eman ta zabal zazu

Universidad del País Vasco
Euskal Herriko Unibertsitatea

FACULTAD DE PSICOLOGÍA

Associative mechanisms of transfer of extinction across contexts and stimuli:

Studies on occasion setting and learning to learn.

Tesis doctoral

Paula Balea Carbajo

Octubre de 2018

AUTORIZACION DEL/LA DIRECTOR/A DE TESIS

PARA SU PRESENTACION

Dr. JAMES BYRON NELSON con N.I.F X7767112N y la Dra. MARÍA DEL CARMEN SANJUÁN ARTEGAIN, con N.I.F 15997712Q, como Directores de la Tesis Doctoral:

"ASSOCIATIVE MECHANISMS OF TRANSFER OF EXTINCION ACROSS CONTEXTS AND STIMULI: STUDIES ON OCCASION SETTING AND LEARNING TO LEARN"

realizada en el Programa de Doctorado en Psicología por el Doctorando Doña. PAULA BALEA CARBAJO, autorizo la presentación de la citada Tesis Doctoral, dado que reúne las condiciones necesarias para su defensa.

En Donostia, a 18 de Octubre de 2018

LOS DIRECTORES DE LA TESIS

Fdo.: James Byron Nelson   Fdo.:

María del Carmen Sanjuán

AUTORIZACIÓN DE LA COMISIÓN ACADÉMICA DEL PROGRAMA DE DOCTORADO

La Comisión Académica del Programa de Doctorado en Psicología en reunión celebrada el día 15 de Octubre de 2018 ha acordado dar la conformidad a la presentación de la tesis Doctoral titulada:

"ASSOCIATIVE MECHANISMS OF TRANSFER OF EXTINCION ACROSS CONTEXTS AND STIMULI: STUDIES ON OCCASION SETTING AND LEARNING TO LEARN"

dirigida por la Dra. Mª Carmen Sanjuan Artegain y el Dr. James Byron Nelson y presentada por Doña Paula Balea Carbajo adscrita al Departamento de Procesos Psicológicos Básicos y su Desarrollo.

En Donostia, a 18 de Octubre de 2018

EL MIEMBRO DE LA COMISIÓN ACADÉMICA RESPONSABLE DEL PROGRAMA DE DOCTORADO

Fdo.: Gabriela Chotro Lerda

AUTORIZACIÓN DEL DEPARTAMENTO

El Consejo del Departamento de Procesos Psicológicos Básicos y su Desarrollo en reunión celebrada el día 17 de Octubre de 2018 ha acordado dar la conformidad a la admisión a trámite de presentación de la Tesis Doctoral titulada:

"*Associative mechanisms of transfer of extinction across contexts and stimuli: Studies on occasion setting and learning to learn*"

dirigida por el Dr. D. James Byron Nelson y la Dra. Doña Mª del Carmen Sanjuán Artegain y presentada por Doña Paula Balea Carbajo ante este Departamento.

En Donostia, a 17 de Octubre de 2018

DIRECTOR/A DEL DEPARTAMENTO SECRETARIO/A DEL DEPARTAMENTO

Fdo.: Joxean Iraola Baquedano Fdo.: Oscar Vegas Moreno

ACTA DE GRADO DE DOCTORA

ACTA DE DEFENSA DE TESIS DOCTORAL

DOCTORANDA DOÑA: Paula BALEA CARBAJO
TITULO DE LA TESIS: *“Associative mechanisms of transfer of extinction across contexts and stimuli: Studies on occasion setting and learning to learn”*

El Tribunal designado por la Comisión de Postgrado de la UPV/EHU para calificar la Tesis Doctoral arriba indicada y reunido en el día de la fecha, una vez efectuada la defensa por la doctoranda y contestadas las objeciones y/o sugerencias que se le han formulado, ha otorgado por__________________la calificación de:
unanimidad ó mayoría

SOBRESALIENTE / NOTABLE / APROBADO / NO APTO

Idioma/s de defensa (en caso de más de un idioma, especificar porcentaje defendido en cada idioma):

Castellano ____
Euskera ____
Otros Idiomas (especificar cuál/cuales y porcentaje) ________________________

En Donostia, a 14 de Diciembre de 2018

LA PRESIDENTA, EL SECRETARIO,

Fdo.: Dra. Gumersinda Alonso Martínez Fdo.: Dr. Juan Manuel Rosas Santos

VOCAL

Fdo.: Dr. Steven GLAUTIER

LA DOCTORANDA,

Fdo.: Paula BALEA CARBAJO

eman ta zabal zazu

Universidad del País Vasco
Euskal Herriko Unibertsitatea

PSIKOLOGIA FAKULTATEA
FACULTAD DE PSICOLOGÍA

Paula Balea Carbajo

Associative mechanisms of transfer of extinction across contexts and stimuli: Studies on occasion setting and learning to learn.

DIRECTORES:

James Byron Nelson

María del Carmen Sanjuan

TESIS DOCTORAL

Octubre de 2018

Procesos psicológicos Básicos y su Desarrollo.

Facultad de Psicología.

Universidad del País Vasco / Euskal Herriko Unibertsitatea (UPV/EHU)

eman ta zabal zazu

Universidad del País Vasco
Euskal Herriko Unibertsitatea

MDe
Master eta Doktorego Eskola
Escuela de Máster y Doctorado
Master and Doctoral School

La presente tesis doctoral ha sido financiada por el Ministerio de Economía, Industria y Competitividad de España. Ayuda predoctoral BES-2015-074309, enmarcada en el proyecto PSI2014-52263-C2-2-P.

“*A vague sense of order emerges from any sustained observation of human behavior.*”

B.F. Skinner, Science and Human Behavior (1951).

Agradecimientos

En primer lugar, quiero dar las gracias a mis directores de tesis. Gracias a Byron, has sido un acompañante perfecto a lo largo de estos tres años. Me has servido de guía en todo momento, sin dejar de impulsarme a trabajar de forma autónoma y a desarrollar mis propias ideas. Eres un auténtico manual de cómo hacer ciencia. Gracias a Niki, por estar siempre disponible, por tu carácter, tu capacidad de resolver cualquier entuerto y, especialmente por la oportunidad que me has dado de aprender de la docencia. Sinceramente, tengo la sensación de haber aprendido de los mejores.

Gracias también al resto de gente del departamento. Gabriela, Joxan, gracias por hacer todo este proceso más fácil. Sindi, tu fuerza y tu dedicación a la investigación son un modelo a seguir. Gracias especialmente también a Gabi por tus consejos siempre sabios y por cuidar de los doctorandos. Ambos sois inspiradores.

Gracias al equipazo de Jaén. En primer lugar, gracias a Juanma. La vida está llena de casualidades y yo tuve la suerte de coincidir contigo en ese maravilloso congreso de la SEPC en Sevilla. Ahí comenzó esta historia. José Enrique, Jose Andrés, Pedro, Gabi… es un auténtico placer colaborar con vosotros.

Gracias a Mark por acogerme en Vermont. He disfrutado realmente de verte hacer ciencia y de verte dar clase. Eres un modelo de profesionalidad. Espero que se me haya pegado algo. Mike y Eric, gracias por vuestra paciencia conmigo durante todo ese tiempo.

Gracias a toda la gente del Laboratorio de Conducta Animal y Neurociencia de Sevilla, donde tuve el primer contacto con la investigación. Cuando estás fuera de casa tus compañeros de trabajo son lo más parecido a una familia, y así me sentí en el laboratorio. Juan Pedro, Juan Carlos, Gonzalo, Estrella, Manuel... Mención especial merecen Auxi, Juan Carlos, Capea, Paola, Lalo e Inma. Gracias por todo el tiempo que hemos pasado juntos, por las risas, por esos desayunos que tanto echo de menos y por vuestro apoyo en la distancia. Sois mis personas favoritas.

Gracias al resto de doctorandos de la facultad de psicología. Especialmente a mis compañeros de área, Unai (meu!), Asier, Fernando. Sois grandes compañeros. Manuel, gracias por tu apoyo. De no ser por ti aún estaría con la introducción de esta tesis. Y también gracias especialmente a mis compañeras de despacho: Roxa, Ixone, vuestra llegada ha sido un golpe de aire fresco. Gracias por las risas y vuestro buen humor. Flor, desde el primer día sentí que había tenido suerte al compartir despacho contigo, y no me equivocaba. Gracias por tu apoyo incondicional, en lo bueno y en lo malo, eres muy grande.

Ya fuera de la facultad, gracias a Borja y a Arantza, otra de las loterías que me han tocado en la vida, sois la mejor cuadrilla que se puede tener. Y también a Nani, qué suerte he tenido de tenerte cerca todo este tiempo, amiga.

Finalmente, gracias infinitas a mi familia. A mi padre por ser la mejor guía, a mi madre porque, simplemente, eres maravillosa, a Víctor por cuidar de todos nosotros y a mi hermana porque es una tía increíble.

Gracias!

Resumen

El aprendizaje de condicionamiento y el de extinción no se transfieren con la misma facilitad a situaciones nuevas. Mientras que la transferencia del aprendizaje excitatorio entre contextos distintos es habitual (ver Bouton, 1993, para una revisión), la investigación sobre la renovación de respuesta indica que el aprendizaje de extinción es mucho más sensible a cambios en los estímulos contextuales (p. ej., Bouton, 2004). Con respecto a la transferencia del aprendizaje de extinción entre estímulos, parece existir una dicotomía similar. Mientras que el aprendizaje excitatorio se transfiere entre estímulos (p. ej., Holt & Kehoe, 1985; Honig & Urcuioli, 1981), los estudios sobre el efecto de extinción secundaria indican que no sucede lo mismo en el caso del aprendizaje de extinción (p. ej., Kasprow, Schachtman, Cacheiro & Miller, 1984; Richards & Sargent, 1983; Vurbic & Bouton, 2011). Este paralelismo parece apoyar la idea, ya sugerida por Pavlov (1927), de que la extinción depende de procesos o mecanismos más lábiles o inestables que los que subyacen al condicionamiento. El presente trabajo aborda la transferencia del aprendizaje de extinción tanto entre contextos como entre estímulos distintos con el objetivo de dilucidar los mecanismos que subyacen al establecimiento y la recuperación de este tipo de aprendizaje.

Cuando un estímulo neutro se empareja de manera consistente con la aparición de un estímulo biológicamente relevante (o incondicionado), el primero acabará evocando las respuestas que normalmente se asocian al segundo. En este momento se dice que el estímulo neutro ha sido condicionado. Sin embargo, si las contingencias cambian y el estímulo biológicamente relevante deja de presentarse tras el estímulo condicionado, la respuesta condicionada disminuirá progresivamente hasta extinguirse. Al final de la extinción podría parecer que la respuesta al estímulo condicionado (EC) ha desaparecido, no obstante, si el estímulo se presenta en un contexto distinto a aquel en el que se llevó a cabo la extinción, la respuesta se recuperará. A este fenómeno se le conoce como “renovación de respuesta” (p. ej., Bouton & Bolles, 1979).

La teoría actualmente predominante con respecto a la renovación de respuesta explica este fenómeno asumiendo que el contexto de extinción actúa como un establecedor de ocasiones u *occasion setter*, en su término inglés (Bouton, 1993; 2004). Un estímulo funciona como un establecedor de ocasiones cuando, en su presencia, las consecuencias normalmente asociadas a otro estímulo cambian (p. ej., Ross & Holland, 1981). Así, si entrenamos a un animal en una discriminación en la que un estímulo, por ejemplo, un Tono, es reforzado (T+) excepto cuando va precedido de una Luz (L→T-), la Luz actúa modulando el significado del Tono; en este caso, *estableciendo la ocasión* para no responder ante él.

Según Bouton (1993; 2004), durante el condicionamiento se crea una asociación excitatoria entre el EC y el estímulo incondicionado (EI). Por su parte, la extinción, conlleva la formación de una nueva conexión inhibitoria entre ambos estímulos. Puesto que ambas conexiones coexisten, al final de la extinción el significado del EC es ambiguo. Bouton propone que, en esta situación, el contexto en el que se llevó a cabo la extinción modula el significado del EC igual que lo hacía la Luz con respecto al Tono en la discriminación mencionada anteriormente. El contexto resolvería la situación de ambigüedad *estableciendo la ocasión* para no responder al estímulo en su presencia. Como consecuencia, la extinción se mantendrá siempre que el contexto de extinción esté presente, pero se perderá cuando el estímulo se presente en un contexto nuevo, como sucede en un diseño de renovación de respuesta.

Una teoría alternativa a la hora de explicar la renovación de respuesta es la que se deriva del modelo propuesto por Rescorla y Wagner (1972) y el concepto de *protección de la extinción* de Rescorla (2003). Desde este marco, se entiende que la ausencia del EI durante la extinción dotaría al contexto de extinción de propiedades inhibitorias (p. ej., Glautier, Elgueta, & Nelson, 2013), lo que protegería al EC de ser extinguido en su totalidad (Rescorla, 2003). De esta manera, cuando el estímulo se presenta fuera del contexto en el que ha sido extinguido, puesto que no hay nada que inhiba la respuesta, su fuerza excitatoria se volvería a manifestar.

En el primer capítulo de este trabajo se examina la transferencia entre contextos de la extinción. Se presentan tres experimentos que trataron de determinar si el contexto de extinción cumple con una de las propiedades características de los establecedores de ocasiones. En concreto, un establecedor de ocasiones no muestra sumación con otros ECs, a no ser que éstos hayan estado involucrados en una discriminación similar; es decir, hayan sido entrenados con otro establecedor de ocasiones. Se utilizó una tarea de aprendizaje predictivo (León, Abad, & Rosas, 2011) en la que los participantes tenían que informar de la probabilidad con la que los comensales de un restaurante iban a padecer trastornos gastrointestinales tras ingerir un determinado alimento. Los distintos contextos se representaron con distintos restaurantes. El diseño experimental fue similar en los tres experimentos. Todos los participantes recibieron un test de renovación de respuesta del tipo ABC con una clave determinada (Y). Las condiciones experimentales principales difirieron en cuanto a si el contexto C era un contexto neutral o, en su lugar, una clave distinta (X) se había extinguido previamente en su presencia, convirtiéndolo así en un posible establecedor de ocasiones negativo. Si un contexto de extinción funciona como un establecedor de ocasiones debería ser capaz de transferir sus propiedades moduladoras a claves nuevas que han tomado parte en una discriminación similar (es decir, que han sido extinguidas en un contexto distinto). Por lo tanto, la renovación de respuesta debería ser menor cuando el test se realiza en un contexto donde ha tenido lugar la extinción de otra clave que cuando se realiza en un contexto nuevo.

En el Experimento 1 no se encontró renovación de respuesta en ninguna de las condiciones experimentales. Tras realizar cambios en el procedimiento destinados a simplificar la tarea, el Experimento 2 mostró renovación de respuesta, pero, en contra de lo que se esperaría si el contexto actuase como un establecedor de ocasiones, la renovación fue similar en ambos grupos. El Experimento 3 incluyó además grupos experimentales en los que una clave neutra se presentaba bien en un contexto neutral, bien en un contexto de extinción. Esto permitió poner a prueba la explicación de la renovación de respuesta derivada del modelo de Rescorla-Wagner (1972). Si el contexto se asocia de manera directa con el US, la respuesta a un estímulo neutro debería verse reducida cuando es presentado dentro de un contexto de extinción. En contra de esta idea, los resultados indicaron una respuesta similar en ambos casos. Además, al igual que en el Experimento 2, tampoco se encontró evidencia de que el contexto muestre las propiedades de transferencia características de un establecedor de ocasiones.

Los resultados de esta línea de investigación no apoyaron ninguna de las dos explicaciones más habituales al fenómeno de renovación de respuesta. Sin embargo, los datos son consistentes con la idea de que la interferencia (o el error de predicción) que se produce al inicio de la extinción, provocaría un tipo de procesamiento configuracional de los estímulos. Como consecuencia de este tipo de procesamiento de los estímulos durante la extinción, el aprendizaje de extinción dependería de la presencia de la clave única (Wagner, 2003) que resulta de la presentación conjunta tanto del contexto como del estímulo presentes durante la extinción original. Esta propuesta coincide con la de Bouton (1993; 2004) en predecir el efecto de renovación de respuesta, puesto que la clave única desaparecería cuando se elimina el contexto de extinción. No obstante, difiere de él en que no predice la transferencia de las propiedades moduladoras del contexto a otros estímulos que hayan sido condicionados y extinguidos, puesto que la sustitución del estímulo original por uno nuevo, eliminaría también la clave única que controla la extinción.

En el segundo capítulo se aborda la transferencia del aprendizaje entre estímulos. En concreto, se evaluó el efecto “aprender a aprender” tanto en el aprendizaje de adquisición como en el de extinción. El efecto aprender a aprender es un tipo de transferencia del aprendizaje que aparece entre estímulos de modalidades sensoriales diferentes cuando éstos han sido presentados en tareas con una estructura similar (p. ej. Harlow, 1949; Kehoe & Holt, 1985), y se manifiesta como una tasa relativamente rápida de aprendizaje con un estímulo como consecuencia de la experiencia previa con un estímulo distinto. Tres experimentos examinaron este efecto en humanos, tanto en el aprendizaje de condicionamiento como en el de extinción. Este último es de especial relevancia dados los fracasos en la literatura a la hora de obtener transferencia de la extinción entre estímulos distintos (ver Vurbic & Bouton, 2011, para una revisión)

Los participantes jugaron a un videojuego (Nelson, Navarro & Sanjuan, 2014) en el que debían defenderse del ataque de unas naves espaciales presionando una tecla del teclado. Durante los ensayos de condicionamiento, la aparición de estas naves (el EI) era señalada por sensores visuales o auditivos (el

EC) con cinco segundos de antelación. La tarea requería que los sujetos diesen una respuesta anticipatoria (presionar la tecla) con el objetivo de tener el arma cargada y estar listos para disparar en el momento en el que apareciesen las naves. Esta respuesta anticipatoria se utilizó como indicador del grado de asociación entre el sensor y la nave a lo largo de varias fases de condicionamiento y extinción.

En todos los casos el diseño experimental constó de cuatro fases. En el Experimento 1, el condicionamiento de un estímulo (A) en la primera fase, incrementó la tasa de condicionamiento con un estímulo B en la segunda fase. De manera similar, y en contra de lo esperado, la extinción de uno de estos estímulos en la tercera fase, facilitó la extinción del otro estímulo en la cuarta fase. La transferencia fue casi total en el segundo ensayo de entrenamiento, recordando así al aprendizaje en un único ensayo descrito por Harlow (1949) en el ámbito de la psicología cognitiva. Además, la magnitud del efecto fue similar tanto cuando A y B eran de la misma modalidad sensorial como cuando pertenecían a modalidades diferentes. Esta evidencia, unida al hecho de que la transferencia solo apareciese una vez que se había presentado la consecuencia (presencia o ausencia del EI) en el primer ensayo con un estímulo nuevo, indican que este tipo de transferencia es independiente de la generalización física entre los estímulos (p. ej., Guttman & Kalish, 1956), donde la transferencia del aprendizaje entre estímulos es inmediata. El Experimento 2, mostró que el efecto en la extinción, no se incrementó cuando los ensayos de condicionamiento con cada estímulo se presentaron de manera entremezclada, algo que según Vurbic y Bouton (2011) debería favorecer un efecto de extinción mediada. En el Experimento 3, las fases se reordenaron, de manera que la extinción y el condicionamiento del segundo estimulo (B) se llevaron a cabo después de que el estímulo A fuese condicionado y extinguido. El objetivo de este cambio era determinar la posible contribución de tres potenciales fuentes para la transferencia del aprendizaje: la posible representación compartida del estímulo incondicionado, una historia de reforzamiento común, y la presencia de asociaciones intracompuesto entre los estímulos. Si el efecto aprender a aprender se basa en alguno de estos mecanismos, no debería aparecer cuando en la secuencia de entrenamiento el primer estímulo se extingue antes de iniciar el entrenamiento con el segundo. Los resultados mostraron una transferencia tanto del condicionamiento como de la extinción comparable a la hallada en los experimentos anteriores.

Los resultados sugieren que el efecto aprender a aprender es una forma emergente (no inmediata) de generalización mediada en la que el error de predicción producido en el primer ensayo con un nuevo estímulo tendría un papel clave. Así, la presencia (en el condicionamiento) o ausencia (en la extinción) del EI en este primer ensayo podría actuar como una clave en sí misma capaz de evocar episodios anteriores asociados con errores de predicción similares, promoviendo así la transferencia del aprendizaje. Además, el hecho de que la extinción de un estímulo se beneficiase de la extinción previa a otro estímulo en la misma medida en la que lo hizo el aprendizaje excitatorio, indica que la extinción no es en sí misma un tipo de aprendizaje lábil o inestable (Pavlov, 1927).

Las dos líneas de investigación son consistentes en indicar que la extinción no implica la eliminación total de la respuesta adquirida durante el condicionamiento (p. ej., Bouton, 1993). Por un lado, los experimentos sobre la transferencia entre contextos mostraron renovación de respuesta tras la extinción. Por otro lado, el Experimento 3 de la serie sobre aprender a aprender mostró que puede haber una transferencia rápida del condicionamiento tras la extinción. Ninguno de estos efectos se esperaría en el caso de que la extinción eliminase totalmente la respuesta condicionada.

En general los resultados de ambas líneas indican que el error de predicción podría tener distintas funciones en el aprendizaje asociativo. Los modelos formales del condicionamiento (e.g., Pearce & Hall, 1980; Rescorla & Wagner, 1972) entienden que el error de predicción se utiliza para ajustar la fuerza asociativa de los estímulos, de manera que sean capaces de predecir de manera adecuada las consecuencias de estos estímulos. No obstante, el presente trabajo indica que esta podría ser solo una de sus funciones. Por un lado, los resultados de la primera serie de experimentos indican que el error de predicción negativo generado durante la extinción impulsaría un tipo de procesamiento configuracional. Por otra parte, la serie de experimentos sobre el efecto aprender a aprender indica que el error de predicción podría actuar como una clave en si misma capaz de evocar episodios de aprendizaje anteriores. Estos hallazgos abren diversas preguntas en cuanto a cómo es representado el error de predicción de manera que sea capaz de cumplir todas estas funciones.

Abstract

Conditioning and extinction do not transfer equally to new situations. While transfer of excitatory learning is often observed, research on the renewal and secondary extinction effects indicates that extinction learning is particularly resistant to transfer across contexts and stimuli.

The prevalent theory regarding renewal (Bouton, 1993; 2004) explains this phenomenon by appealing to the extinction context functioning as a negative occasion setter. A predictive learning task was used in three experiments with human participants to test the extinction context for one of the main properties of occasion setters: the ability to modulate responding to other stimuli that have taken part in another occasion-setting discrimination. The experimental design was similar in all experiments. In the key conditions, participants received an ABC test for renewal with a give cue (Y). Groups differed on whether context C was a neutral context or was one that was previously established as a possible negative occasion setter by having extinction of another cue (X) within it. If there is transfer of negative occasion setting, the renewal observed in an extinction context should be diminished. Across all three experiments, with variations in the designs, no transfer of extinction was observed when testing took place in a context where extinction of another CS had taken place. The results indicate that the contexts do not function as negative occasion setters. Instead, it appears that extinction performance depends on the presence of a unique cue that results from the joint presentation of both the context and the cue that were present during extinction.

Learning to Learn (LTL) is the transfer of learning, separate from stimulus generalization, that appears across stimuli involved in tasks that have a similar structure. Three experiments used videogame task to examine this phenomenon in both conditioning and extinction learning in humans. The latter effect is of special interest given the failures in the literature to obtain transfer of extinction between stimuli. Conditioning and extinction with one stimulus

increased the rate of conditioning and, surprisingly, extinction of a different stimulus (Experiment 1). The effects appeared in the absence of physical generalization. The transfer of extinction was not enhanced by conditions that increased the chances of a mediated extinction effect (Experiment 2). Finally, Experiment 3 ruled out three possible sources for the effect in extinction: a common unconditioned-stimulus representation, a common reinforcement history, and within-compound associations. In all cases transfer was almost complete after a single trial. Overall, the findings are consistent with the idea that LTL is an emergent (non-immediate) form of mediated generalization that is dependent upon memory structures retrieved by trial outcomes. The over- or under-prediction of the outcome on the first trial with a new task might retrieve prior episodes associated with similar prediction errors promoting transfer.

Overall the results from both lines indicate that the error in prediction can serve different functions. The prediction error generated during extinction might trigger a configural processing of the stimuli. Additionally, this error may serve as a retrieval cue itself, with the ability to evoke prior learning episodes.

Index

Index of figures

Chapter 1. Transfer of extinction across contexts.

Chapter 2. Transfer of extinction across stimuli.

Index of tables

Chapter 1. Transfer of extinction across contexts.

Chapter 2. Transfer of extinction across stimuli.

Introduction

To survive, organisms have to identify the significant stimuli in their environment and respond according to the biological relevance of those stimuli. Classical conditioning, a presumably simple form of learning, serves such a function by allowing the organisms to adjust their behavior to stimuli based on their ability to predict significant events in this environment. For instance, animals forage based on the presence of cues that predict food, use signals for fearful events to avoid or prepare for dangerous outcomes, and so forth. Simple associative learning also underlies human behaviors, from something as simple as to take the umbrella when the sky is grey to complex cognition (McLaren et al., 2018). Associative learning is relevant to understand maladaptive behaviors as well, such as phobias (e.g., Mineka & Zinbarg, 2006).

Relationships in the environment are not static. The relationship between stimuli and their consequences may change across time or situations. What used to be a safe place for an animal can become dangerous, what used to be a good location for foraging for food may not be good anymore. Thus, organisms often have to learn new information that interferes what has been previously learned. Both what is known about the stimulus and the correct response in its presence must be updated accordingly.

In the laboratory these situations are studied by associating a stimulus with contradictory outcomes in different experimental phases (see Bouton, 1993 for a review). The most extensively studied of these situations is extinction, where a stimulus is paired with a significant outcome in a first phase, and not followed by anything in the second phase. Consider an experimental preparation where a rat is presented with a light (Conditioned Stimulus, CS) that is consistently followed by delivery of a shock (Unconditioned Stimulus, US). After several presentations of the compound light-shock, the animal will acquire a freezing response in the mere presence of the light, as if the light elicited fear. Then, at some point, extinction begins and the light is no longer followed by the shock. In such a situation, after enough light-alone presentations, the rat stops freezing and the previously-acquired response is said to be “extinguished” (e.g., Wagner, Siegel, & Fein, 1967).

Several questions remain unresolved about the nature of extinction learning. Does extinction simply inhibit a behavior that remains in the behavioral repertoire, or remove it entirely? Does the learning that occurs in acquisition and extinction have the same properties? These questions have inspired decades of investigation and, yet, many aspects remain unsolved. The goal of this dissertation is to investigate the associative mechanisms that are predicted to be involved in extinction learning and will further explore the similarities and differences between simple conditioning and extinction learning with regards to how these processes transfer across stimuli and contexts.

The Rescorla-Wagner theory (Rescorla & Wagner, 1972) is a starting point for understanding the mechanisms of conditioning and extinction. According to their model learning is a process by which the subject uses prior experiences to adjust its expectations until they fit the current state of affairs. For instance, when a CS is first conditioned, the US is surprising and that generates a large discrepancy (or, *prediction error*) between the animal's expectation about the CS and what actually occurred after its presentation. This discrepancy results in the stimulus gaining associative strength until the prediction error equals zero. At that point the US is accurately predicted by the CS and learning stops. The opposite process is assumed to underlie extinction. When extinction begins, the subject has the expectation of the US after the CS. Therefore, the absence of the US generates a mismatch between the subject's expectations and reality, producing a new prediction error. This overprediction of the US leads to a decrement in the associative strength of the stimulus until the error in prediction equals cero. Thus, according to the Rescorla-Wagner (1972) model, extinction of a response implies *unlearn* that response.

If, as Rescorla and Wagner (1972) suggest, responses to a stimulus depend exclusively on its associative strength, the conditioned response (CR) should disappear after extinction of the CS. However, extinction of a response is rarely definitive. A CR may be recovered by means of the mere passage of time (*spontaneous recovery*, [e.g., Pavlov, 1927; Robbins, 1990]), by unsignaled presentations of the US (*reinstatement*, [e.g., Rescorla & Heth, 1975]) or when the animal is tested out of the extinction context (*renewal* [e.g., Bouton & Bolles, 1979]). Another related effect is *rapid reacquisition*, where after extinction, presenting the subject with new CS-US pairings results in a rapid reacquisition of the CR (e.g., Napier, Macrae, & Kehoe, 1992). In a manner of speaking, in all of these phenomena the organism relapses into a previous state with the loss of the new learning that took place in extinction. Together, all these effects indicate that extinction does not result in an elimination of the original associative link between the CS and the US which, instead, seems to be only temporarily suppressed (see Bouton, 1993, 2004; Todd, Vurbic, & Bouton, 2014, for further discussion).

These relapse phenomena are not necessarily incompatible with the Rescorla-Wagner approach. According to their model, extinction of a CS will be definitive only when considering the CS in the modelling process. However, to the extent that other stimuli (e.g., contextual stimuli) are present, those stimuli can acquire inhibition and protect the CS from losing associative strength (see Delamater & Westbrook, 2014, for discussion; Rescorla, 2003). However, the investigations surrounding these phenomena (e.g., Bouton, 2004) agree more with theories that understand extinction as the acquisition of new learning that coexists with the previously established excitatory association (e.g., Bouton, 1993; Konorski, 1948; Pearce & Hall, 1980).

The theory that is perhaps most often applied regarding extinction is that proposed by Bouton (1993). According to Bouton, during conditioning an excitatory link emerges between the CS and US, while extinction results in the formation of a new, inhibitory link, between both stimuli. Since both types of connections coexist, at the end of extinction the meaning of the CS is ambiguous. The central notion of Bouton's (1993) proposal is that the link that is retrieved in a given situation is going to be guided by contextual stimuli. That is, the context will serve to disambiguate the meaning of stimuli that have been paired with contradictory outcomes. Importantly, Bouton understands the context in a broad fashion, which may include not only physical backgrounds but also changes in context accompanying the passage of time as well as contexts formed by different internal states (Bouton, 2004; Bouton, 2002). Extinction learning could experience retrieval failure from the absence of any of these contextual cues when the CS is tested, resulting in a recovery of the response.

A core assumption of Bouton’s theory is that the contextual control of the inhibition assumed to be learned in extinction functions according to an “occasion setting” mechanism (Bouton & Nelson, 1994; Bouton, 1993, 2004). That is, contexts are assumed to act as occasion setters in extinction. An occasion setter (e.g., Holland, 1992) is a stimulus that modulates responding to other stimuli by indicating whether or not the stimulus is going to be followed by the reinforcer. Consider a Light that is consistently reinforced unless preceded by a Tone. In these circumstances, the Tone is said to modulate responding to the Light, setting the occasion to not respond to it.

Occasion setters show certain properties that differentiate them from common CSs. For instance, their ability to modulate responding to other stimuli is independent of their own direct association with the US (e.g., Holland, 1984; Nelson & Bouton, 1997). While it has been argued that these properties are shared by contexts (e.g., Trask, 2017), the evidence is not so clear as might be expected. In particular, one of the principle characteristics, the “transfer” properties of occasion setters, have not been assessed in contexts that appear to control extinction performance. The first chapter of this dissertation reviews the properties of occasion setting that are relevant to extinction along with the evidence that contexts share those properties. Three experiments assessed the adequacy of Bouton’s theory (Bouton, 1993, 2004) by directly examining whether extinction contexts exhibit the transfer properties of occasion setters.

Another core assumption of Bouton’s proposal is that different memories are differentially dependent on context. Extinction is assumed to be more dependent on contextual cues than excitatory learning. This idea has received consistent support. Thus, while conditioning seems to transfer well across contexts (see Bouton, 1993, for review), with some limitations (e.g., Hall & Honey, 1990), extinction learning has shown to be consistently more sensitive to changes in the environmental stimuli (e.g., Bouton, 2004).

Interestingly, a similar dichotomy between conditioning and extinction may exist with regards to the transfer of these processes across stimuli. Kehoe, for example, has extensively studied learning-to-learn effects (e.g., Kehoe, 1988), the transfer of learning that appears across stimuli in different sensory modalities. For instance, by using the nictitating membrane response of rabbits as a measure, he has demonstrated that conditioning of a stimulus can be greatly facilitated by prior conditioning of a stimulus from a different modality (e.g., Holt & Kehoe, 1985; Kehoe & Holt, 1984; Schreurs & Kehoe, 1987), even after the former has been extinguished (e.g., Kehoe, Morrow, & Holt, 1984). His results lead him to articulate a model of learning that assumes that, after a CS has been conditioned, excitatory associations are coded or stored in two different (yet related) links, one that is CS dependent and one that is CS independent. The CS-independent link would permit any stimulus to gain access to some of the learning initially created, allowing not only rapid reacquisition, but also acquisition of the same CR to a different CS. Notably, according to Kehoe, the CS-independent excitatory link will not be affected by extinction. This assumption has two consequences. First, rapid CR acquisition would occur even after the original CS has been extinguished and, second, extinction of any stimulus will require the same effort regardless of whether extinction of a different stimulus has occurred or not. Thus, conditioning is expected to transfer across stimuli, while extinction is not. Some evidence exists suggesting that transfer of extinction across stimuli may be difficult (e.g., Vurbic & Bouton, 2011), but this question has received little systematic exploration.

There may be a correlation between contextual control and learning-to-learn effects. Context effects are not as easily seen on simple conditioning as on extinction (Bouton, 1993) and learning-to-learn effects are more easily seen in simple conditioning (e.g., Holt & Kehoe, 1985) than in extinction (e.g., Kasprow, Schachtman, Cacheiro, & Miller, 1984; Vurbic & Bouton, 2011). Understanding these parallels, in particular the more elusive effect on extinction, may help elucidate the mechanisms that account for extinction learning. If extinction is generally a more “labile” process as discussed by Pavlov (1927), then little transfer of extinction should be observed across contexts or stimuli.

The second chapter, recently published in *Behavioral Processes* with minor changes, will address the transfer of extinction across stimuli. The literature regarding differential transfer of acquisition and extinction across stimuli will be reviewed and I will present 3 experiments that were designed to study transfer of both acquisition and extinction across stimuli, while trying to unravel the mechanisms underlying them. Both chapters will be followed by a final discussion where I will combine the outcomes derived from both lines of research and comment on their contributions to the current knowledge about the associative mechanisms of memory retrieval of extinction learning.

Chapter 1

Transfer of extinction across contexts

Introduction

As discussed briefly in the general introduction, extinction of a response is usually context specific. When a context change occurs between extinction and testing, the response is “renewed”. Such a renewal experiment is composed of three phases: acquisition, extinction and testing. Depending on the identity of the contexts where each of these phases takes place, 3 types of renewal have been defined. The simplest and most robust form is ABA renewal (Thomas, Larsen, & Ayres, 2003). Here, the response is acquired in context A, extinguished in a different context (B), and recovered when tested back in the conditioning context (A) (e.g., Bouton & Bolles, 1979). A second form is ABC renewal, where each phase is conducted in a different context (e.g., Denniston, Chang, & Miller, 2003). Finally, in AAB renewal, acquisition and extinction occur in the same context, and the test is done in a different one (e.g., Bouton & Ricker, 1994; Tamai & Nakajima, 2000). Ultimately, in all of these designs, an extinguished response will be recovered when the CS is tested out of the extinction context.

Beyond its relevance for understanding mechanisms of learning, the context specificity of extinction is of relevance from a clinical perspective. This relevance is particularly clear when therapy consists of eliminating already-established maladaptive behaviors. In such cases, leaving the therapeutic context, which usually acts as the extinction context, may result in renewal of the dysfunctional behavior (see Bouton & Nelson, 1998; Bouton, 2000; for discussion).

There are multiple explanations for why a response can recover after extinction, though not all mechanisms proposed can fully account for results observed in renewal-related studies. Perhaps the most straightforward explanation is that, during extinction, the absence of the expected unconditioned stimulus results in the context acquiring inhibitory properties. Thus, extinction can be viewed as Pavlov’s (1927) conditioned inhibition design, with an X+/BX- discrimination being carried out between phases. In the first phase, the X+ trials establish a conditioned response to X. Then, in a second phase, BX-, extinction of X is accompanied by the extinction context (B), which may serve as the negative feature and become inhibitory. This explanation is in line with formal theories of learning such as that proposed by Rescorla and Wagner (1972), according to which non-reinforcement of a CS during extinction results in the context acquiring inhibition (Cunningham, 1979; Glautier et al., 2013; Polack, Laborda, & Miller, 2012). Interestingly, the inhibition accrued to the context would protect the CS from losing associative strength (Rescorla, 2003; Soltysik, Wolfe, Nicholas, Wilson, & Garcia-Sanchez, 1983). Therefore, when the subject is removed from the extinction context, there is nothing that inhibits the response, and the preserved excitatory strength of the CS is manifested.

Support for this account is mixed. Although some studies have shown conditioned inhibition to the context (Cunningham, 1979; Glautier et al., 2013; Polack et al., 2012), others have not (e.g., Baker, McNally, & Richardson, 2012; Bouton & King, 1983; Bouton & Swartzentruber, 1986, 1989; Grahame et al., 1990; Nelson et al., 2011). Moreover, even if contexts may acquire inhibition under some conditions, several studies have shown that inhibitory context-US associations are not necessary to obtain renewal (Bouton & Bolles, 1979; Bouton & King, 1983; Bouton & Swartzentruber, 1986, 1989; Holmes & Westbrook, 2014; Westbrook, Jones, Bailey, & Harris, 2000). Therefore, a full account of the renewal effect requires a different explanation.

A widely accepted alternative has been suggested by Bouton (e.g., Bouton, 1993, 2004). Bouton’s conceptualization of extinction differs from that of Rescorla and Wagner (1972). Rescorla-Wagner’s theory, and other similar linear models, predict that presentation of the CS in the absence of the US results in a loss of the associative strength accrued to the stimulus. Implicitly, they describe extinction as a process opposed to conditioning that eliminates the previously acquired learning. Bouton, instead, contends that extinction involves the acquisition of a new, inhibitory association between the CS and the US that coexists with the excitatory link that was established during conditioning. Although it was Bouton who applied this notion to the explanation of the renewal effect, the idea that extinction does not destroy the previous learning is not new, going back to Pavlov (1927), expressed somewhat differently by

Konorski (1948) in a form that is present in the work of Wagner (1981) and his subsequent theorizing (Wagner, 2003; Wagner & Brandon, 1989).

Bouton's approach to extinction and renewal is embedded in the model shown in Figure 1. The model assumes that a context-independent excitatory association develops between the stimulus and the US, or the US representation (as is shown by the arrow between bubbles in Figure 1) during conditioning with a stimulus. Then, extinction produces new, inhibitory learning, that counteracts the previous meaning of the stimulus (represented by the blocked line in Figure 1). Such interference might cause the animal to pay attention to the context in which extinction is taking place as a way to disambiguate the CS's meaning (Bouton, 1997; Nelson, Fabiano, & Lamoureux, 2018; Rosas, Aguilera, Álvarez, & Abad, 2006). The result is that inhibition of the response becomes dependent on the presence of both the stimulus *and* the context (shown by the convergence of input from the CS and the Context in Figure 1). From this point, the way in which renewal is explained by the model is straightforward. To the extent that the CS is tested out of the extinction context, the inhibitory link will not be activated, and the excitatory association will be expressed.

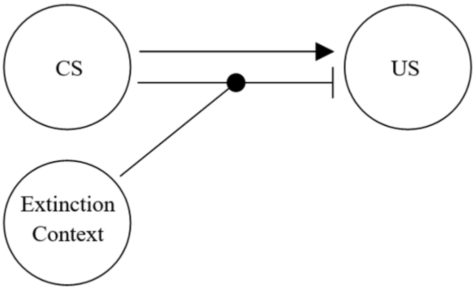


Figure 1. Bouton's (1993) model of extinction. The arrow represents an excitatory association; the blocked line represents an inhibitory association, which is dependent on input from both the CS and the context for expression. Modified from Nelson et al., (2011) with permission.

The role of the context in Bouton's model has been specifically described as an occasion-setting mechanism (Bouton, 1993, 2004). The reason is that, while conventional conditioned stimuli are used to predict the presence of a given outcome, occasion setters (OS) are stimuli that seem to inform on *whether* another stimulus (the CS) is going to be followed by the outcome, or not (Bouton, 1997). In the case of renewal, the extinction context might serve to predict that the CS is not going to be followed by the US.

In the laboratory, two main procedures are known to endow a stimulus with occasion-setting properties: serial feature-positive and serial feature-negative discrimination training. In a serial feature-positive discrimination, a target stimulus (T) is not reinforced (T- trials), unless presented after another stimulus that serves as a positive feature (F), or positive occasion setter (F→T+ trials). In a serial feature-negative discrimination, the arrangement is the opposite; the stimulus is reinforced when presented alone (T+ trials), but not when preceded by the negative feature (F→T- trials). Occasion setting is also obtained with simultaneous presentations of the feature and target stimuli, but in those cases the feature is designed to be much less salient than the target (e.g., Holland, 1989). Indeed, it may be that occasion setting is more probably obtained with a serial presentation of the stimuli because this type of arrangement reduces the salience of the feature in the compound (and therefore its chances to establishes direct associations with the US), particularly when its presence is only a memory trace (Ross & Holland, 1981). As suggested above, the result of procedures that produce occasion setting is that the feature seems to "set the occasion" for responding to the target, indicating whether the target is going to be reinforced or not (Ross & Holland, 1981) rather than controlling the response directly.

One of the hallmarks of occasion setters is that they seem to affect responding to other CSs through a mechanism that is independent of their direct association with the US. Thus, it has been found that manipulations (reinforcement or extinction) of an occasion setter do not remove its ability to modulate responding to a target (e.g., Holland, 1984; Nelson & Bouton, 1997). For instance, by using an appetitive procedure with rats, Nelson and Bouton (1997) showed that when a light was trained as a negative OS (i.e., an otherwise reinforced tone was not reinforced when followed by the light), reinforcement of the light did not abolish its ability to suppress responding to the tone.

As can be inferred from the result just described, another hallmark of OSs is that, contrary to normal CSs, they do not summate with other stimuli (Holland, 1986). Instead, they best transfer their modulatory power to other targets that have taken part in a similar discrimination (Davidson & Rescorla, 1986; Holland, 1989; Lamarre & Holland, 1987; Rescorla, 1985; Swartzentruber, 1995). An experiment by Lamare and Holland (1987) may help to illustrate this property. Using a conditioned suppression procedure with rats, the authors paired a Tone and a Noise with the delivery of a shock (T+, N+). Then all the animals received discrimination training where the tone continued to be reinforced but serial presentations of a Houselight and the Tone were not (T+, H→T-). The groups differed in whether the Noise took part in a similar serial feature-negative discrimination with a Panel Light preceding it (N+, P→N-) (Serial group) or was left as a simple excitor (N+) (Excitor group). During the test, responding to both the Noise and a new compound of the Houselight and the Noise were assessed (N, H→N). The results showed that conditioned suppression to the Noise alone was strong in both groups. However, the Houselight was able to reduce suppression to the Noise only in the Serial group, for which the Noise was trained as the target of another feature negative discrimination, having no effect in the Excitor group. That is, the negative occasion setter only affected a stimulus that had been trained (or occasion set) in a similar occasion-setting relationship.

The first two phases of a renewal design can be viewed as a feature-negative discrimination, as the CS is reinforced during conditioning (CS+ trials) but not reinforced when accompanied by the extinction context (Extinction context → CS – trials). Moreover, given the different temporal attributes of each type of stimulus (the punctate nature of the CS and the more continuous presence of the context), presentation of the stimulus within the extinction context would resemble a serial presentation of the stimuli. In the test, since the negative occasion setter (the extinction context) is not present, the excitatory meaning of the CS would be expressed. That is, the context can be understood as a feature that sets the occasion for retrieval and expression of the second-learned inhibition.

Despite these similarities between a renewal design and a feature-negative discrimination, there are also differences that might question the validity of an occasion setting mechanisms as a proper model for renewal. For example, producing occasion setting in the laboratory usually requires extensive training where reinforced and non-reinforced trials are presented in an intermixed manner. However, renewal is observed after relatively short training, and conditioning and extinction trials occur in sequence. Therefore, while there are conceptual similarities, occasion setting discriminations are substantially different procedurally from a simple conditioning-and-extinction sequence.

One way to assess whether contexts can serve as occasion setters (and therefore support Bouton’s account of renewal) is to test them for the properties of occasion setters. As mentioned before, a first hallmark of occasion setters is that they do not summate with simple CSs. Applied to contexts, conditioning or extinction of the context should not affect its ability to modulate responding its target. According to the second hallmark, the contexts should be able to transfer their modulatory power only to other stimuli that have served as a target in a different serial feature discrimination. For instance, if a cue (Y) is trained in an ABC renewal design, and the test context (C) has had prior extinction within it with a different cue (X) (i.e., has been trained as a negative occasion setter), C should be able to reduce renewal to Y. That is, renewal should be attenuated in a context where some other stimulus has been extinguished.

A recent review by Trask, Thrailkill, and Bouton (2017) has discussed these parallels between occasion setters and contexts. The main conclusion of their review is that, in Pavlovian extinction, contexts function as occasion setters. However, much of the evidence reviewed by Trask et al. may not be as strong as assumed, and the paper might underestimate evidence that challenges an occasion-setting account of extinction. The following paragraphs briefly review these inconsistencies, as a full review is beyond the scope of this introduction.

With respect to the first property, several studies have shown that contexts and CSs do not summate (e.g., Bouton & King, 1983; Bouton & Swartzentruber, 1986, 1989; see Trask et al., 2017, for further review). However, it seems that this idea may have been overstated. There are many examples where contexts show summation with CSs (Cunningham, 1979; Durlach, 1983; Glautier et al., 2013; Grau & Rescorla, 1984; Miller, Grahame, & Hallam, 1990; Polack et al., 2012; Rescorla, 1984). Moreover, although the ABA-type of renewal may be explained as the result of an excitatory summation between the test context and the CS, in ABC renewal this reasoning does not apply since test is done in an associatively neutral context. Therefore, it is clear that renewal does not necessarily depend on excitatory summation between the context and CS, but it is an overstatement to say that contexts and CSs generally do not summate.

The present research is focused on the transfer property of occasion setters. Despite its relevance for validating a model of the context specificity of extinction, this property of contexts has not been directly addressed following extinction. One of the studies discussed by Trask et al., (2017) to this respect is an experiment by Swartzentruber and Bouton (1988). By using a conditioned suppression task, these authors trained rats with Tone-US pairings in context A, alternated with Tone-alone presentations in context B. Similarly, a Light was reinforced in context C, but not reinforced in context D. The Light was then tested in its training contexts (C and D) and also in A, to see whether a presumably positive occasion-setting context (A) would enable suppression to responding to the Light. The results showed that context A transferred its modulatory power to the Light. That is, responding to a target trained in a supposedly positive OS context (the Light) was maintained when tested in a different positive OS context (Context A).

Trask et al. (2017) presented this work as evidence that the context shows transfer properties. However, there is at least one alternative explanation for Swartzentruber and Bouton (1988) results. It is possible that the recovery of the response to the Light in context A was simply due to the stimulus being tested out of the context where it was non-reinforced, e.g., its “extinction context,” thus demonstrating renewal. Therefore, at least in their experiment, there is no need to appeal to any transfer property of the contexts as the source for responding. Moreover, to the extent that the result represents transfer of positive occasion setting, this experiment does not necessarily bear on the conclusion that simple conditioning and extinction endow contexts with *negative* occasion-setting properties, which is the core assumption of the occasion setting-account for renewal.

As just discussed, the most compelling evidence in favor of Bouton's (1993, 2004) account of renewal would come from a demonstration of the context showing the transfer properties of a negative occasion setter. A study that begins to address that possibility is one by Swartzentruber (1993) with pigeon autoshaping. In his experiment, a cue X was conditioned in Context A, and extinguished (i.e., occasion set) in Context B. A different cue Z, was similarly conditioned in C and extinguished in D. Presumably, this training should have endowed contexts B and D with negative occasion-setting properties. After training, responding to both X and Z was assessed in contexts A, B, C, and D. As expected, when tested in the contexts where the stimuli were conditioned there was a renewal of the response. It did not matter whether the stimuli were tested in the context where they were conditioned (i.e., ABA renewal), or in the context where the other stimulus was conditioned (i.e., ADC renewal). The animals showed extinction performance when tested in the context where the stimulus had been extinguished. But, interestingly, no recovery of the response was found when the stimuli were tested in the context where the *other* stimulus had been extinguished, although that test would conceptually be an ABC test for renewal. Therefore, it appeared as though transfer of negative occasion setting was observed, as though the contexts were able to transfer their modulatory power to another cue that had itself been occasion set.

The experiment by Swartzentruber (1993) appears to show that extinction contexts can acquire some property that transfers to other stimuli. However, that that property is occasion setting cannot be inferred, because the same result would be expected if the extinction contexts were inhibitory (Cunningham, 1979; Glautier et al., 2013; Polack et al., 2012). That is, the contexts might have suppressed responding to any CS, rather than only one that had undergone extinction, as an occasion-setting account would require.

More recently, Todd (2013, Experiment 4) conducted an experiment with the same objective: to determine whether an extinction context would demonstrate the transfer property of an occasion setter. Todd's (2013) design can be seen in Table 1. He trained rats to perform an operant response (R1) in context A, and a different response (R2) in context B. The same food outcome was used in both cases and the R2 response was the response of interest in the experiment. During the extinction phase, all animals had extinction of R2 in context A, but differed in the treatment they received with R1. While the Ext-B group had extinction of R1 in context B, the Ext-C group had extinction of R1 in a different context (context C). After training, both groups were tested for R2 responding in the context where it had been extinguished (A), or in the context where it had been trained (B). For the Ext-C group, the test in B (the conditioning context) should produce renewal. And the same should be true of the Ext-B group, unless extinction of the alternate response (R1) in B, endowed context B with negative occasion-setting properties.

Inconsistent with the idea that the extinction context acted as a negative occasion setter, the results showed robust and equivalent renewal in both groups. It should be noted that this was operant conditioning and that there is evidence (also reviewed in Trask et al., 2017) that suggest that, in instrumental procedures, the context is more likely to act as a conditioned inhibitor of the response itself. In that case, inhibition of R2 would not be expected to affect R1. Another issue arises from the complexity of occasion setting. Designs that look for occasion setting, or desire to rule it out as a mechanism, must consider several confounding variables. Thus, one problem with the conclusion that no occasion setting was observed in the Ext-B group is that the test took place in a context where both conditioning and extinction occurred, something that could make the context an "ambiguous" occasion setter (Holland, 1991; Holland & Reeve, 1991). That is, context B could have acquired positive occasion setting properties with respect to R2 and negative occasion setting properties relative to R1.

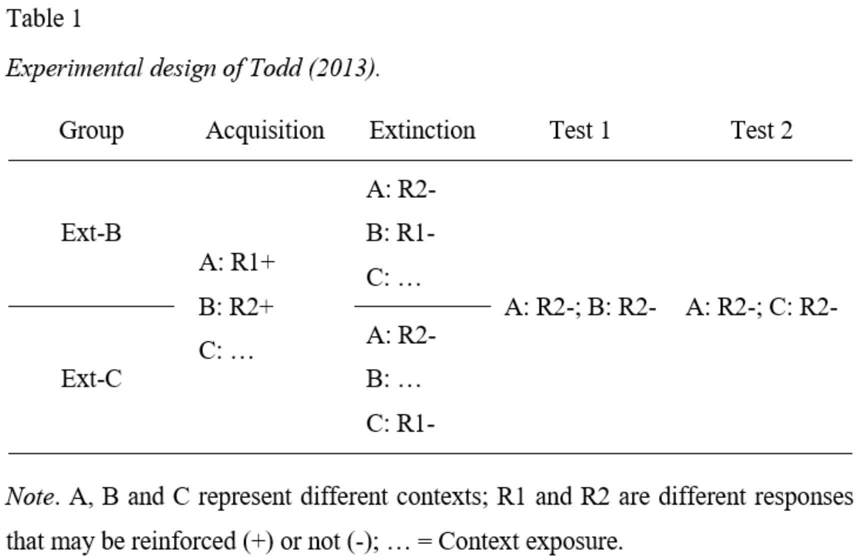


Table 1

Experimental design of Todd (2013).

Group	Acquisition	Extinction	Test 1	Test 2
Ext-B	A: R1+ B: R2+ C: …	A: R2- B: R1- C: …	A: R2-; B: R2-	A: R2-; C: R2-
Ext-C		A: R2- B: … C: R1-		

Note. A, B and C represent different contexts; R1 and R2 are different responses that may be reinforced (+) or not (-); … = Context exposure.

Although conclusions regarding occasion setting are clouded in test 1 by the possibility of the renewal context being an ambiguous occasion setter, that criticism does not apply to the second test. On test 2, the rats were tested again within the extinction context (A) and also in C. Given that C was established as a negative occasion setter only in the Ext-C group, transfer could appear only in that group. The results showed that, renewal was not reduced in this group. If anything, renewal was bigger when the testing context was trained as a potential occasion setter. The renewal on test 2 was considerably smaller than in test 1, which could restrict the range in which to observe transfer.

The idea that the context could be an ambiguous occasion setter prevents us from drawing firm conclusions regarding many experiments that control the conditioning and extinction histories of the contexts (e.g., Campese & Delamater, 2013; Delamater, Campese, & Westbrook, 2009; Grahame et al., 1990; Lovibond, Preston, & Mackintosh, 1984; Rescorla, 2008). For example, using a design similar to Todd (2013), Rescorla (2008) autoshaped pigeons such that cue X was reinforced in context A, and cue Y was reinforced in context B. Then, each cue was extinguished in the alternate context. After this training, if extinction renders the extinction context as a negative occasion setter, or a conditioned inhibitor, then all contexts should be equal with respect to those mechanisms and no recovery would be expected. The results showed that, when tested in the context where the cue was extinguished, extinction was observed. However, when a cue was tested in the context where it was initially trained, there was a recovery of the response, even though extinction of the alternate cue had taken place in that context. So either the contexts were not occasion setters, or had become ambiguous occasion setters after the extinction phase. Even if the conditioning context is not specifically trained as a positive occasion setter during the first phase, it could have acquired such properties after extinction occurred. Indeed, there is evidence that extinction does retrospectively alter the properties of the conditioning context (Harris, Jones, Bailey, & Westbrook, 2000). Recovery has been observed in all experiments employing this balanced design with the exception of Lovibond et al., (1984) and Grahame et al., (1990).

To fully assess an occasion setting account, a design must manipulate the status of the test context. In one condition the test context should have extinction conducted in it so that it might acquire some ability to control extinction performance, while in another condition no such extinction should have occurred. That alone is not enough, as occasion setting should only transfer to targets that have themselves been occasion set. For example, the transfer result obtained by Swartzentruber (1993) does not permit differentiation between occasion setting which should only operate on an extinguished "occasion set" stimulus, or conditioned inhibition, the latter of which should operate on any CS paired with the same outcome. Thus, the test target should be one that has been extinguished (potentially occasion-set) or not. Therefore, a full 2 (target occasion set by extinction or not) × 2 (test context being an occasion setter by way of extinction, or not) is required.

To my knowledge, the only attempt to assess the transfer properties of the context while distinguishing between a conditioned inhibition and an occasion setting account is a presently unpublished experiment conducted in our research group using a behavioral suppression task with humans designed by Nelson and Sanjuan (2006). The design of the experiment can be seen in Table 2. In a video-game task a red sensor (R) predicted an attack in context A and a green sensor (G) predicted the attack in context D. Then, in the extinction phase, R, the target stimulus, was extinguished (occasion set) or not in context B. The second experimental manipulation also occurred in the extinction phase, where the alternate stimulus, G, was extinguished or not in context C. Therefore, the test context (C) was either trained as an occasion setter by having extinction of G within it, or not.

Note that, as done by Todd (2013, Experiment 4, test 2), this was an ABC design where no conditioning with the test target took place in Context C, so that there is no problem with the test context potentially serving as an ambiguous occasion setter.

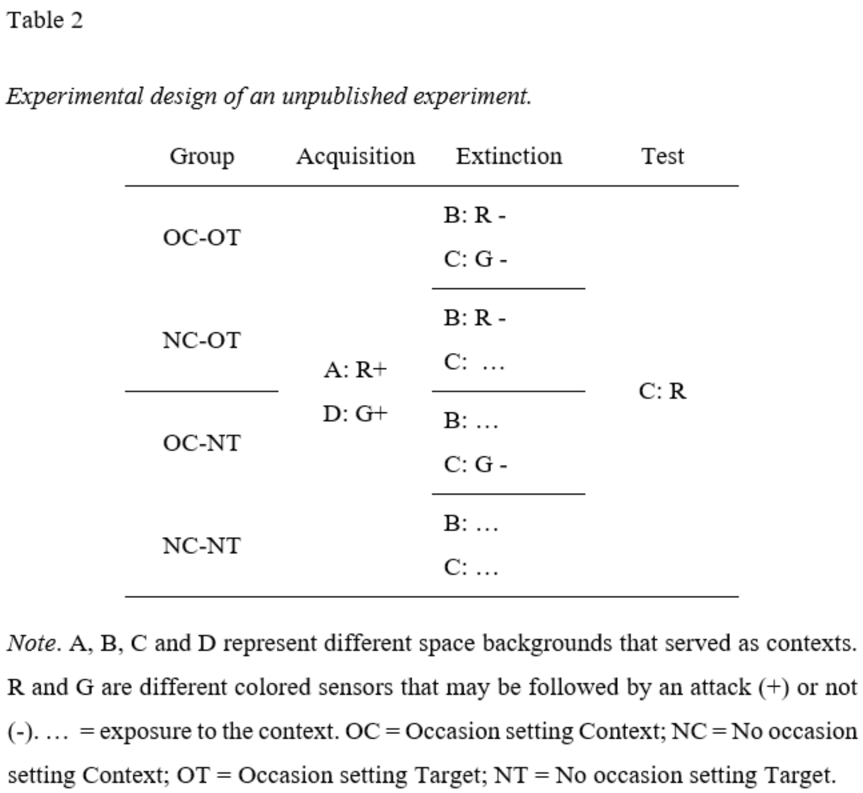


Table 2

Experimental design of an unpublished experiment.

Group	Acquisition	Extinction	Test
OC-OT	A: R+ D: G+	B: R - C: G -	C: R
NC-OT		B: R - C: …	
OC-NT		B: … C: G -	
NC-NT		B: … C: …	

Note. A, B, C and D represent different space backgrounds that served as contexts. R and G are different colored sensors that may be followed by an attack (+) or not (-). … = exposure to the context. OC = Occasion setting Context; NC = No occasion setting Context; OT = Occasion setting Target; NT = No occasion setting Target.

Conclusions regarding the contribution of an occasion setting mechanism to renewal would come through comparison of the OT groups. If there is transfer of negative occasion setting, Context C should be able to reduce responding to the target only in the OC-OT group, resulting in a smaller ABC renewal in this group compared to that observed in the NC-OT condition, where the test is conducted in a neutral context. On the other hand, if the extinction context acquires inhibitory properties during extinction, responding should also differ in the NT groups, with the response being smaller when the non-extinguished cue is tested in a context were extinction took place (OC-NT group) than when is tested in a neutral one (NC-NT group).

The results of well-powered experiments showed no differences in any of these comparisons. Responding to R was similar in the two groups that did not have extinction with the cue (NT groups), with no impact of extinction having occurred in the test context (OC-NT group). Therefore, extinction did not make the test context inhibitory. Additionally, the groups that had extinction with the target cue (OT groups) showed renewal. However, if anything, the renewal was bigger when tested in a context with potential occasion setting properties (OC-OT group). Overall, the results were inconsistent with both conditioned-inhibition and occasion-setting accounts of renewal.

To summarize, there is no compelling evidence in the literature that indicates that extinction contexts have the transfer characteristics of an occasion setter. In the case of the transfer property, transfer has either not been found (Todd, 2013; Table 2 above) or, in the cases where is assumed, the experiments cannot rule out alternative explanations such as conditioned inhibition (Swartzentruber, 1993) or renewal (Swartzentruber & Bouton, 1988).

The objective of the experiments presented here was to further assess whether extinction contexts can demonstrate transfer by using a predictive learning task. Although there is evidence of renewal in predictive learning tasks in humans (e.g., Bustamante, Uengoer, & Lachnit, 2016; Paredes-Olay & Rosas, 1999; Üngör & Lachnit, 2006, 2008), there have been no assessments of the mechanisms, conditioned inhibition or occasion setting, that could be involved.

The experimental designs used were similar to that of Todd (2013), using an ABC design to avoid any complications of the test context being an ambiguous occasion setter. In Experiments 1 and 2 were aimed to simply first determine whether transfer could occur without any effort to determine the nature of that transfer (either occasion setting or conditioned inhibition). Participants had to rate the probability of some foods producing gastric malaise in different fictitious restaurants that served as contexts. Two main cues were used. The test cue (Y) was conditioned in one context, extinguished in a different one and then tested in a third context. The alternate cue (X) was used to potentially endow the test context with negative occasion setting or inhibitory properties, by extinguishing X within it, nor not. If there is transfer of either negative occasion setting or conditioned inhibition accrued to the text context, smaller renewal should be observed in the former case. In Experiment 3 transfer was examined again but, to differentiate between transfer of negative occasion setting and conditioned inhibition, tests of a non-extinguished CS were also involved.

Experiment 1

The design of Experiment 1 is presented in Table 3. The target stimuli and manipulations are presented in bold. The task was based on the one used by León, Abad and Rosas (2011). On a trial, participants were informed that someone had eaten a particular food and the participants had to rate the probability that the food would lead to a gastric problem. After rating the food, they received feedback as to whether malaise was produced or not. Contexts were provided by having the trials take place in different fictitious restaurants. Two groups received conditioning trials with foods X and Y in context A. Then, both groups had extinction of Y in context B. The groups differed in whether X was extinguished (OS group) in the test context (C) or a filler cue was presented without reinforcement (NO-OS group). According to an occasion-setting account for renewal, context C could acquire occasion setting properties only in the OS group. Finally, responding to Y in context C was assessed. Pretest trials were included before the acquisition and extinction phases, to mirror the procedure of (Rosas & Callejas-Aguilera, 2006) and to detect possible pre-existing differences between the groups.

Contexts B and C were pre-exposed during acquisition and non-relevant cues (fillers) were used to equate their excitatory and inhibitory histories. Note that the reinforced filler trials in context C during extinction should minimize the possibilities of context C acquiring inhibitory properties, though that possibility was not directly assessed.

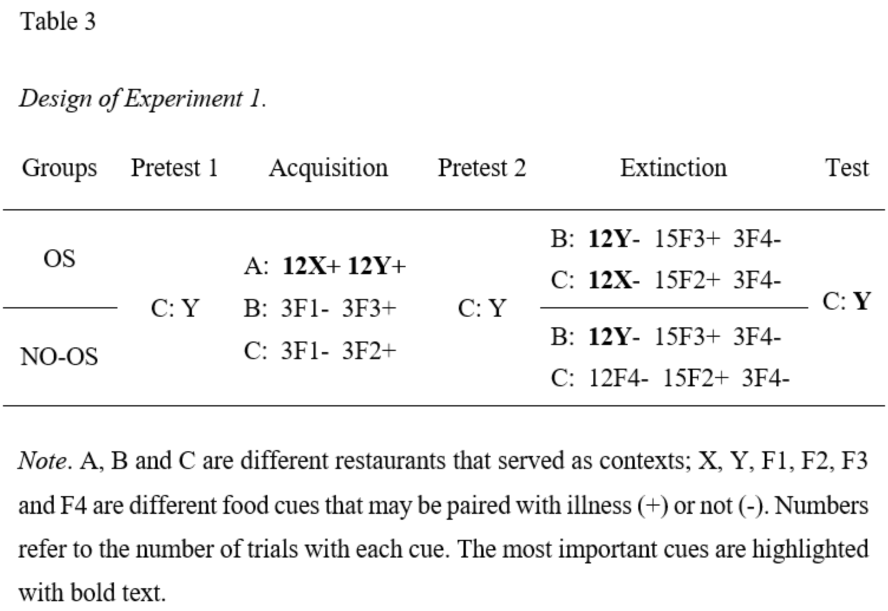


Table 3

Design of Experiment 1.

Groups	Pretest 1	Acquisition	Pretest 2	Extinction	Test
OS	C: Y	A: **12X+ 12Y+** B: 3F1- 3F3+ C: 3F1- 3F2+	C: Y	B: **12Y-** 15F3+ 3F4- C: **12X-** 15F2+ 3F4-	C: **Y**
NO-OS				B: **12Y-** 15F3+ 3F4- C: 12F4- 15F2+ 3F4-	

Note. A, B and C are different restaurants that served as contexts; X, Y, F1, F2, F3 and F4 are different food cues that may be paired with illness (+) or not (-). Numbers refer to the number of trials with each cue. The most important cues are highlighted with bold text.

For both groups, the test was an ABC assessment for renewal. In the NO-OS condition a normal loss of extinction (renewal) was expected when Y was tested out of its extinction context (C). However, since C could have been established as a negative occasion setter in the OS group, C could transfer its negative occasion setting power to Y (a cue that has been occasion set) and reduce the magnitude of renewal compared with the NO-OS group. The same result would be expected if C acquired inhibitory properties during the extinction phase.

Method

Participants

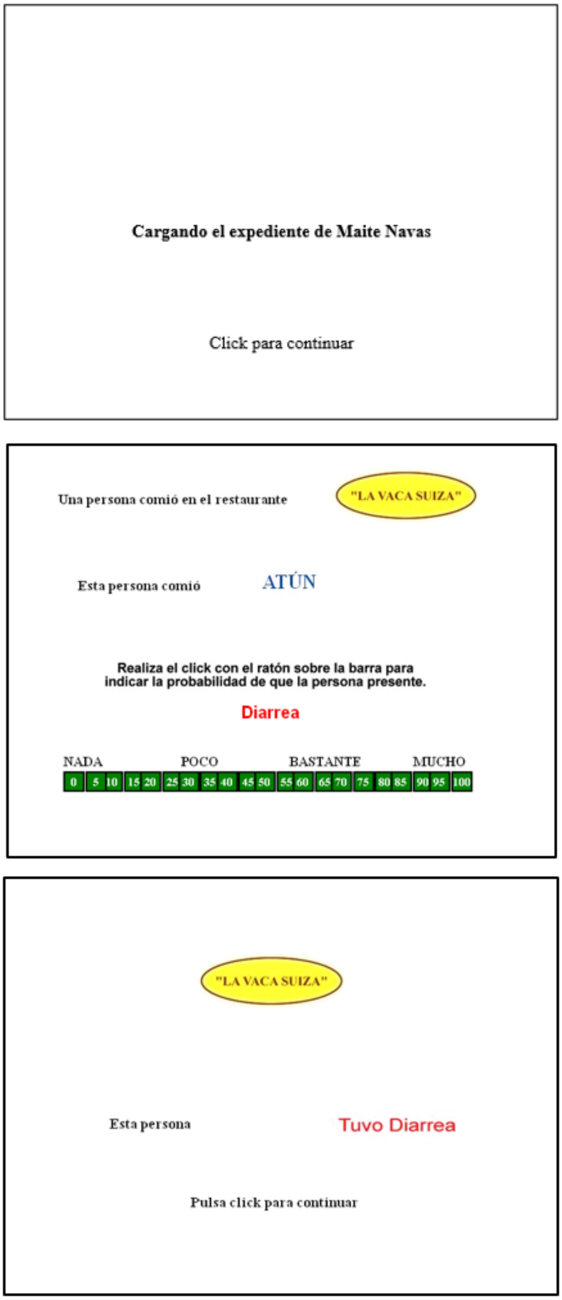
Participants were college-aged volunteers. No volunteer who showed up was turned away and, eventually, 55 participants took part in this study. All procedures were approved by the relevant institutional review board.

Apparatus

The task was run on five Dell OptiPlex computers with 22-inch monitors with an aspect ratio of 1.6 (Width / Height). The resolution was set at 1280 × 800 pixels. A trapezoidal box constructed of black foam board with rectangular ends and the front face uncovered was placed over the monitor and keyboard. The opening was 70 by 70 cm and the back wall was 70 by 50 cm (width × height), the overall length of the side walls was 1 meter. The front opening allowed participants to sit at the table with their head and shoulders just inside the box, isolating each participant. The procedure was implemented using the E-prime 2.0 Professional software (Psychology Software Tools, Pittsburgh, USA), and the participants interacted with the computer using the mouse. Stimuli and instructions were presented in Spanish.

Food names were chosen from the pool selected by García-Gutiérrez and Rosas (2003). Garlic and Tuna were counterbalanced across participants as cues X and Y. Four cues were used as fillers: Caviar served as F1, Eggs as F2, Corn as F3 and Cucumbers as F4. Three fictitious restaurants served as contexts A, B and C. A was always a restaurant called “The Danish Pantry”. The other two restaurants (“The Canadian Cabin” and “The Swiss Cow”) were counterbalanced as contexts B and C.

Each trial consisted of a *customer screen*, a *stimulus screen* and a *feedback screen*. The layout of these screens, based on the task used by León, Abad and Rosas (2011), is shown in Figure 2.



Cargando el expediente de Maite Navas

Click para continuar

Una persona comió en el restaurante "LA VACA SUIZA"

Esta persona comió ATÚN

Realiza el click con el ratón sobre la barra para indicar la probabilidad de que la persona presente.

Diarrea

"LA VACA SUIZA"

Esta persona Tuvo Diarrea

Pulsa click para continuar

Figure 2. Structure and layout of a trial in Experiments 1 and 2. Customer's screen (top), Stimulus screen (middle) and Feedback screen (bottom) showing the outcome of a conditioning trial.

The *customer screen* (top panel of Figure 2) contained the sentence "Loading the file of (a randomly chosen name and surname)". This sentence was placed on the middle of the screen. Below, another sentence read "Click to continue".

On the top of the *stimulus screen* (middle panel of Figure 2) a sentence read "This person ate at the restaurant (name of the restaurant)". On the middle it was written "This person ate (name of the food)". Below, another sentence read "Click with the mouse on the scale to indicate the probability that this person presents diarrhea". In the bottom of the screen, there was a 0-100 scale containing 21 green buttons. Each of them had a number representing a 5-point interval on the scale. To facilitate interpretation of the scale, the words "None", "Little", "Quite" and "Much" were evenly separated from each other, covering the whole scale.

The *feedback screen* (bottom panel of Figure 2) contained the name of the restaurant at the middle top. Below a sentence read "This person (had diarrhea / had no disorder"). Finally, in the middle bottom it was written "Click to continue".

Different logos were used to represent each restaurant. The name of "The Danish Pantry" appeared within a green square. The name "The Canadian Cabin" was written within a blue rectangle with rounded corners. The name of the restaurant "The Swiss Cow" was presented within a yellow oval.

The foods' names were written in blue and with capital letters. The words "had diarrhea" in the feedback screen were presented in red. Color blue was used for the alternate outcome ("had no disorder"). Black letters were used in the remainder text. The screen background was white.

Procedure

Conditions were randomly assigned to participants without replacement until each condition had been assigned once, then the conditions were replaced into the pool. The participant read and signed the informed consent and was placed at the computer.

Four screens were used to deliver instructions and subsequently thank the participant for his/her collaboration. These texts were written in black font over a white background. The participant advanced these screens by pressing a green button placed at the lower right corner with the word "Continue". The *first screen* read "Before beginning, we want to thank you for your presence in this experiment. Without people like you, this research will not be possible. You should know that in this task there are no correct and incorrect answers. We want to study the basic mechanisms which are present in all people and we need you to participate with the highest interest possible. The data provided by you will be anonymous. If, after finishing the task, you want to know what has been tested, ask the experimenter. If you do not want to continue, you can leave the cabin now". The *second screen* had the following text: "Recent developments in food technology have led to the chemical synthesis of food. This creates a great advantage as is very low cost and easy to both store and transport. This revolution in the food industry may solve hunger in third world countries". The *third screen* read "However, it has been detected that some foods produce gastric problems in some people. For this reason, we are interested in selecting a group of experts to identify the foods that lead to some type of illness, and how it appears in each case". The *forth screen* included the text "You are about to receive a selection test where you will be looking at the files of persons that have ingested different foods in a specific restaurant. You will have to indicate the probability that the intake of such food will result in gastric problems. To respond you should click the option that you consider appropriate. Your response will be random at the beginning, but do not worry; little by little you will become an expert".

After these instructions, the participant received a demonstration trial that was identical to those used in the experimental phases except that a different cue (Pasta) was used. This trial took place in context A ("The Danish Pantry") and was not reinforced.

At this point, an additional screen read “Very good, you have just familiarized yourself with the procedure. Press the CONTINUE button to start”. After the participant pressed such button, the experimental part begun.

Pretest 1. The experiment followed the procedure of Rosas and Callejas-Aguilera (2006), and began with a pretest to determine if there were any differences between the groups prior to the experimental manipulation. The first pretest screen read “Before beginning, please, answer the following question”. After that screen the participant received a test trial where the food Y was presented in context C. This trial was identical to that described in the apparatus section, except that no feedback screen was presented.

Acquisition. Acquisition began without announcement after pretest 1. Both groups received conditioning trials with cues X and Y in context A, 12 trials each. Contexts B and C were pre-exposed in this phase. In context B, the participants received three non-reinforced trials with F1 and three reinforced trials with F3. In context C, they received three F1 non-reinforced trials and three trials with F2 that were reinforced. Training during this phase was organized in 3 blocks, each of which contained two trials in context B (one with F1 and one with F3, randomly intermixed), two trials in context C (one with F1 and one with F2, randomly intermixed), and four reinforced trials with X in context A randomly intermixed with 4 reinforced trials with Y (also in context A). Trials in B and in C were always presented at the beginning of each block (before context-A trials), but the order in which they were presented within a block was alternated between blocks, and the resultant arrangement counterbalanced between groups. This gave rise to two different sequences. The “B-first” participants received the BC-CB-BC sequence (where each pair of letters represents the context order within a given block) and the “C-first” participants had the CB-BC-CB sequence. Context changes were preceded by a screen with the sentence “Now you should analyze the files of the people that ate at restaurant (name of the restaurant)”.

Pretest 2. For this second pretest, the procedure was the same as for Pretest 1, except that it was given with no announcement.

Extinction. The OS group received 12 extinction trials with Y in context B and 12 extinction trials with X in context C. Filler trials were added to try to prevent C from acquiring inhibitory properties itself and to equate the reinforcement histories of B and C. Thus, each context contained three non-reinforced trials with F4 and 15 reinforced trials with a different filler, which was F3 in context B and F2 in context C.

The NO-OS group had the same treatment, except that F4 was used instead of X in context C. Since F4 had not been reinforced before, these participants did not receive actual extinction in context C.

Like acquisition, extinction was organized in three blocks. Within each block, the participants had, in context B, four trials with Y, five trials with F3 and one trial with F4, all randomly intermixed. In context C, they had four trials with X or F4 (depending on the group), five trials with F2 and one trial with F4, all of them randomly intermixed. The order in which each context was presented within each block was maintained with respect to the acquisition phase, so that the participants that were previously assigned to the "B-first" subgroup, received the sequence BC-CB-BC also in the extinction phase, and vice versa for those assigned to the "C-first" condition.

Test. The final test proceeded just as the Pretest 2.

The length of the experiment varied by participant (15-20 minutes, approximate).

Data analysis

The computer recorded the predictive ratings given in each trial. Those ratings were analyzed using mixed (within-between) analysis of variance (ANOVA). Where relevant for supporting a lack of effect, the odds of the data favoring the null were computed using the methods described in Wagenmakers (2007).

Results

Screening

Participants' data were screened and removed if, during the acquisition phase, their ratings in two out of the last three trials with each of the conditioned cues (X and Y) did not achieved a value of at least 70. One participant was removed from the OS group and five from the NO-OS condition. Since during recruiting no participant was turned away, group sizes were still similar after removing those participants. Final group sizes were of 24 in the OS group and 25 in the NO-OS group.

Pretest 1

A one-way ANOVA with Group as the factor revealed no effect of Group, $F < 1$. Both groups had similar expectations with Y at the beginning of the experiment.

Acquisition

Performance during conditioning of X and Y is depicted in Figure 3, panel A at left. During acquisition no differences were anticipated between groups nor between cues. A Group × Cue (X or Y) × Trials ANOVA confirmed that expectation. The only significant effect was an effect of Trials, $F(11,517) = 73.36$, $p < .0001$, $\eta^2_p = .61$. No other differences were significant, $p_s \geq .1$.

Pretest 2

Given that the groups did not differ during the acquisition phase, the groups were not expected to differ regarding ratings to Y. A one-way ANOVA with Group as the factor run on the second pretest yielded a non-significant effect of group, $p = .59$, that confirmed that expectation.

During pretest 2, responding to Y was assessed out of its conditioning context. That change likely resulted in a reduction of the ratings observed. The mean rating in the last conditioning trial was 95.21; after the context change, the mean was 81.33. A Phase (last conditioning trial vs. pretest 2) × Group ANOVA showed a significant effect of phase $F(1,47) = 8.76$, $p = .005$, $\eta^2_p = .16$. that confirmed that impression. There were no significant effects of, nor interactions with, the Group variable, $p_s \geq .54$.

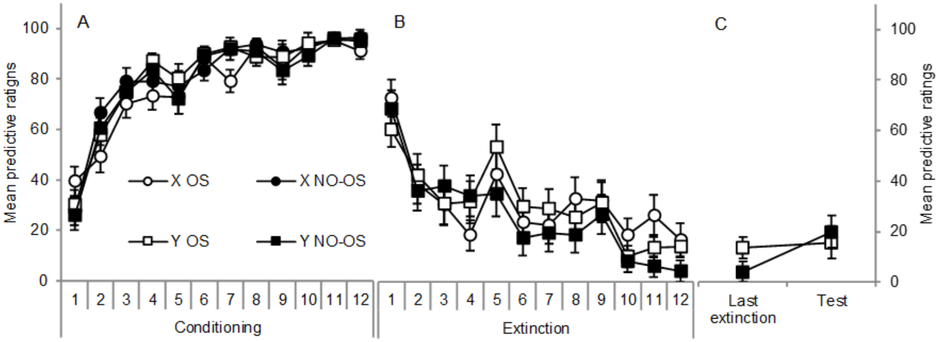


Figure 3. Results of Experiment 1. Panel A contains mean predictive ratings to cues X and Y on each trial during the acquisition phase. Panel B shows responding during each trial of the extinction phase. Panel C depicts the ratings given to Y during the last extinction trial vs. the test. Vertical bars in all panels represent the standard error of the mean.

Extinction

Performance during extinction of both X and Y can be seen in panel B of Figure 3. The decrease in responding to X in the OS group along extinction was supported by a one-way ANOVA with Trials as a factor, $F(11,253) = 7.5$, $p < .0001$, $\eta^2_p = .25$.

The same analysis was repeated with Y, this time including both groups. A Group × Trials ANOVA showed an effect of Trials, $F(11,517) = 15.55$, $p <$

.0001, η^2_p = .25. The lack of effects involving the Group variable, $p_s \geq .42$, indicates that extinction of the testing cue (Y) did not differ between conditions.

Test

Renewal was assessed by comparing performance on the last trial with Y in the extinction context (B) with performance during the test in C. Panel C of Figure 3 shows the mean ratings for each group during those trials. A Recovery (last extinction trial vs. test trial) × Group ANOVA showed a weak and marginal effect of Recovery $F(1,47) = 3.66$, $p = .062$, $\eta^2_p = 0.72$. There was no effect of group, $F < 1$, or Recovery x Group interaction, $F(1,47) = 2.28$, $p = .14$, η^2_p = .046. Bayesian analysis provided weak support for the null (2.19 to 1) regarding the interaction. Responding was equivalent regardless of the experimental treatment.

Overall, these results indicate that there was no renewal of the response in either group. However, given the special interest of this result, further simple effects analyses were conducted. The statistics showed a lack of Recovery effect in the OS condition, $p = .77$, with the odds favoring the null 4.68 to 1, but a significant Recovery in the NO-OS group, $F(1,24) = 5.5$, $p = .028$, $\eta^2_p = .19$.

Looking close at the figure, it is apparent that both groups had similar ratings on the test. The mean ratings were 15.67 and 19.96 in the OS and NO-OS group, respectively. However, there was a bigger difference at the end of extinction. While the NO-OS group showed very low ratings (4.08), extinction seems to be less complete in the OS group, with a mean predictive rating of 13.79. Thus, any smaller “renewal” that may have occurred in the OS group could well be due to its slightly poorer extinction, rather than from a reduced responding at test.

Discussion

Two groups received conditioning with Y in context A, extinction of Y in context B and a final test where responding to Y was assessed in a different context (C). Between groups, extinction of another cue (X) took place in the testing context (OS group), establishing C as a potential negative occasion setter, or not (NO-OS group). If context C acquired negative occasion setting properties in the OS group, transfer of negative occasion setting should appear in the form of reduced renewal in this group. The same result would be expected if C had become a conditioned inhibitor.

No recovery was found in either group. Mining the data showed a tendency for renewal in the NO-OS group that was absent in the OS condition. Such a pattern might indicate transfer of extinction across contexts in this later condition, either through transfer of negative occasion setting, or due to negative summation with an inhibitory context. However, the support for that conclusion is very weak. The effect was observed only after data mining and the lack of recovery in the OS group appeared to be due mostly to a higher response in that group at the end of extinction than due to a reduced responding at test.

The lack of renewal in this experiment made it impossible to assess any type of transfer. Thus, Experiment 2 retained the same the objective and main design of Experiment 1, but introduced procedural differences to increase the chances to obtain a renewal effect.

Experiment 2

In Experiment 1 no renewal effect was found in either group. If anything, a small renewal appeared only in the NO-OS condition. That is the result that would be expected if the test context acts as either as either a negative occasion setter or a conditioned inhibitor. However, the weakness of this result, and the importance of having good renewal upon which to assess its reduction, necessitated a second experiment.

The design, similar to the previous one, is summarized in Table 4. All participants had conditioning with two different cues (X and Y) in context A, and extinction of Y in context B. Along with extinction of Y, participants in the OS condition had X extinguished in a different context (C); in the NO-OS group no such extinction of X took place. Therefore, C could acquire properties of either a negative occasion setter or a conditioned inhibitor only in the OS condition.

Unlike Experiment 1, the OS and NO-OS group were further split into halves. For half of the participants in each group, Y was tested in its extinction context (B) to provide a baseline upon which to assess renewal in the groups that were tested in C. A within-subjects test against the last extinction trial, as was used in the prior experiment, does not account for the potential effect of that trial in reducing responding that could be evident on the test.

Several changes were made with respect to the prior experiment to increase the possibilities of finding consistent renewal in the NO-OS group. Mainly, the number of cues, trials, and context changes during training was reduced. Training was also organized differently. During acquisition, instead of 3 blocks of trials (Experiment 1), 2 blocks were used. Furthermore, pre-exposure to contexts B and C was eliminated so no context changes occurred during this phase. Extinction was organized into four blocks. Despite that Experiment 1 contained fewer blocks of extinction training (three), in Experiment 2 all the trials within each block occurred in the same context, which resulted in a reduction of context changes within that phase.

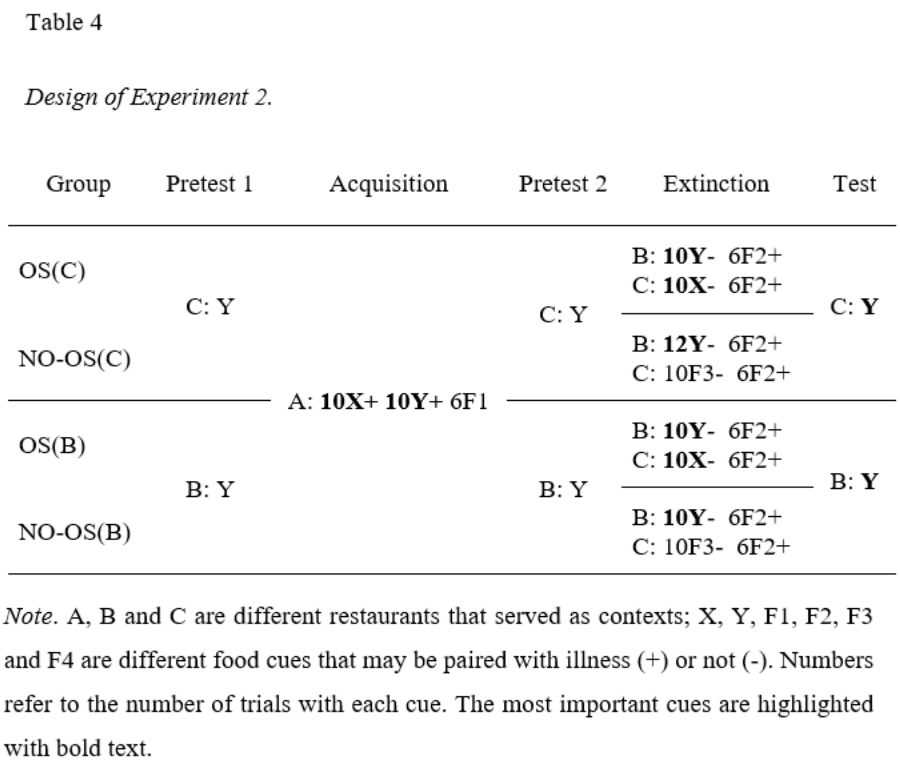


Table 4

Design of Experiment 2.

Group	Pretest 1	Acquisition	Pretest 2	Extinction	Test
OS(C)	C: Y	A: **10X**+ **10Y**+ 6F1	C: Y	B: **10Y**- 6F2+ C: **10X**- 6F2+	C: **Y**
NO-OS(C)				B: **12Y**- 6F2+ C: 10F3- 6F2+	
OS(B)	B: Y		B: Y	B: **10Y**- 6F2+ C: **10X**- 6F2+	B: **Y**
NO-OS(B)				B: **10Y**- 6F2+ C: 10F3- 6F2+	

Note. A, B and C are different restaurants that served as contexts; X, Y, F1, F2, F3 and F4 are different food cues that may be paired with illness (+) or not (-). Numbers refer to the number of trials with each cue. The most important cues are highlighted with bold text.

Predictions are much like those of Experiment 1. Since the NO-OS(C) group was tested out of the extinction context, ABC renewal was expected compared to the NO-OS(B) group, that, instead, was tested in the extinction context. However, the renewal that results from comparing the OS(C) and OS(B) condition should be smaller if, as a result of the experimental treatment, the test context acquired the properties of either a negative occasion setter or a conditioned inhibitor in the former group.

Method

Participants

113 college-aged volunteers took part in this study. As in the previous experiment, all procedures were approved by the relevant review board.

Apparatus

The apparatus was the same as in Experiment 1.

Tuna was always used as cue Y. Garlic and Corn were counterbalanced as cues X and F3. Two additional cues were used as fillers, F1 and F2 (Eggs and Cucumbers, respectively). The contexts identity and counterbalancing were the same as in Experiment 1.

The *customers screen*, *stimulus screen* and *feedback screen* were also like those used in Experiment 1.

Procedure

Details not specified here were the same as in Experiment 1.

Pretest 1. After receiving the instructions, and the demonstration trial, the participants could read the sentence “Before beginning, please, answer the following question”. Then, they were tested with Y in their correspondent test context. The OS(C) and NO-OS(C) groups were tested in context C. The OS(B) and NO-OS(B) groups were tested in B. The participants did not receive feedback on this trial.

Acquisition. All participants received ten conditioning trials with food X, ten conditioning trials with Y and six reinforced trials with F1. The entire phase took part in context A.

Training was organized in 2 blocks. Each of which contained five trials with X, five trials with Y and three trials with F1. All trials were randomly intermixed.

Pretest 2. Pretest 2 proceeded the same as Pretest 1, except that it appeared with no announcement.

Extinction. During extinction, the participants had trials in both B and C. In context B, all groups received ten extinction trials with Y and six reinforced trials with F2. The experimental manipulation took place in in context C. There, the OS groups had 10 extinction trials with X, presumably endowing C with occasion setting or inhibitory properties. The NO-OS groups had non-reinforced trials with F3, a stimulus that was never reinforced. Additionally, all participants had six conditioning trials with F2 in context C, that were intended to reduce the probability of conditioned inhibition to the context.

Extinction was organized in 4 blocks (2 blocks in each context) of 8 trials each. In a B-block, the participants had five trials with Y and three trials with F2 in context B, randomly intermixed. In a C-block, they had five trials with either X or F3 (depending on the group), and three trials with F2 in context C, also randomly intermixed. The order in which each type of block was presented (either in B or in C) was counterbalanced within each group: half of the participants received the sequence BCCB and the other half had the sequence CBBC, where each letter represents the context used in each of the four blocks of extinction.

Test. In the final test the participants were tested just as pretest 2.

Data analysis

Predictive ratings were analyzed as in the previous experiment.

Results

Screening

Participants' data were screened and removed as in Experiment 1. Screening resulted in five participants removed from the OS(C) group, and another five from the NO-OS(C) condition. Three were removed from the OS(B) group and two from the NO-OS(B) group. The final group sizes were, 25 for the former two groups and 24 for the later ones.

Pretest 1

Ratings in each group were very close to each other during the first assessment of responding to Y, ranging from 30.76 to 38.88. The lack of differences between groups was confirmed with an OSdesign (OS vs. NO-OS) × TestContext (test in C vs. test in B) ANOVA that showed no significant effect of either variable nor interactions between them, $p_s \geq .18$.

Acquisition

An OSdesign × TestContext × Cue (X or Y) × Trials ANOVA revealed a significant effect of trials, $F(9,846) = 283.08$, $p < .0001$, $\eta^2_p = .75$, as the predictive ratings to both X and Y increased during the acquisition phase. Acquisition to cue Y can be seen in Figure 4, panel A. Ratings with X (not shown in the figure) increased from 27.31, on the first conditioning trial, to 96.94, in the last conditioning trial. The ANOVA revealed an unexpected OSdesign × TestContext × Trials interaction, $F(9,846) = 2.45$, $p = .009$, $\eta^2_p = .03$, with no other effects whose interpretation is not superseded by this interaction, $p_s \leq .19$.

Simple effects showed a significant TestContext, $F(1,47) = 23.23$, $p < .0001$, $\eta^2_p = .33$, and a TestContext × Trials interaction, $F(9,423) = 2.95$, $p = .002$, $\eta^2_p = .06$ in the NO-OS conditions. Further analyses of the Trials effect in this latter interaction revealed that there was a trend in the NO-OS(C) group to give higher ratings than the NO-OS(B) condition in every single trial, $F(1,47)_{\text{range}} = 4.3 – 14.58$, $p_{\text{range}} = 3.92 \times 10^{-4} – .044$, $\eta^2_{p\ \text{range}} = .08 – .24$. Such a tendency, was not present in the OS groups, where simple analyses revealed no significant effect of, or interactions with, the TestContext variable, $p_s \geq .23$. At this point all groups had received the same treatment, so there is no clear explanation for these differences.

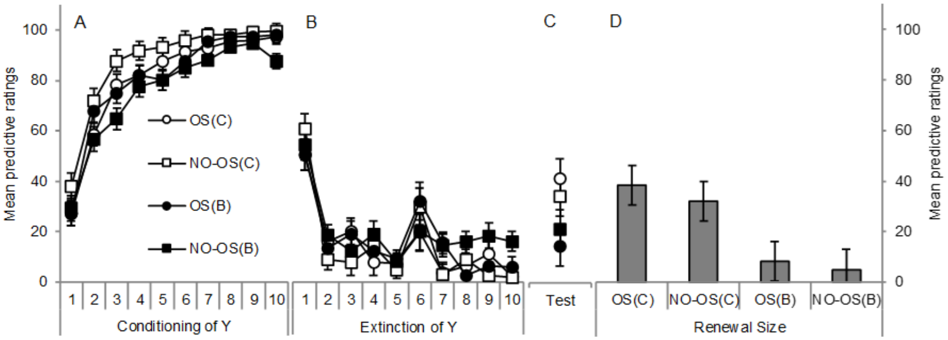


Figure 4. Results of Experiment 2. Panel A depicts mean predictive ratings to cue Y in each conditioning trial. Panel B shows ratings given during each trial of the extinction phase. Panel C represents performance in the test. Panel 4 shows the size of renewal computed by subtracting performance during the last extinction trial from performance during the test. Vertical bars in all panels represent the standard error of the mean.

Pretest 2

Responses to Y in context C were assessed with an OSdesign × TestContext ANOVA on Pretest 2. The analyses showed no effect of, nor interactions between, these variables, $p_s \geq .26$. Mean predictive ratings were close between groups, ranging from 69.04 to 78.68.

To see whether, as in Experiment 1, testing Y out of the conditioning context resulted in a loss of conditioning performance, a Phase (last conditioning trial vs. pretest 2) × Group ANOVA was conducted. The analysis showed a significant effect of Phase, $F(1,94) = 37.94$, $p < .0001$, $\eta^2_p = .29$, with no main effect nor interactions with the group variable, $F_s(3,94) \leq 1.62$, $p_s \geq .19$. The average rating at the end of training was 95.68 while on the pretest in Context C it was 75.05.

Extinction

Figure 4, panel B, shows extinction of Y in all groups. An OSdesign × TestContext × Trials ANOVA revealed an effect of Trials, $F(9,846) = 34.94$, $p < .0001$, $\eta^2_p = .27$, as the participants' ratings decreased during extinction, and another unexpected effect, a main effect of TestContext, $F(1,95) = 3.97$, $p = .049$, $\eta^2_p = .04$, that resulted from better extinction in the groups that were to be tested in context C. There were no effects of, nor interaction with, any of the grouping variables, $p_s \geq .15$.

Not shown in the figure, ratings to X decreased during its extinction in the OS conditions. A TestContext × Trials ANOVA revealed an effect of Trials, $F(9,423) = 17.98$, $p < .0001$, $\eta^2_p = .28$, and a main effect of TestContext, $F(1,47) = 6.13$, $p = .017$, $\eta^2_p = .12$, that was due to an overall poorer extinction to X in the OS(C) group than in the OS(B) condition.

Test

The mean predictive ratings during the test are shown in Figure 4, Panel C. Because of the random differences observed in training, renewal was assessed by making a comparison with the training data. The differences between the ratings on the test and the last training trial, i.e., the size of the renewal effect, in each group are shown in panel D of Figure 4. An OSdesign × TestContext × Trials (last extinction trial vs. test) ANOVA yielded a significant Trials, $F(1,94) = 28.44$, $p < .0001$, $\eta^2_p = .23$, and a TestContext × Trials interaction, $F(1,94) = 13.31$, $p < .0001$, $\eta^2_p = .12$. Simple effects assessing the interaction showed that the effect of Trials (the renewal effect shown by the differences in Panel C) was present only in the groups that were tested in C,

$F(1,49) = 34.56$, $p < .0001$, $\eta^2_p = .41$. There was no Trials effect in the groups tested in B, $F(1,47) = 1.81$, $p = .19$. The lack of effects of, or interactions with, the OSdesign variable, $p_s \geq .19$, indicates that renewal was equivalent regardless of whether C was trained as an occasion setter or not. Regarding the three-way interaction, necessary to support a transfer interpretation, the null was favored 9.67 to 1. On the test trial itself, the odds favored a lack of differences between the OS and NO-OS groups by 5.91 to 1.

Discussion

Experiment 2 was designed to determine whether an extinction context shows transfer of control to another extinguished CS. Two groups had conditioning with a cue (Y) in context A, extinction in context B, and were tested in a third context (C). Since no further treatment was provided to the NO-OS(C) group, normal (ABC) was expected renewal when Y was tested out of its extinction context. In the OS(C) group, however, extinction of a different cue (X) has taken place in context C prior to the test, potentially endowing the test context (C) with negative occasion-setter properties. If that were the case, C should be able to transfer its negative modulatory power to Y (a different cue that has itself been occasion set), thus reducing the amount of response to Y in the renewal test. It is important to note, though, that the same result would be expected if context C has acquired inhibitory properties during extinction. To have a baseline for renewal, the OS(B) and NO-OS(B) groups received the same treatment (i.e., they differed on whether they had extinction in context C, or not, respectively) except that they were tested within the extinction context.

During conditioning, there was a tendency in the NO-OS(C) group to give higher ratings than the NO-OS(B) condition. Comparison between these two groups served as the measure for ABC renewal. Since such a test-context difference was not present in the OS groups, had that pattern in the OS groups persisted on test, observation of reduced renewal in the OS groups due to the experimental treatment would be confounded with these preexisting differences between pairs of groups. Despite the head-start produced by the random differences in training, there were no differences on test.

Extinction of Y also revealed an unexpected TestContext effect, showing that the groups that were going to be tested out of the extinction context achieved greater extinction to Y during this phase. If such tendency for the OS(C) and NO-OS(C) conditions to respond less to Y persisted on the test, the magnitude of renewal would appear to be reduced. However, given the lack of interaction with the Group variable, such reduction would be present in both groups, leaving the comparisons between them relatively unaffected.

No transfer of control of extinction performance was found. Similar recovery was observed regardless of whether extinction of a different CS had occurred in the test context. This conclusion can be further supported by the fact that there were pre-existing differences between the groups in the direction of showing greater renewal in the NO-OS groups.

The experiment was not designed to directly assess whether any transfer of extinction that might be observed was due to the test context being a negative occasion setter or a conditioned inhibitor. That is, the design did not include a test of a non-extinguished target in the test context, where only conditioned inhibition should affect responding. However, the results, showing a lack of transfer of extinction across contexts, suggest that context C had not become a conditioned inhibitor during extinction.

Overall, the results indicate that extinction does not endow the extinction context with either occasion setting or inhibitory properties. There is something, though, that obscures this conclusion. During extinction of X, there was a trend in the OS(C) group to respond more than the OS(B) group, indicating that there was room for more extinction to X than that showed by the OS(C) group. Incomplete extinction in the OS(C) group may have resulted in context C being not so well established as either a negative occasion setter or conditioned inhibitor, reducing the possibilities of finding evidence for such phenomena in the test.

Experiment 3

Experiments 1 and 2 assessed whether ABC renewal could be reduced by conducting extinction with another stimulus in the test context. Such result would be expected with either a negative occasion setting or conditioned inhibition account of the contextual control of extinction. The first experiment showed little or no recovery in either group, making it difficult to assess any reduction of renewal. After some procedural modifications, Experiment 2 yielded renewal, but it was equivalent in both groups suggesting that the extinction context does not function as either a negative occasion setter or a conditioned inhibitor. Experiment 3 had the same objective: to determine whether renewal can be reduced because of prior extinction within the test context. The procedure was modified with respect to the prior experiments with the goal of making the task simpler and, perhaps, producing greater ABC renewal. Additionally, unlike the previous experiments, Experiment 3 was also designed to identify the source for any transfer that might occur.

The design followed the same logic as that shown in Table 2, and can be seen in Table 5. In phase 1, four groups (the first groups in the table) were trained with a cue (X) in context A. In phase 2, half of these groups had extinction with X in context B, which is going to be the test context. Therefore, B was trained either as a potential occasion setter or a conditioned inhibitor by having extinction in it, or not, between groups. This treatment resulted in the "OC" (Occasion setting Context) vs. "NC" (No occasion setting Context) groups' distinction (see Table 5). In phase 3, all groups were conditioned with the test cue (Y). Then, in phase 4, Y was extinguished only in half of the participants of both the "OC" and "NC" groups. Therefore, the test target, Y, was occasion set by way of extinction, or not, giving us the "OT" (Occasion set Target) vs. "NT" (No occasion set Target) distinction. The test thus assessed responding to Y in X's extinction context (B).

Table 5

Design of Experiment 3.

Group	Phase 1	Phase 2	Phase 3	Phase 4	Test
OC–OT	A: **10X**+ 3F3+	B: **10X-** 3F3+	C: **10Y**+ 3F3+	D: **10Y-** 3F3+	B: **Y**
NC–OT		B: 10F1- 3F3+		D: **10Y-** 3F3+	
OC–NT		B: **10X-** 3F3+		D: 10F1- 3F3+	
NC–NT		B: 10F1- 3F3+		D: 10F2- 3F3+	
OC–OT (D)		B: **10X-** 3F3+		D: **10Y-** 3F3+	D: **Y**
NC–OT (D)		B: 10F1- 3F3+		D: **10Y-** 3F3+	

Note. A, B, C and D are different restaurants that served as contexts; X, Y, F1, F2 and F3 are different food cues that may be followed by illness (+) or not (-). Numbers refer to the number of trials with each cue. The most important cues are highlighted with bold text. OT = Occasion setting Target; NT = No occasion setting Target; OC = Occasion setting Context; NC = No occasion setting Context.

Predictions by group are as follows. In the NC-NT group, Y was not extinguished and no extinction has taken place in the test context. Therefore, transfer of conditioning was expected when tested in B. If extinction endowed the context with inhibitory properties, such transfer should be reduced in the OC-NT group, where the non-extinguished cue was tested in a context where extinction of another stimulus occurred. Note that if context C acquired occasion setting properties during extinction, it should not affect responding to Y since this cue has not been extinguished (occasion set) and therefore is not a suitable target for transfer. In the NC-OT group, Y was conditioned in C, extinguished in D and tested in B, which was a neutral context. Therefore, ABC renewal was expected. However, if extinction endows the context with occasion setting properties, renewal should be reduced in the OC-OT group, for which extinction of a different cue took place in the test context.

To serve as a further baseline for measuring, two groups (those at the bottom of Table 5) were tested within their extinction context (D). The OC-OT(D) group had extinction of X in B and thus served as baseline for renewal for the OC-OT condition; the group NC-OT(D) did not have such extinction and was used to assess renewal in the NC-OT condition.

Method

Participants

Group sizes of 12 people were planned, so initially 72 participants were recruited. After screening the data, 13 more people were needed to replace poor learners and maintain adequate group sizes. Eventually, 85 college-aged volunteers took part in this study. All procedures were approved by the relevant review board.

Apparatus

The apparatus was the same as in the previous experiments, except that the task was run using SuperLab Pro (Cedrus Corporation) software and the stimuli in the predictive were substantially modified (see Figure 5).

Each trial consisted on a *stimulus screen* and a *feedback screen*. The *customers screen* (used in Experiments 1 and 2) was eliminated.

In the middle of the *stimulus screen* (top panel of Figure 5), a picture of a real restaurant occupied approximately 65% of the total space. This picture contained two further elements, the name of the restaurant and a picture of the food. The name of the restaurant appeared in black bold fonts within a white square on the picture's top left corner. A different squared placed in the middle of the restaurant's picture contained the food, which, unlike the prior experiments, was represented with a real picture of the food. Above the restaurant’s picture, a sentence read “How much diarrhea will this person suffer from?”. Below it, there was a 0-100 scale similar to that used in Experiments 1 and 2, except that, a “poop” symbol (derived from the popular internet emoticon) was presented above the words “Little” “Quite” and “Much”, with its size increasing accordingly to the word it was over (i.e., smallest above “Little”, medium above “Quite” and the largest above “Much”).

¿Qué cantidad de diarrea padecerá esta persona?

“El Callejón”

NADA DE DIARREA

Respuesta Registrada

Figure 5. Structure and layout of a trial in Experiment 3. Stimulus screen (top) and Feedback screen (bottom) showing the outcome of an extinction trial.

The *feedback screen* (bottom panel of Figure 5) was like the *stimulus screen* except that, the question was eliminated, the scale was replaced by a large rectangle containing the sentence “Response Recorded”, and the outcome was presented in a white rectangle just below the food’s picture. The outcome could be either “Much diarrhea”, presented in capital red font; or “No diarrhea”, written in capital black font. Screen background was white for both the *stimulus* and *feedback screen*.

Unlike Experiments 1 and 2, contexts in this experiment were represented not only by their name, but also with an image of a real restaurant. Images were chosen so that the restaurants were sufficiently different from each other. The restaurant named “The Oven”, was a typical country restaurant, the furniture was made of wood and there was a wood fired oven in the background of the picture. The walls were ocher with stone details. A garden was visible through a large window. The restaurant called “Modern Restaurant” had smooth black walls that contrasted with colorful-metal chairs. Small tables were individually illuminated with lamps made of green glass bottles. The picture of “The Blue Lake” restaurant shows a terrace placed next to a lake surrounded by mountains. A white awning covered the tables and wicker chairs. Finally, the image of “The Alley” restaurant (shown in Figure 5) showed tables on a shadowy alley on a sunny day.

Cucumbers was always used as cue X. The identities of cues Y, F1 and F2 was fully counterbalanced as “Fish”, “Garlic” or “Eggs”, so that within each group, participants were assigned to one of the six possible combinations of these three foods. F3 was always Corn. Four restaurants were used. The restaurants “The Oven” and “Modern Restaurant” served as contexts A and C, respectively. “The Blue Lake” and “The Alley” were counterbalanced across participants as contexts B and D.

Procedure

Any procedural detail not specified here was the same as those of Experiment 1.

Phase 1. All participants received ten reinforced trials with X and three reinforced trials with F3 in context A. One F3 trial divided the ten X trials in two blocks of five trials each. The other two F3 trials were given at the very beginning and at the end of the phase, (one trial in each position).

Phase 2. Phase 2 took place in context B. Participants in the "OC" groups received ten extinction trials with X. Participants in the "NC" groups had 10 non-reinforced trials with a filler (F1) instead.

As in phase 1, all participants received three additional conditioning trials with F3. One of them split the training with X/F1 into two blocks of five trials each. The additional two F3 trials were given at the beginning and at the end of this phase.

Phase 3. In phase 3 all participants had ten conditioning trials with the test cue (Y) in context C. As in prior phases, one reinforced-F3 trial was given at the beginning of this phase, one in the middle (dividing the ten trials with Y in two blocks of five each), and one at the end of the phase.

Phase 4. Phase 4 was carried out in context D. This phase was designed to establish the test cue, Y, as a negative occasion setting target in the OT groups. This variable was factorially combined with whether the test context was trained as a negative occasion setter or not in phase 2 (see the former 4 groups of Table 5). Thus, half of the OC participants had 10 extinction trials of extinction with Y (OC-OT group), while the other half (OC-NT group) received ten non-reinforced trials with F1. Likewise, the NC group was split by halves depending on whether the participants had ten extinction trials with Y (NC-OT group), or received ten non-reinforced trials with F2 instead (NC-NT group).

As in prior phases, the ten extinction trials (with either Y, F1 o F2) were provided in two blocks of five trials each. One reinforced trial with F3 occurred between those two blocks, one at the beginning, and one at the end of the phase.

Test. The four groups that resulted from the factorial combination of the main two variables manipulated were tested with Y (a cue that had either been occasion set or not) in context B (a context that has been trained or not as an occasion setter). Two additional groups, called OC-OT(D) and NC-OT(D) groups, had the same treatment as the OC-OT and NC-OT groups, respectively, except that they were tested within the extinction context (D).

Data analysis

As in Experiments 1 and 2, the ratings given in each trial were analyzed using mixed (within-between) analysis of variance (ANOVA).

Results

Screening

The criteria for screening the participants' data was the same as in prior experiments. Its application resulted in five participants being removed from group NC-OT, three from group OC-NT, two from group NC-NT, and three from group NC-OT(D). Those people were replaced to ensure adequate group sizes. Although none of the participants in OC-OT and OC-OT(D) conditions were removed, removal was independent of Group, $X^2(5) = 7.47$, $p = .19$.

Phase 1

Conditioning of X proceeded uneventfully. The mean predictive ratings increased from 33.82, in the first conditioning trials, to 95 in the last. A Group × Trials ANOVA, including all trials, showed an effect of Trials, $F(9,594) = 98.48$, $p < .0001$, $\eta^2_p = .6$, confirming an increase in the predictive ratings along training. There were no effects of, or involving, the Group variable, $p_s \geq .37$.

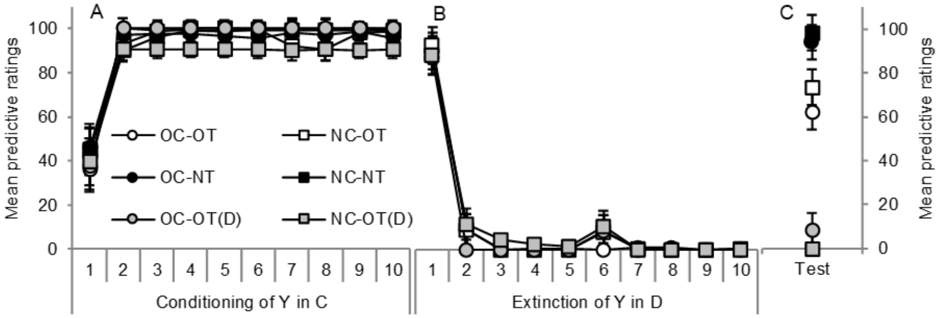


Figure 6. Results of Experiment 3. Panel A shows the mean predictive ratings to cue Y given on each trial during the acquisition phase. Panel B represents responding during each of the extinction trials. Panel C contains the ratings given on the test trial. Vertical bars in all panels represent the standard error of the mean.

Phase 2

A Group × Trials ANOVA was conducted to assess extinction of X in the OC groups that had extinction with that cue. The analysis revealed an effect of Trials, $F(9,297) = 95.99$, $p < .0001$, $\eta^2_p = .74$, and no effects of, or interactions with, the Group variable, $p_s \geq .88$, suggesting that extinction was similar in all the OC groups.

Phase 3

During phase 3, all groups had conditioning with Y. Performance in this phase is depicted in Figure 6, Panel A. A Group × Trials ANOVA revealed an effect of Trials, $F(9,594) = 124.6$, $p < .0001$, $\eta^2_p = .65$, as the predictive ratings to Y increased along training. There were no effects of, or involving, the grouping variable, $p_s \geq .56$.

Phase 4

Figure 6, Panel B, represents the mean ratings in the groups that had extinction of Y during this phase. The decrease in predictive ratings was confirmed by a Group × Trials ANOVA that revealed an effect of Trials, $F(9,396) = 177.17$, $p < .0001$, $\eta^2_p = .8$. The lack of significant effects involving the Group variable, $p_s \geq .77$, suggests that the test cue was similarly extinguished in all groups that had extinction of Y.

Test

Performance during the test is shown in Figure 6, Panel C. To assess renewal and the effect of extinction in the test context a Group (OC-OT group vs. NC-OT group) × Trials (last extinction trial vs. test) ANOVA was conducted. A significant effect of Trials, $F(1,22) =61.61$, $p < .0001$, $\eta^2_p = .74$, confirmed that testing Y out of its extinction context resulted in a renewal of the response. The lack of significant effects involving the Group variable, $p_s \geq .52$, indicates similar renewal regardless of whether B was trained as an occasion setter or not. The lack of interaction was favored 3.89 to 1. On the test trial itself, the odds favored no group differences 3.9 to 1.

Furthermore, a Test Context (Test in B or D) × Group (OC-OT groups vs. NC-OT groups) between-subjects factorial was conducted to determine the level of renewal in the groups tested in their extinction context vs. the test context, and to see whether any effect of extinction in the test context could be detected. The analysis revealed a significant main effect of Test Context, $F(1,44) =44.08$, $p < .0001$, $\eta^2_p = .5$, but no main effect of, nor interactions with, the Group variable, $F_s(1,44) \leq 1.03$, $p_s \geq .31$. The lack of an interaction was favored 3.97 to 1.

To assess the effect of extinction in the test context on a non-extinguished target a Group (OC-NT vs. NC-NT) × Trials (Last conditioning vs Test) ANOVA was conducted. None of the variables had a significant effect, $F_s(1,22) \leq 1.48$, $p_s \geq .24$. That is, there was no reduction in responding to Y in context B in either group. The odds favored a lack of interaction 6.73 to 1, indicating that context B did not acquire the properties of a conditioned inhibitor after extinction having taken place within it. Considering only the test trial the odds favored the null 3.1 to 1.

Discussion

Experiment 3 was designed to determine whether there is transfer of extinction across extinction contexts while trying to identify the source for any potential transfer. All participants had conditioning of a cue in context A, extinction in B and a test in C. Similar to the unpublished experiment previously conducted in our laboratory, whether the test context had extinction of another cue within it (OC groups) or not (NC groups) was factorially combined with whether the test cue was established as a potential occasion setting target by way of extinction (OT group) or not (NT group). As one of the hallmarks of occasion setters, transfer should occur best when both conditions are met. That is, if there is transfer of negative occasion setting, the renewal effect observed in the NC-OT group should be reduced in the OC-OT group. Such a result would also be expected if the context acted as a conditioned inhibitor. This latter possibility would be observed through comparisons between the NT groups. If extinction makes the context inhibitory, responding should be smaller when a non-extinguished target is tested in a context where extinction occurred (the OC-NT group) than when tested in a neutral context (NC-NT group).

Two additional groups, the OC-OT(D) and NC-OT(D) conditions, were added to assess the amount of renewal. These groups had the same treatment as the OC-OT and NC-OT conditions (respectively) except that the target cue was tested in its extinction context (D).

Results showed equivalent renewal in the groups that had extinction of the target and were tested out of its extinction context. That is, no transfer of negative occasion setting was found. Moreover, conditioned inhibition to the context was not found: Testing a non-extinguished cue within an extinction context did not reduce the amount of control by the cue compared to testing in a neutral context. Overall, the results are inconsistent with either a conditioned-inhibition, or an occasion-setting account of the renewal effect.

General discussion

The renewal effect (e.g., Bouton & Bolles, 1979) has been explained as the extinction context becoming a negative occasion setter (Bouton, 1993, 2004), so that for extinction to be expressed, both the CS and the extinction context should be present. Support for such account has been recently reviewed by Trask et al., (2017). Although they argue that contexts can function as occasion setters in Pavlovian conditioning, the literature is not as clear as might be expected based on their review. Furthermore, whether or not extinction contexts exhibit the transfer properties of occasion setters has not been clearly addressed.

Occasion setters are stimuli that have a minimal effect on stimuli unless those stimuli have been trained as targets in other occasion-setting discriminations (Davidson & Rescorla, 1986; Holland, 1986, 1989; Lamarre & Holland, 1987; Rescorla, 1985; Swartzentruber, 1995). Therefore, if the extinction context acts as a negative occasion setter, it should be able to reduce responding to another CS that has been extinguished (i.e., occasion set) in a different context.

Three experiments were designed to test this parallel between the contexts and occasions setters. A predictive learning task was used where human participants rated the probability of fictitious customers getting sick after eating certain foods (the cues) in different restaurant (the contexts). All three assessed the possibility that presenting an occasion setting target (i.e., an extinguished CS) within a context that has been trained as a negative occasion setter (i.e., has had extinction within it) reduces the responding observed in an ABC renewal design. Experiment 3 further explored the specific conditioned inhibitory properties of the extinction context.

None of the experiments provided evidence of transfer of negative occasion setting (or conditioned inhibition). Experiment 1 showed little or no recovery of the response on the test, making it difficult to observe any transfer. The control group showed a tendency for renewal that was absent in the experimental condition (where transfer was expected), but such a tendency appeared only after mining the data and was due to poorer extinction in the experimental condition rather than due to less responding on the test. Experiment 2 showed a clear ABC renewal effect, but it was similar regardless of whether the test context was trained as a supposed negative occasion setter or not. That null result is somewhat strengthened considering that there was an initial tendency for the groups to differ in training in a direction that would look like transfer on test. Finally, in Experiment 3 a consistent renewal effect was found but, again, no evidence of transfer. Recovery of the response was the same regardless of the potential occasion setting properties of the context.

Trask et al., (2017) concluded that the extinction context functions as a negative occasion setter in Pavlovian conditioning, but she also suggested that the context may acquire inhibitory properties under circumstances that make the context especially salient. Contextual inhibition could have been detected in all of the experiments. However, in none of them was there an effect of extinction having taken place in the test context on responding to a cue. No effect was found on a cue that was undergoing renewal (Experiments 1-3) or on a simple excitor (Experiment 3). Thus, overall, the results are consistent with those by Todd (2013) and also with the previous unpublished results in our laboratory. The data do not support accounts of renewal that rely on extinction contexts acting as negative occasion setters or conditioned inhibitors.

Renewal in these experiments requires an alternative explanation. Wagner's unique-cue model (Wagner, 2003) might apply to these results with certain considerations. According to Wagner's theory, when two stimuli, A and B, are presented together a new, distinct "unique" cue "X" is created. This unique cue is assumed to replace some of the elements of A and B. Therefore, although the total representation of the stimuli present consists of elements of A, B, and X, not all elements of A or B will be present.

This idea can explain many, but not all, aspects of renewal. When the target cue Y is conditioned in context A, we can consider that there are elements of both Y and A that are present, as well as the unique cue that is formed by the joint presence of A and Y ($_{A}X_{Y}$). During conditioning all of these become associated with the US (see Figure 7, left panel). Then, when Y is presented for the first time in context B, the conditioned response is predicted to be lost, because ${}_{A}X_{Y}$ is no longer present and because the new unique cue ${}_{B}X_{Y}$ will replace some of the Y elements which control the response (Figure 7, right panel). That mechanism would explain why some of the initial conditioning is affected by a context change as was observed in Pretest 2 of Experiments 1 and 2. However, it fares less well with situations where no effect of context is observed on simple conditioning (e.g., Bouton & King, 1983; Bouton & Peck, 1989).

During extinction, Y is in a new context. Elements of the context (e.g., B) and Y will be present, along with a new unique cue, ${}_{B}X_{Y,}$ which all can acquire inhibition. Finally, when tested in a different context (C), the inhibitory influence of ${}_{B}X_{Y}$ will be removed. Moreover, some elements of Y that were replaced by ${}_{B}X_{Y}$ and never underwent extinction will be recovered. The result is that renewal should be observed out of the extinction context.

Wagner's (2003) approach would explain the lack of negative occasion setting transfer observed in these experiments. For instance, in Experiment 3 non-reinforced presentations of Y in context D would result in the unique cue (${}_{D}X_{Y}$) acquiring inhibitory strength in the NC-OT group. Since such a cue is absent at test, the response is recovered. The OT-OC group differed in that extinction of X in context B should have produced conditioned inhibition to the unique cue formed by the joint presentation of B and X (${}_{B}X_{x}$). However, since the cue that controls extinction of cue X (${}_{B}X_{x}$) is different from that which controls extinction of Y (${}_{D}X_{Y}$), there is no transfer of extinction across context and the amount of renewal is equivalent to the recovery found in the OT-NC group. The same reasoning would apply to the unpublished experiment mentioned in the introduction.

A problem with a straightforward application of this theory is that, initially, it would predict similar generalization (or similar context specificity), for both conditioning and extinction learning. That implies that the transfer of conditioning found in the groups that did not have extinction with the test cue (the NT groups) between the conditioning (C) and the test context (B) will not be expected since the unique cue that controls excitatory learning (${}_{C}X_{Y}$) will also be lost when Y is presented in B. Moreover, losses of both excitation and inhibition would make ABC renewal a tenuous phenomenon. A possibility is that during conditioning, the attention paid to the unique cue is not especially high, or at least low enough to allow conditioning to transfer based on the elements of the particular cues. However, the interference generated by extinction might enhance attention to the unique cues, making extinction more dependent on the specific unique cue produced by the context and CS. The same reasoning would apply to Experiment 2. Regardless of whether or not the test context has had extinction within it, if attention was devoted primarily to the unique cues, then no transfer would be expected because the cue controlling inhibition would be lost.

In Experiment 1 there was no significant renewal observed. This result does not fit with the proposed extension of Wagner’s unique approach. The lack of recovery could have been due to the much larger variety of trials and number of context changes in training. As many of the context changes in training were not accompanied by changes in outcomes, participants could have come to ignore the contexts, leading to difficulty in discriminating them later. Those procedural differences, along with the small loss of conditioning observed with a context change in pretest 2, could weaken any potential renewal effect.

The idea of extinction leading to shifts in attention is not new (for a revision see Nelson et al., 2018). Shifts in attention are predicted to occur when there is a prediction error (e.g., Kruschke & Johansen, 1999; Le Pelley, 2004; Mackintosh, 1975). According to the Attentional Theory of Context Processing (ATCP) (Rosas et al., 2006; Rosas & Callejas-Aguilera, 2006), extinction results in attention being shifted to contextual cues, which might result not only in extinction being context specific (such as in renewal), but also in conditioning learning been linked to the extinction contexts (Rosas & Callejas-Aguilera, 2006, 2007). This latter effect has been referred to as the EMACS effect (Extinction Makes Acquisition Context Specific). Support for the idea that extinction tends to shift attention to the context can be found in an experiment by Nelson, Lamoureux, and León (2013). In their experiment, half of the participants received conditioning and extinction with a stimulus, while the other half were simply conditioned. Then, participants learned a biconditional discrimination (RG+/BG-/RY-/BY+) involving stimuli that differed from the one used in prior training. In the discrimination, contextual stimuli were arranged to be either relevant, but not necessary, to solve the discrimination, (i.e., RG+ and BG- trials occurred in one context while RY+ and BY- trials occurred in another context), or not. The results showed that when the contexts were relevant, acquisition of the discrimination was facilitated only if participants had prior extinction, as if extinction had enhanced attention to the contexts. However, it is also true that their experiment could be equally explained by assuming that extinction increased attention to unique cues, rather than to the contexts. That is, it is possible that the unique cues required to solve the discrimination also included the contexts, and that such inclusion was enhanced in the participants that had prior extinction.

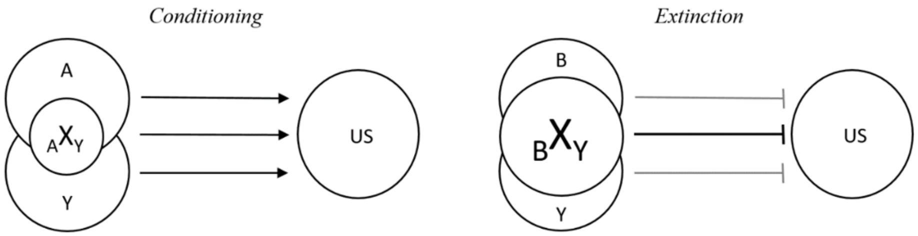


Figure 7. Model of extinction based on an enhancement of attention to unique cues. A and B are context cues, Y is a CS. $_{A}X_{Y}$ and $_{B}X_{Y}$ are unique cues that result from the joint presentation of Y with A and B, respectively. Note that $_{B}X_{Y}$ is bigger than $_{A}X_{Y}$ due to the superior attention the unique cue receives during extinction.

In summary, the results are inconsistent with both a conditioned inhibition and an occasion setting account for renewal. Instead, the replaced elements model proposed by Wagner (2003) could perfectly apply with the assumption that extinction might result in attention being driven to the unique cues that result from the joint presentation of the context and the CS. The unique cue would gain strong inhibition in detriment to that of the separate elements of the compound. Thus, extinction would result in little inhibition between the CS and the US that could be switched on or off by the extinction context, as proposed by Bouton (see Figure 1). Instead, the absence of the US would be predicted by a new cue which is mainly composed by unique elements (see Figure 7). Renewal would appear because the unique cue that controls extinction is lost when the stimulus is presented in a different context, regardless of whether the test context has had extinction within it or not. The control unit proposed by Bouton (1993; Bouton & Nelson, 1994) that gates the inhibition acquired by the CS, and supposedly operates as an occasion setting mechanism, may be better described as a unique Context-CS cue in Wagner's terms.

Chapter 2

Transfer of extinction across stimuli

Introduction

Transfer of learning allows organisms to perform adapted responses despite variations in environmental stimuli. Arguably, the simplest form of transfer is stimulus generalization, where physical similarity between stimuli is the condition assumed to produce transfer (Guttman & Kalish, 1956; Honig & Urcuioli, 1981). However, some stimuli may not be ordered along a physical dimension and yet require the same response. In these situations, transfer across stimulus modalities permits the animals to respond adaptively.

Cross-modal transfer can emerge under different conditions. In associative learning, the importance of a common reinforcement history (e.g., Honey & Hall, 1989) and within-compound associations (Shevill & Hall, 2004; Vurbic & Bouton, 2011) between the stimuli have been emphasized. Within the cognitive field, emphasis has been placed on the task structure as a source for cross-modal transfer. In this case, performance on a task is facilitated by prior experience with tasks with similar demands regardless of the physical similarities between the stimuli involved. For instance, in the seminal work by Harlow (1949) rhesus monkeys had to solve successive discrimination problems. Within each problem, responses to one of two stimuli were reinforced during 6 trials, followed by presentation of a new pair of objects in a new discrimination problem. The results showed that the animals were progressively better in solving the discriminations, to the point where a single trial with a new pair of objects was sufficient to produce the correct response on following trials (Harlow, 1949). This form of cross-modal transfer has been commonly referred to as learning to learn (e.g., Brown & Kane, 1988; Kehoe, Horne, & Macrae, 1995; Langbein, Siebert, Nürnberg, & Manteuffel, 2007), general transfer (Hall, 1975; Kehoe et al., 1984), cross-modal transfer (Campolattaro, Kashef, Lee, & Freeman, 2011; Holt & Kehoe, 1985) and learning-set formation (e.g., Harlow, 1949).

Most accounts of learning to learn (hereafter LTL) are found in the cognitive literature (e.g., Bourne, 1970; Brown & Kane, 1988; Halford, Bain, Maybery, & Andrews, 1998; Harlow, 1949; Hultsch, 1974; Levine, 1959; Zable & Harlow, 1946), where the phenomenon has been linked to intelligence (e.g., Harlow, 1949), concept formation (e.g., Bourne, 1970), categorization (Hanggi, 1999), and forms of cognitive learning presumed different from that of associative learning (Bailey, McDaniel, & Thomas, 2007; Kangas & Bergman, 2014). The LTL effect has been also demonstrated in non-primate animal research by using associative learning preparations, suggesting that the effect may rely on simpler associative processes which have been argued to underlie cognition (McLaren et al., 2018). Neurophysiological studies of the effect indicate that it relies, at least in part, on an enhancement in the neurons' synaptic plasticity and connectivity (e.g., Saar, Grossman, & Barkai, 1999; Sehgal, Song, Ehlers, & Moyer, 2013; Zelcer et al., 2005).

In classical conditioning, the effect has been widely studied by Kehoe in the rabbit nictitating-membrane (NM) response (Holt & Kehoe, 1985; Kehoe & Holt, 1984; Kehoe et al., 1984; Kehoe, Weidemann, & Dartnall, 2004; Schreurs & Kehoe, 1987). For instance, Kehoe and Holt (1984) found that conditioning of the eyeblink reflex with a conditioned stimulus (CS) (e.g., a light) enhanced the rate of conditioned response (CR) acquisition to a CS in a different modality (e.g., a tone). The effect has also appeared in operant preparations with species as diverse as rats (Hall, 1975; Thomas, Miller, & Svinicki, 1971) and pigeons (Rodgers & Thomas, 1982) to dwarf goats (Langbein et al., 2007).

Understanding the LTL effect in these basic processes is important because they may indicate limits to the effect that can help elucidate the mechanisms underlying this type of transfer. In particular, boundaries may exist for extinction learning, where the CS is present without the US, leading to a decline in the CR. Extinction and conditioning are not symmetric processes, and there are grounds for thinking that it may be difficult for extinction learning to transfer. For instance, the renewal effect, a phenomenon in which the CR is recovered when an extinguished CS is tested outside of the extinction context (Bouton & Bolles, 1979; Bouton & King, 1983), shows that what has been learned during extinction is largely context specific (e.g., Bouton, 1993).

Transfer of extinction has also been shown to be limited across successive discrimination reversal or extinction phases. For instance, in a study by Kangas and Bergman (2014), squirrel monkeys were reinforced for responding to one of two digital photographs during 100 trials. Then, the contingencies were reversed so that the animals were rewarded to choose the previously non-rewarded stimulus for the next 100 trials. The same procedure was used during 30 sessions, with a new pair of stimuli in each session. Their results showed that the rates of both acquisition and reversal learning increased across sessions; less trials were progressively needed to reach the criterion for mastery (give a correct response in 9 of 10 consecutive trials). Eventually, performance reached an asymptote. The asymptote in the acquisition portion of the task was around 15–20 trials to mastery. However, the minimum number of trials beyond which no further improvement was observed in the discrimination reversals, which involved extinction of the previously reinforced stimulus, was around 40–50. These results suggest that prior experience does not equally benefit both types of learning. Despite other studies have shown fast learning across discrimination reversal tasks (e.g., Harlow, 1949; Rayburn-Reeves, Stagner, Kirk, & Zentall, 2013), the results of Kangas and Bergman show that such findings are not ubiquitous.

Similar restricted transfer of extinction has been found when the same CS was used during successive acquisition and extinction cycles (Kehoe, 2006), but there are also examples in the literature of the opposite pattern (Scavio & Thompson, 1979; Smith & Gormezano, 1965). Complementarily, there is evidence that hippocampal destruction impairs performance improvement across several extinction, but not conditioning phases (Schmaltz & Theios, 1972).

Together, the work described in the previous paragraphs shows that unlike repeated acquisitions, findings are inconsistent with respect to the transfer observed in procedures that have a component of extinction. Such inconsistency suggests that there could be differences between the mechanisms that underlie transfer of these two types of learning.

The LTL effect implies an increased learning rate across tasks. That is, fewer trials are required to master a new task when the subjects have been exposed to similar response requirements. Thus, unlike generalization, the LTL effect cannot be appreciable on single-trial tests and its measurement requires trial-by-trial monitoring. With respect to such simple generalization of extinction learning, Pavlov (1927) reported a situation where a conditioned salivary response was established to three different CSs. Extinction of the response to one of the stimuli greatly attenuated responding to the others. He termed this effect “secondary extinction” and the procedure he used was a simple test of generalization of extinction across stimuli. After this first positive report, several investigations have tried unsuccessfully to replicate the effect (e.g., Bouton & King, 1983; Kasprow et al., 1984; Richards & Sargent, 1983). In most cases the conclusions drawn from these studies are based on the subjects’ performance across several test trials; trials which might themselves provide new extinction learning. Thus, those tests can also be considered as failures to observe a LTL effect in extinction (LTL-E) rather than solely a failure to obtain the secondary extinction effect (i.e., immediate generalization of extinction).

To illustrate, in an experiment by Richards and Sargent (1983, Experiment 1), barpressing was established and then rats received conditioning with two CSs from different modalities (a flashing Houselight and a Tone), each paired with shock. During extinction, the TH group received extinction trials with the Tone followed by extinction with the Houselight; in the HT animals the order was reversed. Their results showed that extinction with the Houselight slightly facilitated extinction with the Tone, however comparable rates of extinction to the light were found between groups regardless of whether it was extinguished first or last. A lack of transfer has been found even after extinction of two non-target CSs (Richards & Sargent, 1983, Experiments 2 and 3) and when CSs were from the same sensory modality, where both stimulus generalization and LTL could operate (Kasprow et al., 1984).

By contrast, several experiments have demonstrated that extinction of a given CS can affect responding to another CS, but one that has already been extinguished. It is known that after two stimuli (e.g., X and Y) have been conditioned, and one (Y) subsequently extinguished, either a single presentation of the unconditioned stimulus (US) or the passage of time produces a recovery of the response to Y. Yet, providing extinction trials with X prior to testing Y "erases" both recovery effects (Rescorla & Cunningham, 1977, 1978). A similar procedure has been shown to attenuate renewal (Vurbic & Bouton, 2011). Together, these studies indirectly demonstrate that some aspect of extinction learning is susceptible to transferring across stimuli.

Further investigation of that transfer of extinction was undertaken by Vurbic and Bouton (2011). They assessed whether facilitated extinction can be more readily observed with a target CS that has undergone some extinction, as has the target CS in erasure research. That is, after conditioning of X and Y, they asked whether extinction of Y would enhance extinction of X when X has already received some extinction trials immediately after conditioning. They reasoned that as the context specificity of extinction learning can be explained in terms of the context acting as a negative-occasion setter (Bouton, 2004), a CS that has received some extinction might be especially sensitive to transfer of negative-occasion setting by the extinction context (Swartzentruber & Rescorla, 1994), therefore facilitating its extinction. Vurbic and Bouton's (2011) results showed that the initial partial extinction of X led to more rapid extinction with Y but, contrary to their expectations, and inconsistent with a general LTL effect in extinction, this latter extinction did not facilitate further extinction of X.

Finally, in a third experiment, Vurbic and Bouton (2011) showed that intermixing conditioning trials was required to obtain the LTL-E effect they observed with X. While one group received intermixed conditioning trials with X and Y, conditioning of each CS was separated by 24 h for the other group. The data revealed that subsequent extinction of Y affected extinction of X only in the former group. According to the authors, intermixed acquisition trials could permit the animals to associate X and Y over the ITI so that extinction trials with Y might evoke the representation of X, allowing its extinction to occur indirectly.

In brief, LTL effects have been clearly shown in cognitively oriented tasks with humans, but little is known about its appearance in very simple learning paradigms that are amenable to associative learning explanations. Renewal and other phenomena suggest that extinction transfers less well across situations than does excitation. Thus, while LTL effects have been found in simple excitatory classical conditioning (Holt & Kehoe, 1985; Kehoe & Holt, 1984; Kehoe et al., 1984, 2004; Schreurs & Kehoe, 1987), a failure to observe a LTL effect of extinction occurs often (Bouton & King, 1983, Experiment 4; Kasprow et al., 1984; Kehoe et al., 2004; Richards & Sargent, 1983, Experiments 2 and 3) with positive reports being only partially successful (Richards & Sargent, 1983, Experiment 1) or subject to qualified conditions (Vurbic & Bouton, 2011). Observing whether there is a difference in LTL between conditioning and extinction, and then understanding why any resulting difference exists, can inform on the processes involved in both LTL and extinction in humans.

Experiment 1 assessed whether acquisition and extinction with a CS enhances subsequent acquisition and extinction learning (respectively) with a different CS. To determine the extent to which physical generalization might contribute to the transfer, the stimulus similarity was manipulated between groups by using CSs of the same or different modalities. Experiment 2 addressed the possibility that intermixing conditioning trials further facilitates transfer of extinction learning between stimuli (Vurbic & Bouton, 2011). Finally, Experiment 3 was conducted to determine whether LTL effects emerge under conditions that should prevent mediation between the stimuli by a common US representation, a common reinforcement history or within-compound associations.

A science-fiction based video game (Nelson, Navarro, & Sanjuan, 2014) was used. Participants were first trained to respond to the appearance of a spaceship by rapidly pressing a key to activate a weapon. After responding to the ship was established, it was used as an “unconditioned stimulus” in later phases (see Arcediano, Ortega, & Matute, 1996; Franssen, Clarysse, Beckers, van Vooren, & Baeyens, 2010; Ivanov-Smolensky, 1927, for similar procedures). There, different “sensor” stimuli (different flashing lights or a sound) were presented before and during the appearance of the spaceship. The procedure encourages the participants to emit an anticipatory response (charging a weapon) that allowed us to trace the course of the assumed sensor-spaceship association along multiple conditioning and extinction phases.

Experiment 1

Experiment 1 was designed to determine whether prior training facilitates subsequent learning in both acquisition and extinction procedures. The differential contributions of LTL and physical generalization to the transfer of learning were also investigated by a between-groups manipulation of the perceptual similarity of the stimuli used.

The design is summarized in Table 6. The EXPacq group received conditioning trials with A during phase 1. The CTRLacq group was merely exposed to the context in this phase. During phase 2, both groups received conditioning trials with B. The first trial of this phase served as a measure of generalization: Higher responding in the EXPacq group would indicate immediate generalization between A and B. On the other hand, the LTL effect in conditioning (LTL-C) should take the form of increased performance in the EXPacq group with respect to the CTRLacq group on subsequent trials.

A and B were separately extinguished in phases 3 and 4 in the EXPext group. Though not reflected in the table, the order of extinction of A or B across these phases was counterbalanced. The control group for LTL in extinction (CTRLext) was exposed to the context during phase 3, and therefore, had no extinction training prior to phase 4. Trial 1 of phase 4 allowed us to observe any immediate generalization of extinction in the EXPext group. Then, if extinction learning is facilitated by prior extinction training, differences in the extinction rate should appear between the EXPext and CTRLext along subsequent trials.

Except for the CTRLacq group, all groups were divided depending on whether A and B were presented in the same vs. different modality. In the Same groups, A and B were two different visual stimuli, counterbalanced. In the different modality conditions, the CSs were visual and auditory, counterbalanced. There was no condition where both stimuli were auditory due to current limitations of the program used. All three stimuli (the two lights and the tone) served as B, between subjects, in the CTRLacq group.

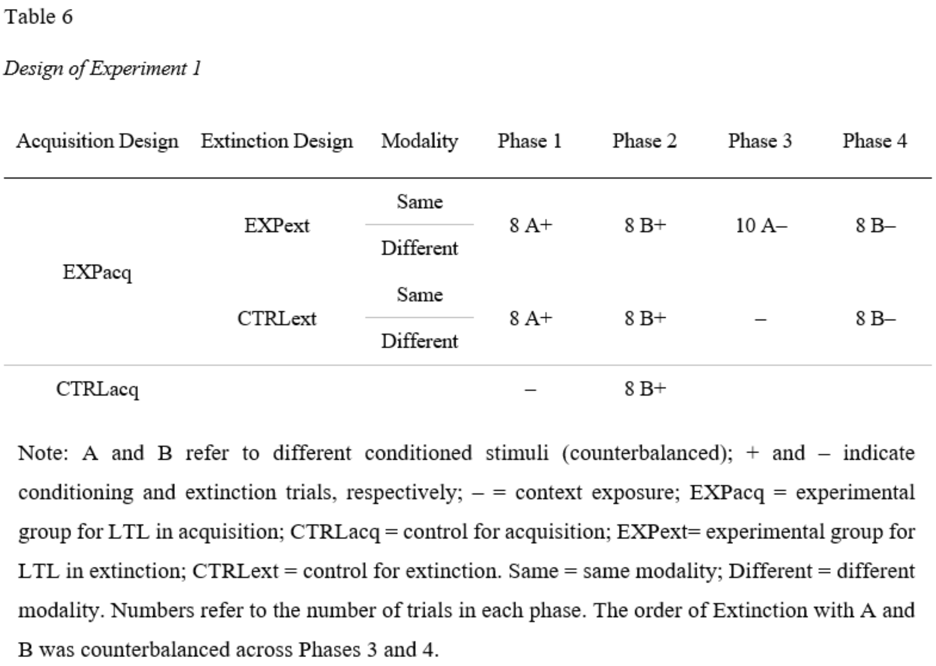


Table 6

Design of Experiment 1

Acquisition Design	Extinction Design	Modality	Phase 1	Phase 2	Phase 3	Phase 4
EXPacq	EXPext	Same	8 A+	8 B+	10 A–	8 B–
		Different				
	CTRLext	Same	8 A+	8 B+	–	8 B–
		Different				
CTRLacq			–	8 B+		

Note: A and B refer to different conditioned stimuli (counterbalanced); + and – indicate conditioning and extinction trials, respectively; – = context exposure; EXPacq = experimental group for LTL in acquisition; CTRLacq = control for acquisition; EXPext= experimental group for LTL in extinction; CTRLext = control for extinction. Same = same modality; Different = different modality. Numbers refer to the number of trials in each phase. The order of Extinction with A and B was counterbalanced across Phases 3 and 4.

Method

Participants

In the Same Modality conditions counterbalancing the 2 lights and the extinction sequence (AB vs. BA) required participants in multiples of 4. In the Different Modality groups, counterbalancing the identity of the Phase1 stimulus (auditory or visual) combined with the other variables required multiples of 8. In the CTRLacq group multiples of 3 were needed to balance the 3 stimuli. To ensure that each combination of variables would remain adequately represented in each group, a minimum of 4 participants per combination was planned, requiring 108 participants. Since no volunteer who showed up was turned away, 122 college-aged volunteers participated in the experiment. All procedures were approved by the relevant institutional review board.

Apparatus

The video game used was that of Nelson et al. (2014), and all visual details described below are pictured there. A download is available by visiting http://drjbn.wordpress.com/the-learning-game-download- links/. The game was played on four Dell OptiPlex computers with 22-inch monitors with an aspect ratio of 1.6 (Width / Height). The resolution was set at 1280 × 800 pixels. A trapezoidal box constructed of black foam board with rectangular ends and the front face uncovered was placed over the monitor and keyboard. The opening was 70 by 70 cm and the back wall was 70 by 50 cm (width × height), the overall length of the side walls was 1 m. The front opening allowed participants to sit at the table with their head and shoulders just inside the box, isolating each participant.

Participants played a three-dimensional first-person space-themed video game with graphics comparable to that of modern video games. Their view was as if they were inside of a spaceship looking out of a viewscreen. The viewscreen contained a crescent-shaped panel near the bottom that contained two rows of oval, canister-shaped devices. There were 5 on the upper row, and 3 on the lower row. In this experiment, the CS was either a red or a blue light presented in the middle canister of the top or bottom row, respectively. The illumination consisted of an on/off flashing of color at a rate of 3 cycles per second. The diameter of each canister was 50 pixels when lit. The auditory stimulus was a combination of two different overlapping sounds which created an oscillating siren-type sound. The first was a low-pitched reverb siren (https://freesound.org/people/Syna-Max /sounds/59022/ created by user “Syna-Max” and licensed under the Attribution Noncommercial License, see https://creativecommons. org/licenses/by-nc/3.0/), the second sound had rapid and cyclic changes in the tone and the volume, resembling the sound of a boomerang (https://freesound.org /people/Linkis20/ sounds/209092/).

A black translucent panel could rise from the bottom of the screen where instructions could be presented to the participant. Instructions were presented in yellow Arial font.

Environments were visible through the view screen. The first was a “training environment” which appeared as if the participant’s craft was inside of a large, green wireframe cube with green square grid lines on each wall. The second, referred to as “Nicholosia”, was a colorful star-system consisting of a green ringed planet surrounded by stars and a yellow gaseous nebula. There was a large 3D spiral-shaped rotating space station present near participants’ center of view and a custom-made music track looping in the background.

Four spaceships were available to use as outcomes, and each one could be repelled by a different weapon. All four were used in an initial “response training” phase, described below, and afterwards a single spaceship (the “Learian”) was used in the experimental phases. The Learian was a blue saucer-shaped craft and was repelled by a weapon in the upper right of the screen named the “SOP Cannon” that fired glowing green balls. The other three ships and associated weapons were as described in Nelson et al., (2014).

Each weapon was activated by pressing a different key on the keyboard. A weapon became active once 15 keypresses at a rate of at least 3 per second had been accumulated. From that moment, every other keypress resulted in the weapon firing at the spaceship, but only when it was present and a response occurred at least every 0.75 s. The backspace key was used to activate the SOP Cannon.

Procedure

Conditions were randomly assigned to participants without replacement until each condition had been assigned once, then the conditions were replaced into the pool. The experiment was conducted in a single session. Informed consent was obtained, and each participant was positioned at the computer and wore headphones. When the subject was ready to start, a press on the “B” key initiated the experiment. Instructions were delivered to the participant through the game by being presented on the instruction panel and spoken through the headphones in a pre-recorded voice.

Response training. Participants were instructed that they must learn to activate weapons to repel invading spaceships and received practice trials with all four of the different ships. On the first trial with a particular ship the instructions informed the participant of the name of the ship, the weapon used to repel it, and the key to press to activate the weapon. They were instructed that the key must be pressed rapidly and repeatedly. The participant was then left to press the key and discover the effort necessary to activate the weapon. The ship was repelled after firing 8 shots. An instruction screen then appeared congratulating the participants and reminding them of the weapon to use on that ship. On subsequent appearances of the ship, no further instructions were provided. The ship simply remained on the screen until the participant repelled it. Participants were trained to respond to the four different space-ships (five trials each) in the manner described in the "response training" phase of Experiment 2 in Nelson et al. (2014).

After the final response training trial, participants were informed that they were ready for patrol. The final instructions encouraged participants to have the weapons ready if they thought invaders were going to appear so that they might attack the invader upon its arrival before it attacked the space station. They were told that invaders might appear, or that they may pass their patrol enjoying "the beauty of the galaxies and music beamed from the stations" without invaders. They were then virtually transported to the galaxy where the experimental manipulations took place. A single spaceship (the "Learian") was used in the remainder of the experiment.

Phase 1. During phase 1, the EXPacq group received 8 conditioning trials with stimulus A. In the same modality group, A was either a red or a blue light, counterbalanced. In the different modality groups, a sound was used with half of the subjects and a light (red or blue, counterbalanced) was used for the other half. Participants in CTRLacq were simply exposed to the context during this period.

On each conditioning trial, the CS was presented for 20 s. The spaceship appeared 5 s after the CS onset and remained for 15 s, regardless of participants' behavior. The CS offset was coincident with the spaceship flying away. If the weapon was not activated by the participant, the relevant weapon fired once at the end of the trial, without user input, and the spaceship fled the screen. The inter-trial interval (ITI) from the offset of the CS to the onset of the next trial was variable across trials and phases, averaging 20 s across the experiment.

Phase 2. In Phase 2 all participants received 8 conditioning trials with B. The Same Modality groups were presented with the light not used in phase 1. In the Different Modality groups, those who had training with the auditory CS during phase 1 received conditioning trials with one of the two lights, counterbalanced. For those who had prior conditioning with a light, B was the sound. In the CTRLacq condition, each CS (Red light, Blue light, Sound) served as B, by thirds.

Phases 3 and 4. Extinction began uninterrupted after phase 2. Participants in the EXPext group received 10 presentations of A or B alone, counterbalanced. The CTRLext group received equivalent exposure to the context during this phase. In phase 4, both the EXPext and CTRLext groups were presented 8 extinction trials. For the former, the alternate CS (A or B depending on the stimulus extinguished in phase 3) was used. The CTRLext group received extinction trials with A or B, counterbalanced.

Data analysis

The computer recorded the number of responses made on the backspace key during each second of the CS. Periods of time during the CS when the spaceship was not present were analyzed with mixed (within-between) factorial analysis of variance (ANOVA).

Results

Data were screened, and participants were removed if, during their first conditioning phase, the mean responding in two out of the last three conditioning trials did not exceed their responding on the first conditioning trial (2 from group

EXPext-Same, 6 from EXPext-Different, 1 from group CTRLext-Same, 3 from CTRLext-Different and 1 from the CTRLacq group). The final group sizes were 15 participants in the EXPext-Same group, 32 in both the EXPext-Different and CTRLext- Different groups, 16 in participants in the CTRLext-Same group and 14 in the CTRLacq group.

Phase 1. First conditioning

Panel A in Figure 8 shows the mean presses per second during each trial in the EXPacq-Same and EXPacq-Different groups. The CTRLacq group (not shown) showed practically no responding, averaging 0.07 presses per second across this phase. A Group (EXPext vs. CTRLext) × Modality (phase 2 same/different) × Trials ANOVA revealed an effect of Trials, $F(7, 637) = 122.56$, $p < 0.0001$, $\eta^2_p = 0.57$, and no effects of, or involving, any of the grouping variables, $p_s \geq 0.27$. A second analysis (Visual vs Auditory CS × Group × Trials) confirmed no differences in rate of conditioning as a function of whether the CS was auditory or visual, $p_s \geq 0.25$. The auditory and visual stimuli conditioned equally, and did so equally between groups.

Phase 2. Immediate generalization of excitatory learning

Immediate transfer (i.e., generalization) between stimuli, if present, would appear on the very first trial of phase 2. The left portion of Panel B (Figure 8) shows responding on each second of this trial, prior to the arrival of the outcome. The figure shows the Same and Different groups, collapsed across the Extinction Design variable, and the CTRLacq condition. Since responding was extremely low, and absent for many participants, a series of Kruskall-Wallis non-parametric tests on each second was used.

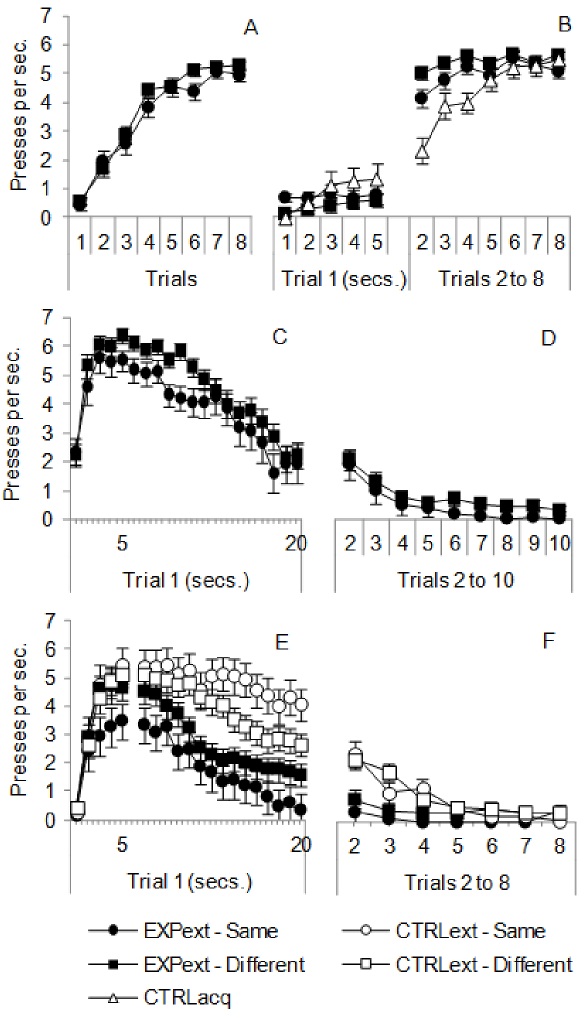


Figure 8. Results of Experiment 1. Panel A shows responding averaged across seconds on each trial (± SEM) during phase 1. Panel B, left, shows responding on each of the first five seconds of trial 1 in phase 2 (± SEM), and responding averaged across seconds on trials 2-8 at right. Panel C shows presses per second (± SEM) on each second of trial 1 of the first extinction phase. Panel D shows responding averaged over each trial (± SEM) during the remaining trials of the first extinction phase. Panel E shows responses per second (± SEM) during the first trial of the second extinction phase. Panel F shows responses per second averaged across each trial (± SEM) on the remaining trials of the second extinction phase. See text and legend for further details. Vertical bars in all panels represent the standard error of the mean.

The analysis suggests differences on the first second, $X^2 = 13.14$, $p = 0.001$. On that second the EXPacq-Same condition responded more than both the EXPacq-Different and CTRLacq conditions, X^2s = 9.48, $p = 0.002$, and 5.58, $p = 0.018$, respectively. The EXPacq-Different and CTRLacq conditions did not differ, $X^2 = 1.15$, $p = 0.28$. This finding suggests some immediate generalization, but the lack of any effect on the subsequent seconds, $p_s \geq 0.25$, where responding in the EXPacq-Same condition was numerically less than the CTRLacq group leaves that conclusion weak at best.

Phase 2. Learning to learn in conditioning

An initial ANOVA compared phase 1 of the EXPacq conditions to phase 2 of the CTRLacq condition simply to determine whether the delay in conditioning produced by phase 1 in the latter group had any effect. A Group × Trials ANOVA revealed that there were no effects involving the Group variable, $p_s \geq 0.26$. The experience of conditioning later in the game (open triangles in the right portion of Panel B) was equivalent to the experience of conditioning early in the game (Panel A).

As the right portion of Panel B shows, groups that had prior conditioning during phase 1 showed higher rates of responding during phase 2. This was confirmed by an AcqDesign × Trials ANOVA carried out on trials 2–8. There was a main effect of AcqDesign, $F(1,107) = 8.16$, $p = 0.005$, $\eta^2_p = 0.07$, and a significant AcqDesign × Trials interaction, $F(6, 642) = 9.99$, $p < 0.0001$, $\eta^2_p = 0.09$, as the advantage of the EXPacq group disappeared over trials. Simple effects on each trial showed that the EXPacq and CTRLacq groups differed on trials 2 thru 4, $F(1, 107)_{\text{range}} = 7.65–24.26$, $p_{\text{range}} = 3.08 \times 10^{-6} – 0.007$, $\eta^2_p = 0.07 – 0.18$.

To assess the effect of Modality, a Modality × ExtDesign × Trials ANOVA was conducted only with the EXPacq-Same vs. EXPacq-Different modality groups. ExtDesign was included to ensure that there were no pre-existing differences along that variable. The only effect from the analysis not anticipated by the analysis above was a Trials × Modality interaction, $F(7, 637) = 2.92$, $p = 0.005$, $\eta^2_p = 0.03$. There were no effects of, or involving, the ExtDesign variable, $p_s \geq 0.31$. Contrary to what would be expected based on stimulus generalization, and observed on the first second of Trial 1, the group for which A and B were different modalities (squares in Figure 8, Panel B), responded more than the Same modality group on trials 2 and 8, $F_s \geq 4.84$, $p_s \leq 0.03$, $\eta^2_p \geq 0.05$, complicating the use of this group as a generalization control. Nevertheless, the group EXPacq-Same responded still significantly more than the CTRLacq group on trials 2 and 4, $F_s \geq 7.44$, $p_s \leq 0.009$, $\eta^2_p \geq 0.15$.

Separate trials analyses (2–8) within each group confirmed that the LTL effect did not produce asymptotic learning in a single trial. There were effect of Trials in all groups $F_s \geq 4.6$, $p_s \leq .0001$, $\eta^2_p \geq .18$. Despite the rapid increase in performance between trials 1 and 2, there was still a small improvement in the experimental groups on the remaining trials.

Phase 3. First extinction

Mean responses during the first extinction phase in the EXPext-Same and EXPext-Different conditions are summarized in Figure 8 (Panels C and D). Since no US was presented, the CR encompasses the participants' key presses during the entire 20-seconds CS duration. A Modality × Trials × Seconds ANOVA revealed a main effect of Trials $F(7,315) = 73.12$, $p < 0.001$, $\eta^2_p = 0.62$, as overall responding decreased along extinction, Seconds $F(19,855) = 28.56$, $p < 0.001$, $\eta^2_p = 0.39$ as responding increased up until around second 5 where the outcome was expected, and then began to decrease, and a Trials × Seconds interaction, $F(133, 5985) = 10.0345$, $p < 0.001$, $\eta^2_p = 0.19$, as responding decreased over trials and the seconds effect, thusly, disappeared.

The effect of seconds is important and shown in Panel C on trial 1. The effect shows that participants expect the outcome around second 5 (see also, Nelson et al., 2018; Nelson et al., 2014). As extinction depends on the detection of the absence of the outcome, extinction cannot begin until after that second. The remaining trials are shown in Panel D, collapsed across seconds. Despite the trend for more responding in the different modality conditions, there were no effects of, or involving, the Modality variable, $p_s \geq 0.09$.

Phase 4. Second extinction: immediate generalization of extinction

The groups' performance on the first trial of phase 4 is shown in Figure 8, Panel E. An ExtDesign × Modality × Seconds analysis of all 20 s on this trial revealed main effects of ExtDesign, $F(1, 91) = 20.02$, $p < 0.0001$, $\eta^2_p = 0.18$ and Seconds, $F(19, 1729) = 39.55$, $p < 0.0001$, $\eta^2_p = 0.3$, along with interactions of ExtDesign × Modality, $F(1,91) = 4.74$, $p = 0.032$, $\eta^2_p = 0.05$, and ExtDesign × Seconds, $F(19,1729) = 5.76$, $p < 0.0001$, $\eta^2_p = 0.06$.

As discussed above, due to timing, the first 5 s are the appropriate test for the immediate generalization of extinction. Simple effect tests between the experimental and control groups on each of the first 5 s when the modality was Same showed no differences, with an effect perhaps beginning to appear on second 5, $F(1, 29) = 4.01$, $p = 0.055$, $\eta^2_p = 0.12$. No differences were present, near or otherwise, in the other 4 s, $F_s(1, 29) \leq 2.77$, nor in the Different modality group on any second, $F_s(1, 62) \leq 0.64$.

The odds the data favoring the null were computed on these seconds using the methods described by Wagenmakers (2007). Comparing the experimental and control groups in the Same Modality condition, the odds favored the null in seconds 1–4 ranging between 1.35 to 1 and 4.76 to 1. On second 5, though, support was weak, being only 0.75 to 1.

When the modality was different, the odds strongly favored the null hypothesis in every comparison, ranging between 5.74 to 1 and 8 to 1. Hence, the lack of immediate transfer was robust except for second 5 in the Same Modality group where generalization could occur.

Phase 4. Second extinction: learning to learn in extinction

In the remaining 15 s of the first extinction trial of phase 4, simple effects revealed that the effect of prior extinction was greater when the modality was the Same: There were significant differences between the experimental and control groups on all seconds, $F(1,29)_{range} = 4.65–34.34$, $p_{range} = 2.34 \times 10^{-6}–0.039$, $\eta^2_{p\ range} = 0.14 – 0.54$. When the modality was Different the groups differed on seconds 10–14, $F(1, 62)_{range} = 4.18–9.32$, $p_{range} = 0.003 – 0.045$, $\eta^2_{p\ range} = 0.06 – 0.13$, with no other differences being reliable.

As is evident in Panel F, the remaining trials (2–8, collapsed over the seconds variable) showed the same general pattern, though the differences disappeared as responding was eliminated. An ExtDesign × Modality × Trials ANOVA revealed an ExtDesign × Trials interaction, $F(6, 546) = 14.77$, $p < 0.0001$, $\eta^2_p = 0.14$. The effect of Modality had already disappeared after trial 1, as there were no effects involving this variable, $p_s \geq 0.18$. There were no other reliable effects whose interpretation is not superseded by the interaction, $p_s \geq 0.09$.

Discussion

Studies on the LTL effect in associative preparations (Holt & Kehoe, 1985; Kehoe & Holt, 1984; Kehoe et al., 1984, 2004; Schreurs & Kehoe, 1987) indicate that, regardless of the contribution of higher cognitive functions, associative mechanisms might also apply to the phenomenon in humans. The LTL effect was assessed both in conditioning and extinction by using a simple task where participants associated sensors with forthcoming attacking spaceships. Results showed that learning rates of conditioning and extinction were greatly facilitated by prior conditioning and extinction experiences. The transfer found in extinction is of special interest given the literature that suggests that extinction learning does not transfer between contexts (Bouton, 1993) nor consistently between CSs (Bouton & King, 1983; Kasprow et al., 1984; Kehoe et al., 2004; Richards & Sargent, 1983). The effects were apparent after single trial and, overall, did not depend on generalization processes.

In relation to excitatory learning, conditioning with A facilitated subsequent conditioning with B. The transfer effect did not materialize immediately. Instead, it emerged only after the subjects had the opportunity to experience the consequences of the new CS. Moreover, the rapid increase was largely consistent with the one-trial learning pattern described by Harlow (1949) in his studies on learning-set formation.

Conclusions regarding the contribution of physical generalization were slightly obscured by minor differences between the groups, with the Different modality group showing higher responding than the Same modality group in phase 1. A close inspection of Figure 8, panel A, shows similar ordinal differences on trials 4 and 6–8, suggesting that these may have been pre-existing differences due to random assignment. It is possible that in the absence of those differences the Different modality group might have responded less than the Same modality condition during phase 2. However, if the physical generalization had contributed to the effect, one should expect immediate transfer of responding in the Same modality group. The fact that the Same condition was not consistently higher than the control group on the first conditioning trial with B (differences appeared only on the first second), supports the idea that direct physical generalization contributed very little, if any, to the enhanced excitatory learning seen in phase 2.

Experiment 1 also showed that prior extinction learning with a CS enhanced extinction of a different CS. The effect did not appear in the first 5 s of training with the second stimulus. Therefore, no evidence of immediate secondary extinction as it was described by Pavlov (1927) was obtained. Instead, the transfer effect appeared once the participants had the opportunity to experience new extinction learning. On the first trial (seconds 6 to 20), those differences were bigger in the Same modality condition, indicating an initial summation between both types of transfer effects (physical generalization and LTL). However, the superiority of the Same modality group lasted for only one trial, while the advantage of the two experimental groups over their controls was still evident. This suggests that the modality effect either disappeared after trial 1 or became masked by a LTL type of transfer which was independent of physical similarity. Again, a strong decrease in the response from the first to the second trial in the experimental groups indicates a one-trial learning pattern (Harlow, 1949).

It could be argued that the LTL conditions performed better due to having more practice with the task by the time of testing. That explanation, however, would not apply as readily to the LTL-C and LTL-E effects. It seems unlikely that non-responding (which is “practiced” in the ITI for both groups) requires practice to adequately perform, and yet a LTL-E effect was found. Rather, it appears that the participants rapidly learned that responding was no longer appropriate because of prior experience with a similar scenario.

The enhanced extinction found is of special importance because it contrasts with several studies which failed to obtain the effect (Bouton & King, 1983; Kasprow et al., 1984; Kehoe et al., 2004; Richards & Sargent, 1983). Given that the stimuli were conditioned in different phases, this result is inconsistent with Vurbic and Bouton’s (2011) positive report that depended on intermixing trials with both CSs during conditioning. A possibility is that, though not mandatory, intermixing conditioning trials increases the size of the LTL-E effect observed in Experiment 1. The next experiment was designed to explore this possibility.

Experiment 2

Experiment 1 showed that it is possible to obtain a LTL effect in a simple associative procedure in humans, particularly in extinction. To further understand the mechanisms that might underlie this facilitation in extinction, Experiment 2 assessed the possibility that intermixing conditioning trials of A and B enhances the transfer of extinction learning (Vurbic & Bouton, 2011). Presumably, this type of training will be more effective at establishing associations between the stimuli over the ITI, which will in turn facilitate the emergence of a mediated extinction effect (Shevill & Hall, 2004). That is, with associations established between A and B, extinction of B would be accomplished by way of its associative activation on non-reinforced A trials.

The design is summarized in Table 7. Both groups received conditioning with A and B, which were stimuli in different modalities in all conditions. In the Blocked group the stimuli were presented separately in phases 1 and 2, respectively. By contrast, in the Intermixed group the A + and B + trials were quasi randomly interspersed. The stimuli were separately extinguished in phases 3 and 4 in both groups. Though not reflected in the table, the order of extinction of each CS was counterbalanced. If intermixing conditioning trials facilitates the LTL-E effect, between-group differences should appear in phase 4 in the form of an increased extinction rate in the Intermixed group.

Method

Participants

Participants were 83 college-aged volunteers. All procedures were approved by the relevant institutional review board.

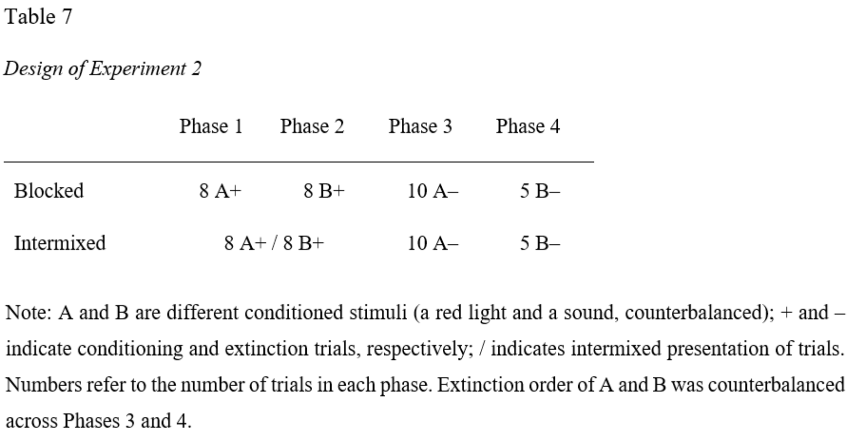


Table 7

Design of Experiment 2

	Phase 1	Phase 2	Phase 3	Phase 4
Blocked	8 A+	8 B+	10 A–	5 B–
Intermixed	8 A+ / 8 B+		10 A–	5 B–

Note: A and B are different conditioned stimuli (a red light and a sound, counterbalanced); + and – indicate conditioning and extinction trials, respectively; / indicates intermixed presentation of trials. Numbers refer to the number of trials in each phase. Extinction order of A and B was counterbalanced across Phases 3 and 4.

Apparatus

The apparatus and stimuli were the same as in Experiment 1, except that only the red light and the sound were used. Another change was that the experimental phases took place in a galaxy called “Boutonia”, a colorful star-system consisting of a blue ringed planet surrounded by stars and blue gaseous nebulae illuminated by a white sun. In this case, near the participants’ center of view, there was a large, rotating, sphinx-like station. Galaxies were changed because the visuals and accompanying music of this galaxy could be somewhat more entertaining for participants.

Procedure

Response training. Participants were instructed to play the video game following the procedure detailed in Experiment 1.

Phases 1 and 2. In phase 1, the Blocked group received 8 conditioning trials with the red light or the sound, counterbalanced. The alternate stimulus was used in the 8 trials of phase 2. In the Intermixed group presentation of the CSs was random except in that no more than two AB or BA alternations were allowed in a row and, no more than 3 presentations of a stimulus were permitted to occur consecutively to prevent any blocked-like presentation of the stimuli.

The parameters of each trial resemble those used in Experiment 1. The ITI varied across trials and phases and averaged 19 s.

Phases 3 and 4. Within each group the subjects received 10 extinction trials in phase 3 and 5 in phase 4. The phase 1 or 2 stimulus (A or B) was extinguished first in phase 3 and the other in phase 4, counterbalanced between subjects.

Details not specified here were the same as those of Experiment 1.

Data analysis

Data were collected and analyzed as in the previous experiment.

Results

Data were screened as in Experiment 1. Five participants were removed from the Blocked condition and six from the Intermixed condition, leaving group sizes of 35 and 37, respectively.

Conditioning of A

Panel A of Figure 9 shows the mean presses per second in each trial in the Blocked and Intermixed groups. A Group × Trials ANOVA revealed an effect of Trials, $F(7, 490) = 98.28$, $p < 0.0001$, $\eta^2_p = 0.58$. The lack of effects involving the grouping variable, $p_s \geq 0.12$, shows that conditioning developed similarly in both groups, though there was a trend for conditioning with A to be superior in the Intermixed condition, something that would be expected as the interspersed conditioning trials with B could produce a mild LTL effect in this group.

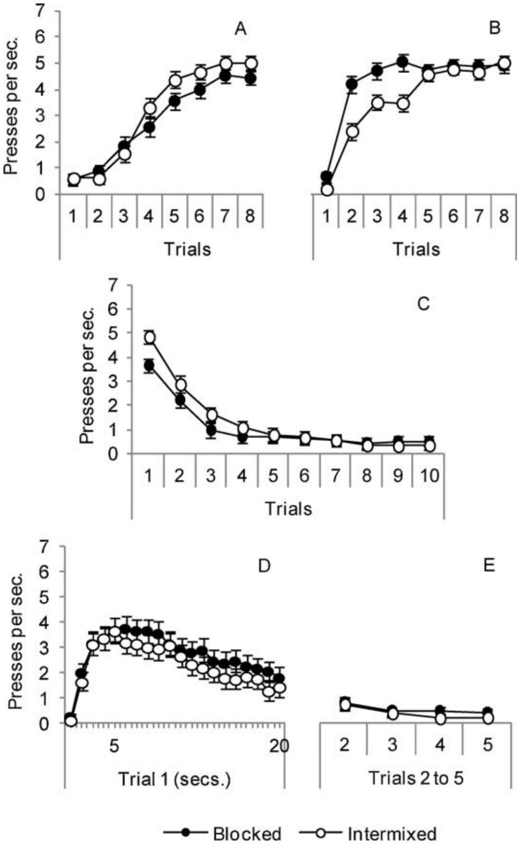


Figure 9. Results of Experiment 2. Panels A and B show responding averaged (± SEM) across seconds on each trial of phase 1 and phase 2, respectively. Panel C shows responding averaged (± SEM) across seconds on each trial during the first extinction phase. Panel D shows responding (± SEM) on each second during the first extinction trial in phase 3. Panel E depicts the remaining trials of the final phase averaged across seconds.

Conditioning of B

Panel B of Figure 9 shows the mean responding along training with B. An initial Group × Trials ANOVA revealed a Group × Trials interaction, $F(7, 490) = 5.23$, $p < 0.0001$, $\eta^2_p = 0.07$, indicating that the pattern of acquisition of the response differed between groups. Simple effects showed higher response in the Blocked group on trials 2–4, $F(1, 70)_{\text{range}} = 8.29–15.43$, $p_{\text{range}} = 0.0002 – 0.005$, $\eta^2_{p\ \text{range}} = 0.11 – 0.18$.

There were no differences on trials 5–8, $p_s \geq 0.56$, where the groups converged at the end of training.

The first trial in the Blocked group was examined in detail by each second of responding and no evidence of immediate transfer was found. The pre-CS responding averaged 0.72, and a series of Wilcoxon tests (using the normal approximation) showed that it did not differ from responding during the CS on any second, $p_s \geq 0.41$.

Phase 3. First extinction

Responding of both groups during the first extinction phase is depicted in Figure 9, Panel C. A Group × Trials × Seconds ANOVA revealed a main effect of Trials, $F(9, 630) = 113.74$, $p < 0.0001$, $\eta^2_p = 0.62$, Seconds, $F(19, 1330) = 36.69$, $p < 0.0001$, $\eta^2_p = 0.34$, and a significant Trials × Seconds interaction, $F(171, 11970) = 12.58$, $p < 0.0001$, $\eta^2_p = 0.15$, (interpretation of these effects is the same as in the first extinction phase of Experiment 1). Finally, a Group × Trials interaction, $F(9, 630) = 3.62$, $p = 0.0002$, $\eta^2_p = 0.05$, reflects a higher response in the Intermixed group on the very first trial, $F(1, 70) = 8.30$, $p = 0.005$, $\eta^2_p = 0.11$. No other effects were significant, $p_s \geq 0.64$. The difference on the first trial was due to a tendency for less responding in participants in the blocked group for which phase 3 involved extinction of A (extinction of A and B was counterbalanced across phases 3 and 4 in this group). Therefore, those participants had an interval between training and testing that resulted in a decrease in responding, something that may not have happened for those who had extinction of B instead. A Group × ExtinctionOrder (AB/BA) × Seconds

ANOVA on that trial revealed a Group × ExtinctionOrder interaction confirming that impression, $F(168) = 5.05$, $p = 0.028$, $\eta^2_p = 0.07$.

Phase 4. Second extinction

Panels D and E of Figure 9 show the responses during the second extinction phase. Though this experiment cannot directly assess whether immediate transfer occurred, performance on the first trial of phase 4 allowed us to assess differences between the groups with respect to any immediate generalization of extinction that might have occurred. Analyses of each second of this trial (shown in Panel D) showed no significant differences between the groups on the first five seconds, $F_s \leq 0.65$, nor on the remaining 15 s, once extinction had begun, $F_s \leq 1.13$.

Extinction was very rapid. As can be observed in panel E, which collapses over seconds, responding was practically eliminated by trial 3, thus, these trials were not included in the analyses. A Group × Trials × Seconds ANOVA between trials 1 and 2 revealed a main effect of Trials, $F(1, 70) = 51.29$, $p < 0.0001$, $\eta^2_p = 0.42$, Seconds, $F(19, 1330) = 22.55$, $p < 0.0001$, $\eta^2_p = 0.24$, and a Trials by Seconds interaction, $F(19, 1330) = 9.51$, $p < 0.0001$, $\eta^2_p = 0.12$. There were no effects involving the Group variable, $p_s \geq 0.54$. On the first two trials, the odds favored the null hypothesis regarding group differences on every second of each trial by a range of 3.03 to 1 to 8.5 to 1, indicating equivalent extinction learning in both groups regardless of their differential treatment during conditioning.

It is safe to assume that both groups showed a LTL-E effect considering that the same effect was observed in the equivalent blocked group in the previous experiment, and that the groups did not differ here. The first extinction phase took place at a different time in the experiment and, therefore, is not necessarily the most appropriate comparison. Nevertheless, Phase × Trials ANOVAS analysis comparing the first 5 trials of phase-3 extinction to that of phase 4 revealed a Phase × Trials interaction in each group, $F_s \geq 3.35$, $p_s \leq 0.012$, that confirmed that the second extinction was more rapid in both groups.

Discussion

Experiment 2 determined whether intermixing conditioning trials with two CSs would produce better transfer of extinction learning than blocked training (Vurbic & Bouton, 2011). The results showed no differential transfer of extinction as a function of the type of training.

Comparison of the learning curves to stimulus A (Figure 9, Panel A) suggest that acquisition developed faster in the intermixed group. Though both groups had the same experience with A, the interspersed trials with B in the intermixed group, might have had a cumulative effect that produced higher responses to A in that group. A similar, and reliable, between-trial LTL effect has been reported previously by Schreurs and Kehoe (Schreurs & Kehoe, 1987).

Of most importance the experiment found no differences between the groups during the second extinction phase. Both the Blocked and the Intermixed groups showed an increase in the rate of extinction learning compared to their primary extinction. However, and contrary to Vurbic and Bouton's (2011) assumption, no evidence of greater facilitation was observed in the Intermixed group.

There are several possible explanations for the differences between these results and those of Vurbic and Bouton (2011). First, it might be that the small number of trials used in the experiments prevented the formation of within-compound associations. By increasing the number of trials not only could those associations be more possible in the Intermixed group, but also less probable in the Blocked condition, thus maximizing the opportunity of finding a difference. Another possibility is that Vurbic and Bouton's (2011) blocked group had conditioning with each CS separated by 24 h, while in this experimental series both stimuli were presented to humans in the same, relatively short, experimental session. These procedural differences may have made the blocked condition used here to be similar to Vurbic and Bouton's intermixed condition, allowing the formation of associations between A and B in both groups. It is not possible, therefore, to completely rule out that associations between stimuli partially mediated the LTL-E effect in this experiment, whether these are direct associations between the stimuli or mediated by way of a common US representation (Rescorla & Cunningham, 1977, 1978). Experiment 3 was conducted to observe whether the same transfer could be observed in a situation where associations between stimuli cannot explain the effect.

Experiment 3

Experiment 2 revealed that the transfer in extinction did not necessarily depend on the stimuli being intermixed during conditioning. However, providing conditioning trials with both stimuli in the same session might have permitted the formation of within-stimuli associations that would, in turn, serve as the basis for a mediated extinction effect (Shevill & Hall, 2004). Another possibility in these experiments is that extinction of the second stimulus is mediated by a common US representation. Rescorla and Heth (1975) highlighted the importance of that mechanism in extinction by arguing that primary extinction is partly caused by weakening of the US representation during CS-alone presentations. If we assume that the US representation is shared by all stimuli conditioned with the same US, the first extinction phase would ensure a weak US representation at the beginning of the second extinction phase, thus speeding extinction of the second stimulus. Finally, pairing both stimuli with the same outcome during phases 1 and 2 might have render both stimuli equivalent (Honey & Hall, 1989), so that changing the meaning of one of them during extinction would affect responding to the other stimulus.

Experiment 3 was designed to eliminate these potential sources of transfer. The design is shown in Table 8. In this case, the LTL group received conditioning and extinction with A before conditioning and extinction with B. A similar design simply looking at the LTL effect in conditioning has been used by Kehoe et al. (1984). In these circumstances, conditioning with B should not benefit from its association with A. Moreover, providing conditioning trials with B immediately before its extinction rules out the mediation of a degraded US representation. Finally, extinguishing A in phase 2 before B is conditioned in phase 3 would prevent the stimuli from having a similar reinforcement history. Groups without prior conditioning (CTRLacq) or extinction experience (CTRLext) provided the baselines to assess the LTL effect in acquisition and extinction, respectively.

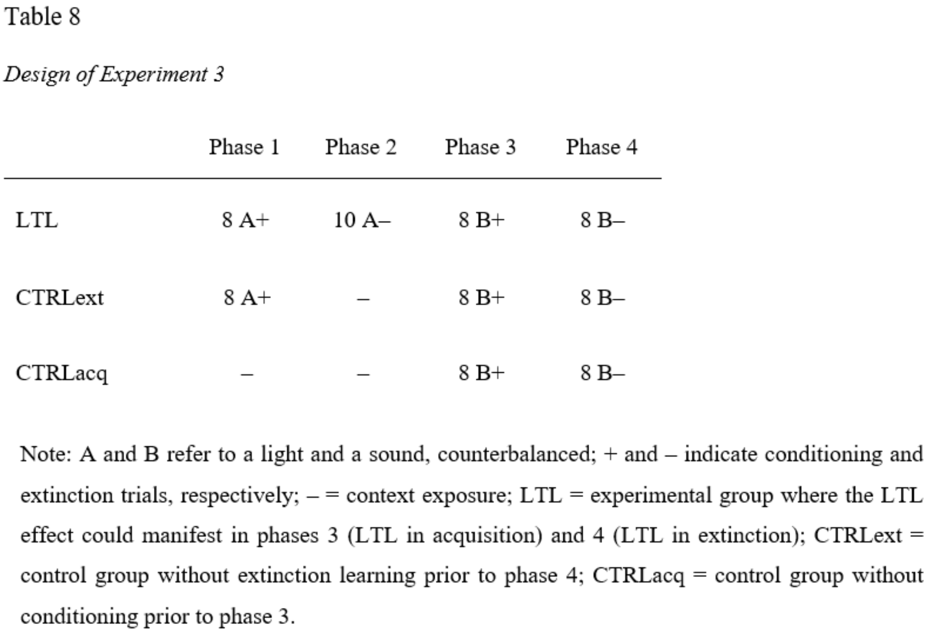


Table 8

Design of Experiment 3

	Phase 1	Phase 2	Phase 3	Phase 4
LTL	8 A+	10 A–	8 B+	8 B–
CTRLext	8 A+	–	8 B+	8 B–
CTRLacq	–	–	8 B+	8 B–

Note: A and B refer to a light and a sound, counterbalanced; + and – indicate conditioning and extinction trials, respectively; – = context exposure; LTL = experimental group where the LTL effect could manifest in phases 3 (LTL in acquisition) and 4 (LTL in extinction); CTRLext = control group without extinction learning prior to phase 4; CTRLacq = control group without conditioning prior to phase 3.

Method

Participants

30 college-aged volunteers, and subsequently 9 more, took part in this study. As in the previous experiments, all procedures were approved by the relevant review board.

Apparatus

The apparatus, the experimental environment and stimuli, were the same as those used in Experiment 2.

Procedure

Response training. Participants were trained to respond by using the procedure detailed in Experiment 1.

Phases 1 and 2. Phase 1 consisted of 8 A-US presentations. The red light served as A for half of the participants while the sound was used for the other half. The CTRLacq group received equivalent context exposure during this phase.

In phase 2, the LTL group received 10 A-alone presentations. The CTRLacq and CTRLext groups were merely exposed to the context.

Phases 3 and 4. In phase 3, all groups received 8 conditioning trials with B. For those participants who had conditioning with the red light during phase 1, B was the sound; and vice versa for the other half. Participants of the CTRLacq group received conditioning with one or the other stimulus by halves.

Phase 4 consisted of 8 extinction trials with B in all groups. B’s identity corresponded to that of phase 3.

The ITI was variable and averaged 20 s across phases. Any other detail not specified here proceeded as described for Experiment 1.

Data analysis

Key pressing was analyzed as in the previous experiments.

Results

Application of the exclusion criteria resulted in 3, 2 and 4 participants removed from groups LTL, CTRLext and CTRLacq, respectively from the first 30 participants. These subjects were replaced to maintain adequate group sizes (ns = 10).

Phase 1. First conditioning

The data are shown in Panel A of Figure 10. A Group (LTL vs. CTRLext) × Trials ANOVA revealed a main effects of trials, $F(7, 126) = 29.47$, $p < 0.0001$, $\eta^2_p = 0.62$, that indicates a progressive increase in responding along training. There were no effects of, or involving, the Group variable (whether the participants were to receive extinction trials or not in phase 2), $p_s \geq 0.6$. Performance of the CTRLacq group (excluded from this analysis) averaged 0.21 presses per second in the absence of any stimuli.

Phase 2. First extinction

Panel B of Figure 10 displays responding during phase 2. The two control groups were excluded from this analysis as their responding was practically absent, averaging 0.14 in the CTRLext group and 0.07 in the CTRLacq group. Though analyzed, the figure collapses across seconds on each trial. A Trials × Seconds ANOVA carried out in the LTL group revealed main effects of Trials, $F(9,81) = 21.27$, $p < 0.0001$, $\eta^2_p = 0.7$, Seconds, $F(19,171) = 20.16$, $p < 0.0001$, $\eta^2_p = 0.69$ (not shown in the figure), and a Seconds by Trials interaction, $F(171, 1539) = 2.91$, $p < 0.0001$, $\eta^2_p = 0.24$. Interpretation of these effects is the same as in the first extinction phase of experiment 1.

Phase 3. Second conditioning

As shown in Panel C of Figure 10, responding was very low during the first conditioning trial with B. The number of presses per second averaged 0.64, 0.14 and 0 in groups LTL, CTRLext and CTRLacq, respectively. Kruskall-Wallis non-parametric comparisons between the groups confirmed the lack of differences, $X^2 \leq 4.14$, $p \geq 0.13$. In this experiment the second conditioning phase was preceded by an extinction phase with the prior CS, so no generalization of excitatory learning was expected between the stimuli.

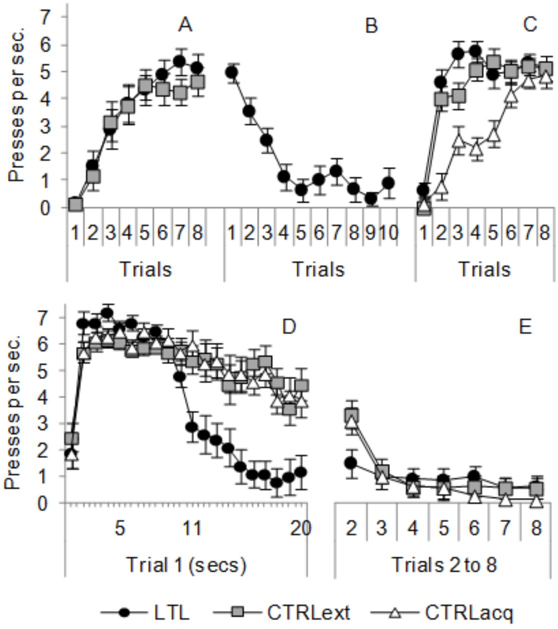


Figure 10. Results of Experiment 3. The top panels represent responding averaged across seconds on each trial (± SEM) during conditioning (Panel A), extinction (Panel B) of A, and during conditioning of a stimulus in a different modality (B) (Panel C). Panel D shows responding (± SEM) on each second of the first extinction trial with B. Panel E shows responding on the remaining trials of the last phase averaged across seconds (± SEM). See text and legend for further details.

A Group (LTL vs. CTRLext) × Trials (2–8) ANOVA found no effects of, or involving, Group, $p_s \geq 0.17$. It is worth noting that this analysis revealed no effects of, nor interactions with, the Trials variable, $p_s \geq 0.1$. A single trial of conditioning was all that was necessary for these groups to reach their maximum response and having had extinction prior to the second phase of conditioning did not affect any LTL effect. These groups were combined and compared to the

CTRLacq condition with a Group × Trials (2–8) ANOVA. There was a Group × Trials interaction, $F(6, 168) = 7.77$, $p < .0001$, $\eta^2_p = .22$. Simple effects showed that the two groups that received prior conditioning differed from the control on trials 2 to 5, $F(1, 28)_{\text{range}} = 13.7–40.74$, $p_{\text{range}} = 6.58 \times 10^{-7} – .001$, $\eta^2_{p\ \text{range}} = .33 – .6$.

Phase 4. Second extinction

Panels D and E of Figure 10 show responding in all groups during phase 4. A Group × Seconds analysis of the first trial (Panel D) revealed a Group × Seconds interaction, $F(38, 513) = 6.95$, $p < 0.0001$, $\eta^2_p = 0.34$. There were no differences among the groups on the first five seconds, $F(2, 27) = 1.73$, $p = 0.19$. Since the same stimuli were used in phases 3 and 4, the first five seconds of the test were identical to the previous conditioning trial and, unlike in the other experiments, there was no reason to expect any possibility of immediate transfer of extinction learning. However, after second 5, where extinction begins to occur, the differences appeared. The LTL and CTRLext conditions differed on second 6 and from seconds 11 to 20, $F_{\text{s}}\ (1,18) \geq 4.74$, $p_s \leq 0.04$, $\eta^2_p \geq 0.21$. The differences between the LTL group and the CTRLacq condition were reliable on seconds 11 to 20, $F_{\text{s}}(1,18) \geq 5.45$, $p_s \leq 0.03$, $\eta^2_p \geq 0.23$. A Group × Seconds × Trials analysis of the remaining trials (Panel E, collapsed over seconds) showed an effect of Seconds, $F(19,513) = 19.8$, $p < 0.0001$, $\eta^2_p = 0.42$, Trials, $F(6, 162) = 30.92$, $p < 0.0001$, $\eta^2_p = 0.53$, and a Trial × Second interaction, $F(114, 3078) = 5.4$, $p < 0.0001$, $\eta^2_p = 0.17$. A Trials × Group interaction, $F(12,162) = 3.43$, $p < 0.0001$, $\eta^2_p = 0.2$, indicates that the advantage of the LTL over the other groups described in trial 1, was still evident on trial 2, $F(2, 27) = 3.7$, $p = 0.04$, $\eta^2_p = 0.21$. There were no group differences on subsequent trials, $F_{\text{s}}(2,27) \leq 0.81$, $p_s \geq 0.46$.

Any possible differences between the CTRLext and CTRLacq groups were separately addressed with a Group × Trials × Seconds ANOVA of these groups alone. These analyses revealed no effect of Group, nor interactions with this variable, $p_s \geq 0.62$.

Discussion

The goal of Experiment 3 was to determine whether it is possible to obtain a LTL-E effect in the absence of the conditions where several forms of mediated generalization between the stimuli could contribute. In Experiments 1 and 2, consecutive conditioning of both CSs might allow the formation of associations which would eventually be responsible for the effects observed in the next phases. To prevent such associations, the phases were reordered so that A was conditioned and extinguished before training with B began. Results indicated that both LTL-C and LTL-E effects were still obtained after these procedural changes.

Facilitation of learning during B + trials was evident in the groups that received prior conditioning with A. Both groups were better than the control for LTL in acquisition, for which B + trials constituted the first conditioning phase. Furthermore, introduction of an extinction phase between both conditioning phases in the LTL group did not reduce the effect. That result shows that the LTL-C effect did not depend on the integrity of the US representation (Rescorla & Heth, 1975), which should have deteriorated over the course of A- trials in group LTL.

A LTL-E effect was also obtained in phase 4. Extinction of B was more rapid in the group that had prior extinction learning than in the other two groups, even after B's conditioning during phase 3 should have restored any degraded US representation. Similarly, having found a LTL-E effect with this design allow us to rule out a common reinforcement history as the source for the effect (Honey & Hall, 1989). Thus, it seems that, whatever the cause of the LTL-E effect may be, it does not necessarily involve the processes alleged by the mediational accounts alone.

General discussion

Physical or primary generalization applies to situations in which the stimuli differ along a dimension (e.g., color, intensity). A different type of transfer emerges when different tasks share a common structure. The term that has been used for this kind of transfer is learning to learn, which denotes the idea of the organism becoming a more efficient learner as it gains experience with different situations.

The effect was investigated in humans by using a largely Pavlovian conditioning task. Special emphasis was placed on the transfer of extinction learning as it appears to be difficult both between contexts and CSs (Bouton, 1993; Bouton & King, 1983; Kasprow et al., 1984; Kehoe et al., 2004; Richards & Sargent, 1983) and understanding it could elucidate both mechanisms of LTL and extinction.

In Experiment 1, conditioning and extinction with a CS increased the rate of conditioning and extinction learning (respectively) with a different stimulus. Both effects were evident only after a single trial. The lack of immediate transfer on the first conditioning and extinction trials with the alternate CS indicated that physical generalization processes played a minimal role, if any, in the effects. That pattern, characterized by an initial absence of generalization and a subsequent enhancement of the learning rate, is consistent with Kehoe's work in the rabbit NM response (Kehoe & Holt, 1984; Kehoe et al., 1995, 1984, 2004; Schreurs & Kehoe, 1987) and supports his classification between immediate and emergent forms of transfer (Kehoe, 1992; Kehoe et al., 1995).

Experiment 2 revealed that intermixing conditioning trials with both stimuli did not facilitate extinction when compared to a group that received conditioning in separate phases, as has been observed in animal preparations (Vurbic & Bouton, 2011). Finally, Experiment 3 examined LTL effects when conditioning and extinction of A preceded conditioning and extinction of B. This experiment revealed two important findings. First, it was possible to obtain a LTL-C effect even after the responses to the first stimulus had been extinguished, which agrees with previous studies that indicate that cross-modal transfer does not depend on the maintenance of the response to the first stimulus (Kehoe et al., 1984). And second, LTL effects were observed under conditions that should not allow mediation-based processes.

These results are not likely to be the result of simply practicing aspects of the method that might be maintained by operant contingencies. While the presence of the ship is signaled by way of a Pavlovian relationship with the sensor, pressing of the key could be considered to be rewarded by the firing of the weapon, which, in turn, only occurs in the presence of the ship. As discussed in Experiment 1, simple practice on the operant component is unlikely to be sufficient to produce the effect, particularly in the case of the facilitation of extinction. Moreover, Bouton (Bouton, Trask, & Carranza-Jasso, 2016) has argued that operant extinction may result in the context acquiring inhibitory properties for the response (see also Trask et al., 2017). Since the context was kept constant along the experiment, it is possible that extinction of the first stimulus (A) promotes extinction of the second stimulus (B) through such context inhibition. However, that explanation would predict an immediate effect on B in Experiments 1 and 2, which did not occur. Moreover, such an effect should eliminate the LTL-C effect observed in Experiment 3, where extinction of A should make the context inhibitory for the response, reducing or eliminating any benefit that B might have during its conditioning in the following phase.

Kehoe (1988; Kehoe et al., 1995) has offered a connectionist model that can be readily applied to the LTL-C effects found in these experiments. He proposed that two different sets of connections are formed within a network during conditioning with a stimulus (see Figure 11). The first links a CS unit to an interior hidden unit (X), and the second connects the hidden unit (X) with a response unit (R) that will eventually be the responsible of the subject’s response. The key of his proposal is that the latter connection can be shared by different stimuli. For instance, in Experiment 1, conditioning with the first stimulus would be relatively slow because both A-X and X-R connections must be formed. No response is observed on the first B + trial because the B-X link has not yet formed. However, once the B-X connection begins to form, the existing X-R association would allow responding to emerge quickly. The model also applies to the LTL-C effect seen after extinction of A’s response in Experiment 3. According to Kehoe (1988), as the A-X link declines during extinction, X is activated less and less frequently. The result is that the X-R connection is protected from extinction and remains available for conditioning of B in the next phase. Nevertheless, that aspect of the model does not predict the LTL-E effect that was found. Since the interior connection remains largely intact regardless of extinction procedures, extinction of any stimulus will always involve the elimination of the CS-X connections, regardless of whether a different CS has been extinguished before or not.

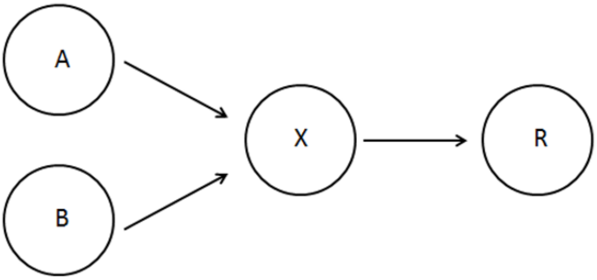


Figure 11. Kehoe’s (1988) model for LTL in conditioning. Two sensory elements (A and B) connect to a hidden unit (X), which in turns triggers the response generator unit (R). Adapted from Kehoe et al., (1995).

An explanation based on the US representation can also account for the transfer effects seen in acquisition. Rescorla and Heth (1975) proposed that the CR depends, not only on the CS-US association, but also on strength of a non-associative representation of the US. In Experiment 1 it could be assumed that conditioning with A would ensure that the participants have access to an already formed US representation when conditioning with B begins, thus reducing the number of trials needed to reach asymptotic levels of conditioning. Moreover, this account correctly predicts a lack of immediate transfer during the first trial with B. The participants may have a good representation of the US, but it cannot affect responding as it has not yet been associated with B. Interestingly, this view can also explain the LTL-C effect found after extinction in Experiment 3. In that study, since extinction of A in phase 2 may have degraded the US representation, slow conditioning with a new stimulus might be expected. However, experiments on reinstatement suggest that a single US presentation is sufficient to restore its representation. Thus, presentation of the US during the first B + trial might be enough to recover the representation and yield to good performance on the following trials.

On the other hand, application of Rescorla and Heth's (1975) ideas to the extinction results is difficult. In Experiment 1, a degraded US representation at the end of phase 3 should result in an immediate performance deficit in phase 4. However, diminished responding was not observed until extinction actually began in the latter part of Trial 1. Moreover, in Experiment 3, conditioning of B in phase 3 should have ensured a good US representation at the time extinction with B began, yet phase 4 extinction benefitted by the prior extinction of A.

It is also worth considering the role that attention may play in these experiments. Recently it has been suggested that new cue-outcome associations will be learned more rapidly if the outcome has been reliably predicted in previous situations (Griffiths, Erlinger, Beesley, & Le Pelley, 2018; Griffiths & Thorwart, 2017). That is, attention to outcomes may increase when they have been well predicted, facilitating learning about them in the future. For example, in Experiment 1 the experimental group might have shown fast learning with B because the spaceship was perfectly predicted by A during the prior phase, something that the participants in the control group have not experienced. However, explaining the rapid extinction in those terms is more complicated. After the first extinction phase the outcome is no longer reliably predicted, so further learning with that outcome should not be facilitated, at least not to the same extent as in the second conditioning phase. Even if we consider the "spaceship" and "no-spaceship" as relatively independent outcomes, we cannot say that after extinction the stimulus reliably predicts the absence of the spaceship (i.e., there is no evidence that the extinguished CS is a conditioned inhibitor). Thus, extinction of the second CS should not necessarily be enhanced by such an “Outcome Predictability” effect (Griffiths & Thorwart, 2017).

In summary, the accounts above can deal with the LTL-C effect, but they do not apply to the LTL-E effect, which would remain unexplained. It appears clear that some type of generalization is taking part in this set of experiments, and, in the absence of physical generalization, it could be assumed that the LTL effect is a case of mediated generalization. What remains to be determined is the specific element over which generalization emerges.

There are two key findings in these experiments that can help to begin to address this question. First, results in Experiment 3 suggest that both the LTL-C and LTL-E effects rely on the prior episodes being compartmentalized and stored separately, so that extinction of the original response does not affect LTL-C effects seen in phase 3, and the recent conditioning of the stimulus in phase 3 does not affect the LTL-E effect in phase 4. This finding is consistent with the idea that extinction does not involve unlearning, but rather new learning that coexists with conditioning memories (Bouton, 1993, 2004). And second, since transfer appeared after a single trial, it seems that the critical element is related to the delivery or removal of the outcome on the first trial of the second conditioning and extinction phases, respectively.

A possibility is that generalization is triggered by the similarity of the prediction error that occurs on that first trial and the error in prediction of prior conditioning or extinction episodes. When the first stimulus is paired with the US, the mismatch between the participants’ expectation and the actual outcome generates a large prediction error, which will eventually disappear with further training. Similarly, when the first extinction begins, the absence of the US when it is expected produces a large negative prediction error that will progressively change towards zero. It is possible that once these experiences have been established, subsequent conditioning or extinction with a different CS that resembles the over- or under-expectation already experienced retrieves elements of the prior episode that can mediate generalization. Under-prediction of the outcome would evoke prior conditioning episodes, leading to a fast increase in responding, while its over-prediction would retrieve prior extinction phases, resulting in a rapid decrease in performance. That is, the outcome error may serve as a type of retrieval cue through which transfer between similar episodes appears. This type of mechanism would be advantageous for the organism since it would expand the range of situations in which generalization can operate by including situations in which neither physical nor mediated generalization appear immediately.

This view of the outcome error as a retrieval cue is consistent with the lack of immediate transfer across stimuli, since there is no prediction error until the outcome is delivered. Moreover, it predicts that both transfer effects will appear regardless of whether the two stimuli are successively conditioned (Experiments 1 and 2) or not (Experiment 3). Interestingly, this account can also explain the erasure effects observed by Rescorla and Cunningham (1977, 1978). An extinction trial with X can retrieve episodes with similar prediction errors, such as the prior extinction of Y, preventing reinstatement or spontaneous recovery with that stimulus. This mechanism can also go some way in accommodating the attentional account described earlier. Nelson (Nelson, Craddock, Molet, & Renaux, 2017) has shown that attention to predictive stimuli declines in extinction and recovers with renewal. To the extent that attention to well predicted outcomes also recovers in situations where such outcomes are again expected (e.g., renewal), then such a mechanism could facilitate subsequent conditioning with that outcome. However, the role of this attention mechanism in facilitating extinction still remains to be specified.

Though the methodology used in this series is deliberately simple such that it should not require much reasoning, it is not possible to rule out the abstraction of rules. Nevertheless, the rules may need to be complex, or overly abstract. Experiments 1 and 2 appear to be easily accommodated by simple rules. After phase 1, the rule could be “space ships follow lights/sounds”. But for those rules to work in the Different modality conditions the rule would have to be a very general “spaceships follow any stimulus”. We would also have to assume that the rule requires confirmation, otherwise immediate generalization would be observed. In that way, rule learning would depend on the trial outcome in much the same way as the proposal above suggests. In Experiment 1 (and in the blocked condition in Experiment 2), after the first outcome of phase 2 confirms the rule, it is applied on subsequent trials. After phase 3, the rule has changed, “spaceships no longer follow stimuli”, and the absence of the expected spaceship at the end of second 5 of trial 1 in phase 4 confirms the rule. Experiment 3 can likewise be explained by rules, but, importantly, a rule-based account becomes largely isomorphic to the account above in that these rules must be stored separately and be dependent on future trial outcomes for retrieval and application. Thus, a rule-based explanation is not inconsistent with the suggestion that the operation of the trial outcome as a retrieval cue is the important factor. Regardless of whether the trial structures are represented as elemental events consisting of stimuli, outcomes, and their association, or rules, these mechanisms appear to be stored separately across learning episodes and are dependent on trial outcomes for retrieval which enables their use in facilitating future learning about similar outcomes.

Overall, these experiments demonstrate a clear and unqualified LTL effect on conditioning and extinction learning, provide a contemporary complement to the work by Kehoe and his colleagues (Holt & Kehoe, 1985; Kehoe, 1988; Kehoe & Holt, 1984; Kehoe et al., 1995, 1984, 2004; Schreurs & Kehoe, 1987) and suggest interesting ways in which the effect operates. That is, that generalization emerges between memory episodes which are evoked by the error produced on a trial.

Final discussion and conclusions

Final discussion

To maximize the possibilities to survive organisms have to be able to transfer what they have learned about a stimulus in a given situation to other stimuli and situations. The research presented here was designed to study transfer of extinction learning across both contexts and stimuli in humans.

When a neutral stimulus is consistently paired with a biologically relevant stimulus, the neutral stimulus will come to trigger a response that is related to the latter. However, if the contingencies change and the conditioned stimulus is no longer followed by the outcome, responses to that stimulus will diminish until they no longer appear. As discussed throughout this work, at the end of this extinction process it would seem that the original response has been indeed lost, however, several relapse phenomena indicate that that is not the case. For instance, the conditioned response will be "renewed" if the conditioned stimulus is tested out of the extinction context (e.g., Bouton & Bolles, 1979), making the extinction learning context-specific. Two main accounts have been made for the fact that extinction is only expressed in the extinction context. One possibility is that the extinction context becomes inhibitory during extinction (e.g., Rescorla & Wagner, 1972), the alternate, more prominent, account contends that the extinction context modulates the CS meaning like a negative occasion setter in a feature negative discrimination (Bouton, 1993, 2004).

Experiments in Chapter 1 were designed to determine the associative mechanisms underlying the renewal effect by using a predictive learning task. To determine whether context specificity of extinction is the result of the context acquiring modulatory, occasion-setting properties, during extinction the extinction context was tested for the transfer property of occasion setters.

Chapter 2 examined the extent to which what is learned about a stimulus can be transferred to different stimuli on the bases of different factors. Transfer can appear immediately, such as in generalization studies (e.g., Guttman & Kalish, 1956). Cross-modal transfer, the transfer of learning that appears between stimuli from different sensory modalities (i.e., in the absence of physical generalization), however, can also be manifested as an increase in the rate of learning to a CS as a result of prior conditioning of another (the LTL effect). Experiments in Chapter 2 used a behavioral task to address whether extinction learning transfers across different CSs while trying to reveal the associative grounds for that transfer.

Regarding the transfer of extinction across contexts, the experiments showed the expected renewal effect when an extinguished cue was tested in a new neutral context (Chapter 1 Experiments 2 and 3). However, renewal was just as strong in a context where some other cue had been extinguished. If an extinction context has negative occasion-setting properties, then it should be able to modulate responding to other CSs extinguished outside of it. Therefore, when a context has been endowed with occasion-setting properties by having extinction of a cue within it, and that context serves as the test context of another cue in an ABC renewal design, a reduction in renewal is expected. No such reduction was observed in any experiment. Although those were null results, Bayesian analyses confirmed that the results provided positive (Raftery, 1995) support for the null.

The mere presence of renewal in these experiments shows, in agreement with other reports (e.g., Bouton, 1993, 2004), that expression of extinction learning depends on the presence of certain cues. The results did not support, however, Bouton’s model of renewal (Bouton, 1993, 2004). No evidence of the context serving as occasion-setter was obtained.

According to Trask et al., (2017), occasion setting would appear with experimental preparations where the onset of the context occurs long before the CS presentation, and with relatively long inter-trial intervals (ITIs). Where those conditions are not met, context are assumed to be more similar to cues where they would become inhibitory after extinction. In the procedure used in this experimental series the context was present in both the stimulus and feedback screen, however, each screen was a discrete slide. Thus, the fact that the contexts were not continuously present could have made them more similar to discrete cues, supporting that they could become simple conditioned inhibitors.

As with occasion setting, no evidence of conditioned inhibition was revealed (Chapter 1, Experiment 3).

To explain the renewal effect and the lack of occasion-setting transfer, Chapter 1 ended with the proposal that the interference produced by extinction might enhance attention to a unique-cue that emerges from the joint presentation of the cue and the context (Wagner, 2003). This mechanism would explain renewal and renewal-related phenomena in much the same way as Bouton's account. The location of control is simply moved. Rather than inhibition being controlled by an "and" gate in a separate system that operates as occasion setting, the "and" gate is simply replaced with a unique configural cue whose presence depends on the joint occurrence of the context and the cue. The difference is that, contrary to an occasion-setting account, the unique cue account would also predict a lack of transfer between extinction contexts. Testing a cue in a new context will result in the loss of the unique-cue controlling extinction, regardless of whether that cue had prior extinction or not, or whether the context was associated with extinction or not. In short, according to a unique-cue account, extinction is not only context-specific, but also cue-specific (unless further extinction learning is provided, as we will see when discussing the LTL results).

Additionally, the proposed mechanism also borrows from another theoretical proposal drawn from Bouton's theory. The attentional theory of context processing (ATCP) proposed by Rosas and his colleagues (Rosas et al., 2006; Rosas & Callejas-Aguilera, 2006) assumes, as Bouton does, that an extinction context acts as a modulatory cue which is needed for extinction to be expressed, but their theory goes beyond Bouton in predicting the conditions under which context specificity of learning will be observed. According to Rosas (Rosas et al., 2006; Rosas & Callejas-Aguilera, 2006) interference derived from extinction produces a shift in attention towards contextual stimuli. As a result, the context will take part in the associative structure underlying extinction, or any learning, yielding to context dependency. By assuming that the shift in attention is not towards contextual stimuli but to the unique cue-context configural cues, the unique-cue account can explain results from Rosas lab, such as the EMACS (Extinction Makes Acquisition Context Specific) effect.

If interference enhances attention to unique cues, any learning with a cue that takes place during extinction of another cue should appear context specific (or, *unique-cue* specific).

The unique-cue idea makes testable predictions. Williams and Braker (1999) have shown that it is possible to bias people to processes stimuli in configural ways (see also Melchers, Shanks, & Lachnit, 2008, for a review) which, according to the unique-cue proposal, should affect the context specificity of extinction. For example, if subjects are biased to use configural solutions to solve, say, a discrimination problem, and then receive simple conditioning with a cue, responding to the cue should be affected by a context change to a greater extent than a group that had not been predisposed to use a configural solution. Parallelly, whether or not extinction biases people to solve process the stimuli in configural ways can be assessed. For example, if cues B and C are separately conditioned after cue A has been extinguished, people would respond less to the BC compound, than to either B or C separately. The compound should be represented as a new unique stimulus, different from its elements, as a result of extinction

The experiments regarding transfer of learning across stimuli showed that conditioning and extinction with one stimulus increased the rates of conditioning and extinction of another stimulus, respectively. The effect in in conditioning was obtained even after the first stimulus underwent extinction. The experiments ruled out multiple possible explanations for the effect: physical generalization, a common US representation, acquired equivalence, within-compound associations, and the model proposed by Kehoe (1988). I proposed that the similarities in prediction error experienced with different stimuli may be the responsible for this type of transfer. The prediction error that is produced when a stimulus is conditioned or extinguished for the first time, might evoke prior episodes of condition and extinction that produced similar prediction error, promoting generalization.

The two sets of studies complement each other in their ability to further knowledge about the mechanisms involved in extinction. Having found an LTL-E effect would be consistent with the idea that the context acquires inhibitory properties during the extinction of the first stimulus, facilitating subsequent extinction with any CS in that context. However, some of the findings of those experiments will not fit into that explanation. In Experiment 1 of Chapter 2, had the context had formed an inhibitory association with the US after the first extinction phase, an immediate generalization of extinction to the second stimulus should have been observed. Additionally, the results of Experiment 3 (A+ A– B+ B– design), would not be expected. First, if extinction of the first stimulus renders the context inhibitory, no facilitation of conditioning would be expected in the next phase. Moreover, if the context acquires excitatory properties during conditioning of the second stimulus in phase 3, rapid extinction in phase 4 should not have been observed. Therefore, evidence supporting direct context-US associations was not obtained in either of the two lines of research contained in this dissertation.

As suggested by Vurbic and Bouton (2011), the LTL-E effect could also be explained through an occasion setting mechanism. In Experiments 1 and 2 from Chapter 2 (A+ B+ A– B– designs), extinction of the first stimulus could result in the context being a negative occasion setter. As an occasion setter, that context should transfer its modulatory power to other stimuli that have been both conditioned and extinguished (i.e., that have been occasion-set). For that reason, transfer will not be expected to appear until B had been extinguished at least once. Additionally, an occasion-setting account could explain rapid extinction of the second stimulus in Experiment 3 (A+ A– B+ B– design). That is, even if the first extinction phase was followed by a conditioning phase, the ability of occasion setters to modulate responding to a target should not be affected by any excitation the context might accrue. However, in if the context acts as a negative occasion setter after the first extinction phase, the LTL-C effect observed with B would not be expected, and therefore it should be assumed that the LTL-C and the LTL-E effects would be due to different mechanisms. Apart from violating parsimony, that possibility seems unlikely given the identical pattern of both types of effects. Finally, the lack of occasion setting by contexts observed in Chapter 1, albeit with different methods, does not support the generality of Vurbic and Bouton’s (2011) suggestion.

The recovery effects found in the occasion-setting series replicates many findings that show that elimination of a response through extinction is not permanent. Rather, extinction fundamentally involves some mechanism by which it appears labile or contextually controlled. A similar conclusion was reached by studying the transfer across stimuli in Chapter 2, since rapid transfer of conditioning was observed even after extinction of the first CS (Experiment 3).

The findings of this work also indicate that extinction does not necessarily depend on “labile” processes as Pavlov (1927) stated. Like conditioning, extinction benefits from prior extinction learning. Therefore, it does not seem that extinction itself is more fragile. Extinction may be as strong and durable a form of learning as excitatory learning, but its expression (or its transfer) simply depends on certain retrieval cues, which may be related to the presence of the unique-cues present during the original learning, as in a renewal design (Chapter 1), or related to similarities in the prediction error when further extinction learning is provided, such as in a LTL design (Chapter 2).

Both sets of experiments suggest that conditioning and extinction are stored as separate memories that are available to affect future performance. A common factor that seems to be involved in both of these sets of experiments is prediction error. In formal models of conditioning (e.g., Pearce & Hall, 1980; Rescorla & Wagner, 1972), the prediction error is used to adjust the associative strength of the stimuli so that they become accurate predictors of their consequences. However, this work indicates that the prediction error can serve many functions. In extinction, the negative prediction error may modify how stimuli are processed, making them more likely to be treated as a unique cue. The LTL experiments, instead, indicate that the error itself (both positive and negative) can serve as a retrieval cue when prior learning has taken place. Questions remain open about how prediction error might be represented so that it provides all of these functions.

Conclusions

- The extinction context does not seem to function as an occasion setter, nor as a conditioned inhibitor.
- Prediction error produced by interference may drive attention to unique-cues, making extinction *unique-cue* specific.
- Memory retrieval of extinction may depend on the unique-cues present during the original extinction learning.
- Learning of extinction transfers robustly to new stimuli, as does the commonly observed learning of conditioning.
- Rapid and robust transfer of extinction learning across CS indicates that extinction is not necessarily a labile type of learning.
- Prediction error may allow rapid transfer by acting as a retrieval cue.
- Prediction error serves different functions in the course of learning and the task now is to understand how prediction error itself can be represented to provide those functions.

Bibliography

Arcediano, F., Ortega, N., & Matute, H. (1996). A behavioural preparation for the study of human pavlovian conditioning. *The Quarterly Journal of Experimental Psychology. 49B*, 270–283. https://doi.org/10.1080/713932633

Bailey, A. M., McDaniel, W. F., & Thomas, R. K. (2007). Approaches to the study of higher cognitive functions related to creativity in nonhuman animals. *Methods, 42*(1), 3–11. https://doi.org/10.1016/J.YMETH.2006.12.003

Baker, K. D., McNally, G. P., & Richardson, R. (2012). D-cycloserine does not facilitate fear extinction by reducing conditioned stimulus processing or promoting conditioned inhibition to contextual cues. *Learning & Memory, 19*(10), 461–469. https://doi.org/10.1101/lm.026674.112

Bourne, L. E. (1970). Knowing and using concepts. *Psychological Review, 77*(6), 546–556. https://doi.org/10.1037/h0030000

Bouton, M. E. (1993). Context, time, and memory retrieval in the interference paradigms of Pavlovian learning. *Psychological Bulletin, 114*(1), 80–99. https://doi.org/10.1037/0033-2909.114.1.80

Bouton, M. E. (1997). Signals for whether versus when an event will occur. In *Learning, motivation, and cognition: The functional behaviorism of Robert C. Bolles.* (pp. 385–409). Washington: American Psychological Association. https://doi.org/10.1037/10223-019

Bouton, M. E. (2000). A learning theory perspective on lapse, relapse, and the maintenance of behavior change. *Health Psychology : Official Journal of the Division of Health Psychology, American Psychological Association*, *19*(1S), 57–63.

Bouton, M. E. (2002). Context, ambiguity, and unlearning: sources of relapse after behavioral extinction. *Biological Psychiatry*, *52*(10), 976–86.

Bouton, M. E. (2004). Context and Behavioral Processes in Extinction. *Learning & Memory*, *11*(5), 485–494. https://doi.org/10.1101/lm.78804

Bouton, M. E., & Bolles, R. C. (1979). Contextual control of the extinction of conditioned fear. *Learning and Motivation*, *10*(4), 445–466. https://doi.org/10.1016/0023-9690(79)90057-2

Bouton, M. E., & King, D. A. (1983). Contextual control of the extinction of conditioned fear: tests for the associative value of the context. *Journal of Experimental Psychology: Animal Behavior Processes*, *9*(3), 248–265. https://doi.org/10.1037//0097-7403.9.3.248

Bouton, M. E., & Nelson, J. B. (1994). Context-specificity of target versus feature inhibition in a feature-negative discrimination. *Journal of Experimental Psychology. Animal Behavior Processes*, *20*(1), 51–65.

Bouton, M. E., & Peck, C. A. (1989). Context effects on conditioning, extinction, and reinstatement in an appetitive conditioning preparation. *Animal Learning & Behavior, 17*(2), 188–198. https://doi.org/10.3758/BF03207634

Bouton, M. E., & Ricker, S. T. (1994). Renewal of extinguished responding in a second context. *Animal Learning & Behavior*, *22*(3), 317–324. https://doi.org/10.3758/BF03209840

Bouton, M. E., & Swartzentruber, D. (1986). Analysis of the associative and occasion-setting properties of contexts participating in a Pavlovian discrimination. *Journal of Experimental Psychology: Animal Behavior Processes*, *12*(4), 333–350. https://doi.org/10.1037/0097-7403.12.4.333

Bouton, M. E., & Swartzentruber, D. (1989). Slow reacquisition following extinction: Context, encoding, and retrieval mechanisms. *Journal of Experimental Psychology: Animal Behavior Processes*, *15*(1), 43–53. https://doi.org/10.1037/0097-7403.15.1.43

Bouton, M. E., Trask, S., & Carranza-Jasso, R. (2016). Learning to inhibit the response during instrumental (operant) extinction. *Journal of Experimental Psychology: Animal Learning and Cognition*, *42*(3), 246–258. https://doi.org/10.1037/xan0000102

Bouton, M., & Nelson, J. B. (1998). The role of context in classical conditioning: Some implications for cognitive behavior therapy. In W. O’Donohue (Ed.), *Learning Theory and Behavior Therapy* (pp. 59–84). Needham Heights, MA: Allyn & Bacon.

Brown, A. L., & Kane, M. J. (1988). Preschool children can learn to transfer: Learning to learn and learning from example. *Cognitive Psychology*, *20*(4), 493–523. https://doi.org/10.1016/0010-0285(88)90014-X

Bustamante, J., Uengoer, M., & Lachnit, H. (2016). Reminder Cues Modulate the Renewal Effect in Human Predictive Learning. *Frontiers in Psychology*, *7,* 1968. https://doi.org/10.3389/fpsyg.2016.01968

Campese, V., & Delamater, A. R. (2013). ABA and ABC renewal of conditioned magazine approach are not impaired by dorsal hippocampus inactivation or lesions. *Behavioural Brain Research*, *248*, 62–73. https://doi.org/10.1016/j.bbr.2013.03.044

Campolattaro, M. M., Kashef, A., Lee, I., & Freeman, J. H. (2011). Neuronal correlates of cross-modal transfer in the cerebellum and pontine nuclei. *Journal of Neuroscience*, *31*(11), 4051–4062. https://doi.org/10.1523/JNEUROSCI.4142-10.2011

Cunningham, C. L. (1979). Alcohol as a cue for extinction: State dependency produced by conditioned inhibition. *Animal Learning & Behavior*, *7*(1), 45–52. https://doi.org/10.3758/BF03209656

Davidson, T. L., & Rescorla, R. A. (1986). Transfer of facilitation in the rat. *Animal Learning & Behavior*, *14*(4), 380–386. https://doi.org/10.3758/BF03200082

Delamater, A. R., Campese, V., & Westbrook, R. F. (2009). Renewal and spontaneous recovery, but not latent inhibition, are mediated by gamma-aminobutyric acid in appetitive conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, *35*(2), 224–237. https://doi.org/10.1037/a0013293

Delamater, A. R., & Westbrook, R. F. (2014). Psychological and neural mechanisms of experimental extinction: a selective review. *Neurobiology of Learning and Memory*, *108*, 38–51. https://doi.org/10.1016/j.nlm.2013.09.016

Denniston, J. C., Chang, R. C., & Miller, R. R. (2003). Massive extinction treatment attenuates the renewal effect. *Learning and Motivation*, *34*(1), 68–86. https://doi.org/10.1016/S0023-9690(02)00508-8

Durlach, P. J. (1983). Effect of signaling intertrial unconditioned stimuli in autoshaping. *Journal of Experimental Psychology. Animal Behavior Processes*, *9*(4), 374–89.

Franssen, M., Clarysse, J., Beckers, T., van Vooren, P. R., & Baeyens, F. (2010). A free software package for a human online-conditioned suppression preparation. *Behavior Research Methods*, *42*(1), 311–317. https://doi.org/10.3758/BRM.42.1.311

García Gutiérrez, A., & Rosas, J. M. (2003). The role of the number of cues on retroactive interference in human predictive learning. *Psicológica*, *24*(2), 271–287.

Glautier, S., Elgueta, T., & Nelson, J. B. (2013). Extinction produces context inhibition and multiple-context extinction reduces response recovery in human predictive learning. *Learning & Behavior*, *41*(4), 341–352. https://doi.org/10.3758/s13420-013-0109-7

Grahame, N. J., Hallam, S. C., Geier, L., & Miller, R. R. (1990). Context as an occasion setter following either CS acquisition and extinction or CS acquisition alone. *Learning and Motivation*, *21*(3), 237–265. https://doi.org/10.1016/0023-9690(90)90008-C

Grau, J. W., & Rescorla, R. A. (1984). Role of context in autoshaping. *Journal of*

Experimental Psychology: Animal Behavior Processes, *10*(3), 324–332. https://doi.org/10.1037/0097-7403.10.3.324

Griffiths, O., Erlinger, M., Beesley, T., & Le Pelley, M. E. (2018). Outcome predictability biases cued search. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. https://doi.org/10.1037/xlm0000529

Griffiths, O., & Thorwart, A. (2017). Effects of outcome predictability on human learning. *Frontiers in Psychology*, *8*, 511. https://doi.org/10.3389/fpsyg.2017.00511

Guttman, N., & Kalish, H. I. (1956). Discriminability and stimulus generalization. *Journal of Experimental Psychology*, *51*(1), 79–88. https://doi.org/10.1037/h0046219

Halford, G. S., Bain, J. D., Maybery, M. T., & Andrews, G. (1998). Induction of relational schemas: Common processes in reasoning and complex learning. *Cognitive Psychology*, *35*(3), 201–245. https://doi.org/10.1006/cogp.1998.0679

Hall, G. (1975). An analysis of positive general transfer in discrimination learning in the rat. *Animal Learning & Behavior*, *3*(3), 212–216. https://doi.org/10.3758/BF03213433

Hall, G., & Honey, R. C. (1990). Context-specific conditioning in the conditioned-emotional-response procedure. *Journal of Experimental Psychology: Animal Behavior Processes*, *16*(3), 271–278. https://doi.org/10.1037/0097-7403.16.3.271

Hanggi, E. B. (1999). Categorization learning in horses (Equus caballus). *Journal of Comparative Psychology*, *113*(3), 243–252. https://doi.org/10.1037/0735-7036.113.3.243

Harlow, H. F. (1949). The formation of learning sets. *Psychological Review*, *56*(1), 51–65. https://doi.org/10.1037/h0062474

Harris, J. A., Jones, M. L., Bailey, G. K., & Westbrook, R. F. (2000). Contextual control over conditioned responding in an extinction paradigm. *Journal of Experimental Psychology. Animal Behavior Processes*, *26*(2), 174–85.

Holland, P. C. (1984). Differential effects of reinforcement of an inhibitory feature after serial and simultaneous feature negative discrimination training. *Journal of Experimental Psychology. Animal Behavior Processes*, *10*(4), 461–75.

Holland, P. C. (1986). Transfer after serial feature positive discrimination training. *Learning and Motivation*, *17*(3), 243–268. https://doi.org/10.1016/0023-9690(86)90013-5

Holland, P. C. (1989). Transfer of negative occasion setting and conditioned inhibition across conditioned and unconditioned stimuli. *Journal of Experimental Psychology. Animal Behavior Processes*, *15*(4), 311–28.

Holland, P. C. (1991). Transfer of control in ambiguous discriminations. *Journal of Experimental Psychology. Animal Behavior Processes*, *17*(3), 231–48.

Holland, P. C. (1992). Occasion Setting in Pavlovian Conditioning. *Psychology of Learning and Motivation*, *28*, 69–125. https://doi.org/10.1016/S0079-7421(08)60488-0

Holland, P. C., & Reeve, C. E. (1991). Acquisition and transfer of control by an ambiguous cue. *Animal Learning & Behavior*, *19*(2), 113–124. https://doi.org/10.3758/BF03197867

Holmes, N. M., & Westbrook, R. F. (2014). ABA renewal is greater when extinction occurs in the same context as cue pre-exposure. *Journal of Experimental Psychology: Animal Learning and Cognition*, *40*(3), 369–379. https://doi.org/10.1037/xan0000024

Holt, P. E., & Kehoe, E. J. (1985). Cross-modal transfer as a function of similarities between training tasks in classical conditioning of the rabbit. *Animal Learning & Behavior*, *13*(1), 51–59. https://doi.org/10.3758/BF03213365

Honey, R. C., & Hall, G. (1989). Acquired equivalence and distinctiveness of cues. *Journal of Experimental Psychology. Animal Behavior Processes*, *15*(4), 338–346.

Honig, W. K., & Urcuioli, P. J. (1981). The legacy of Guttman and Kalish (1956): Twenty-five years of research on stimulus generalization. *Journal of the Experimental Analysis of Behavior*, *36*(3), 405–45.

Hultsch, D. F. (1974). Learning to learn in adulthood. *Journal of Gerontology*, *29*(3), 302–308.

Ivanov-Smolensky, A. G. (1927). On the methods of examining the conditioned food reflexes in children and in mental disorders. *Brain*, *50*(2), 138–141. https://doi.org/10.1093/brain/50.2.138

Kangas, B. D., & Bergman, J. (2014). Repeated acquisition and discrimination reversal in the squirrel monkey (Saimiri sciureus). *Animal Cognition*, *17*(2), 221–228. https://doi.org/10.1007/s10071-013-0654-7

Kasprow, W. J., Schachtman, T. R., Cacheiro, H., & Miller, R. R. (1984). Extinction does not depend upon degradation of event memories. *Bulletin of the Psychonomic Society*, *22*(2), 95–98. https://doi.org/10.3758/BF03333773

Kehoe, E. J. (1988). A layered network model of associative learning: Learning to learn and configuration. *Psychological Review*, *95*(4), 411–433. https://doi.org/10.1037/0033-295X.95.4.411

Kehoe, E. J. (1992). Versatility in conditioning: A layered network model. In D. S. Levine & S. J. Levin (Eds.), *Motivation, emotion and goal direction in neural networks.* (pp. 63–90). Hillsdale, NJ: Erlbaum.

Kehoe, E. J. (2006). Repeated acquisitions and extinctions in classical conditioning of the rabbit nictitating membrane response. *Learning & Memory*, *13*(3), 366–375. https://doi.org/10.1101/lm.169306

Kehoe, E. J., & Holt, P. E. (1984). Transfer across CS-US intervals and sensory modalities in classical conditioning of the rabbit. *Animal Learning & Behavior*, *12*(2), 122–128. https://doi.org/10.3758/BF03213130

Kehoe, E. J., Horne, A. J., & Macrae, M. (1995). Learning to learn: Real-time features and a connectionist model. *Adaptive Behavior*, *3*(3), 235–271. https://doi.org/10.1177/105971239500300301

Kehoe, E. J., Morrow, L. D., & Holt, P. E. (1984). General transfer across sensory modalities survives reductions in the original conditioned reflex in the rabbit. *Animal Learning & Behavior*, *12*(2), 129–136. https://doi.org/10.3758/BF03213131

Kehoe, E. J., Weidemann, G., & Dartnall, S. (2004). Apparatus exposure produces profound declines in conditioned nictitating-membrane responses to discrete conditioned stimuli by the rabbit (oryctolagus cuniculus). *Journal of Experimental Psychology: Animal Behavior Processes*, *30*(4), 259–270. https://doi.org/10.1037/0097-7403.30.4.259

Konorski, J. (1948). *Conditioned reflexes and neuron organization. Conditioned reflexes and neuron organization.* New York, NY, US: Cambridge University Press.

Kruschke, J. K., & Johansen, M. K. (1999). A model of probabilistic category learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *25*(5), 1083–1119. https://doi.org/10.1037/0278-7393.25.5.1083

Lamarre, J., & Holland, P. C. (1987). Transfer of inhibition after serial feature negative discrimination training. *Learning and Motivation*, *18*(4), 319–342. https://doi.org/10.1016/0023-9690(87)90001-4

Langbein, J., Siebert, K., Nürnberg, G., & Manteuffel, G. (2007). Learning to learn during visual discrimination in group housed dwarf goats (Capra hircus). *Journal of Comparative Psychology*, *121*(4), 447–456. https://doi.org/10.1037/0735-7036.121.4.447

Le Pelley, M. E. (2004). The Role of Associative History in Models of Associative Learning: A Selective Review and a Hybrid Model. *The Quarterly Journal of Experimental Psychology Section B*, *57*(3b), 193–243. https://doi.org/10.1080/02724990344000141

León, S. P., Abad, M. J. F., & Rosas, J. M. (2011). Context–outcome associations mediate context-switch effects in a human predictive learning task. *Learning and Motivation*, *42*(1), 84–98. https://doi.org/10.1016/j.lmot.2010.10.001

Levine, M. (1959). A model of hypothesis behavior in discrimination learning set. *Psychological Review*, *66*(6), 353–366. https://doi.org/10.1037/h0044050

Lovibond, P. F., Preston, G. C., & Mackintosh, N. J. (1984). Context specificity of conditioning, extinction, and latent inhibition. *Journal of Experimental Psychology: Animal Behavior Processes*, *10*(3), 360–375. https://doi.org/10.1037/0097-7403.10.3.360

Mackintosh, N. J. (1975). A theory of attention: Variations in the associability of stimuli with reinforcement. *Psychological Review*, *82*(4), 276–298. https://doi.org/10.1037/h0076778

McLaren, I. P. ., McAndrew, A., Angerer, K., McLaren, R., Forrest, C., Bowditch, W., … Verbruggen, F. (2018). Mackintosh lecture: Association and cognition: Two processes, one system. *Quarterly Journal of Experimental Psychology*.

Melchers, K. G., Shanks, D. R., & Lachnit, H. (2008). Stimulus coding in human associative learning: Flexible representations of parts and wholes. *Behavioural Processes*, *77*(3), 413–427. https://doi.org/10.1016/J.BEPROC.2007.09.013

Miller, R. H., Grahame, N. J., & Hallam, S. C. (1990). Summation of responding to CSs and an excitatory test context. *Animal Learning & Behavior*, *18*(1), 29–34. https://doi.org/10.3758/BF03205236

Napier, R. M., Macrae, M., & Kehoe, E. J. (1992). Rapid reaquisition in conditioning of the rabbit's nictitating membrane response. *Journal of Experimental Psychology. Animal Behavior Processes*, *18*(2), 182–92.

Nelson, J. B., & Bouton, M. E. (1997a). The Effects of a Context Switch following Serial and Simultaneous Feature-Negative Discriminations. *Learning and Motivation*, *28*(1), 56–84. https://doi.org/10.1006/lmot.1997.0946

Nelson, J. B., & Bouton, M. E. (1997b). The Effects of a Context Switch following Serial and Simultaneous Feature-Negative Discriminations. *Learning and Motivation*, *28*(1), 56–84. https://doi.org/10.1006/LMOT.1997.0946

Nelson, J. B., Craddock, P., Molet, M., & Renaux, C. (2017). Recovery of attention with renewal. *Learning & Memory*, *24*(12), 637–640. https://doi.org/10.1101/lm.045682.117

Nelson, J. B., Fabiano, A. M., & Lamoureux, J. A. (2018). The effects of extinction-aroused attention on context conditioning. *Learning & Memory*, *25*(4), 165–175. https://doi.org/10.1101/lm.046201.117

Nelson, J. B., Lamoureux, J. A., & León, S. P. (2013). Extinction arouses attention to the context in a behavioral suppression method with humans. *Journal of Experimental Psychology. Animal Behavior Processes*, *39*(1), 99–105. https://doi.org/10.1037/a0030759

Nelson, J. B., Navarro, A., & Sanjuan, M. del C. (2014). Presentation and validation of "The Learning Game," a tool to study associative learning in humans. *Behavior Research Methods*, *46*(4), 1068–1078. https://doi.org/10.3758/s13428-014-0446-2

Nelson, J. B., Sanjuan, M. del C., Vadillo-Ruiz, S., Pérez, J., & León, S. P. (2011). Experimental renewal in human participants. *Journal of Experimental Psychology: Animal Behavior Processes*, *37*(1), 58–70. https://doi.org/10.1037/a0020519

Paredes-Olay, M. C., & Rosas, J. M. (1999). Within-subjects Extinction and Renewal in Predictive Judgments.

Pavlov, I. P. (1927). *Conditioned reflexes: An investigation of the physiological activity of the cerebral cortex (G. V. Anrep, translation)*. London: Oxford University Press.

Pearce, J. M., & Hall, G. (1980). A model for Pavlovian learning: Variations in the effectiveness of conditioned but not of unconditioned stimuli. *Psychological Review*, *87*(6), 532–552. https://doi.org/10.1037/0033-295X.87.6.532

Polack, C. W., Laborda, M. A., & Miller, R. R. (2012). Extinction context as a conditioned inhibitor. *Learning & Behavior*, *40*(1), 24–33. https://doi.org/10.3758/s13420-011-0039-1

Raftery, A. E. (1995). Bayesian model selection in social research. In P. V. Marsden (Ed.), *Sociological methodology* (pp. 111–196). Cambridge, MA: Blackwell.

Rayburn-Reeves, R. M., Stagner, J. P., Kirk, C. R., & Zentall, T. R. (2013). Reversal learning in rats (Rattus norvegicus) and pigeons (Columba livia): Qualitative differences in behavioral flexibility. *Journal of Comparative Psychology*, *127*(2), 202–211. https://doi.org/10.1037/a0026311

Rescorla, R. A. (1984). Associations between Pavlovian CSs and context. *Journal of Experimental Psychology: Animal Behavior Processes*, *10*(2), 195–204. https://doi.org/10.1037/0097-7403.10.2.195

Rescorla, R. A. (1985). Conditioned inhibition and facilitation. In R. R. Miller & N. E. Spear (Eds.), *Information Processing in Animals: Conditioned Inhibition* (pp. 229–326). Hillsdale, NJ: Erlbaum.

Rescorla, R. A. (2003). Protection from extinction. *Animal Learning & Behavior, 31*(2), 124–132. https://doi.org/10.3758/BF03195975

Rescorla, R. A. (2008). Within-Subject Renewal in Sign Tracking. *Quarterly Journal of Experimental Psychology, 61*(12), 1793–1802. https://doi.org/10.1080/17470210701790099

Rescorla, R. A., & Cunningham, C. L. (1977). The erasure of reinstated fear. *Animal Learning & Behavior, 5*(4), 386–394. https://doi.org/10.3758/BF03209584

Rescorla, R. A., & Cunningham, C. L. (1978). Recovery of the US representation over time during extinction. *Learning and Motivation, 9*(4), 373–391. https://doi.org/10.1016/0023-9690(78)90001-2

Rescorla, R. A., & Heth, C. D. (1975). Reinstatement of fear to an extinguished conditioned stimulus. *Journal of Experimental Psychology: Animal Behavior Processes, 1*(1), 88–96.

Rescorla, R. A., & Wagner, A. R. (1972). *A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement*. *Classical Conditioning II Current Research and Theory* (Vol. 21). https://doi.org/10.1101/gr.110528.110

Richards, R. W., & Sargent, D. M. (1983). The order of presentation of conditioned stimuli during extinction. *Animal Learning & Behavior, 11*(2), 229–236. https://doi.org/10.3758/BF03199653

Robbins, S. J. (1990). Mechanisms underlying spontaneous recovery in autoshaping. *Journal of Experimental Psychology: Animal Behavior Processes, 16*(3), 235–249. https://doi.org/10.1037/0097-7403.16.3.235

Rodgers, J. P., & Thomas, D. R. (1982). Task specificity in nonspecific transfer and in extradimensional stimulus generalization in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes, 8*(4), 301–312. https://doi.org/10.1037/0097-7403.8.4.301

Rosas, J. M., Aguilera, J. E. C., Álvarez, M. M. R., & Abad, M. J. F. (2006). Revision of retrieval theory of forgetting: What does make information context-specific? *International Journal of Psychology and Psychological Therapy, 6*(2), 147–166.

Rosas, J. M., & Callejas-Aguilera, J. E. (2006). Context switch effects on acquisition and extinction in human predictive learning. *Journal of Experimental Psychology:*

Learning, Memory, and Cognition, *32*(3), 461–474. https://doi.org/10.1037/0278-7393.32.3.461

Rosas, J. M., & Callejas-Aguilera, J. E. (2007). Acquisition of a conditioned taste aversion becomes context dependent when it is learned after extinction. *The Quarterly Journal of Experimental Psychology*, *60*(1), 9–15. https://doi.org/10.1080/17470210600971519

Ross, R. T., & Holland, P. C. (1981). Conditioning of simultaneous and serial feature-positive discriminations. *Animal Learning & Behavior*, *9*(3), 293–303. https://doi.org/10.3758/BF03197835

Saar, D., Grossman, Y., & Barkai, E. (1999). Reduced after-hyperpolarization in rat piriform cortex pyramidal neurons is associated with increased learning capability during operant conditioning. *European Journal of Neuroscience*, *10*(4), 1518–1523. https://doi.org/10.1046/j.1460-9568.1998.00149.x

Scavio, M. J., & Thompson, R. F. (1979). Extinction and reacquisition performance alternations of the conditioned nictitating membrane response. *Bulletin of the Psychonomic Society*, *13*(2), 57–60.

Schmaltz, L. W., & Theios, J. (1972). Acquisition and extinction of a classically conditioned response in hippocampectomized rabbits (Oryctolagus cuniculus). *Journal of Comparative and Physiological Psychology*, *79*(2), 328–333. https://doi.org/10.1037/h0032531

Schreurs, B. G., & Kehoe, E. J. (1987). Cross-modal transfer as a function of initial training level in classical conditioning with the rabbit. *Animal Learning & Behavior*, *15*(1), 47–54. https://doi.org/10.3758/BF03204903

Sehgal, M., Song, C., Ehlers, V. L., & Moyer, J. R. (2013). Learning to learn - Intrinsic plasticity as a metaplasticity mechanism for memory formation. *Neurobiology of Learning and Memory*, *105*, 186–199. https://doi.org/10.1016/j.nlm.2013.07.008

Shevill, I., & Hall, G. (2004). Retrospective revaluation effects in the conditioned suppression procedure. *The Quarterly Journal of Experimental Psychology*, *57B*(4), 331–347. https://doi.org/10.1080/02724990344000178

Smith, M., & Gormezano, I. (1965). Effects of alternating classical conditioning and extinction sessions on the conditioned nictitating membrane response of the rabbit. *Psychonomic Science*, *3*(1–12), 91–92. https://doi.org/10.3758/BF03343035

Soltysik, S. S., Wolfe, G. E., Nicholas, T., Wilson, W. J., & Garcia-Sanchez, J. (1983). Blocking of inhibitory conditioning within a serial conditioned stimulus-conditioned inhibitor compound: Maintenance of acquired behavior without an unconditioned stimulus. *Learning and Motivation*, *14*(1), 1–29.

https://doi.org/10.1016/0023-9690(83)90010-3

Swartzentruber, D. (1993). Transfer of contextual control across similarly trained conditioned stimuli. *Animal Learning & Behavior*, *21*(1), 14–22. https://doi.org/10.3758/BF03197970

Swartzentruber, D. (1995). Modulatory mechanisms in Pavlovian conditioning. *Animal Learning & Behavior, 23*(2), 123–143. https://doi.org/10.3758/BF03199928

Swartzentruber, D., & Bouton, M. E. (1988). Transfer of positive contextual control across different conditioned stimuli. *Bulletin of the Psychonomic Society*, *26*(6), 569–572. https://doi.org/10.3758/BF03330124

Swartzentruber, D., & Rescorla, R. A. (1994). Modulation of trained and extinguished stimuli by facilitators and inhibitors. *Animal Learning & Behavior*, *22*(3), 309–316. https://doi.org/10.3758/BF03209839

Tamai, N., & Nakajima, S. (2000). *Renewal of Formerly Conditioned Fear in Rats after Extensive Extinction Training*. *International Journal of Comparative Psychology* (Vol. 13).

Thomas, B. L., Larsen, N., & Ayres, J. J. . (2003). Role of context similarity in ABA, ABC, and AAB renewal paradigms: Implications for theories of renewal and for treating human phobias. *Learning and Motivation*, *34*(4), 410–436. https://doi.org/10.1016/S0023-9690(03)00037-7

Thomas, D. R., Miller, J. T., & Svinicki, J. G. (1971). Nonspecific transfer effects of discrimination training in the rat. *Journal of Comparative and Physiological Psychology*, *74*(1, Pt.1), 96–101. https://doi.org/10.1037/h0030349

Todd, T. P. (2013). Mechanisms of renewal after the extinction of instrumental behavior. *Journal of Experimental Psychology: Animal Behavior Processes*, *39*(3), 193–207. https://doi.org/10.1037/a0032236

Todd, T. P., Vurbic, D., & Bouton, M. E. (2014). Behavioral and neurobiological mechanisms of extinction in Pavlovian and instrumental learning. *Neurobiology of Learning and Memory*, *108*, 52–64. https://doi.org/10.1016/j.nlm.2013.08.012

Trask, S., Thrailkill, E. A., & Bouton, M. E. (2017). Occasion setting, inhibition, and the contextual control of extinction in Pavlovian and instrumental (operant) learning. *Behavioural Processes*, *137*, 64–72. https://doi.org/10.1016/j.beproc.2016.10.003

Üngör, M., & Lachnit, H. (2006). Contextual control in discrimination reversal learning. *Journal of Experimental Psychology: Animal Behavior Processes*, *32*(4), 441–453. https://doi.org/10.1037/0097-7403.32.4.441

Üngör, M., & Lachnit, H. (2008). Dissociations among ABA, ABC, and AAB recovery effects. *Learning and Motivation*, *39*(3), 181–195. https://doi.org/10.1016/J.LMOT.2007.08.001

Vurbic, D., & Bouton, M. E. (2011). Secondary extinction in pavlovian fear conditioning. *Learning & Behavior*, *39*(3), 202–211. https://doi.org/10.3758/s13420-011-0017-7

Wagenmakers, E.-J. (2007). A practical solution to the pervasive problems of p values. *Psychonomic Bulletin & Review*, *14*(5), 779–804. https://doi.org/10.3758/BF03194105

Wagner, A. R. (1981). SOP : a model of automatic memory processing in animal behavior. In N. E. Spear, R. R. Miller, & B. S. on M. M. in A. Behavior (Eds.), *Information processing in animals, memory mechanisms*. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Wagner, A. R. (2003). Context-Sensitive Elemental Theory. *The Quarterly Journal of Experimental Psychology Section B*, *56*(1b), 7–29. https://doi.org/10.1080/02724990244000133

Wagner, A. R., & Brandon, S. E. (1989). Evolution of a structured connectionist model of Pavlovian conditioning (AESOP). In *Contemporary learning theories: Pavlovian conditioning and the status of traditional learning theory.* (pp. 149–189). Hillsdale, NJ, US: Lawrence Erlbaum Associates, Inc.

Wagner, A. R., Siegel, L. S., & Fein, G. G. (1967). Extinction of conditioned fear as a function of percentage of reinforcement. *Journal of Comparative and Physiological Psychology*, *63*(1), 160–164. https://doi.org/10.1037/h0024172

Westbrook, R. F., Jones, M. L., Bailey, G. K., & Harris, J. A. (2000). Contextual control over conditioned responding in a latent inhibition paradigm. *Journal of Experimental Psychology: Animal Behavior Processes*, *26*(2), 157–173. https://doi.org/10.1037/0097-7403.26.2.157

Williams, D. A., & Braker, D. S. (1999). Influence of past experience on the coding of compound stimuli. *Journal of Experimental Psychology: Animal Behavior Processes*, *25*(4), 461–474. https://doi.org/10.1037/0097-7403.25.4.461

Zable, M., & Harlow, H. F. (1946). The performance of rhesus monkeys on series of object-quality and positional discriminations and discrimination reversals. *Journal of Comparative Psychology*, *39*(1), 13–23. https://doi.org/10.1037/h0056082

Zelcer, I., Cohen, H., Richter-Levin, G., Lebiosn, T., Grossberger, T., & Barkai, E. (2005). A cellular correlate of learning-induced metaplasticity in the hippocampus. *Cerebral Cortex*, *16*(4), 460–468. https://doi.org/10.1093/cercor/bhi125