

**Data analysis.** The analysis was the same as the one performed in Experiments 2 and 3 of this thesis. Second-learned responses to stimulus X and Y were recorded in each test. Participant responses to Y during test presentations were coded as 1 if they reported the no-US outcome and as 0 otherwise. Participant responses to X during test presentations were coded as a 1 if they reported O3 and 0 otherwise. Therefore, the maximum score was 2 if they reported second-learned responses for both replications of the X and Y contingency, and the minimum score was zero if they did not report second-learned responses in either replication of the X or Y contingency.

A 2x2x4 mixed measures ANOVA was conducted. The analysis had two within-participants factors, context (two levels; the second stage versus novel) and cue (two levels; second-learned excitatory and second-learned inhibitory cues) and one between-participants factor, condition (four levels; 3 second and 12 trials, 3 seconds and 26 trials, 6 seconds and 12 trials and 6 second and 26 trials).

**Results.** Figure 14 shows relevant means for Experiment 7. No context sensitivity was observed. At the same time, no differences were observed in the number of second-learned responses between second-learned excitatory and second-learned inhibitory cues. The ANOVA conducted on this data showed no effects of context ( $F(1,124) = 3.27, p > 0.05$ ), cue ( $F(1,124) = 2.23, p > 0.05$ ), and condition ( $F(3,124) = 1.76, p > 0.05$ ). No interaction was found between context and cue ( $F(1,124) = 3.74, p > 0.05$ ), between context and condition ( $F(3,124) = 1.35, p > 0.05$ ), between cue and condition ( $F(3,124) = 1.21, p > 0.05$ ), and between context, cue and condition ( $F(3,124) = .44, p > 0.05$ ).



*Figure 14.* Context x cue interaction for Experiment 7. The bars indicate the number of second-learned responses to second-learned excitatory and second-learned inhibitory cues in second-stage and novel contexts.

**Discussion.** Bouton's (1997) model predicts context sensitivity in both excitatory and inhibitory associations for AAB designs. Yet, results of Experiments 1-3 of this thesis found no context sensitivity for AAB designs. The purpose of Experiment 7 was to explore one possible explanation for the previous results: that context sensitivity in AAB designs depends on the number and length of learning trials. It examined the context sensitivity of second-learned excitatory and inhibitory associations in an AAB design, manipulating the number and length of learning trials. The main question was whether the number and duration of trials, as well as the interaction between both factors, produced differences in context sensitivity in the first and second stages of a learning situation. Based on findings of Haselgrave and Pearce (2003) the expectation was to observe context sensitivity in at least one of the combinations of number and length of trials.

As in Experiments 1-3 of this thesis, the results of Experiment 7 did not support Bouton's (1997) predictions because no context sensitivity was observed for an AAB design. The results are also inconsistent with the predictions based on the findings of

Haselgrove and Pearce's (2003) because manipulating the number and length of trials did not produce context sensitivity in the current experiment. Also, no differences were found in second-learned responses between different combinations of number and length of trials. Therefore, in this experiment, no evidence was found for a role of the duration and number of trials of the CS in explaining the lack of context sensitivity in AAB designs.

Future research should examine if the lack of effect of the manipulation of number and length of learning trials also holds for ABC designs. If the number and length of trials had an influence on the context sensitivity of ABC but not AAB designs, further evidence for important differences among designs in terms of processing of information during the learning situation would be provided. This situation would provide evidence in favour of Üngör and Lachnit's (2008) argument that the codification of context in a learning situation takes place before the context shift or before observing an ambiguity (as the case of extinction).

At the same time, it remains to be seen whether findings of Experiment 7 would have been different if the parameters used would have resembled the original parameters of Haselgrove and Pearce (2003) more closely. For example, Haselgrove and Pearce (2003) used three different durations of the CS (10 seconds, 30 seconds and 270 seconds), while in Experiment 7 only two shorter durations of the CS were used (3 seconds and 6 seconds). Experiment 7 could be replicated using the exact same durations as used by Haselgrove and Pearce.

## Experiment 8

Experiment 7 explored one possible explanation for a lack of context sensitivity for AAB designs: the number and length of trials. Yet, context sensitivity was not observed in any of the considered combinations of number and lengths of trials. Experiment 8 explores a second possible reason for differences in context sensitivity between AAB and ABC designs. It applies the comparator hypothesis (Miller & Matzel, 1988) to the current research to evaluate whether reinforcing Link 3 can help producing a recovery of the first-learned response in AAB designs. In this experiment the reinforcement of Link 3 is achieved through the manipulation of a posttraining exposure of the first-stage context and the US. Based on the comparator hypothesis, a recovery of the response should occur when the target CS is tested in a novel context after the mentioned manipulation.

**Method.** As Experiment 8 was similar to Experiment 2, only differences are described in this section.

**Design.** Table 13 describes the design of Experiment 8. In the first stage participants of Groups 1 and 2 received presentations of X followed by a no-US outcome and Y followed by an excitatory outcome (O2) in Context A. In the second stage all participants received presentations of X followed by an excitatory outcome (O3) and Y followed by a no-US outcome in Context A. The critical experimental manipulation was the exposure to second-stage context during the third stage.

Participants in Group 1 were exposed to second-stage context (A) during the third stage in combination with filling cues. Participants in Group 2 were exposed to a novel context (C) during the third stage in combination with the same filling cues as Group 1. Finally, X and Y were tested for both groups in the second-stage context (A) and in a novel context (C).

**Participants.** Participants were recruited from Barton Peveril College by word of mouth. The experiment was conducted during a site visit. 35 students participated on a voluntary basis. Their average age was 17 (ranging from 16 to 18) and they included 20 females and 15 males.

Table 13

*Design of Experiment 8*

	First stage	Second stage	Third stage	Test
Group 1	A: X → Φ	A: X → O3	A: U → O2	B: X? Y?
	A: Y → O2	A: Y → Φ	A: V → Φ	A: X? Y?
Group 2	A: X → Φ	A: X → O3	C: U → O2	B: X? Y?
	A: Y → O2	A: Y → Φ	C: V → Φ	A: X? Y?

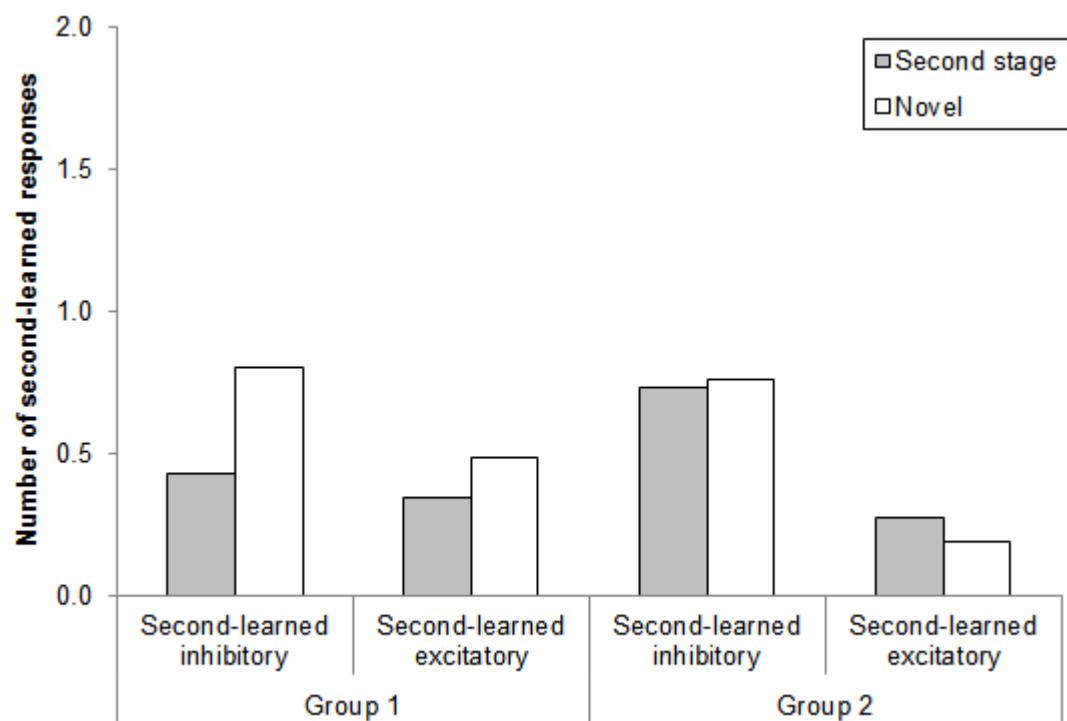
**Stimuli and apparatus.** The same stimuli and apparatus used in Experiment 2 were used in Experiment 8.

**Procedure.** The procedure was very similar to the one described in Experiment 2. This experiment involved two tasks: version 1 and version 2 (explained in the General Method section). The description of the tasks in Experiment 8 is the same as the description of the tasks in Experiment 2. The only difference was the type of images displayed. Instead of images of fruits and vegetables, the images displayed showed cakes and sweets, and the possible effects were “Toothache” and “Stomach ache”. Descriptions, consent form, instructions, structure of the task, ITI, learning stages, testing, replication of the conditions and display of the food were the same as explained for the version 1 task in Experiment 1.

**Data analysis.** Second-learned responses to stimulus Y and X were recorded in each test. Participant responses to Y during test presentations were coded as a one if they reported the no US outcome and zero otherwise. Participant responses to X during test presentations were coded as a one if they reported O3 and zero otherwise. Thus, the maximum score was 2 if they reported second-learned responses for both replications of the X and Y contingency, and the minimum score was zero if they did not report second-learned responses in either replication of the X or Y contingency. A 2x2x2 mixed measures ANOVA was conducted. The analysis had three factors, two within-participant factors - context (two levels; second-stage versus novel) and valence (two levels; inhibitory or excitatory)- and one between-participant factor -

group (two levels; Post training exposure to first stage context versus No Post training exposure to first stage context).

**Results.** Figure 15 shows the results of a  $2 \times 2 \times 2$  repeated-measures ANOVA. A significant effect was found for the valence of second-learned association (inhibitory vs. excitatory),  $F(1,34) = 11.21, p < 0.01$ . No significant effects were found for context (second stage vs. novel),  $F(1,34) = 0.93, p > 0.01$ , and condition (Group 1 vs. Group 2),  $F(1,34) = 0.03, p > 0.05$ . No significant interactions were found between context and condition,  $F(1,34) = 3.33, p > 0.05$ , between valence and condition,  $F(1,34) = 2.97, p > 0.05$ , between valence and context  $F(1,34) = 1.75, p > 0.05$ , and between valence, context and condition,  $F(1,34) = 0.22, p > 0.05$ .



*Figure 15.* Mean number of second-learned responses presented during test phase for Experiment 8. Groups are separated by design, valence of second-learned response and context of testing

**Discussion.** According to the comparator hypothesis (Miller & Matzel, 1988), an indirectly activated representation of the CS competes with a directly activated

representation of the CS in a comparison process to determine the performance of the CR. Three associations are involved. First, there is a link between the target CS and a directly activated representation of the US (Link 1). The associative strength of this link determines the associative power of the directly activated US representation in the comparison process. Second, there is a link between the target CS and the comparator stimulus (Link 2). Finally, there is a link between the indirectly activated representation of the US and the comparator stimulus (Link 3). According to the comparator hypothesis, the reinforcements of Links 2 and 3 would help reducing the performance of the CR in a learning situation.

The current experiment manipulated the exposure to the first-stage context and the target CS to strengthen Link 2 in an AAB design. The expectation based on the comparator hypothesis was to observe context sensitivity in an AAB design as a product of this manipulation (as opposed to the findings of Experiments 1 to 3 of this thesis). The results showed no effect of the manipulation on the number of second-learned responses. Therefore, in this experiment, no evidence was found supporting the comparator hypothesis' explanations about the differences in context sensitivity between AAB and ABC designs.

It remains to be seen whether findings of Experiment 8 would have been different if the parameters used would have resembled the original parameters of Laborda et al. (2011) more closely. For example, Laborda et al. (2011) used rats as subjects while Experiment 8 was conducted using causal judgments tasks with human participants. It is for future research to replicate the current experiments using other experimental parameters.

## General discussion of Experiments 1 to 8

Altogether, the results of the experiments presented in this thesis suggest a consistent lack of context sensitivity in AAB designs and a presence of context sensitivity in ABC designs involving excitatory and inhibitory second-learned responses. Context sensitivity was not found in AAB designs using a range of different parameters and tasks: (a) using second-learned excitatory cues following a different first-learned excitatory outcome (Experiment 1); (b) using second-learned inhibitory cues following an excitatory first-learned association (Experiments 2 and 3); (c) using second-learned excitatory cues following a first-stage preexposure to the target cue (Experiments 2 and 3); (d) using a feature negative procedure to produce inhibitory conditioning (Experiment 6); (e) varying the duration and number of trials (Experiment 7); and (f) reinforcing the link between the target CS and the context of training (Experiment 8).

In this thesis, two hypotheses were tested to explain differences in context sensitivity between ABC and AAB designs: the effect of the number and duration of trials (Haselgrave & Pearce, 2003) and the comparator hypothesis (Miller & Matzel, 1988). Neither theory was able to explain the lack of context sensitivity of AAB designs.

These findings are inconsistent with Bouton's retrieval model (1997) which predicts context sensitivity for both AAB and ABC designs. They are also inconsistent with predictions based on the Rescorla-Wagner model (1972) which predict no context sensitivity for both AAB and ABC designs. However, the results of this thesis are in line with a number of different studies that have found stronger renewal in ABC designs compared to AAB designs (e.g. Bouton & Ricker, 1994; Goddard, 1999; Laborda et al., 2011; Thomas et al., 2003; Üngör & Lachnit, 2008; Yap & Richardson, 2007).

The experimental results reported in this thesis provide evidence in favour of a proposal made by Üngör and Lachnit (2008). The authors conducted experiments using three different designs: ABA, ABC and AAB. They found context sensitivity in ABA and ABC designs, but not in AAB designs. The authors analysed the differences between ABA and ABC designs, on the one hand, and AAB designs, on the other. They concluded that the main difference between both groups of designs is given by the context switch that takes place between the first and second stages in

ABA and ABC designs, but not in AAB designs. Üngör and Lachnit reasoned that a mechanism of codification of context during the first stage can explain why the context switch produces context sensitivity of the second-learned association. The codification of context during the first stage is argued to be incapable of controlling the performance of the behaviour until some type of ambiguity shows up (e.g. the beginning of the extinction training in the second stage, see Rosas, García-Gutierrez, et al., 2006). Üngör and Lachnit (2008) claimed that if there was no codification of context in the first stage it would not be possible to establish a contrast between the context that is present in the first stage and the context that is present in the second stage. This argument is inconsistent with previous theories that have proposed that the subjects do not code the context during the first stage (Bouton, 1997; Rosas, Callejas Aguilera, et al., 2006) unless some of the information provided during the first stage provides some level of ambiguity (see Bouton & Woods, 2008; Pineño & Miller, 2005).

Üngör and Lachnit's (2008) proposal that context is codified during the first stage allows explaining differences between AAB and ABC context sensitivity observed in the experiments of this thesis. The only difference between AAB and ABC designs is the context switch between the first and second stages. Therefore, if the context was not codified during the first stage there would be no differences between the trainings of AAB and ABC designs. As a consequence, observed differences between AAB and ABC designs can be explained through a contextual codification mechanism during the first stage.

Future research could replicate Üngör and Lachnit's (2008) studies using the experimental tasks considered in this thesis. The current thesis only considered AAB and ABC designs. It is particularly relevant to examine whether differences in context sensitivity between AAB, ABC and ABA designs could be found using the experimental tasks of this thesis. If context sensitivity was observed in ABC and ABA designs, more evidence would be provided in favour of Üngör and Lachnit's proposal that the coding of context occurs during the first stage.



## Chapter 6: Conclusions

### **Summary of research questions and findings**

The aim of this thesis has been to explore differences in contextual sensitivity for second-learned inhibitory and excitatory stimuli between AAB and ABC designs. Two theoretical models were discussed to explain contextual sensitivity of second-learned associations in AAB and ABC designs: the Rescorla-Wagner model (1972) and Bouton's retrieval model (1997). According to predictions made based on the Rescorla-Wagner model, context sensitivity should not be observed in either AAB or ABC designs. In both designs the target CS goes through excitatory training during the first stage and through inhibitory extinction training during the second stage. As a consequence, in ABC and AAB designs the associative strength of the target CS should be similar at the end of the experiment. Bouton's retrieval model (1997), on the other hand, predicts context sensitivity in both AAB and ABC designs when the test occurs in a novel context. In both designs the second-learned associations are context-dependent and a context switch takes place between the second and third stages. The context switch should induce a recovery of the first-learned association that is independent of context in both AAB and ABC designs.

In opposition to the predictions made by the Rescorla-Wagner model (1972) and Bouton's retrieval model (1997), a number of studies have found stronger renewal effects for ABC designs than for AAB designs (e.g. Bouton & Ricker, 1994; Goddard, 1999; Laborda, Witnauer, & Miller, 2011; Thomas, Larsen, & Ayres, 2003; Üngör & Lachnit, 2008; Yap & Richardson, 2007). Yet, two important gaps in the literature can be found. First, little research has explored the mechanisms that explain differences in renewal between AAB and ABC designs. The first contribution of this thesis has been to advance in the understanding of these mechanisms. A second understudied issue is whether inhibitory as well as excitatory second-learned associations are context independent. Most research so far has been concerned with inhibitory second-learned associations (see for a review Bouton & Woods, 2008). A second contribution of this thesis has been to explore differences in AAB and ABC designs for both inhibitory and excitatory second-learned associations.

This thesis has been set up to provide answers to the following research questions:

*Q1. Is there a difference in the context sensitivity of extinction produced in AAB and ABC designs?*

*Q2. Are there differences in context sensitivity between inhibitory and excitatory second-learned associations?*

*Q3. Is there an interaction between design type (AAB and ABC) and the value of the second-learned association (excitatory and inhibitory) in terms of the context sensitivity of second-learned associations?*

Based on the predictions of Bouton's retrieval model (1997), the following hypotheses were proposed:

*H<sub>1</sub>: The contextual sensitivity of second-learned excitatory associations will be similar in AAB and ABC designs.*

*H<sub>2</sub>: The contextual sensitivity of second-learned inhibitory associations will be similar in AAB and ABC designs.*

*H<sub>3</sub>: There will be no interaction between design type (AAB and ABC) and the valence of the second-learned association (excitatory and inhibitory) in terms of the context sensitivity of second-learned associations.*

Eight experimental studies in this thesis examined the contextual sensitivity of second-learned inhibitory and excitatory associations in AAB and ABC designs. First, Experiments 1 to 3 showed strong evidence of contextual sensitivity for excitatory and inhibitory second-learned associations in ABC designs. The latter was not the case for AAB designs. These findings question Bouton's (1997) argument that contextual sensitivity should be observed for both AAB and ABC designs and they also question predictions based on the Rescorla-Wagner model (1972) that

contextual sensitivity should not be observed for either ABC or AAB designs. Experiments 4 to 6 used a negative feature procedure to replicate findings of Experiments 1, 2 and 3. Experiments 4 and 5 were not able to produce inhibition. Experiment 6 produced inhibition yet did not find context sensitivity in either AAB or ABC designs. Experiments 7 and 8 tested two alternative hypotheses to explain the mechanisms underlying the findings of Experiments 1, 2 and 3: duration and number of trials and predictions made by the comparator's hypothesis. Yet, findings provided no evidence in favour of any of these alternatives.

In relation to the first question of this thesis ( $Q_1$ ), important differences in context sensitivity were found between AAB and ABC designs. Specifically, no context sensitivity was observed for AAB designs (Experiments 1, 2, 3, 7 and 8), while context sensitivity was observed for ABC designs (Experiments 1, 2 and 3). Furthermore, second-learned excitatory associations did also show differences between AAB and ABC designs (Experiments 1, 2 and 3). In relation to the second research question of this thesis ( $Q_2$ ), no effect of the value of the second-learned association (inhibitory or excitatory) on context sensitivity was found (Experiments 2 to 3). This evidence supports the predictions of Bouton (1997) that the order of the associations determines its context sensitivity and not their value. Therefore, results of these experiments are inconsistent with  $H_1$  and  $H_2$ : a consistent difference in context sensitivity of extinction was observed for AAB and ABC designs, for both excitatory and inhibitory associations.

Finally, in relation to the third question of this thesis ( $Q_3$ ) no interaction between value and design was observed (Experiments 2 and 3). That is, the difference between AAB and ABC designs were present for both inhibitory and excitatory associations. The latter provides evidence in favour of  $H_3$ : differences between both designs were observed regardless of the value of the association.

Overall, the experimental results reported in this thesis provide evidence of context sensitivity of second-learned associations for ABC but not for AAB designs. These findings suggest that the context cannot be codified for the first time during the second stage, when ambiguity appears. AAB and ABC designs differ in that ABC designs consider a context switch between the first and second stages while AAB designs do not. If the context was codified for the first time during the second stage, no differences between AAB and ABC designs would be observed in terms of

context sensitivity of second-learned associations. These conclusions are inconsistent with previous arguments proposing that subjects do not code the context during the first stage (Bouton, 1997; Rosas, Callejas Aguilera, et al., 2006) except if some of the information provided during the first stage introduces some level of ambiguity (see Bouton & Woods, 2008; Pineño & Miller, 2005). Alternatively, the results of this thesis are consistent with Üngör and Lachnit's (2008) argument that the context is codified for the first time during the first stage and before the introduction of ambiguity. According to the authors, the main difference between AAB and ABC designs is the context switch that takes place between the first and second stages in ABC designs, but not in AAB designs. If there was no codification of context during the first stage, no contrast between the context that is present in the first stage and the context that is present in the second stage would be established. Therefore, the argument that context is codified during the first stage helps explaining differences in context sensitivity of second-learned associations between AAB and ABC designs observed in this thesis. If Üngör and Lachnit's proposal would gain more evidence, Bouton's (1997) retrieval model could be adapted to consider the argument that the context is codified during the first stage. The latter would also modify its predictions regarding differences between context sensitivity of second-learned associations between AAB and ABC designs.

### **Future research**

It is for future research to find more evidence regarding Üngör and Lachnit's (2008) proposal that the context is codified for the first time during the first stage. The experiments presented in this thesis provided evidence of differences in context sensitivity of second-learned excitatory and inhibitory associations between AAB and ABC designs. The latter provides evidence in favour of Üngör and Lachnit's proposal. Yet, more research needs to be conducted to examine whether differences in context sensitivity remain considering AAB, ABC and ABA designs.

Second, future research should further examine the contextual sensitivity of second-learned excitatory associations. This thesis has provided evidence of context sensitivity of second-learned excitatory associations after a pre-exposure of the CS and after another excitatory training. Considering the role of context sensitivity of excitatory second-learned associations would be important to validate models that

state that the key to predict context sensitivity is the value of the signal (excitatory or inhibitory) more than the order of the association (first- or second-learned associations, Bouton, 1997). At the same time, more research on the matter could provide substantial evidence against models that predict that context sensitivity depends upon the value of the association (Bouton, 1993).

A third issue that should be further explored are the mechanisms involved in a feature negative training. In this set of experiments (Experiments 4 to 6), the observance of inhibition after feature negative inhibitory training was unreliable. The latter suggests that very specific parameters need to be used for the feature negative training to produce inhibition. More research needs to be conducted to define appropriate parameters to observe inhibition as a result of feature negative training.

Finally, more research is required on the implications of differences between AAB and ABC designs for clinical practice. The results of the studies presented in this thesis provide substantial evidence of differences between the contextual sensitivity mechanisms involved in AAB and ABC designs. Such observation – supported by previous studies (e.g. Bouton & Ricker, 1994; Goddard, 1999; Laborda, Witnauer, & Miller, 2011; Thomas, Larsen, & Ayres, 2003; Üngör & Lachnit, 2008; Yap & Richardson, 2007)- could lead to interesting suggestions in the field of exposure therapy. The difference between AAB and ABC renewal needs to be evaluated in different learning situations and in relation to clinical practice.

### **Implications for drug addiction exposure therapies**

The findings of this thesis have important implications for drug addiction exposure therapies. In the field of drug addiction therapies, research regarding context sensitivity of second-learned associations can provide useful information for the understanding of the effects of certain treatments. In particular, the use of exposure therapy to treat drug addictions involves the extinction of the conditioned responses triggered by CSs associated to the effect of a drug (US). The results of this extinction have been shown to be particularly context dependent (see Bouton, 1997). Studying the context sensitivity of second-learned associations could provide suggestions to improve the generalisation of second-learned associations and to avoid the recovery of the initially conditioned response.

Experiments 1 to 3 of this thesis consistently showed context sensitivity of ABC designs for excitatory and inhibitory second-learned associations. At the same time, no context sensitivity was observed using the same cues in an AAB design. Further exploration of the difference between ABC and AAB designs in terms of context sensitivity of second-learned associations is crucial to provide suggestions for clinical practice. Further confirmation of the lack of context sensitivity of AAB designs would suggest that the latter would be helpful in diminishing renewal effects that occur after therapies have concluded. If this was true, exposure therapies should be conducted in the same context where the original excitatory learning took place. This would provide a powerful tool to help diminish relapse in drug exposure therapy.



## Appendix A

### **Human causality judgement experiments**

#### **Participant information sheet and consent form.**

Thank you for agreeing to take part in this investigation. Please read the information below and ask any questions you may have. If you agree to take part please sign the consent form at the bottom of this page.

Your participation involves carrying out one or more small computer based experiments that last up to about 35min, altogether. The experiments all have a similar general format but are quite separate and the exact details vary from person to person. For example, in one experiment you might be shown images of various viruses that have infected hospital patients and, after being shown each virus, you would find out whether the patient infected by that virus became ill or not. Your task would be to learn which viruses were the most potent causes of illness. Although the precise details of each experiment will vary from person to person they will be explained to you before you start. All the experiments are designed to study how people learn about the causal relationships between events that happen in their environments and each involves simple computer tasks similar to the virus task outlined above.

**Consent form.**

I have read the above information and agree to participate in the experiment as described. I have been given the opportunity to ask questions about the procedure and understand that I am free to withdraw at any time without prejudice. I agree to the publication of study results as long as information about myself is presented anonymously.

Signed:

Age:

Date:

Gender:

Print name:

Occupation (and subject

if you are a

student):

**PLEASE SWITCH OFF YOUR MOBILE BEFORE STARTING!**

If you have any questions about your rights as a participant in this research, or if you feel that you have been placed at risk, you may contact the chair of the Ethics Committee in the Dept. of Psychology, Southampton University, SO17 1BJ, Tel. 023 8059 2612. You may contact too Research Governance Office, [rgoinfo@soton.ac.uk](mailto:rgoinfo@soton.ac.uk) or 02380 595058

## Appendix B

### Instructions for Version 1 using partner cues

#### **Instructions for the fruits and vegetables experiment.**

In this experiment your job is to learn the extent to which each of various foods produce sickness or headaches. You play the role of a doctor investigating recent reports of food poisoning. The food poisoning is believed to be linked to fruit and vegetables purchased at a local market and in order to track the source of the poisoning you have interviewed people who have recently eaten various fruit and vegetables purchased from the market. You are reviewing the information you have collected on a case by case basis. For each case you have information on which foods were eaten and whether or not the person was well or whether they suffered sickness or headaches after eating. Your job is to learn the extent to which each of the foods might be a cause of sickness or headaches. Note, the sequence of trials is randomly ordered so you can only predict the outcomes by learning about the food items themselves. There will be some trials when you will be asked to indicate what your judgements are. When you have to make a judgement this will be signalled on the screen. All you have to do is follow the onscreen instructions and enter a response that reflects your judgement. Instructions will be given on how to make your rating, please take care to read all of the instructions carefully. Once you have made your judgment press return to carry on. If you have any questions please ask the experimenter now, otherwise press another key to start.

## Appendix C

### Instructions for Version 2 using partner cues

#### **Instructions for the cakes and sweets experiment.**

In this experiment your job is to learn the extent to which each of various cakes and sweets produces headache or toothache. You play the role of a doctor who has interviewed people who have recently eaten cakes and sweets. You are reviewing the information you have collected on a case by case basis. For each case you have information on which foods were eaten and whether there was no effect, or whether the person suffered headache or toothache after eating. Your job is to learn the extent to which each of the foods might be a cause of headache or toothache. Note, the sequence of trials is randomly ordered so you can only predict the outcomes by learning about the food items themselves. There will be some trials when you will be asked to indicate what your judgements are. When you have to make a judgement this will be signalled on the screen. All you have to do is follow the onscreen instructions and enter a response that reflects your judgement. Instructions will be given on how to make your rating, please take care to read all of the instructions carefully. Once you have made your judgment press return to carry on. Press a key to continue.

If you have any questions please ask the experimenter now, otherwise press another key to start.

## Appendix D

### Instructions for Version 1 using background context

#### **Instructions for the fruit and vegetables experiment.**

In this experiment your job is to learn the extent to which each of various fruit and vegetables produce fever or sickness when eaten in different places. You play the role of a doctor who has interviewed people who have recently eaten fruit and vegetables. You are reviewing the information you have collected on a case by case basis. For each case you have information on which foods were eaten, the place where they were eaten, and whether there was no effect, or whether the person suffered fever or sickness after eating. Your job is to learn the extent to which each of the foods might be a cause of fever or sickness. The different places where the foods have been eaten, will be signaled by changes in the colour of the screen. Note, the sequence of trials is randomly ordered so you can only predict the outcomes by learning about the food items themselves. There will be some trials when you will be asked to indicate what your judgements are. When you have to make a judgement this will be signalled on the screen. All you have to do is follow the onscreen instructions and enter a response that reflects your judgement. Press a key to continue. Instructions will be given on how to make your rating, please take care to read all of the instructions carefully. Once you have made your judgment press return to carry on. If you have any questions please ask the experimenter now, otherwise press another key to start.

## Appendix E

### Instructions for Version 2 using backgrounds context

#### **Instructions for the cakes and sweets experiment.**

In this experiment your job is to learn the extent to which each of various cakes and sweets produce headache or toothache when eaten in different places. You play the role of a doctor who has interviewed people who have recently eaten cakes and sweets. You are reviewing the information you have collected on a case by case basis. For each case you have information on which foods were eaten, the place where they were eaten, and whether there was no effect, or whether the person suffered headache or toothache after eating. Your job is to learn the extent to which each of the foods might be a cause of headache or toothache. The different places where the foods have been eaten, will be signaled by changes in the colour of the screen. Note, the sequence of trials is randomly ordered so you can only predict the outcomes by learning about the food items themselves. There will be some trials when you will be asked to indicate what your judgements are. When you have to make a judgement this will be signalled on the screen. All you have to do is follow the onscreen instructions and enter a response that reflects your judgement. Press a key to continue. Instructions will be given on how to make your rating, please take care to read all of the instructions carefully. Once you have made your judgment press return to carry on. If you have any questions please ask the experimenter now, otherwise press another key to start.

## Appendix F

### **Debriefing form**

#### **Debriefing information, causality judgement experiments.**

Thanks for taking part in these experiments. They addressed questions about the conditions under which people are able to learn about which things are most likely to be causes of significant events. For example, in a complex environment there are multiple possible causes for every event which happens. However, it would be impractical for us to pay attention to every stimulus in order to determine whether or not it was a candidate cause. If we did our processing capacity may well be overwhelmed. In fact, many experiments on learning indicate that we tend to learn most about stimuli which are informative and less about stimuli which are redundant. For example, if I had found that virus X caused illness and later saw that virus occurring with another virus Y, it is likely that I would attribute any subsequent illness to X regardless of whether or not Y contributed. Most learning theories predict that we would ignore Y in these conditions because stimulus X already “explains” the illness. This kind of mechanism allows us to reduce the number of possible causes we need to consider. The experiments you took part are part of a program of research looking various factors, such as that just described, that influence causal learning. Learning was assessed by asking you to make judgements about different kinds of cues that might play a part in a causal learning scenario. If you want more information please contact Tito Elgueta ([tee1v07@soton.ac.uk](mailto:tee1v07@soton.ac.uk)). You can find out more about this subject by looking at

Chapman, G.B. (1991). Trial order affects cue interaction in contingency judgement. *Journal of Experimental Psychology, 17*, 537-854.

Dickinson, A., & Shanks, D. (1985). Animal conditioning and human causality judgement. In L. Nilsson & T. Archer (Eds.), *Perspectives on Learning and Memory*. Hillsdale New Jersey: Lawrence Erlbaum Associates.

If you have any questions about your rights as a participant in this research, or if you feel that you have been placed at risk, you may contact the chair of the Ethics

Committee in the Dept. of Psychology, Southampton University, SO17 1BJ, Tel. 023 8059 2612. . You may contact too Research Governance Office, [rgoinfo@soton.ac.uk](mailto:rgoinfo@soton.ac.uk) or 02380 595058

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