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ATTENTION, INTERFERENCE, AND CONTEXT EFFECTS ON STIMULUS PRE-EXPOSURE IN HUMAN PARTICIPANTS

Manuel Aranzubia Olasolo

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Euskal Herriko Unibertsitatea

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Doctoral Thesis presented by:
Manuel Aranzubia Olasolo

Supervisors:
James Byron Nelson
María del Carmen Sanjuán Artegain

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Department of Basic Psychological Processes and Their Development
Faculty of Psychology
University of the Basque Country (UPV)

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“*Science is a willingness to accept facts
even when they are opposed to wishes*”.

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

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Abstract

Eight experiments across three chapters were designed to distinguish the predominant theories of latent inhibition (LI), which attribute it to attention (e.g., Mackintosh, 1975; Pearce & Hall, 1980), interference (e.g., Bouton, 1993; Hall & Rodriguez, 2010), or representational changes (e.g., Wagner, 1981). Chapter 1 showed an LI effect that was not dependent on instructions or the use of masking tasks, and ruled out an interference account. Experiments in Chapter 2 demonstrated a Hall-Pearce negative transfer effect (HPNT; Hall & Pearce, 1982), typically attributed to the same cause as latent inhibition, that was smaller than that of pre-exposure alone, and did not depend on interference. It also showed that retarded performance to a pre-exposed CS persists across conditioning and even affects subsequent learning about new outcomes. Results here were consistent with the account of Wagner. Chapter 3 used online participants and replicated aspects of Chapter 2, but, surprisingly, the effects appeared to be due to conditioned inhibition (CI; Rescorla, 1969) in a way that could not be explained by theories of LI that equate latent and conditioned inhibition (Hall & Rodriguez, 2010). In sum, attention alone does not explain LI because it fails to predict a role for context (Chapter 1), nor differences in asymptotic responses (Chapter 2). Interference cannot explain the findings because CS-No Event learning should not affect US-CS bi-directional learning (Chapter 1), and interference should have had no role in the HPNT effect observed in Chapter 2 where initial CS-O1 learning should not interfere with learning about a new outcome that can be expressed independently of O1 responses. Overall, the findings are best accommodated by Wagner who separates learning from performance, and predicts asymptotic differences due Context-CS associations. Relevance to theories of learning is discussed along with the influence of motivation and demand characteristics.

Resumen

Para sobrevivir, los organismos deben identificar los estímulos significativos de su entorno y responder en función de su relevancia biológica. El condicionamiento clásico, una forma presumiblemente sencilla de aprendizaje asociativo se encarga de dotar de significado a estos estímulos y permite a los organismos identificarlos en el entorno y responder en función de su capacidad para predecir acontecimientos importantes. Sin embargo, las relaciones entre los estímulos y sus consecuencias no son estáticas y pueden estar sujetas a cambios. Lo que antes era un buen lugar para buscar comida podría dejar de serlo. Lo que antes fue un lugar seguro podría convertirse en peligroso. Así, los organismos a menudo deben aprender nueva información que, de alguna manera, contradice lo aprendido anteriormente. En el laboratorio, estas situaciones se estudian asociando un estímulo a resultados contradictorios en distintas fases experimentales (para una revisión véase Bouton, 1993).

Un fenómeno de aprendizaje múltiple sobre un estímulo es la inhibición latente (IL; p. ej., Lubow y Weiner, 2010), principal objeto de estudio en esta tesis doctoral. Empíricamente, la IL se observa cuando los participantes de un grupo, pero no los de otro, son expuestos a un estímulo en ausencia de cualquier otro evento. A continuación, los participantes de ambos grupos son expuestos a un emparejamiento entre ese estímulo condicionado (EC) y un acontecimiento significativo desde el punto de vista motivacional (estímulo incondicionado, EI). La respuesta provocada por el EC (respuesta condicionada, RC) se retrasa en los sujetos pre-expuestos al estímulo en comparación con el otro grupo que, o bien no ha sufrido una pre-exposición, o bien la ha experimentado con un estímulo distinto.

La expresión de la IL está modulada por diversos factores. Por ejemplo, en la década de los 80 se descubrió que el efecto de IL depende en gran medida del contexto (p. ej., Bouton, 1993). El término "contexto" suele referirse a los estímulos ambientales que son relativamente constantes durante un experimento (Lubow y Gerwirtz, 1995). Está bien establecido que el efecto de la IL se atenúa si existe un cambio contextual entre la pre-exposición y el condicionamiento (p. ej., Channel y Hall, 1983; Bouton y Swartzentruber, 1986; Gordon y Weaver, 1989). Curiosamente, el condicionamiento que tiene lugar después de los tratamientos de IL también es específico del contexto. Por ejemplo, Westbrook et al. (2000) expusieron ratas a dos contextos contrabalanceados (A y B), y en uno de ellos recibieron presentaciones de

un EC auditivo. Posteriormente, todas las ratas fueron expuestas a un emparejamiento de EC-descarga en el contexto A. Finalmente, se evaluó el *freezing* de las ratas al EC en A (Grupos AAA y BAA) o B (Grupos AAB y BAB). Las ratas pre-expuestas, condicionadas y evaluadas en el mismo contexto (Grupo AAA) mostraron menos respuesta que las ratas pre-expuestas en un contexto, pero condicionadas y evaluadas en otro contexto (Grupo BAA), lo que demuestra la especificidad contextual de la IL.

Sin embargo, el hallazgo más interesante fue que la IL, que había sido atenuada por este cambio de contexto entre la pre-exposición y condicionamiento (Grupo BAA), parecía haberse restaurado cuando el EC se probó en el contexto de pre-exposición (Grupo BAB). La respuesta en el grupo BAB fue menor que la del grupo BAA. De estos resultados surge la siguiente pregunta: ¿se recuperó la inhibición latente o simplemente la segunda fase del aprendizaje fue específica del contexto? El trabajo de Westbrook et al. (2000) no puede responder a esta pregunta, ya que en el procedimiento de prueba se utilizaron cuatro presentaciones no reforzadas del EC en las que se evaluó la respuesta de *freezing*. Las pruebas sin reforzamiento no permiten determinar si se recuperó la IL o se perdió la RC. Nelson (2002), por ejemplo, encontró que independientemente de la naturaleza de la asociación (p. ej., excitatoria o inhibitoria) la información adquirida en segundo orden era más dependiente del contexto, por lo que puede que simplemente la respuesta se perdiera.

Aunque las condiciones que generan la IL son sencillas (la simple pre-exposición a un estímulo antes de ser condicionado), los posibles mecanismos psicológicos subyacentes al fenómeno son complejos. La mayoría de las teorías señalan al fenómeno como una disminución de la atención o asociabilidad al EC (p. ej., Mackintosh, 1975; Pearce y Hall, 1980; y Le Pelley, 2004). En general, estos modelos asumen que la atención al estímulo disminuirá durante la pre-exposición haciendo más difícil su aprendizaje en una etapa posterior en comparación con un grupo para el que ese estímulo es novedoso.

Otros autores han propuesto que la IL se debe a un déficit en la expresión conductual de la asociación EC-EI (p. ej., Bouton, 1993). Según estos modelos, durante la pre-exposición al EC, los sujetos aprenden que al EC no le sigue ninguna consecuencia (p. ej., EC-"noEI"; Bouton, 1993; EC-"No Evento" Hall y Rodríguez, 2010). El aprendizaje posterior de la asociación EC-EI procede con normalidad, pero la relación no se expresa en el mismo grado debido a la interferencia producida por el aprendizaje inicial. En resumen, una vez que el CS ha sido pre-expuesto y condicionado, su presentación puede activar dos tipos diferentes de información, que interfieren entre sí.

En general, estos dos tipos de modelos existen en la literatura, pero no son mutuamente excluyentes. Hall y Rodríguez (2010) proponen que estos dos tipos de explicaciones son compatibles. Según esta perspectiva, durante la pre-exposición se aprende algo así como una asociación EC-"No Evento" que puede contribuir a la aparición de la inhibición latente al producir interferencia. Además, el aprendizaje de esta asociación conduce a una reducción de la asociabilidad del EC porque es un buen predictor del resultado del "No Evento". Como sugirió Hall (1991), la LI puede surgir de una compleja interacción de varios procesos, más que de una causa singular.

La idea de que la atención puede disminuir ante un estímulo que es un buen predictor de su resultado proviene de los hallazgos de Hall y Pearce (1979, 1982). En sus experimentos descubrieron que, tras el emparejamiento entre un tono y una descarga eléctrica de baja intensidad, los participantes aprendieron de forma más lenta una asociación posterior entre el mismo tono y una descarga de mayor intensidad, en comparación con un grupo control que no había experimentado la primera fase. Este hallazgo recibió el nombre de Transferencia Negativa (TN) y fue acomodado en la teoría posterior de Pearce y Hall (1980). Este efecto de TN es importante porque distingue entre modelos de atención. Mientras que Mackintosh (1975) predijo que los buenos predictores serían estímulos bien atendidos, la TN mostró cómo los buenos predictores podían ser desatendidos cuando su importancia ya estaba bien establecida.

La especificidad contextual de la inhibición latente descrita anteriormente es importante porque ayuda a distinguir entre algunos modelos basados en la atención y los basados en la interferencia, al dar pistas sobre el contenido del aprendizaje que tiene lugar en la pre-exposición. En primer lugar, los modelos basados en la atención no prevén que los cambios de contexto afecten a la atención porque estos modelos no incorporan un papel para el contexto (p. ej., Le Pelley, 2004). Por el contrario, los modelos basados en la interferencia pueden predecir la especificidad contextual. Por ejemplo, el punto de partida de la teoría híbrida de la inhibición latente fue la observación de que la inhibición latente es altamente específica del contexto (Hall y Rodríguez, 2010) y que al menos parte del efecto de inhibición latente proviene de la interferencia asociativa.

Una tercera clase de modelos que explican la IL y su especificidad contextual proviene del trabajo de Wagner (1981), que caracteriza el efecto como un efecto ni de atención ni de interferencia. Wagner propuso que cuando se presenta un estímulo, los elementos de su representación interna se sitúan en un estado primario A1 de activación, que luego pasan a un estado secundario A2, antes de pasar a un estado inactivo. Para que estos elementos formen asociaciones con los resultados posteriores, deben estar activos en el estado A1. Sin embargo, cuando un estímulo es predicho por otro, una parte del estímulo predicho pasa automáticamente al estado A2, en el que no puede formar asociaciones con otros estímulos posteriores. En la pre-exposición, el contexto de fondo debe establecer asociaciones con el EC, y el efecto de estas asociaciones es activar asociativamente porciones del EC en el estado A2, donde no puede formar asociaciones con el próximo resultado o EI. Con un cambio en el contexto, la ausencia de asociaciones contexto-EC permite al EC entrar más plenamente en el estado A1, y condicionarse normalmente.

En resumen, el objetivo general de este proyecto fue el de diferenciar las teorías predominantes de la inhibición latente, que la atribuyen a la atención (por ejemplo, Mackintosh, 1975; Pearce y Hall, 1980), a la interferencia (por ejemplo, Bouton, 1993; Hall y Rodríguez, 2010) o a cambios representacionales (por ejemplo, Wagner, 1981). El Capítulo 1 investiga la bi-direccionalidad EC→EI y EI→EC del aprendizaje. El Capítulo 2 examina las diferencias en el rendimiento ante estímulos pre-expuestos y condicionados, y el Capítulo 3 utiliza el control contextual para examinar posibles mecanismos subyacentes. Los objetivos específicos por capítulo fueron: en el capítulo uno, primero demostrar un efecto IL sin el uso de tareas de enmascaramiento o sin guiar al participante a través de las instrucciones del experimento. Después, determinar si el efecto de IL se caracteriza mejor como resultado de cambios en el procesamiento, o de interferencia. En el segundo capítulo, evaluar la persistencia de IL a través del condicionamiento y compararla con un efecto de TN en participantes humanos. Por último, en el tercer capítulo el objetivo fue investigar si la IL puede recuperarse en un paradigma ABA o si el nuevo aprendizaje tras el condicionamiento es simplemente específico del contexto.

En general, la IL es un fenómeno robusto que ocurre en una amplia variedad de especies y en un conjunto diverso de condiciones de prueba. Todos los mamíferos utilizados hasta hoy muestran el efecto y se ha demostrado con muchos procedimientos diferentes (para una revisión, véase Lubow, 1989). No obstante, en comparación con la literatura animal, las pruebas de LI en humanos son más restringidas. El efecto se ha considerado difícil de demostrar de manera convincente, y cuando se ha demostrado, las preocupaciones metodológicas han cuestionado si se ha demostrado únicamente un efecto de la pre-exposición no reforzada o si en realidad había más fenómenos involucrados.

Los experimentos del **Capítulo 1** se realizaron para evaluar si la simple pre-exposición a un estímulo antes de su emparejamiento con otro produciría un efecto consistente con la inhibición latente en participantes humanos adultos. El objetivo era determinar si el efecto se observaría sin utilizar una tarea de enmascaramiento y evitando cualquier expectativa específica de eventos o respuesta que pudiera conducir a priming negativo (Graham y McLaren, 1998), irrelevancia aprendida (Le Pelley y Schmidt-Hansen, 2010) o cualquier otro efecto dependiente de las instrucciones del experimento (por ejemplo, Byrom et al., 2018; Nelson et al., 2021).

Los participantes no recibieron ninguna instrucción para comportarse de una manera específica, ni para esperar que ocurriera ningún evento en particular. Los participantes simplemente vieron un vídeo corto (90 segundos) en el que, tras una fase de pre-exposición, se presentó una luna como EC (pre-expuesta, novedosa o pre-expuesta en un contexto diferente para los grupos Same, No Exposure y Different, respectivamente) junto con los puños iluminados de Superman, como EI. Posteriormente, se realizó una prueba de expectativas. El test del primer experimento consistió en presentar una imagen de Superman en el contexto utilizado durante el condicionamiento con la luna presente, pero sin los puños iluminados. La prueba consistió en una prueba de memoria en la que se le preguntaba al participante si echaba algo de menos en la imagen. Por otro lado, en el segundo experimento se realizaron dos pruebas. En la primera, Superman aparecía con sus puños iluminados, pero sin la luna presente. En la segunda, contrabalanceada, se presentó a Superman en el contexto del condicionamiento sin ningún estímulo alrededor.

En general, los resultados obtenidos fueron consistentes con la idea de que los participantes en el Grupo Same tenían dificultades para asociar el estímulo diana (EC) con el resultado (EI). La interpretación de este resultado es coherente con los modelos basados en la atención (p. ej., Mackintosh, 1975; Pearce y Hall, 1980; Le Pelley, 2004). Sin embargo, los resultados del Grupo Different indicaron que un cambio contextual entre la pre-exposición y el condicionamiento atenuaba el efecto de IL, no señalando diferencias entre el Grupo Different y el Grupo No Exposure.

Este resultado no fue explicable por estos modelos basados en la atención ya que no incorporan un papel para el contexto en el control del fenómeno.

El estudio de la bi-direccionalidad del aprendizaje (Experimento 2) mostró que el déficit observado en el grupo Same no debería deberse a una interferencia. Mientras que la Luna puede estar asociada con "No evento" desde la pre-exposición y con "Puños Iluminados" desde el condicionamiento, los puños iluminados solo se emparejaron con la luna. En este caso, el déficit se describiría mejor como derivado de un cambio en la forma de procesar la luna y sería más coherente con el modelo propuesto por Wagner (1981) u otros modelos que explican la IL como un cambio a la hora de procesar el EC (p. ej., McLaren y Mackintosh, 2000). El mecanismo principal de estas teorías, tanto la de Wagner como la de McLaren y Mackintosh (ver también Schmajuk et al., 1996), en el que se supone que los estímulos predichos tienen dificultades para formar asociaciones posteriores se denominará Asociaciones Dependientes del Contexto (ADC) en el presente trabajo.

En el **Capítulo 2**, se utilizó un método de videojuego (Nelson et al., 2014; Nelson et al., 2021). Durante el entrenamiento se informó a los participantes de que debían proteger galaxias de diferentes naves espaciales invasoras. Así, aprendieron a responder adecuadamente ante la presencia de las naves. Posteriormente, los participantes fueron dirigidos hacia la galaxia experimental, donde podían ser atacados. Durante la fase experimental, los participantes fueron expuestos a diferentes sensores de colores que podían predecir nada (durante la pre-exposición), el ataque de una nave espacial (donde se requería una respuesta específica categorizada como +, durante el condicionamiento), o el ataque de dos naves de manera simultánea (con dos respuestas diferentes e independientes, + y !, durante la prueba).

Los experimentos de este capítulo evaluaron el papel de la atención y la interferencia, tanto en el efecto de IL como el de TN utilizando un método que ha demostrado previamente las propiedades conocidas de la IL (ver Nelson et al., 2021). A su vez, comparar estas teorías y sus implicaciones (p. ej., alcanzar las mismas asíntotas entre grupos) con la propuesta por Wagner (1981). En el caso de la TN se utilizó el ataque de una (intensidad débil) o de dos naves espaciales (intensidad fuerte) para evaluar el fenómeno en participantes humanos. Se compararon los efectos de IL y TN en solitario (Grupo LI y Grupo NT) con un grupo en el que se combinaron la pre-exposición reforzada y no reforzada (Grupo LINT), y un Grupo Control sin experiencia previa con los estímulos.

Los resultados obtenidos en el Experimento 1 fueron consistentes con un efecto de IL durante el condicionamiento. El Grupo LINT mostró una profunda disminución en la adquisición de la respuesta +, en relación con el Grupo LI para el que el EC utilizado era novedoso. Además, el efecto de TN fue evidente en el Grupo NT y en el Grupo LINT durante la adquisición de la respuesta adicional !, lo cual está mejor recogido en los postulados de Pearce y Hall (1980) que proponen que un buen predictor recibirá menos atención cuando se establece completamente su significado. En general, los resultados fueron consistentes con los modelos que predicen diferentes asíntotas de aprendizaje (por ejemplo, Wagner, 1981). Sin embargo, no se encontró efecto de IL en el Grupo LI, lo que demostró que el efecto se ve afectado por el paso del tiempo (Aguado et al., 1994).

El Experimento 2 pretendió aliviar las dudas producidas por una interpretación alternativa de los resultados del Experimento 1. En un diseño similar con los grupos NT y Control se utilizó una prueba de sumación (Rescorla, 1969) después del condicionamiento para comprobar si el estímulo utilizado durante el test (S) fue un inhibidor condicionado para el Grupo NT, descartando la interpretación del efecto de TN. Los resultados mostraron que no hubo diferencias en el patrón de respuesta asociada al EI adicional entre los grupos, descartando así la hipótesis de la inhibición condicionada (IC).

Finalmente, en el Experimento 3, se cambió el orden de las fases para el Grupo LI con el fin de evaluar únicamente el efecto de IL. Durante la respuesta +, se obtuvo un resultado consistente con la IL para el Grupo LI con respecto al Grupo Control. Los resultados obtenidos durante la respuesta ! fueron coherentes con la TN, como en el Experimento 1. Además, durante la adquisición de esta respuesta adicional también se hizo evidente el efecto de IL en Grupo LI. Se alcanzaron diferentes asíntotas durante el condicionamiento entre el Grupo LINT y el Grupo NT, y las diferencias también fueron evidentes durante la adquisición de las respuestas + y ! entre el Grupo LINT y los restantes grupos experimentales, lo que era coherente con un gran efecto obtenido en el Grupo LINT. El efecto de TN se perdió cuando se añadió una fase adicional entre el tratamiento y la prueba, tal y como ocurrió con el Grupo LI en el Experimento 1.

En general, los resultados fueron consistentes con la TN en participantes humanos, lo cual es incompatible con el modelo de atención propuesto por Mackintosh (1975). La TN también era incompatible con los modelos basados en la interferencia (por ejemplo, Bouton, 1993), ya que + no debería interferir con !. Los experimentos con animales no humanos que evalúan el efecto de TN son numerosos (p. ej., Hall y Pearce, 1982; Rodríguez y Alonso, 2011), pero los estudios con participantes humanos son muy limitados (véase Griffiths et al., 2011), lo que implica que los resultados reportados aquí son una contribución novedosa. En resumen, los resultados fueron consistentes con el modelo propuesto por Wagner (1981) porque es capaz de predecir la persistencia del efecto en el Grupo LINT, y también predecir las diferencias en la respuesta asintótica mostrada durante los experimentos 1 y 3.

Por último, el **Capítulo 3** incorporó cambios de contexto con un método online casi idéntico al descrito en Nelson et al., (2014; 2021), y utilizado en el capítulo dos. El objetivo fue determinar si la IL recuperaba sus propiedades en un diseño ABA, donde A y B corresponden a diferentes contextos (véase Westbrook, et al., 2000), o si el segundo aprendizaje se perdía (por ejemplo, Nelson, 2002). Se realizó un experimento inicial para demostrar que los efectos encontrados en los experimentos presenciales eran los mismos que en los participantes online. En el Experimento 2 se evaluó si el efecto de IL, expresado como un déficit de adquisición con !, se recuperó con el retorno al contexto de pre-exposición, además de demostrar la especificidad contextual de la respuesta +. Cuatro grupos (AAA, ABA, AAB y ABB) experimentaron protocolos de cambio de contexto a lo largo de las etapas de pre-exposición, condicionamiento y prueba. Por último, el Experimento 3 se llevó a cabo con una prueba de sumación, después de la fase de condicionamiento, para abordar si el estímulo utilizado durante la pre-exposición adquirió propiedades inhibitorias consistentes con la inhibición condicionada (IC; Rescorla, 1969).

Los resultados del Experimento 1 fueron coherentes con los experimentos anteriores, aunque el efecto del grupo LINT no fue tan profundo y su rendimiento no fue distinto de NT para !. Los obtenidos en el Experimento 2 fueron ambiguos ya que no se observó cómo el cambio contextual atenuaba el efecto. Todos los grupos, pre-expuestos en el mismo contexto o en un contexto diferente al del condicionamiento, respondieron igual durante el condicionamiento. Tampoco se observó un efecto consistente con la TN. Nelson (2002), informó de que un segundo aprendizaje sobre una señal que contradecía el primer aprendizaje estaba controlado contextualmente. Los resultados obtenidos en el experimento fueron coherentes con Nelson. Los grupos que sufrieron un cambio contextual entre el condicionamiento y la prueba (ABA y AAB) respondieron menos que los grupos en los que no se cambió el contexto (AAA y ABB) en la respuesta +.

Por último, el Experimento 3 incluyó una prueba adicional para evaluar si los grupos del Experimento 2 podrían estar experimentando IC (por ejemplo, Rescorla, 1969) que inhibiera la respuesta al sensor S, que se utilizó durante la pre-exposición, el condicionamiento y la prueba. Los resultados obtenidos confirmaron que el sensor S había adquirido propiedades inhibitorias, consistentes con la IC, que inhibían el desarrollo de la respuesta a S en comparación con las respuestas asociadas a otro sensor, ambos en combinación con un excitador (W, en este caso).

En resumen, los resultados obtenidos durante el Capítulo 3 fueron diferentes de los obtenidos en el Capítulo 2, ya que los últimos fueron coherentes con la IC. En el Experimento 1, no se encontraron diferencias entre los grupos NT y LINT, lo que indica que el mismo mecanismo afectaba a ambos grupos. En el Experimento 2, todos los grupos respondieron igual y no se obtuvo un efecto de IL atenuado debido a un cambio contextual entre la pre-exposición y el condicionamiento, lo cual está bien establecido en la literatura (por ejemplo, Hall & Channel, 1985; Nelson & Sanjuan, 2006; Nelson et al., 2021; 2022). La respuesta a + adquirida después del presunto condicionamiento inhibitorio fue específica del contexto, consistente con haber aprendido primero la inhibición (Nelson, 2002). Finalmente, en el Experimento 3 una prueba de sumación mostró que S adquirió propiedades inhibitorias consistentes con IC en la fase 1.

En general, la atención no puede explicar la IL porque no predice una modulación del efecto por parte del contexto (Capítulo 1, Experimento 1) ni las diferencias asintóticas (Capítulo 2, Experimentos 1 y 3). Los modelos de interferencia tampoco pueden explicar los hallazgos porque son incompatibles con la formación bi-direccional de asociaciones EC-EI (Capítulo 1, Experimento 2). La interferencia también es incompatible con el efecto de TN, que se ha demostrado en humanos (Capítulo 2, Experimentos 1 y 3) donde la información aprendida durante el condicionamiento (por ejemplo, +) no interfiere conductualmente con el nuevo resultado adicional (!). El modelo de Wagner (1981) es capaz de predecir con éxito los resultados obtenidos aludiendo a asociaciones Contexto-EC. Por último, se ha demostrado que la pre-exposición puede producir IC, lo cual es predicho por Hall y Rodríguez (2010). Sin embargo, su modelo predice que la IC es específica del contexto, lo cual parece inexacto, pues está bien establecido que la IC es inespecífica del contexto (por ejemplo, Bouton y Nelson, 1994; Nelson, 2002; Nelson y Bouton, 1997), lo que también es coherente con los hallazgos del Capítulo 3.

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Introduction

Introduction

Associative learning

Since Ancient Greece, it has been commonly assumed that two events occurring in close proximity become associated with each other (Escobar & Miller, 2010). The temporal proximity and the probabilistic relationship between one event and another, encompassed in the principles of contiguity and contingency, are the fundamental basis of classical conditioning. In classical conditioning (Pavlov, 1927) a neutral stimulus (e.g., a tone or a light), later called conditioned stimulus (CS), is repeatedly paired with a biologically relevant unconditioned stimulus (US; e.g., a shock or food pellet). The presentation of a US produces responses that can be behaviorally manifested in several manners (e.g., increased heart rate, startle response, freezing, sign tracking, goal tracking). The CS does not elicit this response initially, but after successive pairings, the CS comes to elicit the fear response; the conditioned response (CR). Evocation of the response by the CS is taken as evidence for the association with the US.

Classical conditioning, a presumably simple form of associative learning, allows organisms to identify significant stimuli in the environment and respond according to their ability to predict other significant events. Moreover, it also allows organisms to respond according to the stimuli's biological relevance to better their chances of survival. For example, animals feed based on the presence of signals that predict food and use fear signals to avoid or prepare for dangerous situations (Domjan, 2014).

In humans, simple associative learning is an important mechanism that underlies behaviors as simple as using symbols to guide the choice of bathroom doors to complex cognition (McLaren, et al., 2018). For example, FeldmanHall and Dunsmoor (2019) propose that Pavlovian-learning paradigms can be used to illustrate how moral behaviors are learned and expressed, including altruistic, cooperative, punitive, or trustworthy behaviors. Associative learning is relevant to understand maladaptive behaviors as well, such as phobias (e.g., Mineka & Zinbarg, 2006).

Associative mechanisms: updating knowledge

Relationships between stimuli and their consequences are not static and may be subject to change. What used to be a good place to look for food could stop being profitable, or vice versa. What used to be a safe place could become dangerous. Thus, organisms often must learn new information that, in some way, contradicts what was previously learned. In the laboratory, these situations are studied by associating a stimulus with contradictory outcomes in different experimental phases (see Bouton, 1993 for a review).

One example is extinction, where a stimulus is paired with a significant outcome in a first phase, and not followed by anything in the second phase. When learning between a CS (e.g. a light) and a US (e.g. a shock) is established, the mere presence of the CS produces a CR (e.g., freezing). In a later phase, extinction starts when the light is no longer followed by the shock. In this situation, after enough light-alone presentations, the animal stops freezing and the previously-acquired response is said to be "extinguished" (e.g., Wagner, et al., 1967). However, the original association is not "unlearned" in extinction (Bouton, 1993).

Following extinction, when the CS is tested in the context where extinction took place, no conditioned responding is observed. However, when the CS is tested outside of the extinction context, a renewal of responding occurs (e.g., Bouton & Bolles, 1979). This renewal effect is a very robust effect, which occurs across a wide range of methods, species (including humans) and designs such as ABA, ABC, and AAB, where each letter corresponds sequentially to a different physical context where conditioning, extinction, and testing, respectively, occur (for review see Bouton, 2002).

Latent inhibition

Another example of potentially learning multiple things about a stimulus is Latent Inhibition (LI; e.g., Lubow & Weiner, 2010), which shares many properties with extinction and will be the focus of this project. LI is much like the reverse of an extinction procedure; the non-reinforced exposures occur before the reinforced ones. The LI phenomenon was first reported in a within-subjects experiment conducted by Lubow and Moore (1959), employing a classical conditioning procedure with goats and sheep as experimental subjects. The experiment consisted of two phases. In the first phase, all animals were repeatedly exposed to a stimulus in the absence of reinforcement: half of the animals were exposed to a flashing light and half to the sound of a mechanical rotor. In the subsequent conditioning phase, all animals received conditioning in which the light and sound were presented alternately and each paired with the presentation of the US, which was an electric shock to the animal's right paw. The results showed that the animals took longer to show a CR to the pre-exposed stimulus than to the novel stimulus. The effect is also observed between-subjects where one group, but not another, is exposed to a stimulus in absence of any other event and then subjects in both groups are exposed to a signaling relation between that stimulus (CS) and another event (e.g., US). In both types of designs, the CR is said to have been latently inhibited by the prior stimulus-alone exposures (Westbrook & Bouton, 2010).

The term for this phenomenon, LI, was introduced (Lubow & Moore, 1959) to describe what happens to the future associability or expression of a stimulus that has been repeatedly presented without consequences. Very simply, a stimulus that is assumed to be familiar (i.e., has been exposed) appears to form associations more slowly than a novel stimulus. Therefore, LI seems to promote stimulus selectivity required for rapid, efficient learning. It creates a bias in favor of potentially important stimuli by somehow degrading those stimuli that may have been registered as inconsequential in the past (Lubow, 1989). Overall, it is not only important to adapt to stimuli that predict changes in the environment; ignoring those stimuli that are inconsequential or irrelevant is also important.

Properties of latent inhibition

Similar to other basic psychological processes, the expression of LI is modulated by a variety of factors. The effect is critically stimulus specific (Lubow, 1989). This stimulus specificity can be demonstrated in several ways. A within-subject experimental design may be employed whereby the animal is pre-exposed to stimulus A and tested on both stimulus A and stimulus B. The specificity is shown by slower learning to the familiar stimulus compared to the novel stimulus (e.g. Lubow & Moore, 1959; Reiss & Wagner, 1972). It is also shown in between-subjects designs in which one group is pre-exposed to A, and another to stimulus B, and both are tested with A (e.g., Carlton & Vogel, 1967).

Latent inhibition is affected by the intensity of the CS. Rodriguez and Alonso (2002) studied the relationship between LI and stimulus intensity using rats in a conditioned taste avoidance. They pre-exposed two groups to a weak (0.25%) saline solution and two groups to a stronger (1%) saline solution. Two further groups were not pre-exposed. Across nine conditioning trials, Rodriguez and Alonso found more rapid suppression of intake among rats conditioned with the stronger solution, revealing an effect of CS intensity on conditioning. Moreover, pre-exposure to the stronger solution more effectively retarded conditioning than pre-exposure to the weak solution. To the extent that less- and more-sweet solutions are considered different versions of the same stimulus, like conditioning (e.g., Kamin, 1965), LI is affected by CS intensity.

LI increases with the number of CS pre-exposures. Lantz (1973) gave four groups of rats 0, 10, 30, or 60 pre-exposures to a tone, after which all rats received a single tone-shock pairing. Lantz measured the extent to which presentation of the tone disrupted the rats drinking. She found that the non-pre-exposed group showed the most suppression, the group given 10 pre-exposures showed modest suppression, while groups given 30 and 60 pre-exposures showed little suppression. Generally, the evidence concurs with Lubow (1973), who found that the deficit is most reliably obtained in groups that have received more than 16 pre-exposures to the CS. Subsequently, Lubow (1989) considered that these statements should be reconsidered because, in the case of conditioned taste aversions (CTA), it is possible to find the LI effect with a single pre-exposure to the to-be-conditioned CS (e.g., Siegel, 1974; see also Ayres et al., 1992 for additional evidence.).

Latent inhibition is susceptible to the interstimulus interval (ISI). That interval describes the time between stimulus presentations during the pre-exposure period. Lantz (1973) investigated LI as a function of the interval between pre-exposures in a conditioned suppression test compared a non-pre-exposed group with groups that had an interval of 2, 10, 30, or 150 sec between the end of one stimulus and the start of the following stimulus. LI was obtained only for the 30 and 150 sec groups (poorer conditioning that the others). Schnur and Lubow (1976), with an avoidance conditioning study, supported this finding and concluded that longer intervals between pre-exposures produce stronger LI, in the same way that longer intervals between CS-US pairings produce stronger conditioning (Holmes & Harris, 2010).

In addition, LI is sensitive to the temporal interval between pre-exposure and conditioning, and to the interval between conditioning and test. In a CTA procedure, Aguado et al. (1994) observed that LI was reduced when conditioning occurred 12 days after pre-exposure, or when testing took place 12 days after conditioning. They concluded that the loss of LI depends on the length of time between pre-exposure and test. Westbrook et al, (2000) also showed loss of LI after a delay.

One important finding to emerge regarding LI in the 1980s is that it depends importantly on context (Bouton, 1993). The term “context” typically refers to environmental stimuli that are relatively constant in the background during an experiment (Lubow & Gerwirtz, 1995). To illustrate, Channel and Hall (1983) demonstrated the sensitivity of LI to changes in the experimental context (different Skinner boxes in this case) using rats in a conditioned magazine approach paradigm. Response rates were higher among rats that were conditioned in a context different from that where they had been pre-exposed. The effect is strongly attenuated if the context is changed between pre-exposure and conditioning (e.g., Bouton & Swartzentruber, 1986; Gordon & Weaver, 1989; Lovibond et al., 1984).

The loss of LI that occurs when pre-exposure and conditioning take place in different contexts is said to be restored if the CS is again presented in the same context as pre-exposure (Bouton and Swartzentruber, 1989). However, what is not clear and discussed below is whether the loss of response is because the LI has been recovered or whether it is a loss of CR due to the context switch, which will be an important focus in Chapter 3.

For example, Westbrook et al. (2000) exposed rats to two counterbalanced contexts (A and B) in one of which they received presentations of an auditory CS (a clicker). Subsequently, all rats were exposed to a pairing of the CS and shock in A. Finally, rats were tested for freezing to the CS in either A (Groups AAA and BAA) or B (Groups AAB and BAB). Rats pre-exposed, conditioned, and tested in the same context (Group AAA) froze less than rats pre-exposed in one context but conditioned and tested in another context (Group BAA), demonstrating the standard context-specificity of LI. Nevertheless, the most interesting new finding was that the latent inhibition that had been attenuated by this context shift between preexposure and conditioning (Group BAA) appeared to have been restored when the CS was tested in the preexposure context (Group BAB). The response in the BAB group was less than that of the BAA group. Two questions arise from these results: has the latent inhibition been recovered or simply that the second phase of learning was context-specific?

The work of Westbrook et al. (2000) cannot answer that question since the testing procedure used four non-reinforced presentations of the CS in which freezing was assessed. Testing in extinction does not allow a determination of whether LI was recovered or the CR was lost. Latent inhibition is an acquisition deficit as a function of pre-exposure. The test conducted was not an “acquisition test” because it reflected the same learning that had taken place during conditioning. Thus, it is not possible to discern whether the poor response observed in Context A after conditioning in B was retrieval of LI or whether the learning in context B became context-specific. In this regard, a loss of responding with a context switch, when the response is learned after pre-exposure, is consistent with the predictions of Nelson (2002), who has found that, independent of the nature of training (e.g., excitatory/inhibitory), information acquired later in a sequence was more context dependent. Contextual control of the effect is an important phenomenon that places constraints on theories developed to explain latent inhibition.

Latent inhibition: Theoretical explanations

Although the conditions that generate LI are simple (pre-exposure to the to-be-conditioned CS), the possible psychological mechanisms underlying the phenomenon are complex. Many different mechanisms have been invoked to explain LI (Holmes & Harris, 2010).

Most theories point to it as a decrease in attention or associability to the CS (e.g., Le Pelley, 2004; Mackintosh, 1975; Pearce & Hall, 1980; Schmajuk, Lam, & Gray, 1996). In this set of models, LI is attributed to some active process during the pre-exposure period that would affect the subsequent associability of the stimulus when it is paired with the US. Therefore, a common feature of all these “attention-based” models is that they consider that the presentation of the to-be-conditioned stimulus without consequences produces a decrease in attention, decreasing the rate at which that stimulus subsequently enters into association with a relevant consequence. These models have been grouped within the so-called acquisition failure theories (e.g., Escobar & Miller, 2010; Lubow, 2010). Simply put, attention to the stimulus would decrease during pre-exposure making it more difficult to learn about in a later stage compared to a group for which that stimulus is novel.

Other authors have proposed that LI is not due to a learning deficit, but to a deficit in the behavioral expression of the CS-US association (e.g., Bouton, 1993; Hall, 1991). According to these models, during pre-exposure to the CS, subjects learn that the CS is followed by no consequence (e.g., CS-“noUS”; Bouton, 1993; CS-“No Event” Hall & Rodriguez, 2010). Subsequent learning of the CS-US association proceeds normally, but the relationship is not expressed to the same degree due to the interference produced by the initial learning. Thus, the delay in the appearance of the CR is produced by the activation of the memory of discordant information: the memory of the CS without consequences (acquired during pre-exposure) and the memory of the CS indicating the appearance of the US (acquired during conditioning). Once the CS has been pre-exposed and conditioned, its presentation may activate two different types of information, which interfere with each other.

In general, these two types of models exist in the literature, but they are not mutually exclusive. Hall and Rodriguez (2010) propose that these two types of explanations are compatible. According to this perspective, during pre-exposure something like a CS-“No Event” association is learned that can contribute to the emergence of latent inhibition by producing interference. Additionally, learning this association leads to a reduction in the associability of the CS because it is a good predictor of the “No Event” outcome. As Hall (1991) suggested, LI may arise from a complex interplay of various processes, rather than a singular cause.

The idea that attention may decline to a stimulus that is a good predictor of its outcome comes from acknowledging that a latent-inhibition type effect can occur even if the “pre-exposure” that takes place is during the CS-US pairings themselves. Hall and Pearce (1979) conducted a series of experiments in which rats were given initial training where a tone was paired with a relatively weak electric shock as US. Then, in a test phase training continued, but the shock intensity was increased (strong). In the test phase these subjects learned about the increased shock relatively slowly compared to control subjects that experienced the CS for the first time during the phase of CS-US (strong) training. This effect, known as Hall-Pearce negative transfer (HPNT; Hall & Pearce, 1979, 1982), has been assumed to occur for the same reason as LI (Pearce & Hall, 1980).

The HPNT effect is important because it distinguishes between models of attention. While Mackintosh (1975) predicted that good predictors will be well-attended stimuli, the HPNT effect showed how good predictors could be neglected when their importance was already well established. The model developed by Pearce and Hall (1980) anticipates this effect assuming that the associability of a stimulus depends on the extent to which the consequences that follow it are expected or surprising. This issue will be developed further in Chapter 2.

The context specificity of latent inhibition described above is important because it helps distinguish between some attention-based and interference-based models by giving clues about the content of the learning that takes place in the pre-exposure. First, attention-based models make no provision for changes of context affecting attention because these models do not incorporate a role for the context (e.g., Le Pelley, 2004). In contrast, interference-based models (e.g., Bouton, 1993) can predict context-specificity under the assumption that retrieval of the interfering information learned in phase 1 is somewhat context dependent.

The starting point for the hybrid theory of latent inhibition was the observation that latent inhibition is context specific (Hall & Rodriguez, 2010). Hall and Rodriguez draw parallels between the extinction of the CS-US association in a Pavlovian conditioning paradigm, which is context specific (i.e., the renewal effect) and the extinction of a "CS-some kind of consequences" association during the pre-exposure phase of a latent inhibition experiment. They proposed that people and animals have a general association between novel stimuli and a wide-ranging expectation of some event occurring, at least in part due to generalization between components of novel stimuli and others that have predicted consequences in the past. When no event occurs, as in pre-exposure, they learn a new association with a general representation of “no event.” The representation of no event is thought to subtract from any expectation of an event that is subsequently formed, affecting performance. As the new “no event” learning interferes with the prior association with “event,” it is expected to be context specific. (Nelson, 2002; Nelson & Callejas Aguilera, 2007).

A third class of models that explain LI and its context-specificity stem from the work of Wagner (1981), which characterizes the effect as neither an attention nor interference effect. Wagner proposed that when a stimulus is presented, elements of its internal representation are set to a primary “A1” state of activation, which then transitions to a secondary A2 state, before becoming inactive. For these elements to form associations with subsequent outcomes, they must be active in the A1 state. However, when a stimulus is predicted by another, a portion of the predicted stimulus is automatically placed into the A2 state where it cannot form associations with other subsequent stimuli. In pre-exposure, the background context should establish associations with the CS. The effect of these associations is to activate portions of the CS into the A2 state, where it cannot form associations with the upcoming unconditioned stimulus (US) or outcome. With a change in context, the lack of context-CS associations allows the CS to enter more fully into the A1 state, and condition more normally.

The idea that predicted stimuli have difficulty forming associations with other stimuli was subsequently incorporated into the theorizing of McLaren and Mackintosh (2000). McLaren and Mackintosh assume a reduction in the ability of elements of the cue to enter into associations with an outcome by way of context-cue associations as well as cue-cue associations. When elements of a stimulus are “internally” activated, by way of associations with other stimuli, they are less capable of entering into new associations. The main mechanism of these theories, both Wagner's and McLaren and Mackintosh's, in which predicted stimuli are assumed to have difficulty forming subsequent associations will be referred to as Context Association Dependent (CAD).

Though couched in the construct of “attention,” the CAD mechanism is also present on the model of Schmajuk, Lam, and Gray (SLG, 1996). Associations form between all elements in the situation (Context-CS, CS1-CS2, etc.) that allow the entire environment to be represented, and the overall match of this environmental representation with the actual environment determines “novelty.” Poorer matches lead to greater novelty. The effect of novelty is to boost the internal representations (attention) of the stimuli present. Thus, in an environment where all stimuli are well predicted, there is little novelty, and stimuli receive less attention. The model operates, in principle, similarly to Wagner’s CAD mechanism. However, one difference is that the novelty affecting the internal representation of a stimulus is determined by all the stimuli present in the environment, not simply by those necessarily associated with the CS itself. Thus, the presence of a CS in a new environment produces some novelty and an increase in attention, producing contextual specificity of latent inhibition. Though the construct of “attention” is explicit in this model, the operation of attention is dependent on contextual associations and, thus, this model will be grouped with the CAD mechanism models.

However, an important part of Wagner's idea is that A1 and A2 states not only affect learning, but also performance. Stimuli in A2 are assumed to be less capable of both entering into associations, and eliciting responses. If stimulus X has a consistently larger proportion of elements in A2 than stimulus Y, then X cannot be conditioned to the same level as Y. Moreover, Wagner incorporates a performance rule such that elements that have received conditioning, but are in subsequently in an A2 state, are less effective in producing a response. When comparing, for example, the ability to elicit responses between a novel CS (in a control group) and a pre-exposed CS (in an experimental group with LI treatment), the increased Context-CS associations with the pre-exposed CS affects not only learning but also performance. This “performance rule” will be important to help distinguish these different models in Chapter 2, where it will be discussed in more detail.

Generality of latent inhibition

Apart from inferences as to the mechanisms responsible, demonstrations of acquisition deficits following pre-exposure themselves have produced differing opinions as to whether LI has been demonstrated. Overall, LI appears to be a robust phenomenon occurring across a wide variety of species and a diverse set of testing conditions. All mammals tested show the effect and it has been demonstrated with many different procedures (for a review see Lubow, 1989). But, compared to the animal literature, evidence for LI in humans is more restricted. The effect has been considered difficult to convincingly demonstrate, and when demonstrated methodological concerns have challenged whether an effect of pre-exposure only has been demonstrated (e.g. Byrom et al., 2018; Le Pelley & Schmidt-Hansen, 2010).

Two main obstacles in human LI experimentation are the use of masking tasks and the generation of event- or response-specific expectations by way of instructions. Both of these “methodological problems” could lead to negative priming (Graham & McLaren, 1998), learned irrelevance (Le Pelley & Schmidt-Hansen, 2010), or any other instruction-dependent effects (e.g., Byrom et al., 2018; Nelson et al., 2021). These issues are discussed more completely in Chapter 1 (in press at *Journal of Experimental Psychology: Animal Learning and Cognition*).

Chapter one examined bi-directional associations between a CS and an outcome, following pre-exposure to the CS, with the purpose of differentiating attention-based and interference accounts of latent inhibition. According to attention-based models, pre-exposure should affect the ability of the CS to form associations with other stimuli, whether the association is CS→Outcome, or Outcome→CS. CAD models also make the same prediction here. The reduced processing of the CS caused by context-CS associations should reduce its ability to predict, or be predicted by, an outcome. However, interference-based models base the acquisition deficit on some type of CS→No Event association. Thus, expressing a CS→Outcome association should be impaired by the interference, but expressing the Outcome→CS association should not.

To accomplish this experiment, a new experimental paradigm (concept designed by Gabriel Rodriguez) where the assessment of such bi-directional learning could be accomplished was used. Additionally, the procedure was designed to eliminate concerns about the validity of the latent-inhibition manipulation raised by Le Pelley and Schmidt-Hansen (2010) and Byrom et al. (2018), among others (see e.g., Bennet et al., 1995; Graham & McLaren, 1998).

Chapter 2 attempts to further distinguish interference and attention accounts from CAD mechanisms using a method that has been previously used to investigate latent inhibition (e.g., see Nelson et al., 2014; 2021; 2022). As will be elaborated in that chapter, attentional theories predict an acquisition deficit, but not necessarily a difference in asymptote in conditioning between pre-exposed and novel stimuli. On the other hand, the mechanism proposed by Wagner (1981) can predict that asymptotic differences will be observed.

In addition to examining asymptotic conditioning, the method was designed to allow the introduction of a new outcome that should not behaviorally interfere with the old one. For example, after CS-O1 learning, CS-O1O2 pairings could allow an examination of learning about O2 without behavioral interference from the prior CS-O1 association. Thus, the method should be effective in accomplishing two things. First, it provides a novel way to study the HPNT effect. After CS-O1 training, paring the CS with O1 and O2 should reveal HPNT in the ability to learn about O2 compared to a group without the prior CS-O1 training. Apart from its similarity to LI, this demonstration is important in that the effect has been observed only once in humans (Griffiths et al., 2011), and whether the effect is generally replicable has been called in question (Le Pelley et al., 2016). Second, to the extent that the method reveals that effects of pre-exposure can be observed on the acquisition of a CS-O2 association, it can be used to determine whether LI, measured as an acquisition deficit discussed earlier, is recovered with a change in context, which is examined in Chapter 3.

Chapter 3 incorporates context changes with an online method that was nearly identical to that described in Nelson et al., (2014; 2021) and used in Chapter 2. These experiments were to determine if LI recovers its properties in an ABA design (for a possibility about this interpretation see Westbrook, et al., 2000), or whether second learning is lost (e.g., Nelson, 2002). An initial experiment was conducted to determine if the effects found in face-to-face experiments were the same as in online participants. Next, an experiment was conducted to evaluate whether contexts could retrieve LI properties, in addition to assessing whether the HPNT effect was context-specific. For example, Swartzentruber and Bouton (1986) found that HPNT was not obtained when Phase 1 and 2 occurred in different contexts in an experiment with rats. The last experiment was based on performing a between-groups summation test to determine whether the pre-exposure phase produced some type of conditioned inhibition. Chapter three produced some surprising results that introduced new variables not previously considered in latent inhibition whose study was beyond the scope intended by the present work.

Goals

The general objective of this project was to use designs and methods to differentiate the predominant theories of Latent Inhibition, which attribute it to attention (e.g., Mackintosh, 1975; Pearce & Hall, 1980), interference (e.g., Bouton, 1993; Hall & Rodriguez, 2010), or representational changes (e.g., Wagner, 1981). Chapter one does so by investigating bi-directionality of learning. Chapter two examines differences in performance to pre-exposed and conditioned stimuli, and Chapter three uses contextual control to examine potential mechanisms. The specific objectives per chapter are: 1) A: to demonstrate a LI effect without the use of masking tasks or instructional guidance. B: to determine whether the effect is better characterized as resulting from changes in processing, or interference. 2) To evaluate the persistence of LI through conditioning and compare that to an effect of HPNT in human participants. 3) Investigate whether LI can be recovered in an ABA paradigm or whether the new learning after conditioning is simply context-specific.

Chapter 1

Chapter 1 (Superman)

Compared to the animal literature, evidence for LI in humans is more limited. The effect has been difficult to demonstrate in an unanimously convincing way. Methodological concerns have challenged whether an effect of pre-exposure-only has been demonstrated, or whether the pre-exposure is confounded with other aspects of the task (e.g., Byrom et al., 2018; Le Pelley & Schmidt-Hansen, 2010). To begin, Ginton, Urca, and Lubow (1975), used a procedure that was taken as a reference in the following years involving what has been termed a "masking task" during pre-exposure. In the pre-exposure phase participants heard eight presentations of a white noise while they were involved in the masking task; they were listening to a list of syllables through headphones and were required to count the number of times the list was repeated. This task was intended to decrease attention to the white noise. In the phase-2/conditioning task, all participants listened to the syllables, with the occasionally-occurring white noise sound, and were required to predict when a visual counter would increment based on what they were hearing. Increases in the score were predicted by the white noise. Of the participants who had not heard the white noise in the first phase 75% learned this new predictive relationship well, while only 15% of those pre-exposed learned it.

Masking tasks are introduced within the experimental procedure during pre-exposure under the assumption that it is necessary to divert attention away from the pre-exposed stimuli to promote automatic processing. It is argued that masking tasks occupy controlled cognitive processes which could interfere with the automatic processes that are assumed to be responsible for LI in animals (Lubow & Gewirtz, 1995). Since the publication of Ginton et al.'s results, the use of masking in human latent inhibition preparations had been often regarded as a necessary condition to obtain retarded performance after stimulus pre-exposure (e.g., Lubow & Gewirtz, 1995), and remains a feature of current research (e.g., Holt et al., 2020).

Despite these demonstrations of pre-exposure effects in humans, whether the effect is simple pre-exposure-produced "latent inhibition" has been challenged. Early attempts to demonstrate LI in the absence of masking have been critiqued elsewhere (see Graham & McLaren, 1998, for discussion). More recently, Le Pelley and Schmidt-Hansen (2010) argued that there is a difference in the processes underlying the effect observed following simple pre-exposure in animals and that following masked pre-exposure in human contingency learning. This latter effect may reflect learned irrelevance (e.g., Bennett, Maldonado, & Mackintosh, 1995) made possible by inclusion of the masking task during pre-exposure.

Byrom et al. (2018) raised many of the same doubts about whether the psychological mechanisms underlying the LI phenomenon are the same in animals and humans. For example, they argue that the masking task may favor the creation of a negative priming effect (see also Graham & McLaren, 1998). Negative priming is used to refer to impaired performance with stimuli that have previously been ignored (e.g. pre-exposed stimuli) as they were distractors to a task to which subjects should attend (e.g. masking task) (Graham & McLaren, 1998).

Motivated, at least partially, by such criticisms multiple studies have since shown conditioning deficits following pre-exposure that do not involve masking tasks (e.g., Escobar et al., 2003; Evans et al., 2007; Forrest et al., 2018; Granger et al., 2016; Granger et al., 2012; Nelson & Sanjuan, 2006; Schmidt-Hansen et al., 2009; Shrira & Kaplan, 2009; Young et al., 2005), though the mechanisms are still not clear (Nelson et al., 2021).

Le Pelley and Schmidt-Hansen (2010) argued that some findings such as Escobar et al. (2003), and Nelson and Sanjuan (2006), are the result of participants keeping track of contingencies. For example, if after ten trials of pre-exposure to a stimulus “R,” the participant experiences a conditioning trial, the response in the second trial will be based on a computation based on the total experience with R. The probability of R being followed by an outcome on trial 2 is 1/11 in a pre-exposed group, and 1/1 in the control. They do not attribute this capacity to animal demonstrations, although they lack any strong justification for that. Without that attribution, there is no strong argument or evidence that contingency calculation is not the mechanism of latent inhibition.

Additionally, Le Pelley and Schmidt-Hansen (2010) point out that animals do not know that they are carrying out an experiment and they do not have information about the outcome. This latter point is important in that in all experiments with humans, instructions are necessary to orient the participant to the task and set the framework for what they should be doing. Generally, instructions are such that they generate an expectation of something particular occurring to which the participants must respond, which does not occur during pre-exposure. As suggested by McLaren et al. (2021), when stimuli are presented in a situation where making responses could be expected, pre-exposure might engage a response inhibition mechanism when those responses are not required (see Nelson et al., 2021 for application of this idea to recent demonstrations of possible latent-inhibition effects). Such a mechanism would be absent in animal experiments where animals, presumably, have no information about what stimuli or responses might be expected. This response-inhibition mechanism is similar to a criticism offered by Byrom et al., (2018). Most of the work they reviewed required the participants not to respond to the target in preexposure, prior to learning to respond in conditioning. They argue that without manipulating the response requirements independently across phases there is the “possibility that retarded performance following pre-exposure is an entirely behavioral effect” (Byrom et al., 2018, p. 11).

Byrom et al. (2018) also considered that mismatches in stimulus novelty could facilitate learning, producing the apparent retardation of learning that follows pre-exposure. A mismatch in novelty can be created when pre-exposed and novel stimuli are present in an experimental setting, allowing for a contrast of their relative novelty. A pre-exposed stimulus is relatively less novel in comparison to non-preexposed stimuli. This mechanism was presented as a criticism applied to human research on the phenomena, and was applied mostly in situations where many filler trials were used in human procedures (e.g., Evans et al., 2007; Granger et al. 2016; Lovibond et al., 2023; Rodriguez & Hall, 2017; Rodriguez et al., 2019) whereby there is ample opportunity to contrast the novelty of the stimuli in the situation. Nevertheless, in a typical study the CS is pre-exposed (novelty decreases) in a context (novelty decreases) and conditioning is slower than with a stimulus or group for which a novel CS occurs in a relatively less-novel context.

This criticism could be taken as a possible mechanism by which latent inhibition occurs, rather than a criticism of work specifically with humans as relative novelty should operate just as well in animal studies with parallel designs (e.g., Escobar et al., 2002; Hall & Channel, 1986, Experiment 1; Rodriguez & Hall, 2008). However, the context specificity of latent inhibition must be considered. When exposure to the conditioning and pre-exposure contexts is matched during pre-exposure (e.g., see Bouton & Swatzentruber, 1989, with animals; or Nelson et al., 2021, with humans), then the novelty of the pre-exposed CS relative to the context is the same, whether that context is the same as pre-exposure and latent inhibition is observed, or different from pre-exposure and latent-inhibition is attenuated.

Of the criticisms of human latent-inhibition effects offered in the literature, the most challenging appear to us to be those that are dependent on masking tasks, or instructions. With instructions, the main issue is that instructions generate an expectation of the outcome, which does not occur in preexposure. That absence, in the presence of some expectation, could lead to specific response inhibition, outcome inhibition, learned irrelevance, or negative priming. Presently we know of no experiment designed to directly contrast these possible interpretations against "simple pre-exposure," because the issue appears to be the difficulty of designing a task in humans that involves "simple pre-exposure." Experiment 1 was designed to demonstrate a preexposure effect in humans that, at face value, appears to eliminate concerns raised regarding both masking tasks and instruction and be simply exposure dependent. Experiment 2 used a novel test to determine whether the effect we observed followed more closely with explanations for latent inhibition based on changes in how cues are processed or attended (e.g., Mackintosh, 1975; Pearce & Hall, 1980; Wagner, 1981), or accounts that stress interference between the outcome expectancies possibly learned in the two phases (e.g., Bouton, 1993; Hall & Rodriguez, 2010).

In the online experiments participants simply viewed a short cartoon video of a "Superman" type character flying through various environments where different stimuli might appear1, and were then asked about what should be present in the video in the presence of cues that had been exposed or not, between participants. After being thanked for their participation, the deliberately simple instructions that followed read, "Next, you will view a short video (less than 2 minutes) and afterwards we will ask you a few questions. The video does not have sound. Please watch the entire video without pausing or rewinding." Although participants knew they were in an "experiment" and would be asked questions, the instructions generated no specific response expectation which might be modified during pre-exposure, effectively eliminating concerns regarding expectancies and direction of attention generated by instructions.

In the short cartoon, the character flies through different contexts (e.g., a blue sky) and past different stimuli (e.g., clouds). A Moon was the target stimulus throughout the experiment for all groups. Participants were pre-exposed to the Moon as Superman flew in the blue sky, for example. During a conditioning trial, every time Superman flew past a Moon his hands glowed red. Participants were free to view these events as they wished- there was no masking involved in the task, eliminating concerns associated with the use of such tasks.

Whether associations between those two events (Moon ↔ Glowing Hands) were formed was evaluated with an expectancy test. A frame from the video was presented showing Superman flying in the blue sky, for example, in the presence of a Moon, but without the Glowing Hands (Experiment 1), or in the presence of the Glowing Hands, but without the Moon (Experiment 2). In addition, in Experiment 2, participants were asked about the context (without the target or outcome) to evaluate whether context-cue associations, which are used in some explanations of LI (e.g., McLaren & Mackintosh, 2000; Wagner, 1981), were established, and could be detected.

When presented with a test screen, participants were asked “Do you think something is missing in this picture?” and if they responded “yes”, they were asked what was missing. They were free to report as many items as they wanted and had as much time as needed. Participants should be more likely to say “yes” that something was missing, and report that it was “Glowing Hands” (Experiment 1) or “Moon” (Experiment 2), as a function of the strength of the association that they have between the elements in the image and those that were missing. Thus, if pre-exposure interferes with either the acquisition or expression of that association, pre-exposed participants should be less likely to indicate that the Glowing Hands were missing.

Experiment 1 (C1E1)

The design is shown in Table 1, and shown graphically in Figure 1. Participants viewed a 90-s video of Superman flying through 3 different context/stimulus combinations, followed by a test. The short procedure and immediate testing should facilitate the detection of latent inhibition, as the effect has been shown to dissipate with the passage of time (e.g., Aguado et al., 1994). The combinations consisted of outer-space with a rocket ship (row 3, column 1), a blue sky with a cloud, and a desert-type context with a bird (For an example see Figure 2), counterbalanced as contexts A, B, and C. Context C was not used as any experimental manipulation in the present experiment, but it was included here to add variety to the task and ensure that any effect observed would occur in a procedure that involved exposure to three contexts, for consistency with future experiments where such a manipulation might be necessary. The target stimulus was an image of the Moon (e.g., Figure 1, row 1 and 2, column 1).

A trial consisted of Superman flying for a short inter-trial interval (ITI), followed by the addition of a stimulus moving from the left side of the screen to the right as if Superman were flying past it from right to left. In the pre-exposure phase, the target Moon stimulus replaced the stimulus that would otherwise occur in the context. For example, if the exposure took place in the blue context, participants were exposed to the Moon instead of the cloud. For those in Group Same, the Moon replaced the stimulus in Context A, for those in Group Different it replaced the stimulus in Context B. Group No Exposure received no exposure to the Moon. In the conditioning phase, the Moon appeared and very shortly after (.23 seconds), Superman's hands glowed red for the remainder of the Moon's appearance in Context A (column 2, "Conditioning" in Figure 1).

The procedure was a short-delay conditioning procedure where the presence of the Moon was paired with the occurrence of the Glowing Hands. The procedure should establish stimulus-stimulus (e.g., Rescorla, 1973) associations between the Moon and the Glowing Hands so that some memory or expectation of the Glowing Hands should be evoked by the Moon. A test for that evoked memory asked participants "Do you think something is missing in this picture?" with the picture containing Superman flying through context A with the Moon present and the Glowing-Hands outcome absent (see Figure 2). In the case they responded "Yes" they were required to list what they thought was missing.

The test was more than a simple memory recall test. Participants were not asked to freely recall items associated with the scene (e.g., “do you recall other items in this scene/what items were in this scene”). The wording of the question specifically asked if anything was *missing*, and what it was that was missing. Thus, the item not only had to be recallable, but there should be some expectancy that it was supposed to be present. That is, to be perceived as “missing,” it is assumed that the subsequently listed item was expected. Regardless of the individual interpretations of the word “missing,” the variable of interest was how many participants indicated, in their list of missing items, that it was the Glowing Hands that were absent.

A latent-inhibition effect would appear as fewer participants indicating that Glowing Hands were missing in Group Same compared to Group Different (e.g., Hall & Honey, 1989) and Group No Exposure (e.g., Lubow & Moore, 1959). The design should make a “learned irrelevance” interpretation of the findings difficult. There was nothing in the instructions to suggest any relevancy between the items, and there was no expectation of any particular thing occurring. The presentations of the stimuli (Moon alone or Moon with Glowing Hands) were in different phases of the experiment rather in an explicitly uncorrelated manner appearing in the same phase of the experiment, similarly to conditions that have been used as a control for learned irrelevance (Bonardi & Hall, 1996). The inclusion of the context-change group should also help to rule out relative novelty as an explanation as the relative novelty of the stimuli encountered during conditioning is the same in Group Same and Group Different, yet based on a latent inhibition effect, less effect of pre-exposure is expected in Group Different.

Table 1.
Design of Experiment 1

Context	Pre-exposure	Conditioning	Test
Same	**A:X-** B:Y- C:Z-	**A:X+** B:Y- C:Z-	**A:X?**
Different	A:W- **B:X-** C:Z-		
No Exposure	A:W- B:Y- C:Z-		

Note: Design of Experiment 1 in which there were three groups: “Same”, “Different”, and “No Exposure”. “A”, “B”, and “C” were 3 contexts (space, desert, and sky, counterbalanced) and “W”, “Y”, “Z” were 3 objects (rocket ship, bird, and cloud) while X was the target cue (Moon). “+” indicates Superman’s hands glowed while “-” indicates no change in Superman’s appearance.

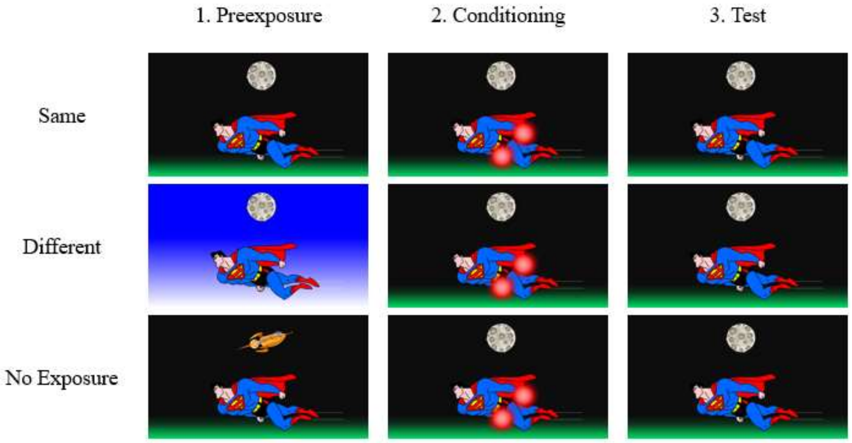


Figure 1: Example screenshots of different groups (Same, Different, and No Exposure) and different phases of the experiment (1. Exposure, 2. Conditioning, and 3. Test). See text for details.

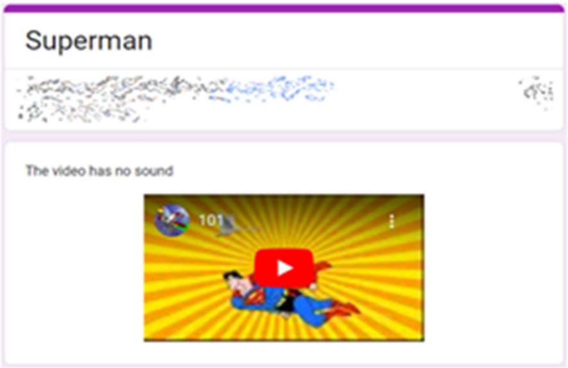
Method

Subjects

Counterbalancing the three contexts and their six sequences across the pre-exposure phase required 36 participants, thus there were 36 participants in Group Same and Group Different. Groups Same and Group Different were both experimental conditions. We matched the number of participants in Group No Exposure (control) with that of the experimental conditions in total so that 72 participants were included in Group No Exposure leading to the recruitment of one-hundred and forty-four students. There were 61 males (mean age = 26.2, standard deviation [SD] = 7.5) and 83 females (mean age = 26.5, SD = 4.3). The participants were recruited among undergraduate, graduate, and doctoral students through e-mail. They were assigned at random to the three groups. All procedures were approved by Commission of Ethics for Research and Teaching of the University of the Basque Country (UPV/EHU; M10/2015/210). The experiment had power of .22, .95, and .99997 to detect small (Cramer's V =.1, medium, V=.3, and large, V=.5, effects respectively).

Apparatus

The experiment was presented through Google forms. The first screen of the form thanked them for their participation and informed them that the experiment they were going to perform was anonymous, then the demographic data (sex and age) were collected. The next screen included the instructions, which are detailed below, which led to the video (see Figure 1; see also, for example, *https://www.youtube.com/watch?v=G7jT51zqeHI*).



Superman

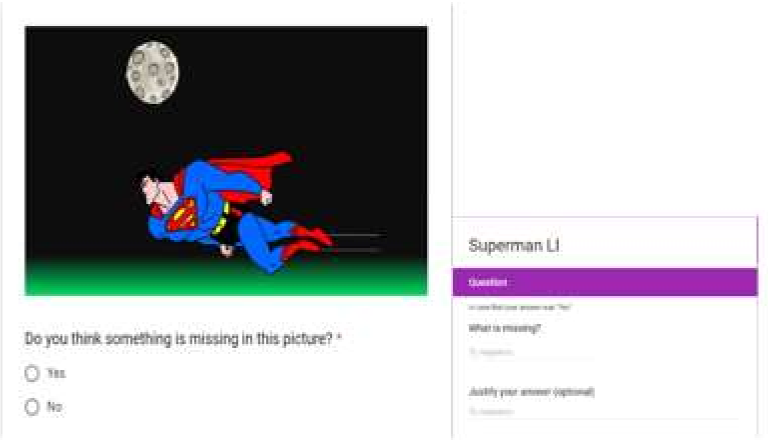
The video has no sound

Figure 2: Example of the screen where the video was viewed. Email, options to change accounts, and whether progress was being saved) are blurred for publication, but were present in the experiment. Video information (e.g., 101) disappeared on play.

The video was built with Microsoft Office PowerPoint (2016 version). On each slide, Superman appeared near the bottom center of the screen. His position varied slightly on each frame to give the illusion of movement. These slides had backgrounds consisting of a blue sky, black outer space that faded to green near the bottom of the screen (e.g., Figure 1), and a comic-striped yellow and orange desert (shown in Figure 2). These three backgrounds were fully counterbalanced as Contexts A, B, and C. On 21 of the slides in each context a stimulus could appear (Moon, cloud, bird, rocket ship) arranged across the slides as if the stimulus was moving from left to right (i.e., Superman flying from right to left). When it appeared, the cloud always appeared in the blue context, the bird in the desert context, and the rocket ship in the space context.

The slides were generated so that when played they showed superman flying in the background context for 1.65 s (the ITI) followed by him flying with the stimuli moving from left to right across the screen for approximately 1.38 seconds on a trial. On a conditioning trial, superman's hands glowed with the glow beginning .23 s after the stimulus first appeared on the left side of the screen and terminated glowing with the stimulus exiting the screen.

There were slides used for transitions between contexts (one transition for each context). Superman flew to the left side of the screen (.36 s) and upon reaching the left side the current context scrolled to the right, off the screen, as the new context scrolled into the scene (.2 s). The presentations were recorded to videos that were uploaded to YouTube and presented on a Google Forms web page (Figure 2). The test questions were presented after the video (see Figure 3 and Figure 5).



Do you think something is missing in this picture? *

○ Yes

○ No

Superman LI

What is missing?

Justify your answer (optional)

Figure 3: Example test screenshot.

Procedure

Participants were tested individually. The link to Google forms was sent through an email. Participants were informed previously that they would be taking part in an experiment involving cognitive tasks. Participants could view the video at a time and place of their choosing and on a device of their choosing (e.g., tablet, desktop computer, cell phone). The Google form first informed participants that an experiment was going to start, their participation was appreciated, collected the participants age and sex, and then delivered the following on-screen instructions in Spanish: "Next, you will view a short video (less than 2 minutes) and afterwards we will ask you a few questions. The video does not have sound. Please watch the entire video without pausing or rewinding." Once the participant had pressed “next,” the video began.

A trial lasted approximately 3 seconds and began with the inter-trial interval where Superman was simply flying with the context in the background. On pre-exposure and conditioning trials, the stimulus then appeared at the left side of the screen and transitioned to the right side of the screen. On the conditioning trials the Glowing Hands outcome appeared .23 s after the cue stimulus and remained while the stimulus was onscreen. Trials were arranged in 3-trial blocks within a context. The context changed every 3 trials.

In Phase 1 (pre-exposure) each context/stimulus combination was presented 6 times in two 3-trial blocks. The order of exposure to the context was fully counterbalanced on the first block (ABC, ACB, BCA, BAC, CAB, CBA) and the order repeated in the second block. In each trial either the stimulus assigned to that context was exposed or the Moon in the Exposed conditions. The Moon was exposed in Context A for Group Same and in Context B for Group Different. Conditioning began and consisted of one block of three conditioning trials and one block of three trials of exposure to each of the other contexts. The order of the blocks in conditioning was the same as in pre-exposure.

Immediately after the presentation of the video an image was presented (see the example in Figure 3, left) in which Superman was flying through context A with the Moon present. The outcome did not appear in the test. A question was shown below the screenshot in Spanish: Do you think something is missing in this picture? The participant marked YES or NO, and went to the next page of the form which contained the image and the questions shown to the right in Figure 3. If the answer was YES, participants were asked to specify what was missing in the image. These answers were used to determine if the participants were expecting the outcome. After this question, an optional justification of the response was requested. A Glowing-Hands response was recorded when the participant marked YES and specified that the specific outcome (Glowing Hands) was the missing element in the test image. All other cases (e.g., not specifying what was missing, naming other elements of the experiment not present in that context, etc.) were not counted as a Glowing Hands response.

Data Analysis

For participants who indicated that something was missing, their list of items indicated as missing were coded as Glowing Hands or No (no Glowing Hands indicated) by the first author and a second individual blind to the goals and conditions of the experiment. The second rater was given a list of the participant responses along with pictures of what had appeared on the screens and asked to indicate what the responses corresponded to in the images, if anything. Discrepancies were resolved by a third rater, also blind to the conditions.

The number of Glowing Hands missing responses vs No responses were analyzed with chi-square tests of independence. Effect sizes are reported as Cramer's V (*V*), and 95% confidence intervals ($CI_{95\%}$) were calculated using the Real-Statistics add-in for Microsoft Excel (Zaiontz, 2023).

Results and Conclusions

All participants who stated that something was missing reported either Glowing Hands, or an equivalent response (i.e., red lights, red circles, illuminated fists, red hands, or fire in the hands). A response was categorized as "No" when participants clicked "no" or indicated something that was not "Glowing Hands" or equivalent (i.e., differences in Superman's clothing, hairstyle, or facial expression, elements in the background context that had not appeared in the experiment such as mountains or stars, differences in the scene´s brightness). Agreement between raters was 100% with one exception. The response "stars on the Hands" was coded as "Glowing Hands" by one, and "No" by the other. The third rater coded it as Glowing Hands (the classification as one or the other had no impact on the conclusions).

As Figure 4 shows, the majority of the participants in Group No Exposure (76.4%) indicated that the test image was missing the Glowing-Hands outcome, whereas only 22.2% in Group Same did so. Those in Group Different showed a stronger expectation of the outcome (61.1%) than Group Same.

A chi-square test of independence (Group x Glowing Hands (yes/no)) confirmed dependence between the groups and the test responses X2(2) = 29.20, p < .001 (V = .45; CI95% .27 - .61). Tests of independence with Group Same showed that fewer participants in Group Same indicated something missing than both Group

Different, X2(1) = 11.2, p < .001 (V = .39 ; CI95% .16 - .63), and Group No Exposure, X2(1) = 28.97, p < .001 (V = .52; CI95% .33 - .71). Group Different and Group No Exposure showed the same response pattern X2(1) = 2.73, p = .098.

The results are consistent with the idea that participants in Group Same had difficulty associating the target with the outcome. This result´s interpretation is consistent with acquisition-deficit models (e.g., Le Pelley, 2004; Mackintosh, 1975; Pearce & Hall, 1980) that would involve a decrease in the associability of the pre-exposed stimulus during phase 1. In other words, the participant may pay less attention to the pre-exposed target, which would make it more difficult to associate with new stimuli at a later stage in comparison with a group for which the target stimulus is novel in conditioning (No Exposure group).

However, the results obtained in the Different group are not explainable by attention-based models that do not incorporate a role for the context (e.g., Le Pelley, 2004). The result is consistent with Wagner (1981) and McLaren and Mackintosh (2000) for which during pre-exposure an association would be established between the context and the target stimulus, reducing the ability of the cue to form associations (see Discussion for elaboration). Results are also explained by Schmajuk, Lam, and Gray (1996) for which attention to a CS is determined not simply by how well a stimulus predicts an outcome, but by how well the current environment is predicted in total by the stimuli present. Thus, the unexpected (novel) presence of the CS in a different environment produces an increase in attention.

Results are also consistent with some interference-based models (e.g., Bouton, 1993; Hall, 1991; Hall & Rodriguez, 2010). According to Hall and Rodriguez, during the first phase of the experiment, participants in Group Same should expect some "Event," some change in what was otherwise occurring, to occur when the target stimulus appears. The subsequent occurrence of no change in the situation, "No Event," would establish a second-learned target-No Event association. In the next phase, during conditioning, target-outcome learning would occur. On the test, interference would occur between the retrieval of "No Event" and the outcome, with most participants expressing the former. This interference would not occur for the No Exposure group, which has only experienced target-outcome learning during conditioning. A change in context (Different group) between pre-exposure and conditioning should lead to some failure to retrieve the second-learned "No Event" consequence (e.g., Nelson, 2002), removing the interference with the outcome expectation.

In their critique of human latent inhibition studies and their compatibility with animal work, Byrom et al., (2018) discuss that relative novelty could explain latent inhibition findings in human work. The pre-exposed stimulus (X) is conditioned in a pre-exposed context, thus there is no novelty of X relative to the other stimuli present (context). In the control group, a novel X is presented in a pre-exposed context, creating more relative novelty of X over the context in the control group, which might produce better conditioning. It is worth pointing out again that in the Different group, participants receive conditioning with a familiar X in a familiar context, thus there should be no relative novelty advantage, yet this group conditioned better than Group Same, and was indistinguishable from Group No Exposure. Relative novelty alone, without a mechanism to restore the novelty of S in the new context (e.g., Schmajuk, Lam & Gray, 1996; Wagner, 1981), cannot account for the results as a whole.

The results can also be explained by template matching, which has been applied to a variety of recognition problems in various forms (e.g., Cave & Kosslyn, 1989; Larsen & Bundesen, 1978; 1996). Group Same could form a template of the pre-exposure imagery, where the moon was present without the glowing hands in a context. Then, during the phase 2 conditioning the moon was present with glowing hands, in the same context, which might create a different template. Thus, the presence of the context and the moon on the test better matches the phase 1 experience, where no glowing hands were present. This explanation is largely isomorphic to that of the interference account offered above. In the absence of instructions directing participants which template to use, there could be interference at the time of testing when deciding whether the question was specifically referring to one template (phase 1) or the other (conditioning). In Group Different, the test imagery better matched that of what occurred in Phase 2, perhaps resolving any ambiguity about which template the question referred to, if participants interpreted the question as specific to one phase's template or the other. Experiment 2 addressed issues related to interference by testing the Glowing Hands, rather than the Moon in Context A.

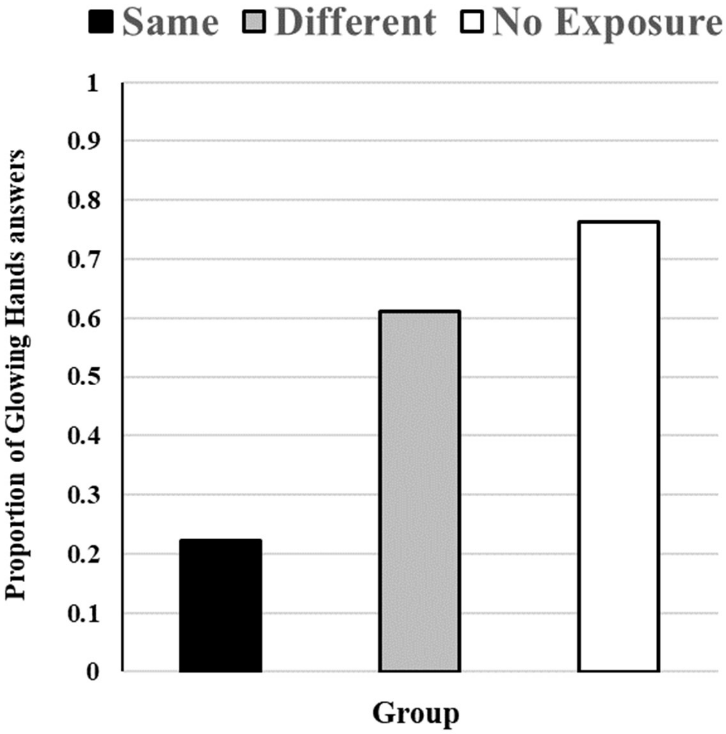


Figure 4: Proportion of Glowing Hands answers on the test in Experiment 1 for groups Same, Different, and No Exposure.

Experiment 2 (C1E2)

In Experiment 1, we conceptualized the target Moon as a “CS” and the Glowing Hands outcome as a “US.” Nevertheless, the target appeared only .23 seconds before the outcome so the presentation was largely simultaneous, and, thus, their roles could be functionally reversed. Experiment 2 assessed the bi-directionality of the learning that occurred by testing the Glowing Hands rather than the target Moon. A latent-inhibition effect between the two elements would be demonstrated if fewer participants in Group Same respond “Yes” and indicated that the target Moon was missing compared to the Different and No Exposure groups.

The design also allows us to contrast accounts that depend on some type of CS processing (i.e., models that depend on changes in the CS, based on attention e.g., Le Pelley, 2004; Mackintosh, 1975; A2 processing, Wagner, 1981; or representational boosts, Schmajuk, Lam & Gray, 1996) from interference-only accounts (e.g., Bouton, 1993). Changes in how the cue is processed should affect how well the cue can be associated with other events. In this case, a reduction in that processing should affect both Moon→Glowing Hands associations, and Glowing Hands→Moon associations. However, an interference account, whereby the Moon predicts nothing or “no Event,” should interfere with learning that the Glowing Hands follow the Moon, but should not affect the Glowing Hands ability to predict the Moon. The Glowing Hands are novel and have no interfering associations. Similarly, if a template matching account explains Experiment 1, then any memory template containing the Glowing Hands also should contain the Moon. If we consider that the participants in Group Same from Experiment 1 formed memory templates of phase 1 (context A + moon, i.e., AM) and phase 2 (AM+hands, i.e., AMH), then the presence of a stimulus complex containing the context and the Glowing hands (AH) should better match the template acquired in phase 2 (AMH) than phase 1 (AM). The groups should be equal in the similarity of the test stimulus to the phase 2 template. In the case that there was still confusion, the moon was also present in the phase 1 context in Group Same, thus template matching should enhance moon reports.

Experiment 2 also assessed contextual associations by testing Superman alone in the context, absent any other stimulus. A result consistent with Wagner (1981), Schmajuk, Lam, and Gray (1996) and McLaren and Mackintosh (2000), who all anticipate context-cue associations, is expected. Participants in all three groups should readily expect stimuli present during the pre-exposure phase in the subsequently conditioned context. All groups will have received exposure to the test context in phase 1 and phase 2, with the Moon appearing in phase 2. Thus, when presented with Superman in the test context and asked if something is missing, they should report that the Moon is missing. Those in Group Same who were pre-exposed to the Moon in the test context, and again experienced the Moon in the conditioning context in phase 2, should have a strong expectation that the Moon should be present. Those in the Different and No Exposure groups have had exposure to the conditioning context with some Other stimulus, followed by trials with the Moon in the test context in conditioning. These groups should have weaker expectations of these stimuli, whether they report the Other stimulus was missing, the Moon was missing, or both. We expect that more participants in Group Same will report the Moon as missing than in the other conditions.

The context-only question also allows us to ask to what extent the participants in E1 could have responded that the outcome was absent based on any association it had with the context. If the manipulation somehow affected context-outcome associations, then the pattern of reports of Glowing Hands missing, given the context, should match the pattern observed in Experiment 1 where the Moon was present.

The design in training was the same as Experiment 1. On the test, participants were presented with Superman in the phase 2 training context (A) with his fists illuminated and then asked if anything was missing (see Figure 5, top). They were also presented with Superman in the training context and no other stimuli and asked if something was missing (see Figure 5, bottom). The order of these two tests was counterbalanced.

Method

Subjects

Counterbalancing the three contexts, their sequence across the phase, and the two tests required 72 participants per condition (144 in the No Exposure group). Two-hundred and eighty-eight students participated, 50 males (mean age = 25.4, standard deviation [SD] = 8.2) and 238 females (mean age = 24.6, standard deviation [SD] = 11.6). The participants were recruited among undergraduate, graduate, and doctoral students through e-mail. They were assigned at random to either Group Same (n = 72), Group Different (n = 72), or Group No Exposure (n =144). The resulting sample had power of .396, .999, and 1 to detect small, medium, and large effects (Cramer's $V = .1$, .3, and .5, respectively).

Apparatus

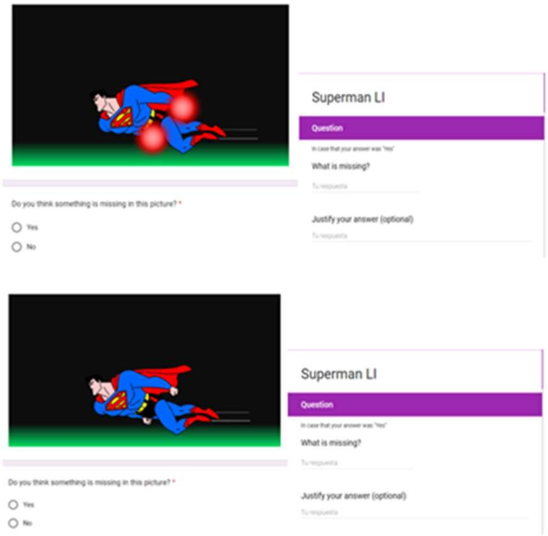
The apparatus used is that described in Experiment 1 with two exceptions. A test image of Superman with his fists glowing was used and a test image for assessing the context was added that was simply Superman flying in the context with no stimulus or Glowing Hands present (see Figure 5).

Procedure

The recruitment and content of the Experiment 2 were the same as described in the Experiment 1 section. In Experiment 2, two counterbalanced tests were conducted. The "Hands-cue" question is shown in Figure 5 (top) and the "context-cue" question is shown in Figure 5 (bottom).

Data Analysis

Data were coded and analyzed in the same manner as Experiment 1.



Do you think something is missing in this picture? *

○ Yes
○ No

Superman LI

Question

In case that your answer was "Yes"

What is missing?

Tu respuesta

Justify your answer (optional)

Tu respuesta

Do you think something is missing in this picture? *

○ Yes
○ No

Superman LI

Question

In case that your answer was "Yes"

What is missing?

Tu respuesta

Justify your answer (optional)

Tu respuesta

Figure 5: Test 1 (top) and Test 2 (bottom).
Tests were counterbalanced.

Results and Conclusions

In the data reported below, there is the possibility that the order of testing (Context-Test/Hand-Test or vice versa) could interact with the findings as the full design was a 2 (Test) x 2 (test order) x 2 (moon reported or not). To address this possibility, we used log-linear multi-way frequency analysis (including all main effects and interactions) in omnibus tests of the full design to examine whether there were interactions with Test order. Test order produced no effects or interactions, *p*s ≥ .21. Chi-square tests of independence were then used to examine the effects of the pre-exposure method (Group) on the moon reports.

All participants who indicated that something was missing in the Hands-cue test reported that the Moon was missing, or they used an equivalent label (judged by the raters) based on how they individually perceived and labeled the stimulus (i.e., meteorite, asteroid, big ball flying over Superman, comet). Inter-rater agreement was

100% and there were no disagreements to resolve. As shown in Figure 6, most of the participants in the No Exposure (79.9%) and Different (73.6%) groups indicated that the Moon was missing from the test image with the Glowing Hands present. However, slightly less than half of the participants in Group Same (48.6%) indicated that the Moon was missing.

A chi-square test of independence (Group x Moon (yes/no)) confirmed dependence between the groups and the test responses $X^2(2) = 22.98$, $p < .001$ ($V = .28$; $CI_{95\%}$ .16 - .39). Tests of independence with Group Same showed that a smaller percentage of participants in Group Same (35/72) indicated something missing than each of the other groups $X^2(1) = 9.47$, $p = .002$ ($V = .26$; $CI_{95\%}$ .09 - .42) (vs. Different; 53/72), and $X^2(1) = 22.09$, $p < .001$ ($V = .32$; $CI_{95\%}$ .19 - .45) (vs. No Exposure group; 115/144). Groups Different and No Exposure showed the same response pattern $X^2(1) = 1.08$, $p = .298$.

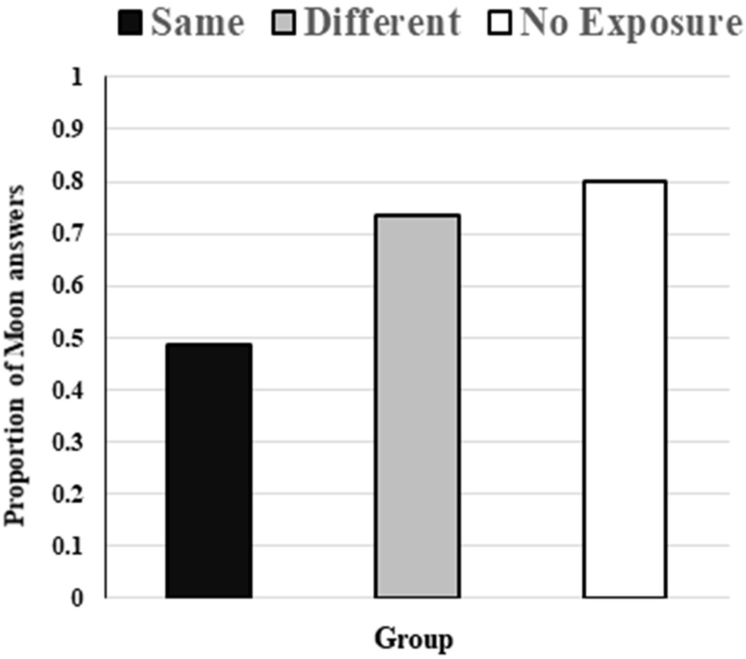


Figure 6: Proportion of Moon answers on the “hands test” in Experiment 2 for the Same, Different and No Exposure groups.

Results are consistent with those obtained in Experiment 1. There, pre-exposure to the Moon appeared to hinder the development or expression of an association with the Glowing Hands in the expectancy test. In Experiment 1, this result could have been the result of attention/associability to the Moon declining in phase 1 in Group Same and Group Different, and being subsequently restored during conditioning in Group Different. Or, the Moon may have first been associated with nothing/No Event, and then the Glowing Hands. Thus, given the Moon, the two outcomes could compete. In Group Different the context change may have attenuated the retrieval of the No Event representation. Group Same may simply have remembered both of their experiences with the context (containing the Moon and normal hands, containing the moon and Glowing Hands). Each possibility matches a template that they may have stored, and without being directed by the question to use one template or the other, there could be decision interference in deciding whether to report that the moon was missing. Any of these explanations apply to the first experiment.

In the present experiment, it seems that the latter two, interference-based, explanations do not apply. The Moon may have been associated with both "No Event" and the Glowing Hands. Yet, the Glowing Hands (in the context), which was the prompt cue on the test, were only associated with the Moon. Likewise, the images containing Glowing Hands only occurred with the moon also present, thus the image should match a template with the moon in it and thus facilitate reporting that the moon was missing. Experiment two is more consistent with accounts that assume the associability or processing of the pre-exposed Moon has been affected (e.g., McLaren & Mackintosh, 2000; Schmajuk, Lam, and Gray, 1996; Wagner, 1981).

The results could be seen as consistent with a blocking effect (e.g., Kamin, 1968) for Group Same. An expectation of the Moon produced by the context could block the ability of the Hands to enter into associations with the Moon. As will be detailed further below, results of the context test are consistent with the idea that an association formed between the context (C) and the Moon (C→M). Thus, the addition of the Glowing Hands (G) creates a standard blocking design (C→M followed by CG→M). When tested with the Glowing Hands present in the context and asked what is missing (Test 1), the blocking effect would appear as a reduction in the response indicating that the Moon is what is missing. Interestingly, according to Wagner (1981), both effects, a latent-inhibition effect and blocking, would be the result of the same context-Moon association.

The results of the Context test are shown in Figure 7. We first counted responses where participants reported that something was missing and indicated that what was missing was the Moon, the Glowing Hands, or the stimulus that had been pre-exposed during phase 1 in what would be the subsequent conditioning context (i.e., the Other stimulus present in the to-be test context during pre-exposure in Group Different and Group No Exposure). Inter-rater agreement was again 100%. Groups Same, Different, and No Exposure, respectively showed 44 % (32/40), 46% (33/72), and 43% (63/144), responses indicating that an expected item, detailed above, was missing. All groups responded the same in this overall assessment. This was confirmed by a Chi-square test of independence (Group x Expected Item (yes/no)) $X^2(2) = .08$, $p = .94$.

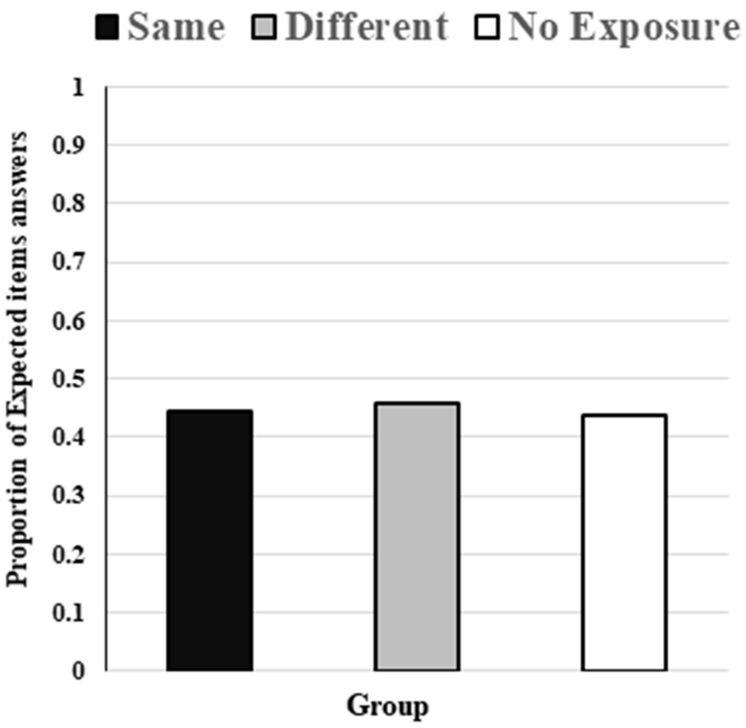


Figure 7: Proportion of Expecting Items answers on the “context test” in Experiment 2 for Same, Different, and No Exposure

Next, we analyzed the individual items. We first examined the Moon which had been present in both phases for groups Same and Different, and in Phase 2 for the No Exposure group. Second, we examined the Other phase-1 stimulus, which was the stimulus present in the conditioning context during phase 1 for Group Different and Group No Exposure (e.g. the cloud, the rocket-ship, or the bird, depending on counterbalancing). Finally, we examined the Glowing Hands which was the outcome for all groups.

Figure 8 shows the percentage of people expecting each item, by group. Participants could report as many missing stimuli as they wished. There were some participants (6.94%) that reported that both the Moon and the Glowing Hands were missing (8, 4, and 8 participants for Groups Same, Different, and No Exposure, respectively). Apart from the Moon and Glowing Hands being reported together, there were joint reports of the Other phase-1 stimulus and the Glowing Hands (1.73%; 0, 2, and 3 participants for Groups Same, Different, and No Exposure). The figure below shows the proportion of participants expecting each item, regardless of whether they reported one or multiple stimuli as we are not comparing the stimuli (comparisons of the stimuli within groups is confounded by the lack of counterbalancing of the individual stimuli, so only group comparisons by stimulus are of interest).

A Group x Moon expected/Not expected Chi square was significant, $X^2(2) = 18.23$, $p < .001$ ($V = .25$; $CI_{95\%}$ .13 - .36). The Moon was better expected in Group Same (26/72) than Group Different (11/72), $X^2(1) = 8.18$, $p = .004$ ($V = .24$; $CI_{95\%}$ .07 - .4), and Group No Exposure (18/144), $X^2(1) = 16.49$, $p < .001$ ($V = .28$; $CI_{95\%}$ .14 - .41). There were no differences between the Different and No Exposure groups $X^2(1)$ .32, $p = .57$.

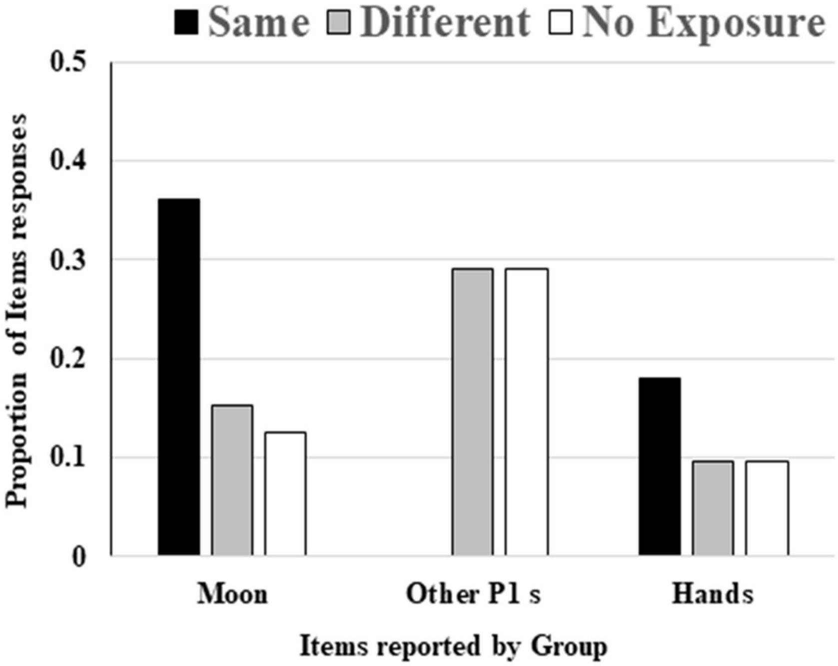


Figure 8: Proportion of responses for the Same, Different, and No Exposure groups that indicated that the Moon, P1 Stimulus, or the Hands were missing.

The context clearly produced some expectation of the Moon in group Same, which could block learning about the Hands-Moon relationship. In group same, 36% (26/72) of the participants reported the Moon missing on the context test, while 49% (35/72) reported the Moon missing on the Hands test. There were 20 people in group Same (28%) reporting the Moon missing on the Hands test that *also* reported it missing on the Context test. Thus, of the 35 people (49%) reporting the Moon missing on the context test, only 15 (21%) may have been responding to the presence of the Glowing Hands.

Analysis of the Hands question, broken down by whether the Moon was expected on the context test, showed that when the Moon was *expected* on the context test there was only marginal dependence between Group and the report of the Moon missing, $X^2(2) = 4.95$, $p = .08$ (note, of the 55 individuals reporting the Moon missing on the context test, only 7 participants reporting "nothing" missing on the Hands test, thus half of the expected values in the analysis were less than 5.) For those reporting the Moon missing on the Context test, observed values for reports of the Moon missing on the Hands test were 20/26, 11/11, 17/18, for groups Same, Different, and No Exposure, respectively.

When the Moon had not been reported on the Context test, the reports of the Moon were more clearly affected by pre-exposure, $X^2(2) = 31.07$, $p < .001$ ($V = .37$; $CI_{95\%}$ .23 - .49). The reports were dependent on the exposure regarding Groups Same (32%; 15/46) and Different (69%; 42/61), $X^2(1) = 13.84$, $p < .001$ ($V = .36$; $CI_{95\%}$ .17 - .55), or Groups Same and No Exposure (77%; 98/126), $X^2(1) = 30.51$, $p < .001$ ($V = .42$; $CI_{95\%}$ .27 - .57), with no dependence between Groups Different and No Exposure, $X^2(1) = 1.74$, $p = .19$.

The Other P1s was clearly better expected in groups Different and No Exposure than in Group Same, who never experienced that stimulus. Groups Different (21/72) and No Exposure (42/144) did not differ $X^2(1) = 0$. With respect to the Hands, the groups did not differ in their expectation of the Glowing Hands outcome being present $X^2(2) = 3.60$, $p = .17$, (13/72, 7/72, 14/144, reporting the Glowing Hands for groups Same, Different, and No Exposure, respectively).

Overall, the Moon was better expected in Group Same on the context test. It is logical to think that the participants in Group Same expect the Moon better than the participants in Group No Exposure, since they have experienced a greater number of exposures throughout the experiment (9 vs 3). In contrast, Group Different has had the same number of Moon exposures as Group Same, but had fewer reports of the Moon missing, responding the same as did Group No Exposure. As Group Different had six of their Moon exposures in a different context, it appears as though the strength of the expectation of the Moon was context dependent (e.g., Bouton et al., 1993). The lack of any differential Context-Hands predictions between the groups suggests that the differential effect of cue exposure we observed in these experiments was indeed due to differing associations between the Moon cue and the Glowing Hands outcome, as opposed to any differential Context-Hands learning that the manipulation might have produced. Despite the stronger context-Moon associations present in Group Same, the Moon was indicated to be missing less often in Group Same on the test where both the context and Glowing Hands were present.

Reports of the Moon on the Hands test were minimally affected by the presence of the Hands outcome when the Moon had been pre-exposed. When participants expected the Moon on the context test, there was only mild change in the expectation as a function of pre-exposure on the Hands test. However, when the reports of the Moon were absent on the context test, exposure to the Moon reduced reports of the Moon's absence in Group Same compared to exposure in a different context or no exposure alone on the Hands test. Exposure to the Moon appeared to affect its ability to be associated with the Hands.

Discussion

The experiments presented here were conducted to assess whether simple pre-exposure to a stimulus prior to its pairing with another would result in an effect consistent with latent-inhibition in adult human participants. The goal was to determine if the effect would be observed without using a masking task and avoiding any expectation of specific events or responding that might lead to negative priming (Graham & McLaren, 1998), learned irrelevance (Le Pelley & Schmidt-Hansen, 2010), or any other instruction-dependent effect (e.g., Byrom et al., 2018; Nelson et al., 2021). The experiments also assessed the type of theory (CS processing / Interference) theory with which the results were more consistent.

Participants were not given any instructions to behave in any particular way, nor to expect any particular event to occur. Participants simply watched a short video. In the video, after a preexposure phase, the target Moon (pre-exposed, novel, or pre-exposed in a different context for Groups Same, No Exposure, and Different, respectively) was presented together with the Glowing-Hands outcome. Afterwards, an expectancy test was conducted. Both Experiment 1 and Experiment 2 (Hands test) showed results consistent with LI. Fewer people reported an expectancy of the outcome in Group Same compared to Group No Exposure. In addition, significant differences were found between Group Same and Group Different, demonstrating context specificity of latent inhibition. There were no differences between Group Different and Group No Exposure. The Context Test (Experiment 2) provided data indicating associations between the context and the stimuli that had been present in them, and that those associations were stronger with more context-stimulus pairings.

There was no masking in the present experiments, thus there was no task with which to direct attention away from the Moon during its pre-exposure. Hence, criticisms of masking tasks cannot be applied to the present work. There were no instructions regarding what participants were about to experience, or how they should behave. In the absence of these expectations, explanations based on expectancies of stimuli or the making of particular responses do not apply.

Most theories point to latent inhibition as a decrease in attention or associability to the CS (e.g., Le Pelley, 2004; Mackintosh, 1975; Pearce & Hall, 1980). Other authors have proposed that LI is not due to a learning deficit, but to a deficit in the behavioral expression of the CS-US association (e.g., Bouton, 1993;

Hall, 1991). Hall and Rodriguez (2010) propose that both interference and a reduction in attention/associability are responsible. Many studies have reported that LI, present when subjects are pre-exposed, conditioned, and tested in the same context, is attenuated when the pre-exposure is in one context but the conditioning and test are in different contexts (ABB) (e.g., Nelson & Sanjuan, 2006). The LI and its context-specificity are well explained by the work of Wagner (1981), which characterizes the effect as neither an attention nor an interference effect, but assume that predicted stimuli have difficulty forming associations with other stimuli because of prior associations formed with the context.

Results from Experiment 2 are more consistent with the theories that attribute the effect to the way the cue is attended, or processed, than with interference-based ideas. The experiment assessed the bi-directionality of the learning that occurred during the conditioning phase by presenting the Glowing Hands as a cue and assessing expectancy of the co-occurring Moon. In this case, the deficit observed in Group Same should not be due to interference. While the Moon may be associated with “No Event” from pre-exposure and “Glowing Hands” from conditioning, the Glowing Hands were only associated with the Moon. In this case, the deficit would be better described as arising from a change in the way the Moon was processed. Also, the results of Experiment 2 are not readily explained by comparing the test stimulus with potentially stored memory templates, particularly as both potential templates (pre-exposure and training) contained the moon in Group Same.

As discussed earlier, this effect could also arise from blocking by the context. Testing the context alone showed that the context was associated with the stimuli presented within it. The number of people expecting the Moon, when presented with the contextual stimuli, varied with the number of times that the Moon had been encountered in the test context. Those associations should lead to blocking by the same CS-processing mechanism responsible for latent inhibition as proposed by Wagner (1981). The associability of the Moon would be low, not due to its association with no event, but due to the context’s association with the Moon. The Moon would be in an “A2” state of activation with reduced associability, producing latent inhibition in the form of depressing its ability to predict the Glowing Hands, and blocking in the form of depressing the ability of the Glowing Hands to predict the Moon. However, we would also have to assume that the Glowing hands and Context was a more effective stimulus than just the Context alone. Groups No Exposure and Different clearly produced more responses to the test containing the

Glowing Hands and the Context stimuli than did Group Same to either the Context alone or to the Glowing Hands and Context. Thus, there was clearly something that decremented the effectiveness of the moon to further enter into associations when the hands were present in Group Same.

With respect to observing pre-exposure effects without masking and minimal instructions these findings are in line with those of Rodriguez and Hall (2017) and Rodriguez et al. (2019). In that procedure participants viewed different actions on slides that Mr. X performed. Among those viewings, they received presentations of a target action (e.g., Mr. X answers a phone call) or of a non-target event in a different group (Mr. X listens to music from his MP3 player), counterbalanced. In both groups, in the last trial the target action was shown with an outcome (e.g., Mr. X answers a phone call and he feels dizzy). Participants were asked what had happened to Mr. X in the last action. Results showed that the exposed group had a lower expectancy of feeling dizzy than the control group.

Both the methodology we used and the results obtained have aspects in common with the two studies mentioned above. Their participants were given instructions that produced no particular expectations. In their case, participants were instructed: "When you are ready, please press the space-bar of the keyboard to start. The automatic presentation of a sequence of screens will then begin". As in the present task, there were no aspects of the instructions that should lead to anticipating any specific action or expectation, and the ability to recall an event based on a single pairing with a cue was attenuated by prior exposure to the cue.

The current study demonstrates a reduction in the ability of a cue to facilitate the expectancy of an item with which it was paired as a function of the cue’s prior exposure without the outcome. Moreover, this reduction was context-specific as would be expected from a latent-inhibition account. The simplicity of the task and absence of expectations of specific events generated by the instructions effectively address criticisms leveled at other latent-inhibition research with humans. The result does not imply that the mechanism of action here is the same as in other demonstrations, but it does provide a more comparatively equivalent analogue to animal experiments where participants do not have specific expectations as to what they will encounter, nor what specific responses will be required.

Chapter 2

Chapter 2 (The Learning Game)

The purpose of this chapter was to examine the persistence of latent inhibition across phases to distinguish attentional and interference accounts, from the CAD mechanism of Wagner (1981). The progression of a HPNT effect, in theory, should mirror that of LI. Moreover, because assessing latent inhibition across phases (i.e., a context change after conditioning in Chapter 3) involves investigating it after conditioning, the Hall-Pearce negative transfer effect (e.g., Hall & Pearce, 1979; 1982) was also assessed.

The Rescorla-Wagner theory (Rescorla & Wagner, 1972) serves as a fundamental framework for understanding much of the process of conditioning. The model assumes trial by trial learning where the strength of an association (V) between the CS and US is determined by the amount learned on that trial (ΔV), plus the amount of learning present on the previous trial (V^{n-1}). The current association is formally expressed as follows:

$$V^{n}{}_{A} = V^{n-1}{}_{A} + \Delta V^{n}{}_{A}.$$

The increase in the associative strength of the CS ($\Delta V^{n}{}_{A}$) is produced by the following formula,

$$\Delta V^{n} = \alpha \cdot \beta \cdot (\lambda - \Sigma V^{n-1}).$$

The parameters α and β represent the presumed intensity of the CS and the US, respectively; λ represents the maximum (asymptotic) strength that the CS-US association can reach, and V^{n-1} represents the sum of the associative strength that all stimuli present in trial n have before the start of that trial. The basic tenet of the model refers to the surprisingness of US, and Rescorla-Wagner model defines surprising and expected USs in terms of the value of $\lambda - \Sigma V$. The US is expected when the value of $\lambda - \Sigma V$ is small, and the US is surprising when the value is large. Thus, the model considers that learning occurs when there is surprise, defined as a discrepancy between what the animal expects (ΣV) and what the animal receives (λ). The greater the discrepancy, the greater the learning. Regardless of the strength of α or β, learning should continue until ΣV is equal to λ.

However, the model of Rescorla and Wagner (1972) cannot explain LI. When a CS is presented for the first time, its associative strength is zero. Without the presence of an outcome producing an expectancy discrepancy, no learning occurs. Thus, no matter how many times CS presentations are repeated alone, the Rescorla and Wagner model will keep the associative strength of the CS intact, at zero. Subsequently, when the CS is paired with a US, the behavior will be identical as if it were a novel stimulus, when latent inhibition should occur instead (e.g., Lubow, 1989).

Subsequent theories addressed the Rescorla-Wagner (1972) model’s shortcoming with regards to LI by shifting the focus from processing of the effectiveness of the US to that of the associability of the CS in terms of attention. Mackintosh (1975) proposed a model where learning depended on the attention devoted to the CSs present in the trial, so that the associability of a stimulus (the magnitude of α) will be determined by its ability to predict important changes in the environment. The fundamental characteristic of Mackintosh's model (1975a) in comparison with the model of Rescorla and Wagner’s, is that the value of α is not constant. Initially this value appears to be determined by the physical characteristics of the stimulus and by the animals’ sensory system. However, this value changes with experience, increasing when the stimulus correlates with changes in reinforcement and decreasing when the stimulus does not correlate with changes in reinforcement.

Thus, the associability of a stimulus will vary throughout conditioning depending on the animals’ previous experience with the stimulus. Animals will pay more attention (i.e., a higher α) to those stimuli that are good predictors of significant events (i.e., λ -V is closer to zero). In order to obtain the animals’ full attention, a CS must not only be a good predictor of the US, but it must also be a better predictor than the rest of the stimuli present in the situation. LI occurs because pre-exposure to specific stimulus causes α to decline as both the stimulus and the context equally predict non-reinforcement. Therefore, at the start of conditioning, α of the pre-exposed stimulus will be lower than α of a novel stimulus, and hence conditioning of the pre-exposed stimulus will proceed more slowly than novel.

Though Mackintosh (1975) predicts that good predictors will be stimuli that are well attended, and there is evidence to this effect (e.g., Bennet et al., 2000), there is also evidence to the contrary. For example, the HPNT effect (Hall and Pearce, 1979) demonstrated how good predictors could be neglected when their significance was already well established. The models discussed above have different predictions from the results obtained.

The HPNT effect was explained by the model developed by Pearce and Hall (1980). There, the associability of a stimulus depends on the extent to which the consequences following it are expected or surprising. According to the model, only those stimuli that have been followed by surprising consequences will be actively processed and attended. Thus, the associability will decrease when the consequences that follow are not surprising. The model assumes that the concurrent activation of the mental representations of the CS and the US results in the establishment and strengthening of an association between both. This idea is formally represented by the following equation:

$$\Delta V = S \cdot \alpha \cdot \lambda.$$

The term ΔV represents the change in associative strength. It is assumed that this increase in ΔV will be directly proportional to two parameters related to the intensity of the CS and the US. Both S and λ are constant parameters that can take values between 0 and 1, and represent the activation of the physical representation of the CS and the US, respectively. The central tenet of Pearce and Hall's (1980) model is the assumption that the parameter, α, which represents the associability of the CS, will change as experience with the stimulus allows estimating the extent to which the CS predicts its consequences. Thus, the initial value of α will be determined by its physical properties (the more intense the CS, the higher is the α), but when information on its predictive capacity is already available (from the previous occurrence of the CS) its value will be determined by the following equation:

$$\alpha^{n} = |\lambda - \Sigma V|^{n-1}$$

This equation states that the associability of a CS (i.e., the degree of processing that allows a stimulus to enter associations) on a given trial n, is determined by the events that occurred with the presentation of the CS on the previous trial (*n*-1). Specifically, α is calculated as the absolute value of the discrepancy between λ (representing the physical presentation of the US) and ΣV (representing the expectation of US occurrence triggered by all stimuli present on that trial, including the CS). This equation thus captures the idea that a stimulus will be processed to the extent that there is still a prediction error or a difference between what physically occurs (λ) and what is expected (ΣV). However, in its original form the model made the α-value of a CS on trial *n* entirely dependent on the situation on trial *n*-1. Changes in associability occur more gradually, and the α equation can been modified to allow the value of α on trial *n* to be determined by an average predictability of its values on a run of preceding trials (Pearce et al., 1982; Hall, 2008). According to the model, the HPNT effect (1979, 1982; see also Rodriguez and Alonso, 2011) occurs because the formation of the CS-US association during the first phase leads to a reduction in α that delays subsequent conditioning with the intensified US.

According to Wagner (1979, 1981) and CAD mechanisms both phenomena, LI and HPNT effects are explained as a consequence of how elements of a stimulus are processed in different states of activation. In Wagner's terms the initial conditioning with the CS with the weak outcome should allow some associations to form between the Context and CS, placing a portion of the CS into the A2 state where it cannot be further conditioned. The now-predicted stimulus will have a portion of its elements in the secondary "A2" state of activation, reducing the A1 elements available to form new associations with other subsequent stimuli.

According to interference models (e.g., Bouton, 1993), during pre-exposure to the CS, subjects learn that the CS is followed by no consequence (e.g., CS-"noUS," Bouton, 1993; CS-"No Event," Hall & Rodriguez, 2010). The CS-US association is not expressed to the same degree due to the interference produced by the initial learning at the time of retrieval. Despite that the HPNT result has been attributed to a loss of associability by the CS (e.g., Rodriguez & Alonso, 2011), interference is also a construct used in the Pearce and Hall (1980) model and one cannot rule out an interference-only based explanation of HPNT. Retrieval of CS→Weak shock might interfere with the expression of the subsequent CS→Strong shock learning.

Nevertheless, subsequent learning of the CS-US relationship could proceed differently between interference models because there are two ways that a CS→NoUS/Event representation might factor into the learning. Hall and Rodriguez (2010) allow the representation to subtract from the expectation produced by ΣV. From that perspective, performance after pre-exposure should still reach the same asymptote as a novel stimulus. The use of the construct by Bouton (1993) makes no specification as to how the representation might affect learning. Should the representation not factor into the overall prediction, but simply cause a performance effect, then that interference could be persistent. That interpretation of interference has yet to be formalized.

Pearce and Hall (1980; Hall & Rodriguez, 2010) and Mackintosh (1975) predict differences in learning rates, but expect the asymptotes to be approximately equal. In attention-based models, the asymptote is reached not because the US comes to be fully predicted but because the CS fully predicts its consequences (α; e.g., Hall & Rodriguez, 2020). In the SLG model, the same asymptotes should be reached because, again, only the rate of learning should be affected. However, with Wagner (1981) the presence of the A2 elements reduce both the amount of stimulus that can be learned about and that which affects performance.

Nelson et al. (2021) observed that pre-exposure produced not only a retardation in the acquisition of responding, but also a difference in the asymptote reached in a human learning method. Nelson and colleagues manipulated the similarity between the CS and the US in order to regulate the extent of response that the CS could unconditionally generate, and extinguish, during the pre-exposure phase. The acquisition of responses in conditioning was limited independently of whether the CS triggered a response during pre-exposure. Response reduction during pre-exposure contributed to observed response deficits at the beginning of training compared to controls. However, pre-exposure reduced the conditioning asymptote regardless of whether it reduced responding prior to conditioning. The different asymptotes observed in the method are important in that they can differentiate models based on a Wagner (1981) priming type mechanism from those based on changes in attention or interference as construed by Hall and Rodriguez (2010).

The delay in response acquisition produced by the pre-exposure results in Nelson et al. (2021) provided some support for attentional explanations of latent inhibition (e.g., Pearce & Hall, 1980). However, the attentional explanations, while predicting differences in learning rates, expect the learning asymptotes to be approximately equal which was not observed in the reported experiments (Nelson et al., 2021). Moreover, formal interference-based models (Hall & Rodriguez, 2010) also do not expect such differences, as discussed earlier. Informal descriptions of interference processes (Bouton, 1993) are unclear as to the roles of interference in learning, performance, or both (Nelson et al., 2021).

The CAD mechanism anticipates that prior exposure leads to noticeable variations in the asymptotic response (Nelson et al., 2021). The “learning rule" presented by Wagner (1981) represents what happens during a conditioning trial involving a novel stimulus (S). Elements of S in the activation state A1 ($P_{A1,CS}$) are associated with elements of the outcome present in the pairing, which are also in A1 ($P_{A1,US}$), by a constant proportion (L). Thus, the learning rule is represented as follows, $\Delta V = L \times P_{A1,CS} \times P_{A1,US}$. This same process allows associations to form between elements of the context and S, whose function is to place elements of S into the A2 state. On the other hand, the "retrieval rule" determines performance based on the ability to predict the outcome across V and the term $r_1 P_{A1,CS} + r_2 P_{A2,CS}$. The subscripts r_1 and r_2 refer to different weights for the influence of A1 and A2 items, respectively. The A2 weighting, r_2, is assumed to be less than r_1, reflecting the idea that nodes activated by association are less effective than those activated by a stimulus.

Trial by trial, the context and S form connections that cause S to move to the A2 state, reducing the magnitude of $P_{A1,CS}$ and, consequently, reducing ΔV. During pre-exposure a CS has already established associations with the context. According to the learning rule the CS, with a higher proportion of items in A2 has fewer elements available to enter A1 and acquire V. One might suppose that in a standard LI procedure, either of the two CSs (pre-exposed for the experimental group and novel for the control group) could achieve the same V. However, the increasing context-CS associations cause $P_{A1,CS}$ to decrease continuously, which affects both the learning and retrieval rules. Since these associations also depend on decreasing $P_{A1,CS}$, differences in asymptotic response can be obtained. According to Nelson et al., (2021) an equivalent response between groups can only be obtained when all context-CS associations across stimuli are also equivalent.

Nevertheless, the Pearce and Hall perspective, and Wagner’s CAD mechanism agree in interpreting the HPNT effect as a variant of the LI effect (e.g., Pearce & Hall, 1980; Wagner, 1981). For example, Hall and Pearce (1979) referred to this effect as a case of "latent inhibition during CS-US pairings." However, direct comparison of the two effects is difficult because they compare learning about an outcome at different states of acquisition. For latent inhibition, the comparison between pre-exposed and novel stimuli begins at the start of conditioning, while for HPNT the experimental group has already received conditioning at the time the comparison begins. What is required is a method where the comparisons between LI and HPNT can be made with stimuli that begin with neutral associations with respect to the outcome.

In the experiments of this second chapter attempt to distinguish between CS processing accounts (attentional changes, CAD) and the effects of LI, HPNT, and their combination (LI-NT) were compared. The experiments take advantage of a method used by Nelson et al., (2021) where participants were first trained to respond to the appearance of spaceships (four different ones) by rapidly pressing specific keys to activate specific weapons for each ship. After responding to the ship was established, it was used as a "US" in later phases. There, different "sensor" stimuli (different flashing lights) 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 observation of the course of the assumed sensor-spaceship association along pre-exposure, conditioning, and test phases.

The method also allows the use of two simultaneous and different outcomes at the same time. Participants can respond independently to both ships, using both their right and left hands, counterbalanced. Presumably, this procedure would produce little or no interference between the two responses. Drawing a parallel with a traditional HPNT experiment, it is possible to condition a stimulus with an apparently weak or moderate consequence (the attack of a spaceship) compared to a stronger one (the attack of two different spaceships to which the subject must respond independently). Using this instrument's capacity provides a novel way to assess HPNT in human participants. HPNT or LI should affect the ability of the sensor to be associated with the new spaceship. Thus, whether the stimulus was pre-exposed in the first phase (LI) or conditioned with one spaceship (HPNT), it has no association with the second spaceship (O2). In this way, learning about O2 should allow us to directly compare HPNT and LI.

Another goal of the project was to perform the context-change experiments of Chapter 3, requiring a procedure that would allow LI to be evaluated with a context change after conditioning. The method allows the assessment of whether LI continues after conditioning through the use of a second outcome. But, the conditioning of the pre-exposed stimulus with a first outcome introduces the possibility of HPNT also affecting responding to the second outcome, in addition to any effect of non-reinforced pre-exposure. Thus, experiments concurrently assessed the impact of LI, NT, and their combination.

Experiments with nonhuman animals evaluating the effects of the negative transfer effect are numerous (e.g., Hall & Pearce, 1982; Rodriguez & Alonso, 2011). However, studies of HPNT effect with human participants are very limited. For instance, Griffiths et al., (2011) showed HPNT in human participants using an allergist task in which participants learned about the strength of allergic reactions (minor or critical) produced when Mr. X ate different foods. In an initial phase of training, the target cue was paired with an outcome of moderate strength (A+). In the second phase, the strength of the outcome paired with the target increased (A++). Participants in the Negative Transfer group took longer to acquire the new association A++ than the control group, where stimulus A was novel. However, it was reported that “unpublished attempts to replicate the negative transfer effect of Griffiths et al. (2011), by the original researchers, have been mixed” (Le Pelley et al., 2016, p. 1121).

Here, to assess the HPNT effect, participants could be attacked by one ship (in the reinforced exposure phase) and two ships (in the test). Learning about the second ship in the test phase constitutes a test of HPNT. According to Hall and Pearce (1980) and CAD mechanisms the effect depends on processing the CS and should be outcome independent. That is, the effect should be observed when learning about an entirely new outcome as opposed to a more intense version of a previous outcome.

In summary, this series of experiments compared the effects of LI and HPNT alone (Groups LI and NT) with a group in which both unreinforced and reinforced pre-exposure (Group LINT) were combined. An additional control group, without prior experience with the stimuli, was included. The aim of this series was to compare the main attentional theories (e.g., Mackintosh, 1975; Pearce & Hall, 1980) and their predictions about the LI and HPNT phenomena. In turn, to compare these theories and their implications (e.g., reaching the same asymptotes between groups) with the one proposed by Wagner (1981). LI and NT should be equivalent effects according to Pearce and Hall (1980), and Wagner (1981). LI has been shown to be able to affect asymptote (e.g., Nelson et al., 2021) after preexposure, and should also affect NT if the mechanism is similar. Therefore, the acquisition of the second outcome response should be delayed when the participant has experienced pre-exposure of the sensor during the first phase. Slower acquisition of the second outcome should also be shown after reinforced exposure during conditioning with a one outcome. Finally, both non-reinforced and reinforced exposure in the combined group should produce a profound delay in the acquisition of the second outcome during test.

Experiment 1 (C2E1)

A video game method (e.g., Nelson et al., 2014; 2021) was used, in which participants are trained to respond to a spaceship for subsequent use as a US during conditioning in which the spaceship arrival is predicted by sensors. In this first outcome-response training phase participants are in a "training" context and informed that they must protect various galaxies (i.e., contexts) from invading spaceships. Participants are told that that to accomplish that task they must learn to activate different weapons to repel different spaceships. They then receive several practice trials, accompanied by minimal instructions, in which spaceships appear and participants learn to rapidly press keys on the keyboard in the presence of the ships to repel them. This phase included trials with more than one ship at the same time and participants were instructed to use both hands simultaneously to activate two weapons to repel both ships.

During pre-exposure stimuli occur in a substantially different background context, which did not vary in any subsequent phase, representing a galaxy with a space station spinning within it. The design is shown in Table 2. Participants in pre-exposed groups received pre-exposures to a flashing red sensor, whereas those in the no pre-exposure groups simply experienced the background context. During the conditioning phase, the appearance of the spaceship is signaled by the appearance of a colored flashing sensor light. Learning is evidenced by the participants coming to emit the ship-appropriate response(s) in the presence of the sensor, prior to the arrival of the spaceship(s).

Finally, in the test phase, the red sensor (S) precedes the appearance of two different spaceships in testing indicated by "+", the ship used in the prior phase, and "!", a new ship (physical identity counterbalanced). The two ships appear at the same time. All participants received these conditioning trials. Each response is largely, if not completely, behaviorally independent of the other with the participant able to use their right and left hands to respond.

Group LI received 6 exposures to a sensor (S, red or green, counterbalanced) without any consequences. Then, that was followed by 12 trials where D (different sensor from S; green or red, counterbalanced) was paired with a particular spaceship (+). In this phase they also received 3 trials where B (blue) was paired with the simultaneous appearance of both + and !. The D and B trials were intermixed. The

B+! trials provided practice using two keys and were the same for all groups in phase 2. Finally, in the third phase S (pre-exposed in phase 1) was paired with both +, and ! (S+!) for a total of 8 trials. The crucial question in this phase is whether S pre-exposure affects the acquisition S! learning (i.e., whether latent inhibition persists into the test).

Group NT received context exposure in phase 1 (the participant simply patrols the galaxy without any sensors appearing or enemy spaceships) followed by the conditioning treatment with S+ in Phase 2, and S+!. The critical question here is how well would they learn the new S! association. Any retardation of learning S! would be the result of a HPNT-type effect.

Group LINT received 6 exposures to a sensor S, as did Group LI, without any consequences. Then, that was followed by 12 S+ trials. Finally, in the third phase S was paired with both +, as in the previous phase, and ! (S+!) for a total of 8 trials. The critical question in this phase is how well would they learn the new S! association where both LI and HPNT could contribute.

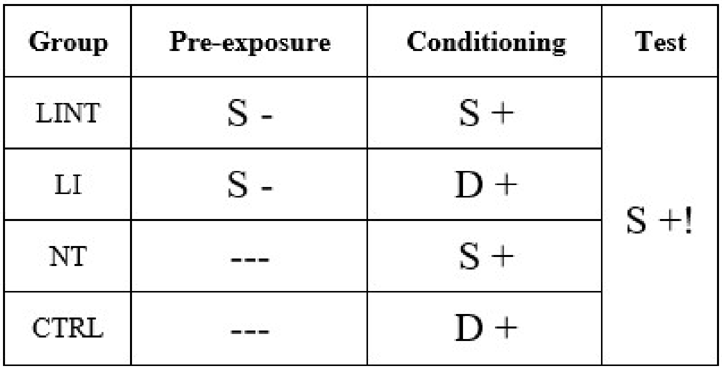
Finally, Group Control received no exposure to S in either phase. There was conditioning that occurred in the second phase, but it was with a different stimulus than that used in the test. This group allowed us to observe the "normal" S+! conditioning without prior experience with the predictive sensor stimuli.

Phase 1 should retard conditioning in phase 2 for Group LINT versus Group LI (conditioning in group LI was with a different, non-pre exposed CS; e.g., Lubow, 1989). That is, comparison of Group LINT to Group LI in *phase 2* should reveal a latent-inhibition effect. In the Test phase, acquisition of the ! response to S should allow us to assess LI in Group LI, as compared to Group Control, as well as HPNT in Group NT, thus permitting an explicit comparison of LI and HPNT. Group LINT offers the interesting possibility of determining whether these effects summate, and how LI in particular may be affected by conditioning. For example, in the conditioning phase (phase 2) acquisition of the + response in Group LINT should reflect LI. In the Test phase, the + response should continue to increase if it had not yet reached asymptote, and further acquisition be affected by both LI and HPNT. If the LI effect is changed by conditioning, then the behavior of Group LINT should be similar to either Group LI or Group NT, as only one effect is being manifest. If the

LI effect is not affected, then the two effects should combine and responding of Group LINT should be below the other two groups.

A Mackintosh (1975) account, or learned predictiveness as described by Le Pelley (2004), would predict that attention to S should be high at the end of phase 2, so there should be facilitation of learning S!. But, a Pearce-Hall account (1980) would have attention to S low at the end of phase 2 because S is a good predictor of + (i.e., the basis for HPNT effect. The introduction of the new unpredicted O2 should rapidly restore attention according to a Pearce-Hall account, leading to acquisition after a short delay. The CAD mechanism should operate in Group LI and Group NT, as S and the context can become associated. For Group LINT, forming associations should be even more difficult due to having had more opportunities to form Context-S associations. The mechanism predicts different asymptotes because the amount of stimulus in A2 is not the same between groups.

Table 2.
Design of Experiment 1.



Group	Pre-exposure	Conditioning	Test
LINT	S -	S +	S +!
LI	S -	D +	
NT	---	S +	
CTRL	---	D +	

Note: Design of Experiment 1 in which “S” and “D” were two sensors that served as CSs (red and green, counterbalanced). “-” indicates no US or nor enemy attack while “+” and “!” indicates the appearance of the enemy spaceships or US (Learian or Stellarian, counterbalanced). Finally, “---” indicates no CS or US (exposure to the context).

Method

Subjects

The experiment required counterbalancing two types of CSs and USs so participants were recruited in multiples of four. To ensure that the combination of variables was adequately represented in each counterbalance group, a minimum of eight participants per combination was planned, requiring 128 participants (n = 32). One hundred twenty-eight college-age 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; 2021), and all visual details described below are pictured there. Five Dell OptiPlex PCs with 22-inch displays and a 1.6 (Width / Height) aspect ratio were used to play the game. The resolution was set at 1280 x 800 pixels. Over the monitor and keyboard was a trapezoidal enclosure made of black foam board with rectangular ends and an exposed front face. The aperture measured 70 by 70 cm in width and the rear wall measured 70 by 50 cm in height; the side walls' total length was 1 m. The computers were separated by approximately 1.5 meters. Participants were isolated from one another by sitting at the table with their heads and shoulders just inside the box. Participants were run in groups of 1 to 5.

Participants engaged in a first-person, three-dimensional, space-themed video game with visual quality similar to that of contemporary games. They had the impression of peering out of a viewscreen while inside a spacecraft. Near the bottom of the viewscreen was a crescent-shaped panel with two rows of oval canister-shaped gadgets. Three were in the bottom row and five were in the upper row. In this experiment, the CS was a light that was displayed in the center canister of the top row and was either red, green, or blue. Red and Green were counterbalanced as S and D. When lit, the light flashed at three on/off cycles per second. The diameter of each canister was 50 pixels when lit.

A black translucent panel could rise from the bottom of the screen where instructions could be presented to the participant. Instructions (detailed below) 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 "Boutonia" (shown in Figure 9), was 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 space station.

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 two spaceships (the "Learian" and the "Stellarian") were 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 Stellarian was an off-white colored craft and was repelled by a weapon in the upper left of the screen that emitted orange fireballs, referred to as "Extinction Fire". These two ships were counterbalanced as "+" and "!". The other two ships and associated weapons were as described in Nelson et al., (2014; 2021). The Learian and Stellarian are shown in figure 9, along with the screen and context elements which the participant experienced.

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 three per second had been accumulated. From that moment, every keypress resulted in the weapon firing at the spaceship, but only when the ship was present and a response occurred at least every 0.75 s. The Backspace key was used to activate the SOP Cannon while the left Tab key was used to activate the Extinction Fire.

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, at which point there were no other interactions with the attending researcher.

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 female 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. In addition, the instructions warned them that in this experiment two ships might appear attacking at the same time to which they were to use both hands at the same time to activate both weapons. 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 eight 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 discovered the effort to repelled it. Participants were trained to respond to the four different space-ships (three trials each) and the space-ships combinations (two trials of Stellarian – Learian (left tab and right backspace keys, respectively), and two trials of Juk Destroyer – Gluckonian (right number-pad zero key and left control, respectively).

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. Only two spaceships (the “Learian” and the “Stellarian”) were used in the remainder of the experiment.

Phase 1. During Phase 1, Group LINT and Group LI received six pre-exposure trials with stimulus S alone. S was either a red or a green light, counterbalanced. Group NT and Group Control were simply exposed to the context during this period.

On each pre-exposure trial, the CS was presented for 20 s. 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. The appearance of the spaceship was signaled by the appearance of a colored flashing sensor light (S or D counterbalanced). Learning is evidenced by the participants coming to emit the ship-appropriate response in the presence of the sensor, prior to the arrival of the spaceship (see Figure 9, panel A). During Phase 2, Group LINT and Group NT received twelve conditioning trials with S while Group LI and Group Control received conditioning trials with D. For all groups there were three conditioning trials with a blue sensor (B) followed by the two USs. These trials were used to allow practice in simultaneously responding to the two outcomes.

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.

Test. All groups received eight conditioning trials with S and both Uss (see Figure 9, panel B). Participants could respond independently to both Uss, using both their right and left hand independently (see Figure 9, panel C). Timing parameters were the same as Phases 1 and 2.

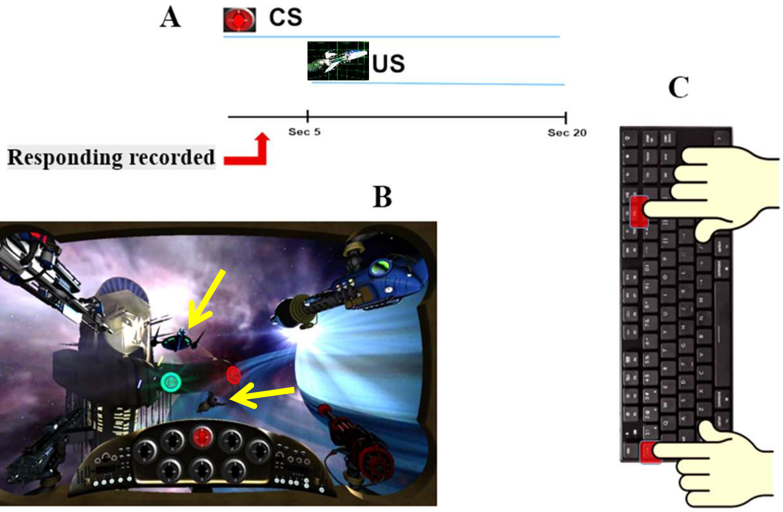


Figure 9: (A) The drawing represents a schematic of the sequence of a conditioning trial. During 5s the sensor appears alone, after that time the spacecraft appears (learian shown) and both terminate (sensor goes off, ship flies off screen) at second 20. (B) The image shows an example of a test trial with both the learian (blue saucer-shape) and the stellarian (rocket-plane shaped), indicated by the yellow arrows. The sensor (red light in the crescent-shaped panel) has predicted the appearance of the ships, which appear together and require responses on both keys (C). Red and green circles near the sphinx station in panel B are rapidly fading, randomly-colored after-effects of the explosions from the invader weapons that attacked the station.

Data analysis

The computer recorded the number of responses made on the backspace (Learian ship key) and the left tab (Stellarian key) during each second of the CS. The first five seconds of the CS when the spaceships were not present were analyzed with mixed (within-between) factorial analysis of variance (ANOVA). Effect sizes are reported as partial-eta squared (η^2_p).

Results and Conclusions

Phase 1. Pre-exposure

Figure 10 shows the mean key presses per second during each trial by group. Since no US was presented, the "anticipatory" responding encompasses the participants' key presses during the entire 20-seconds CS duration. Regardless of whether participants received an experimental treatment (Group LINT and Group LI; exposure to the CS without consequences) or not (Group NT and Group Control; patrolling the galaxy/context) there were practically no responses, averaging 0.19 presses per second during this phase. Due to the low responding (multiple zeros), the data were analyzed with nonparametric tests. Kruskal-Wallis tests showed no significant differences between groups on any trial (*ps* $\geq$ .23). There were no differences between the CSs identities, or the outcomes to be used as +/! ($p \geq .11$) or US ($p \geq .15$) to be used. With no differences between groups, within-subject analyses were performed by collapsing across groups. Friedman's nonparametric test indicated a trials effect $p < .001$. Unconditioned responding averaged .31 on trial 1 and .17 by the end of training, and these did differ, $p = .002$, showing a small tendency to decrease over trials (see also, Nelson et al., 2021).

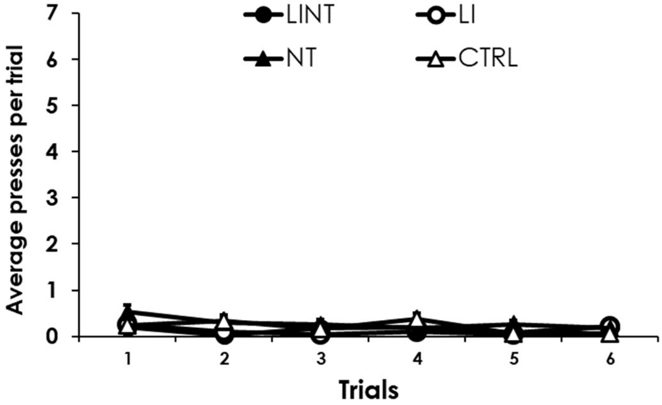


Figure 10: Responses averaged (1-20 seconds) on each trial (± SEM) by group during pre-exposure.

Phase 2. Conditioning

During conditioning in Phase 2, latent inhibition and its stimulus specificity were addressed. Figure 11 shows a very profound retardation in performance in Group LINT. Sometimes latent-inhibition studies only detect a retardation in the early trials, but they reach the same asymptote as Group Control (e.g., Bonardi et al., 2016; Rodriguez & Hall, 2008). In this case a deficit was observed not only in the rate of acquisition (see Nelson et al., 2021), but as an overall acquisition deficit.

The responses per second on each of the first 5-seconds of the sensor, prior to the arrival of the outcome, were analyzed. The data are shown in Figure 11. A Group (LINT, LI, NT, Control) × Trials × Seconds ANOVA revealed a main effect of Group $F(3, 124) = 5.65$, $p = .001$, $\eta^2_p = .12$, and effects of Trials $F(11, 1364) = 100.13$, $p < .001$, $\eta^2_p = .45$, effects of Seconds $F(4, 496) = 242.58$, $p < .001$, $\eta^2_p = .66$, Trials × Seconds interaction $F(44, 5456) = 33.61$, $p < .001$, $\eta^2_p = .21$, and Group × Seconds interaction $F(12, 1488) = 4.61$, $p < .001$, $\eta^2_p = .1$. Of most importance, the Trials × Group interaction was significant, $F(33, 4092) = 2.21$, $p < .001$, $\eta^2_p = .051$. The three-way interaction was not reliable, $p = .158$. Because the three-way interaction between Group, Trials and Seconds was not found, the seconds were collapsed to obtain the mean number of responses per second during the 5-s of the CS prior to the ship for each of the 12 trials for Group comparisons.

After collapsing seconds, trials were dropped (i.e., analyzing trials 1-12, 2-12, 3-12...) with the goal of finding where responding over trials stopped changing. After dropping the first 8 trials, a Group × Trials ANOVA showed no changes across trials on the last four trials $F(3, 372) = .05$, $p = .99$, $\eta^2_p = .0$. In trial 9 the learning asymptote was reached for all groups as there was no Group × Trials interaction, $p = .321$, but an overall effect of Group was reliable, $F(3, 124) = 3.16$, $p = .027$, $\eta^2_p = .07$. Group LINT differed from both Group NT, $F(1, 62) = 6.17$, $p = .016$, $\eta^2_p = .09$, and Group Control, $F(1, 62) = 6.58$, $p = .013$, $\eta^2_p = .096$. However, Group LINT did not differ from Group LI, $p = .061$. Although overall responding in Group LINT did not differ specifically from that of Group LI on these trials according to the $p < .05$ convention, group LI did not differ from Group NT, $p = .57$, or Group Control, $p = .56$; and Group LINT differed from the other groups combined, $F(1, 126) = 9.19$, $p = .003$, $\eta^2_p = .08$.

Group LINT showed a profound decrement in the acquisition of the + response, relative to groups for which the CS was novel in that phase, particularly early in training (see trials 3-8). This result showed that change of CS alleviated the latent inhibition effect, demonstrating the stimulus specificity of the phenomenon (e.g., Lubow, 1989). In addition, results are consistent with models that predict different asymptotes of learning with latent inhibition (e.g., Wagner, 1981).

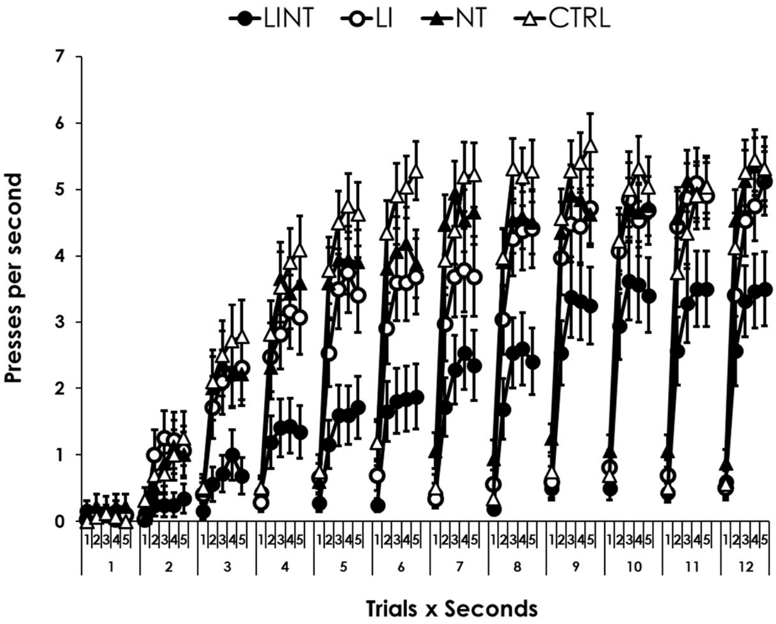


Figure 11: Responses averaged across seconds on each trial (± SEM) by group during conditioning.

Test with "+"

On trial 1 (see Figure 12) Group NT and Group LINT continued to respond as in the prior phase as they were receiving the same stimulus that had been conditioned. There was no response in group LI and Control as they were either receiving a stimulus that had simply been pre-exposed (Group LI) or was being encountered the first time (Group Control).

The most interesting observation is that the learning deficit of Group LINT continued despite 8 more conditioning trials. However, Group LI was expected to suffer retarded acquisition because of the pre-exposure in phase 1. To the contrary, no evidence was found for delayed or attenuated acquisition. Group LI behaved in the same way as Group Control. Both showed rapid learning in the + test. Inserting the conditioning phase with a different CS produced a retention interval between pre-exposure and conditioning for stimulus S. That interval could have attenuated the latent-inhibition effect for Group LI as latent inhibition is very sensitive to context changes, which can include "recent events" (e.g., Bouton, 1997), and the passage of time (e.g., Channel & Hall, 1983; Aguado et al., 1994).

The differences on trial 1 are obvious and reflect what was observed at the end of phase 2. Trials 2 through 8 were analyzed with a Group (LINT, LI, NT, Control) × Trials × Seconds ANOVA and showed an effect of Group $F(3, 124) = 3.204$, $p = .026$, $\eta^2_p = .072$, effect of Trials $F(6, 744) = 8.23$, $p < .001$, $\eta^2_p = .06$, and an effect of Seconds $F(4, 496) = 302.93$, $p < .001$, $\eta^2_p = .71$. In addition, the Trials × Seconds interaction $F(24, 2976) = 1.94$, $p = .004$, $\eta^2_p = .02$, and the Group × Seconds interaction $F(12, 1488) = 3.98$, $p < .001$, $\eta^2_p = .09$, were reliable. Effects of Trials × Group and Trials × Seconds × Group were not found, $ps \geq .338$.

The most interesting effects were those of Group and Group × Seconds. The effect of seconds and its interactions were clearly predominately due to the low responding on the first second. To determine the asymptotic responding, I eliminated seconds beginning at second 1 until the effects of seconds disappeared. That elimination process identified the last 3 seconds as the stable responding on the trials (no effects involving seconds, $p = .557$).

With the seconds collapsed (3-5), trials were dropped beginning at trial one to determine where the asymptote was reached, which occurred on Trial 3 where the Trials effect disappeared, $p = .164$, yet the effect of Group was still present, $F(3, 124) = 3.98$, $p = .009$, $\eta^2_p = .09$. Groups LI, NT, and Control did not differ, $p = .560$, but Group LINT differed from each of the others, $F(1, 62) = 6.12$, $p = .016$, $\eta^2_p = .09$ (vs. LI); $F(1, 62) = 4.06$, $p = .048$, $\eta^2_p = .06$ (vs. NT); and $F(1, 62) = 10.16$, $p = .002$, $\eta^2_p = .14$ (vs. Control).

The interposition of phase 2 training with a different CS may have led to some loss of latent inhibition in Group LI. The effect is affected by the passage of time (Aguado et al., 1994). In that case, Group Control, Group LI, and Group NT should reach the same asymptote with respect to expecting outcome +, which is consistent with main attention-based theories (e.g., Mackintosh, 1975; Pearce & Hall, 1980). However, a result compatible with attentional theories would predict an acquisition deficit in early trials but that acquisition failure should not be persistent as was observed in Group LINT who clearly reached a lower asymptote of responding to +. The results for Group LINT show a lower response over 20 trials, which would be most consistent with Wagner (1981).

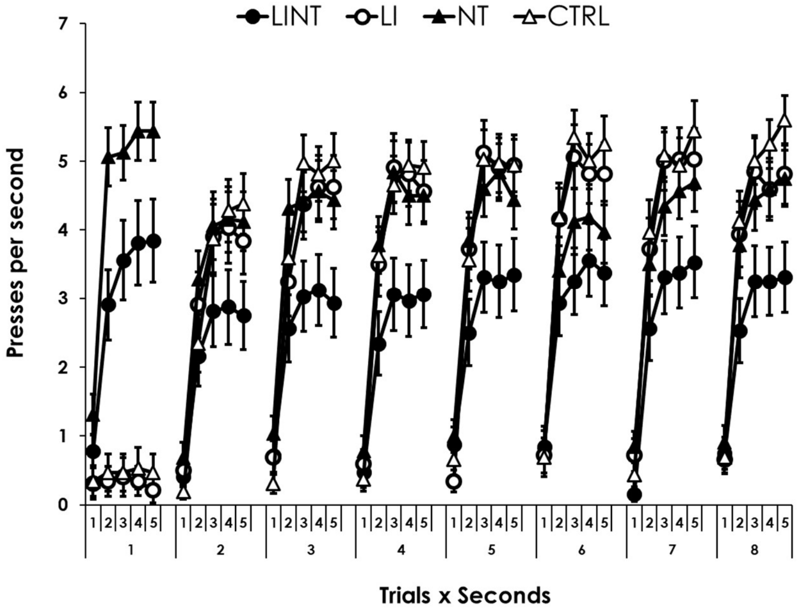


Figure 12: Responding by second on each trial (± SEM) by group on the + response during the test phase.

Test with "!"

In this section, the ! responses are presented (see Figure 13). In the ! test, Group LINT showed a deficit in acquiring the new ! response, and a deficit in performance overall. Group NT also showed a decrement in learning the new ! response as shown clearly on trial 2, but no consistent deficit. Across trials, the deficit was not as profound as in Group LINT. That is, there appeared to be some effect of pre-exposure in Group LINT that carried over through the second conditioning phase that differed from NT alone.

A Group (LINT, LI, NT, Control) × Trials × Seconds ANOVA revealed an effect of Group $F(3, 124) = 3.94$, $p = .01$, $\eta^2_p = .09$. In addition, effects of Trials $F(7, 868) = 131.09$, $p < .001$, $\eta^2_p = .51$, of Seconds $F(4, 496) = 299.36$, $p < .001$, $\eta^2_p = .71$, Trials × Group $F(21, 2604) = 2.84$, $p < .001$, $\eta^2_p = .06$, Trials × Seconds $F(28, 3472) = 36.34$, $p < .001$, $\eta^2_p = .23$, and Group × Seconds $F(12, 1488) = 5.65$, $p < .001$, $\eta^2_p = .12$, were found. Of most importance, there was a three way interaction Trials × Seconds × Group, $F(84, 10416) = 1.495$, $p = .003$, $\eta^2_p = .04$.

Inspection of the figure shows that the interaction was likely due to lower responding on the first two seconds. Responding during the last three seconds appeared relatively stable on each trial. This was confirmed by finding no effect of seconds during seconds 3-5, $F(2, 248) = 1.56$, $p = .213$, $\eta^2_p = .01$. Tests of group differences on these last seconds average showed that on Trial 2 Group LI and Group Control did not differ, $p = .88$. Nor did groups LINT and NT differ, $p = .587$. Group LINT and Group NT together differed from Group LI and Group Control together, $F(1, 126) = 22.98$, $p < .001$, $\eta^2_p = .15$.

These results are consistent with a Hall-Pearce negative transfer effect (Hall & Pearce, 1979) which has previously only been reported in humans by Griffiths et al. (2011). The NT effect is visible both in Group NT (delayed acquisition in trial 2) and especially in Group LINT which had a profound deficit in response acquisition with !. Group LI behaved in the same way as the control, $p = .722$, a result compatible with those obtained with the + responses. The learning asymptote in Group LINT was lower than that of the other groups. From trial 4, the effect of Trials disappeared, $p =.102$, but there was a simple effect of Group, $F(3, 124) = 3.65$, $p = .014$, $\eta^2_p = .08$. The last three seconds of stable responding in group LINT from trial 4 (trials 4-8) differed from both Group LI, $F(1, 62) = 5.68$, $p = .02$, $\eta^2_p = .08$; and Group Control, $F(1, 62) = 8.952$, $p = .004$, $\eta^2_p = .13$. However, Group LINT did not differ from Group NT, $p = .062$, although there was a trend in Group LINT to respond less (averaging 3.27 presses in the last five trials) than Group NT (4.45). Nevertheless, the differences were significant on trials 4, $F(1, 62) = 5.43$, $p = .023$, $\eta^2_p = .08$, 5, $F(1, 62) = 5.61$, $p = .021$, $\eta^2_p = .08$, and 8, $F(1, 62) = 5.98$, $p = .017$, $\eta^2_p = .09$. The LI, NT, and Control groups did not differ among themselves, $p = .562$.

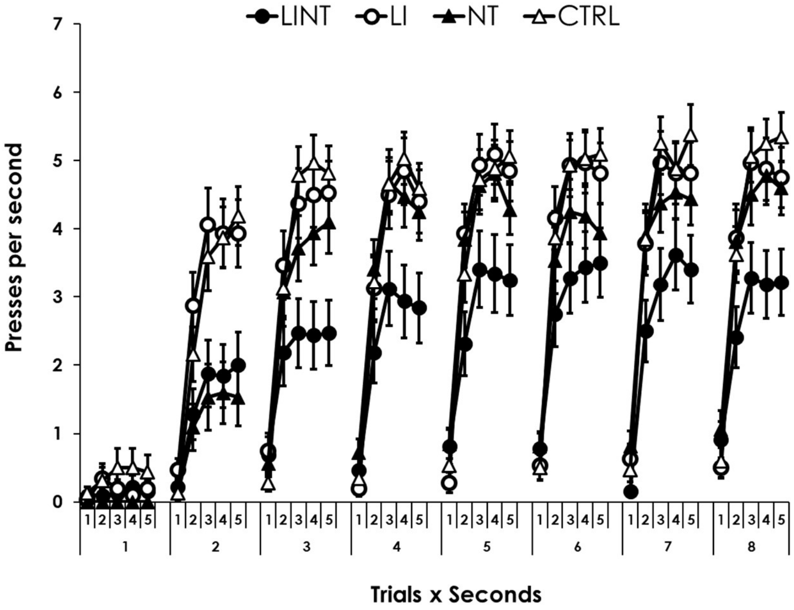


Figure 13: Responding on each second on each trial (± SEM) by group on the ! response during the test phase.

Experiment 2 (C2E2)

Experiment 1 demonstrated a latent inhibition effect in group LINT during phase 2 conditioning. Prior work by Nelson et al., (2021) with the same method and procedures has shown that, despite learning about the spaceships in the response training phase, exposure to the sensor does not endow it with the properties of a conditioned inhibitor in this method. A pre-exposed sensor had less of an impact on responding produced by a separately conditioned sensor (a summation test, Rescorla, 1969) than did a novel sensor.

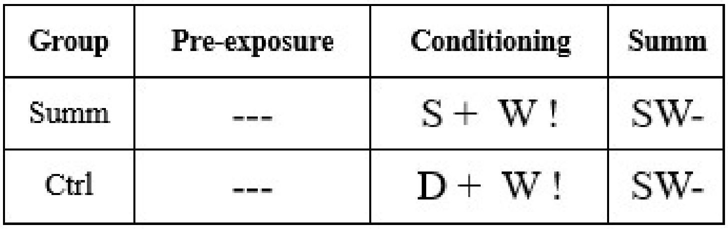
The experiment also demonstrated a HPNT effect where, after learning that a cue predicted one outcome, learning that it also predicted a non-interfering second outcome was delayed. Moreover, this effect appeared to summate with that of the effect of simple stimulus pre-exposure. However, there is an alternative explanation for the HPNT effect that is addressed in Experiment 2. The two outcomes + and ! appeared together in the response-training phase, and with the B+! trials, thus they could be associated with each other. If that were the case, S could become a conditioned inhibitor for ! on S trials where + is present, but the expected ! is absent. Experiment two used a summation test (Rescorla, 1969) in order to test this possibility.

Conditioned inhibition (CI; Miller et al., 1991; Rescorla, 1969) is a Pavlovian learning phenomenon in which a stimulus that predicts the absence of an otherwise expected outcome comes to control an organism's responding. Conditioned inhibition can result in the retarded acquisition of a response, as the inhibition must be overcome prior to expressing any learned excitatory association. Both conditioned and latent-inhibition type effects produce retarded acquisition. However, a conditioned inhibitor will suppress responding to another cue trained with the same outcome (e.g., Rescorla, 1969; 1971) in the so-called summation test where the inhibitory and excitatory stimuli are presented together. Generally, this effect is not seen with latent inhibition (but see Liberal et al., 2020). Only the stimulus with acquired inhibitory properties in conditioned inhibition should readily pass a summation test compared to a stimulus in which an excitatory cue is presented with a neutral stimulus (e.g., Reiss & Wagner, 1972; Rescorla, 1971).

Thus, in a second experiment it was asked whether learning about one outcome, when two could appear together, might make the cue an inhibitor for the second, initially absent, outcome. The design is summarized in Table 3. The Summation group received the same treatment in phase 1 and 2 as did group NT in the previous experiment. Group Control received exposure to the context as did Group Control from the previous experiment. During phase 2, there were 12 conditioning trials with S+ for the Summation group and D+ for the Control (S and D were green or red, counterbalanced). The B+! trials (not shown in the table) were also included as in the prior experiment. At the end of phase 2 they received two trials with a white sensor (W) paired with ! followed by a summation test of S with W (SW-). Only two trials were used to try to ensure that the associative strength of W with ! would not be in a ceiling when tested with S, and a learning-to-learn effect (Balea et al., 2018) could be expected with W following B+! training.

If S becomes inhibitory for ! during S+ training it should suppress the ! response to W in the Summation group more so than in the Control. To foreshadow, the results produced a convincing null result. There were no differences in the ! response between the two groups indicative of conditioned inhibition.

Table 3.
Design of Experiment 2.



Group	Pre-exposure	Conditioning	Summ
Summ	---	S + W !	SW-
Ctrl	---	D + W !	SW-

Note: Design of Experiment 2 in which "W" was a new sensor associated with the ! spaceship. A summation test with S and W combined assessed whether S became inhibitory for ! during + training.

Method

Subjects

Participants were 128 college-aged volunteers (n=64). The relevant institutional review board approved all procedures.

Apparatus

The apparatus and stimuli were the same as in Experiment 1, except that a new white light sensor was used in W! trials of phase 2, and combined with red sensor (S) on test. D was green.

Procedure

All aspects prior to conducting the experiment were the same as in Experiment 1.

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

Phase 1. During Phase 1, Group Summation and Group Control were simply exposed to the context during. Trial duration and ITI were the same as in Experiment 1.

Phase 2. During conditioning Group Summation and Group Control received the same treatments as Group NT and Group Control in Experiment 1 except the additional two trials at the end of the phase. There were 2 conditioning trials with a new sensor (W, white) and ! (O2). Trial duration and ITI were the same as in Experiment 1.

Summation Test. The sensor W, which was conditioned with ! in the previous phase, appeared combined with S without any consequence. The 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. Details not specified here were the same as those of Experiment 1.

Results and Conclusions

Phase 2. Conditioning

Phase 1 contained no stimuli, thus there was no analysis of Phase 1. Figure 14 shows the response acquisition for both Summ and Control groups. For simplicity, we collapsed over seconds and analyzed the data with a Group × Trials ANOVA. The main effect of Group was not reliable, $p = .345$. However, a main effect of Trials was found, $F(11, 1386) = 136.03$, $p < .001$, $\eta^2_p = .52$, with no interaction of Trials × Group, $p = .11$. Dropping trials showed the asymptote was reached at trial 6, $p = .345$. Both Group Summ and Group Control acquired the response equally and responded the same.

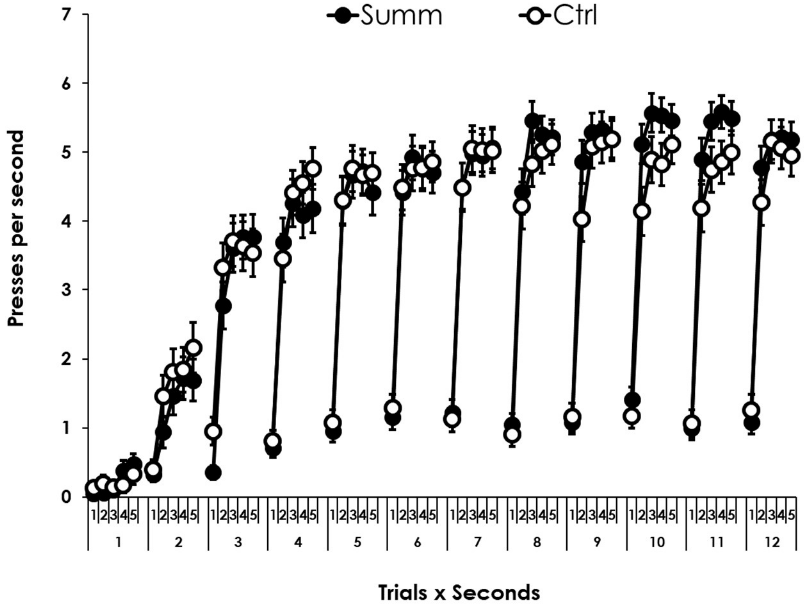


Figure 14: Responses averaged across seconds on each trial (± SEM) by group during conditioning.

Phase 2. Conditioning (W!)

Once S+ and D+ conditioning had been established for Group Summation and Group Control, respectively, two trials with W! were carried out. As seen in Figure 15 (panel B) during the first trial there was no response to the W sensor, which was novel. On trial 2 (Figure 15, right panel B) response acquisition was observed for both groups. We analyzed these data in detail, looking at each second of responding. The same response pattern was obtained. A Group (Summ, Control) × Trials × Seconds ANOVA revealed that there was no effect of Group, $p = .6$. Nor were there any significant interactions with Group, $ps \geq .544$. However, simple effects of Trials $F(1, 126) = 314.57$, $p < .001$, $\eta^2_p = .71$, and Seconds $F(4, 504) = 160.472$, $p < .001$, $\eta^2_p = .56$, and Trials × Seconds interaction $F(4, 504) = 105.35$, $p < .001$, $\eta^2_p = .46$, were found. Panel A was included to show that there was no response to W associated with US +. Just as both groups acquired the same response to + (with either S or D), so they did with the ! responses associated with the W sensor.

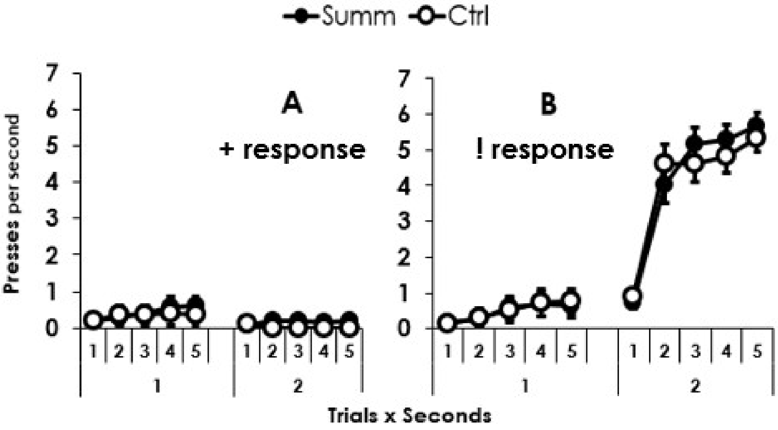


Figure 15: Responding per second on each trial (± SEM) by group during two W! trials. Panel A shows the + responses, and Panel B shows the ! responses..

Summation Test

The summation test consisted of presenting S and W at the same time. A CI effect would be confirmed if Group Summation produced a lower response than Group Control in the SW- test with the ! response. The same response pattern on the ! key would indicate the absence of conditioned inhibition, ruling out conditioned inhibition as the cause of the HPNT effect observed for Experiment 1.

The results with the + key are presented in Figure 16. The entire 20-second first trial with both sensors together was analyzed, as there was no outcome on the trial. S was conditioned with + in the Summ group (closed circles), but S was novel in the Control (open circles), thus the Summ group shows a greater + response than the control (see Figure 16). A Group × Seconds confirmed differences between groups $F(1, 126) = 197.65, p < .001, \eta^2_p = .61$. In addition, main Seconds, $F(19, 2394) = 35.35, p < .001, \eta^2_p = .21$; and Group × Seconds interaction, $F(19, 2394) = 27.44, p < .001, \eta^2_p = .18$, were reliable.

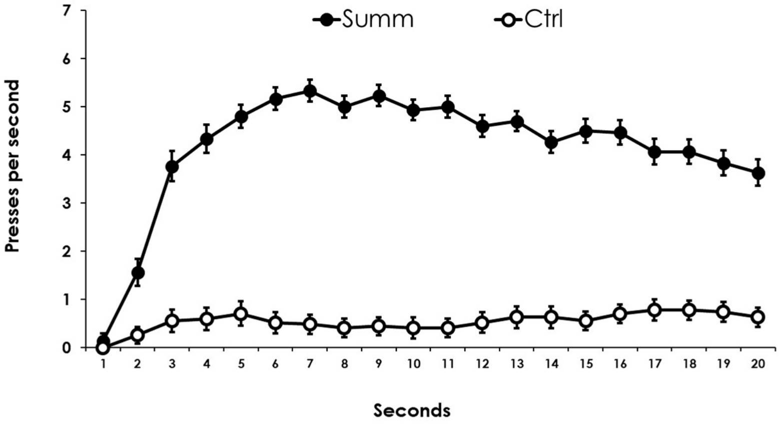


Figure 16: Responses averaged across seconds (± SEM) by group during the + responses in the summation test (RW-).

However, the most important data are the responses to ! (see Figure 17). Group Summation, where conditioned inhibition might be detected, is shown in closed circles with Group Control shown in open circles. The combination of W with S produced the same response to ! in both groups. A Group (Summ, Control) × Seconds ANOVA confirmed that there was no effect of Group, $F(1, 126) = 0.005$, $p = .94$, $\eta^2_p = .0$. The main effect of Seconds, $F(19, 2394) = 77.5$, $p < .001$, $\eta^2_p = .38$, and the Group × Seconds interaction, $F(19.2394) = 3.75$, $p < .001$, $\eta^2_p = .03$, were reliable. Simple effects of Group on each second indicated significant differences on trials 3, $p = .02$, and 18, $p = .031$. However, when controlling for the false discovery rate (alpha = .05) using the Benjamini-Hochberg (1995) procedure, adjusted *p-values* indicated no differences.

The shape of the response over trials may have varied slightly in the Summ group relative to the control, but it does not indicate the presence of inhibition, which should have generally depressed responding. If anything can be made of the pattern, Group Summ tended to respond slightly more rapidly prior to the point at which the attack was expected (second 5) and then perhaps extinguished more rapidly. Group Summ may have evidenced better temporal control.

The potentially reliable differences were found in two seconds of the trial but they behave in the opposite way as expected conditioned inhibition. The Summ Group seems to acquire the fastest response and then extinguish it at a faster rate as well. The only thing that can be inferred from these two data points, if reliable, could be that the Summ Group was better at timing the appearance of the ship than the Control Group. That control, if present, could arise from the expectation of both + and ! in group Summ at second 5, neither of which did occur.

This test indicates that the red sensor did not acquire inhibitory properties to become a conditioned inhibitor. Doubt might arise as to whether the green sensor could act as a conditioned inhibitor in Experiment 1 (half the subjects of Experiment 1 received green through counterbalancing) but the data obtained there showed that red and green did not differ at any time during the experiment. Likewise, here there were no differences in conditioning with red (S) or green (D) in the present experiment.

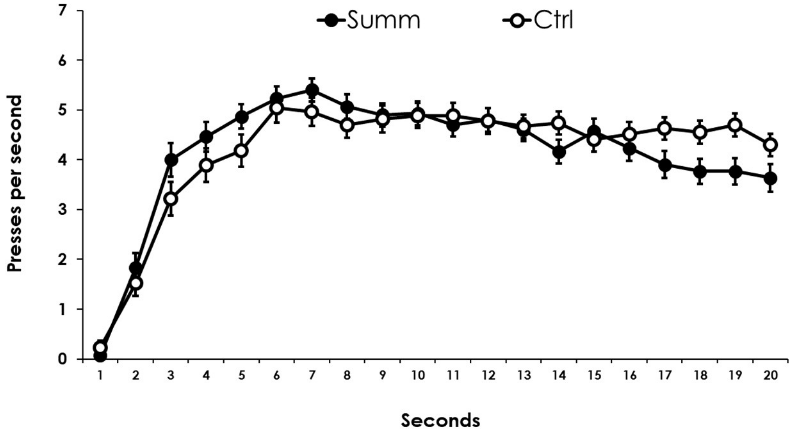


Figure 17: Responses averaged across seconds (± SEM) by group during the ! responses in the summation test (RW-).

In summary, with respect to responding to !, it did not matter if they were also responding on the + key due to the conditioning of S in Group Summ, or only to W as in Group Control, there was no difference in the overall ! responding. If + interferes with ! then that interference in group Summ could lessen the response to !, mimicking a conditioned inhibition effect (e.g., Rescorla, 1971). That no reliable effect was detected strengthens the idea that no inhibition was present. Thus, the result suggests that not only did S not become a conditioned inhibitor in Group NT; the result strongly supports that the two responses do not interfere with each other as was intended by design.

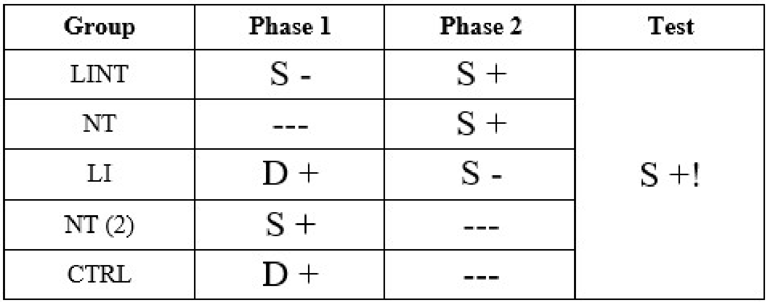
Experiment 3 (C2E3)

Experiment 2 strongly suggests that the differences obtained between Group NT and Group Control in Experiment 1 were not the result of S inhibiting ! responses on trials with S. Thus, the delay evident in Group NT from Experiment 1 (see trial 2, Figure 13) was unlikely to have resulted from a conditioned-inhibition mechanism produced by the procedure.

In Experiment 1, Group LINT showed a greater deficit in responding than group NT, which might reflect the contribution of LI accrued during pre-exposure. However, the experiment lacked a demonstration of LI alone. Group LI experienced pre-exposure with S and conditioning with a different sensor, D, and behaved in the same way as control for both + and ! responses during testing. There was either no effect of pre-exposure, which is unlikely as the effect has been shown robustly with this method (see Nelson et al., 2021), and occurred in the LINT condition, or the effect of pre-exposure was lost when a conditioning phase was added that did not include the pre-exposed stimulus (e.g., D+ for Group LI). Perhaps the possibility to retrieve what was learned in phase 1 for Group LINT during phase 2, even though contradictory information was being learned in that phase, may have permitted the continued retrieval and expression of that learning in test. The effect may have been larger in Group LINT than in Group NT due to the presence of both effects, but without a clear effect in Group LI, there is no clear NT/LI comparison possible.

A third experiment was designed to obtain a pre-exposure effect in Group LI and study the more profound deficit in Group LINT. Experiment 3 is summarized in Table 4. It also investigated the effect of inserting a delay between initial conditioning and testing in Group NT. Group LINT and Group NT experienced the same treatment as in Experiment 1 and their behavior is expected to be the same. The changes occur, first, in Group LI, where phases 1 and 2 of the experiment were interchanged. After conditioning with sensor D (green or red, counterbalanced), participants in group LI experienced exposure to sensor S. Then, the acquisition test was carried out. As discussed above, Group LI in the original experiment showed no effect of the pre-exposure relative to their control. In this case, the phases were swapped so that the pre-exposure could be evaluated in the case that the phase between exposure and testing was responsible for attenuating the effect. Finally, Group NT2 and Group Control also underwent a phase swap relative to their original treatment. This was done so that Group Control could serve as a control for Group LI and to evaluate the effect of an interval between "exposure" and testing in Group NT2.

Table 4.
Design of Experiment 3.



Group	Phase 1	Phase 2	Test
LINT	S -	S +	S +!
NT	---	S +	
LI	D +	S -	
NT (2)	S +	---	
CTRL	D +	---	

Note: Design of Experiment 3 in which "S" and "D" were two sensors served as CSs (red and green colored, counterbalanced). "-" indicates no US or nor enemy attack while "+" and "!" indicates the appearance of the enemy spaceships or US (Learian or Stellarian, counterbalanced). Finally, "---" indicates no CS or US (exposure to the context).

Method

Subjects

Participants were 160 college-aged volunteers (n=32). The relevant institutional review board approved all procedures.

Apparatus

The apparatus and stimuli were the same as in Experiment 1.

Procedure

All aspects prior to conducting the experiment were the same as in Experiment 1 and 2.

Response training. Participants were instructed to play the video game following the procedure detailed in Experiment 1 and 2.

Phase 1. During Phase 1, Group LINT received the same treatment as in Experiment 1. They experienced six non-reinforced trials of sensor S. Group NT patrolled the context without any experience with any CS or US. Group LI, started in phase 1 with 12 conditioning trials with sensor D. Similarly, Group NT2 and Group Control started the experiment with conditioning trials with the S and D sensors, respectively. These last three groups had trials with sensor B and both outcomes interleaved during conditioning, as occurred during conditioning in the previous experiments. Trial duration and ITI were the same as in Experiment 1 and 2.

Phase 2. During Phase 2, groups that underwent exposure experienced the conditioning phase with the S-sensor (LINT and Group NT), while those that had received conditioning trials went on to receive pre-exposure to the S-sensor (Group LI) or simply to patrol the galaxy (Group NT2 and Group Control). As in phase 1, conditioning trials were twelve S+ trials and three additional trials with B; while non-reinforced trials were six presentations of the S without consequences, or the same amount of time just patrolling. Trial duration and ITI were the same as in Experiment 1 and 2.

Test. Testing occurred as in Experiment 1. All groups received eight conditioning trials with S and both USs. Timing parameters were the same as Experiment 1.

Results and Conclusions

Phase 1.

As there were two treatments in phase 1 (pre-exposure or conditioning), they were analyzed separately. Figure 18 shows the behavior of Group LINT and Group NT, which received exposure to S or the context, respectively, during phase 1. Kruskal-Wallis test showed no differences on any trial between groups, *ps* $\geq$ .077. Averaging across groups, Freidman's test showed no effect of Trials, *ps* $\geq$ .508.

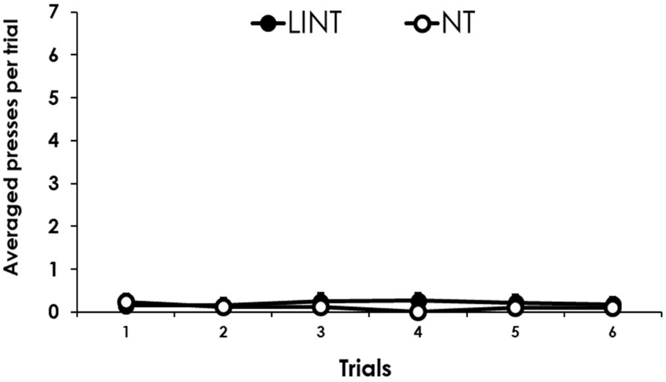


Figure 18: Responses averaged collapsing seconds (1-20) on each trial (± SEM) by group during pre-exposure in Phase 1.

On the other hand, Group LI, Group NT2 and Group Control experienced conditioning trials from the start of the experiment (see Figure 19). A Group (LI, NT2, Control) × Trials × Seconds ANOVA confirmed no effect of Group, $p = .678$. Effects of Trials $F(11, 1023) = 75.66, p < .001, \eta^2_p = .45$, Seconds $F(4, 372) = 176.44, p < .001, \eta^2_p = .67$, and Trials × Seconds interaction $F(44, 4092) = 26.84, p < .001, \eta^2_p = .22$, were reliable. Of more interest, no interactions with group were observed, *ps* $\geq .078$.

The effect of Seconds persisted until the last three seconds (3-5) of each trial, where there was no effect, $p = .338$. After collapsing the last three seconds, trials were dropped to determine the asymptote. The effect of Trials persisted until trial 9 (9-12), $p = .083$. During the last four trials, the response was established but there were no differences between groups, $p = .21$. Despite a clear trend in the samples for the control group to respond less, the asymptote was reached and it was the same for Group LI, Group NT2 and Group Control.

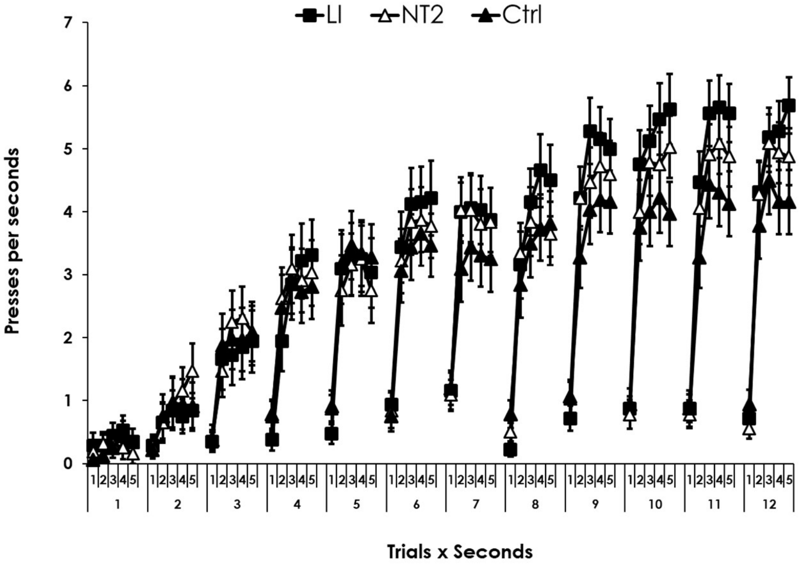


Figure 19: Responses averaged across seconds on each trial (± SEM) by group during conditioning in Phase 1.

Phase 2.

As in Phase 1, Phase 2 had different treatments over groups, so analyses were conducted in two ways. Group LI, Group NT2, and Group Control, which received exposure to S (Group LI) or the context (Group NT2 and Group Control), during phase 2, showed the same absence of responses. Kruskal-Wallis tests showed no differences on any trial between groups, *ps* $\geq$ .411. Averaging across groups, Freidman's test showed no effect of Trials, *ps* $\geq$ .841.

Group LINT and Group NT experienced conditioning trials in Phase 2 (see Figure 20). A Group (LINT, NT) × Trials × Seconds ANOVA showed no main effect of Group, $p = .09$. The effects of Trials $F(11, 682) = 38.34$, $p < .001$, $\eta^2_p = .38$, Seconds $F(4, 248) = 80.37$, $p < .001$, $\eta^2_p = .57$, and the Trials × Seconds interaction $F(44, 2728) = 13.11$, $p < .001$, $\eta^2_p = .18$, were reliable. In addition, the interaction of Group × Seconds, $F(4, 248) = 5.48$, $p < .001$, $\eta^2_p = .08$, was found. However, Group × Trials, $p = .057$, and the three-way interaction Group × Trials × Seconds were not reliable, $p = .225$.

The effect of Seconds persisted until the last three seconds (3-5), where it disappeared, $p = .86$. After collapsing the last three seconds, trials were dropping to examine the asymptote. Effect of Trials persisted until trial 11 (11-12), $p = .94$. During the last two trials, the response was established and an effect of Group was found, $F(1, 62) = 4.88, p = .031, \eta^2_p = .07$. The asymptote was reached in both groups and both differed in the asymptote, which is consistent with Experiment 1.

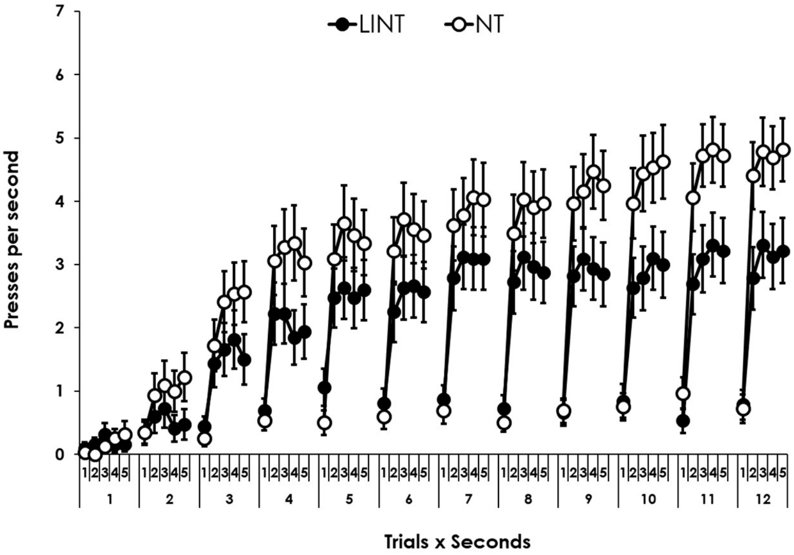


Figure 20: Responses averaged across seconds on each trial (± SEM) by group during conditioning in Phase 2.

Test with "+".

On trial 1 (see Figure 21) Group LINT and Group NT continued to respond as in the prior phase as they were receiving the same stimulus that had been conditioned. Although a phase where nothing happened preceded the test in Group NT2, they continued to respond in trial 1. There was no response in groups LI and Control as they were either receiving a stimulus that had simply been pre-exposed (Group LI) or was being encountered the first time (Group Control).

The differences on trial 1 are obvious and reflect what was observed at the end of phase 2. Trials 2 through 8 were analyzed with a Group (LINT, LI, NT, NT2, Control) × Trials (2-8) × Seconds (1-5) ANOVA and showed no overall effect of Group, $p = .111$. Effects of Trials $F(6, 930) = 18.77$, $p < .001$, $\eta^2_p = .12$, Seconds $F(4, 620) = 295.01$, $p < .001$, $\eta^2_p = .66$, and Trials × Seconds interaction $F(24, 3720) = 3.21$, $p < .001$, $\eta^2_p = .02$ were found. Of more interest, the Group × Seconds interaction $F(16, 2480) = 3.26$, $p < .001$, $\eta^2_p = .08$, Trials × Group interaction $F(24, 3720) = 6.42$, $p < .001$, $\eta^2_p = .14$ and Trials × Seconds × Group three-way interaction $F(96, 14880) = 1.84$, $p < .001$, $\eta^2_p = .05$, were reliable.

The effect of seconds and its interactions were clearly predominately due to the low responding on the first second. To determine the asymptotic responding, I again eliminated seconds beginning at second 1 until the effects of seconds disappeared. That elimination process identified the last 2 seconds as the stable responding on the trials (no effects of seconds, $p = .291$). On these last two seconds there were differences between groups, $F(4, 155) = 2.65$, $p =.035$, $\eta^2_p = .06$, but there was an effect of Trials, $F(6, 930) = 14.92$, $p < .001$, $\eta^2_p = .09$, and a Trials × Group interaction, $F(24, 3720) = 5.52$, $p < .001$, $\eta^2_p = .13$.

With the seconds (4-5) collapsed, trials were dropped beginning at trial one to determine where the asymptote was reached, which occurred on Trial 3 where the Trials effect disappeared, $p = .257$, yet the effect of Group was still present, $F(4, 155) = 3.03$, $p = .019$, $\eta^2_p = .07$. Groups LI, NT, NT2, and Control did not differ, $p = .494$. They reached the same asymptote, but LINT differed from each of the others, $F(1, 62) = 8.51$, $p = .005$, $\eta^2_p = .12$ (vs. LI); $F(1, 62) = 6.99$, $p = .01$, $\eta^2_p = .1$ (vs. NT); $F(1, 62) = 7.796$, $p = .007$, $\eta^2_p = .11$ (vs. NT2); except to Group Control, $p = .162$. Within the samples, Group Control responded less than groups LI, NT, and NT2, though it did not differ significantly, $ps \geq .207$. Group LINT differed collectively from groups LI, NT, NT2 and Control combined, $F(1, 158) = 9.84$, $p = .002$, $\eta^2_p = .06$.

It is important to point out that there is a result consistent with latent inhibition effect for Group LI with respect to Group Control in trial 2. Participants in Group LI (shown in black squares), who experienced sensor pre-exposure prior to test, responded less than Group Control (shown in open circles) on trial 2, $F(1, 62) = 7.64$, $p = .008$, $\eta^2_p = .11$, which is compatible with a LI effect. However, caution is encouraged with this interpretation as the D+ trials in the prior phase could have generated a stronger expectation of +, making S inhibitory for that outcome during pre-exposure. Nevertheless, the D+ trials should have minimum impact on making S inhibitory for !, yet retarded acquisition was observed, reported next.

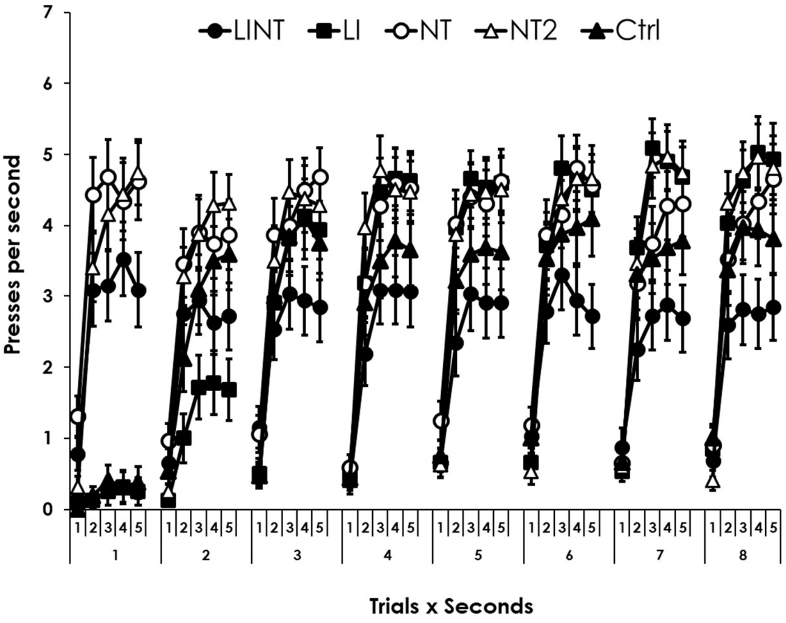


Figure 21: Responses averaged across seconds on each trial (± SEM) by group during + test.

Test with "!".

In this section, the ! responses are presented (see Figure 22). As in the ! test in Experiment 1, Group LINT showed a deficit in acquiring the new ! response, and an overall deficit in performance. Group NT also showed a decrement in learning the new ! response as shown clearly on trial 2. In addition, Group LI also showed retardation when acquiring the new response ! on trial 2. Finally, Group NT2 which experienced a delay between phase 1 and test as did Group LI in Experiment 1 (i.e., patrolling the context in phase 2), showed no performance deficit.

A Group (LINT, LI, NT, NT2, Control) × Trials × Seconds ANOVA revealed no overall effect of Group, $p = .208$. Effects of Trials $F(7, 1085) = 148.88, p < .001, \eta^2_p = .492$, Seconds $F(4, 620) = 282.03, p < .001, \eta^2_p = .65$, and Trials × Seconds interaction $F(28, 4340) = 35.06, p < .001, \eta^2_p = .18$ were found. Of more interest, the Group × Seconds interaction $F(16, 2480) = 3.18, p < .001, \eta^2_p = .08$, Trials × Group interaction *F*(28, 4340) = 4.01, $p < .001$, $\eta^2_p = .09$, and Group × Trials × Seconds three-way interaction *F*(112, 17360) = 1.67, $p < .001$, $\eta^2_p = .04$, were reliable.

Again, it was obvious that the impact of seconds and their interactions was mostly caused by the low response in the first second. Elimination of seconds to find the stable responding on the trials identified the last 2 seconds as the stable responding (no effects of seconds, $p = .166$). A Trials × Group ANOVA on these trials showed no effect of Group, $p = .09$. However, main effect of Trials, *F*(7, 1085) = 134.41, $p < .001$, $\eta^2_p = .46$, and Trials × Group interaction, *F*(28, 4340) = 3.84, $p < .001$, $\eta^2_p = .09$, were reliable.

In the prior experiment, the NT effect was observed on trial 2, where it was again evident. A lower response was observed in groups NT (closed triangles), LINT (closed circles), and LI (black squares). Results from LINT and NT were consistent with those obtained in Experiment 1 of this chapter, with the new result from Group LI. These findings were confirmed by a Group (LINT, LI, NT, NT2, Control) ANOVA conducted on Trial 2, showing an effect of Group *F*(4, 155) = 5.32, $p < .001$, $\eta^2_p = .12$. Groups LINT, LI, and NT did not differ, $p = .409$, and responded less than Control, *F*(1, 62) = 4.24, $p = .044$, $\eta^2_p = .06$ (vs. LINT); *F*(1, 62) = 12.01, $p < .001$, $\eta^2_p = .16$ (vs. LI); and *F*(1, 62) = 4.37, $p = .041$, $\eta^2_p = .07$ (vs. NT). Group NT2 did not differ from the Control group, $p = .618$, and did differ from NT, *F*(1, 62) = 7.1, $p = .01$, $\eta^2_p = .1$, suggesting that the interval between the initial conditioning and testing attenuated the effect, as was suggested to have occurred for Group LI in the previous experiment.

Trials were dropped beginning at trial one to determine where the asymptote was reached, which occurred on Trial 3 where the Trials effect disappeared, $p = .071$. On these trials, Group Control and groups NT2, NT, and LI were homogenous and did not differ, $p = .65$. Group LINT differed from the average of the other groups, *F*(1, 158) = 8.09, $p = .005$, $\eta^2_p = .05$. Asymptote was reached and Group LINT performance was lower than the other groups.

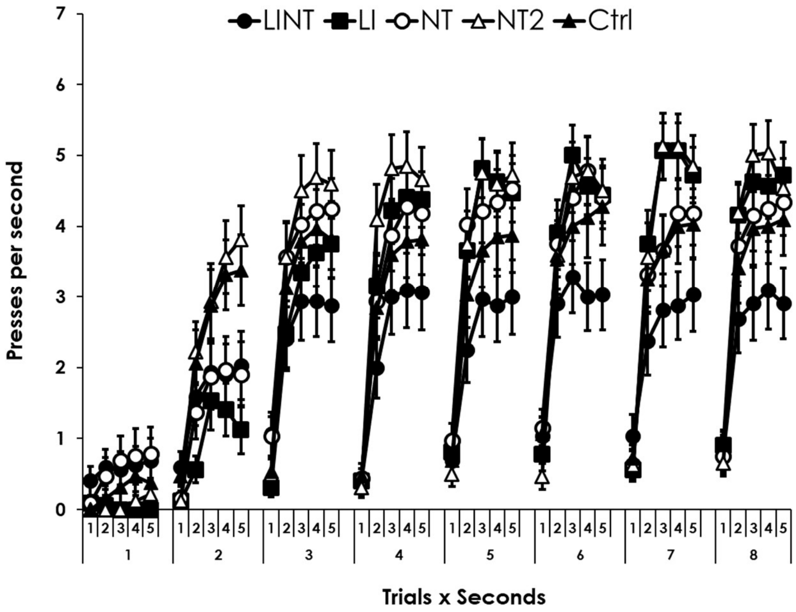


Figure 22: Responses averaged across seconds on each trial (± SEM) by group during the ! test.

These results are consistent with a Hall-Pearce negative transfer effect (Hall & Pearce, 1979) which has previously only been reported in humans by Griffiths et al. (2011). The NT effect is visible both in Group NT (delayed acquisition in trial 2) but especially in Group LINT which had a more profound deficit in response acquisition with !. A possible latent inhibition effect (e.g., Nelson et al., 2021) was found this time in form of lower response in the ! test for Group LI in trial 2 compared to the Control.

Results are also compatible with those obtained in the + responses. The result obtained with group LI is somewhat compromised by the conditioning with D+ in the prior phase. Here, S may have been pre-exposed with a greater expectancy of "+" than in the prior experiment, which could give it some stronger conditioned-inhibitory property with respect to +. However, comparison of the + response to the to ! response, for which the S stimulus would be less inhibitory in group LI showed no differences in either the overall response rate (2.87 presses per second during + responses, and 2.78 during ! responses) or the asymptotic response (4.59, 4.45). More specifically, the maximum response difference between + and ! on any second of that trial was .31 (trial 2), with the + response being greater. That difference was not significantly different from zero when considered alone, p = .053, and certainly not when adjusted for the 40 comparisons.

Discussion

The experiments presented here were conducted to assess the effects of latent-inhibition, Hall-Pearce negative transfer, and their combination. The goal of this series was to distinguish between CS processing (attentional changes, e.g., Mackintosh, 1975; Pearce & Hall, 1980; or CAD, e.g., McLaren & Mackintosh, 2000; Wagner, 1981) accounts. The experiments also can eliminate interference-based accounts of the HPNT effect. Traditionally, conditioning is conducted with a weak outcome and that results in delayed acquisition with a strong version of the same outcome. The result could be interference produced by retrieval of the weak outcome. In the present experiments, HPNT was assessed with a new outcome for which the prior outcome produces little-to-no behavioral interference. Thus, retrieval of O1 should not affect the expression of O2.

Participants were first trained to respond to the appearance of spaceships by rapidly pressing specific keys to activate specific weapons for each ship. There, different "sensor" stimuli were presented before and during the appearance of the spaceship/outcome. The procedure encourages the participants to emit an anticipatory response (charging a weapon) that allowed observation of the course of the assumed sensor-spaceship association along pre-exposure, conditioning, and test phases. The method permits the use of two simultaneous and different outcomes at the same time. Participants could respond independently to both ships, using both their right and left hands. Using this instrument's capacity provided a novel way to assess HPNT in human participants, for which there are few investigations (Griffiths et al., 2011) and questionable replicability (Le Pelley, et al., 2016). HPNT or LI should affect the ability of the sensor to be associated with the new spaceship. Thus, whether the stimulus was pre-exposed in the first phase (LI) or conditioned with one spaceship (HPNT), it has no association with the second spaceship (O2). Thus, learning about O2 can allow us to directly compare HPNT and LI.

The method also allowed second-by-second and trial-by-trial assessment of the acquisition of the response associated with O1 and subsequently with O2. In a recent investigation, Nelson et al., (2021) evaluated the asymptotic response in an LI procedure using this same method. The results obtained there were that the asymptotic response was different between experimental and control groups. This poses a challenge to the main attention-based theories (e.g., Mackintosh, 1975; Pearce & Hall, 1980) that predict differences in learning rates, but expect the asymptotes to be approximately equal, and for the hybrid model proposed by Hall and Rodriguez (2010). The entirely interference-based model proposed by Bouton (1993) does not directly address the discussion of asymptotic response as it is unclear as to the roles of interference in learning, performance, or both. Nelson et al., (2021) reported that pre-exposure reduced the conditioning asymptote. The different asymptotes observed in the method are important in that they differentiate models based on a Wagner (1981) priming type mechanism from those based on changes in attention or also interference.

The results obtained in Experiment 1 were consistent with latent-inhibition effect during conditioning. In phase 2 Group LINT showed a profound decrement in the acquisition of the + response, relative to Group LI for which the CS used was novel. The change of CS alleviated the latent inhibition effect, demonstrating a specificity to the stimulus of the phenomenon (e.g., Lubow, 1989). Also, results were consistent with a Hall-Pearce negative transfer effect. The HPNT effect is visible both in Group NT (delayed acquisition in trial 2) and especially in Group LINT which had a profound deficit in response acquisition with the ! response. In addition, results were consistent with models that predict different asymptotes of learning (e.g., Wagner, 1981) during conditioning and both tests. However, no LI effect was found in Group LI, perhaps showing that the effect is affected by the passage of time (Aguado et al., 1994) or extinction of context-sensor associations that might occur during phase 2 where S was not present. The absence of LI makes it difficult to compare the single effects of LI and HPNT in Experiment 1.

Experiment 2 was intended to alleviate the doubts produced by an alternative interpretation of the results of Experiment 1 regarding the HPNT effect. Because the two outcomes, + and !, appeared together in the response-training phase, and with the B+! trials, they could be associated with each other. Stimulus S could become a conditioned inhibitor for ! on S trials where + is present, but the expected ! is absent. Experiment 2 used a summation test (Rescorla, 1969) to test this possibility. Results showed there was no difference in the ! response pattern between groups indicative of conditioned inhibition. In addition, the result strongly support that the two responses do not interfere with each other.

Finally, in Experiment 3, the order of the phases for Group LI was switched to evaluate the single effect produced by LI. A result consistent with LI for Group LI, with respect to Group Control, was obtained during the acquisition of both the + and

! responses. In group NT, the results obtained during the ! response were consistent with HPNT as in Experiment 1. In the phase-3 test, the LI and NT effects appeared comparable. The NT effect is visible both in Group NT (delayed acquisition in trial 2) but especially in Group LINT which had a profound deficit in response acquisition the ! response. Consistent with the idea that an interval between phases in the test context reduces the effect of exposure, there was no effect of conditioning of S with + on the acquisition of ! in the NT(2) group. Different asymptotes were reached during conditioning between Group LINT and Group NT, and the differences were also evident during the acquisition of both the + and the ! responses between Group LINT and the other groups.

Overall, results were consistent with HPNT in human participants, which is incompatible with the attention model proposed by Mackintosh (1975). The HPNT observed here is also inconsistent with interference accounts (e.g., Bouton, 1993), since + should not behaviorally interfere with !. Experiments with nonhuman animals evaluating the effects of the negative transfer effect are numerous (e.g., Hall & Pearce, 1982; Rodriguez & Alonso, 2011), but studies with human participants are very limited (see Griffiths et al., 2011), which leads to the results reported here being relatively novel in their demonstration of the effect. The use of two outcomes that eliminate an interference-based account, is entirely novel.

Results in the LINT group, overall, were consistent with the model proposed by Wagner (1981) because it is capable of predicting the persistence of the effect and also predict differences in the asymptotic response showed during conditioning and test (both + and !) in Experiment 1 and Experiment 3. However, it might be expected on the same basis that the LI and NT results should also be observed at asymptote. Nevertheless, group LINT had more exposure to S, and more opportunity to form the Context-Stimulus associations necessary to produce asymptotic differences.

Chapter 3

Chapter 3 (The Learning Game Online)

The experiments of this chapter were intended to examine the contextual control of latent-inhibition and Hall-Pearce negative transfer effects. The goal was to determine whether the LI recovered its properties in an ABA paradigm. The acquisition test used back in context A should determine whether the LI could be recovered or whether the loss of response often observed on test in A (see for example Westbrook et al., 2000) could be due to the second learning (conditioning in B) being context specific (e.g., Nelson, 2002).

Since the finding of Lubow and Moore (1959), there are at least two major groups of associative models that attempt to address the implications of latent inhibition: theories based on acquisition failure (explained in detail above), and those based on retrieval failure or interference theories. Interference accounts are particularly interesting because they have been shown to be involved in extinction. According to Rescorla-Wagner model (1972), extinction operates in the opposite manner to conditioning, and implies unlearning. However, many studies have demonstrated that extinction is sensitive to the physical context (e.g., Bouton & Bolles, 1979), effects of time (e.g., Aguado et al., 1994), and affected by reminder treatments (e.g., Bouton, 1991). These findings suggest that the original learning is not unlearned since it can be re-expressed following any of the above manipulations. Therefore, interference has been used as an explanation for extinction because "unlearning" is inadequate. 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).

Hall (1991), in a thorough analysis of the latent-inhibition phenomenon, suggested that one way to overcome the problems faced by models based entirely on attention (such as contextual control) was to understand latent inhibition as the result of learning about the consequences of stimuli. Hall described this learning as the formation of a Stimulus-NoEvent association. Thus, as in CS-US pairings, this learning about the predictive value of the stimulus would produce the decrease in CS-associability. Hall emphasized that a "hybrid" theory of latent inhibition emerged from this conceptualization, in which two distinct, but related, learning processes contributed to the occurrence of the phenomenon. Learning the stimulus-NoEvent association would lead to a decrease in the prediction error during pre-exposure and, thus, a decrease in the associability of the stimulus, as proposed in Pearce and Hall's (1980) model. In addition, this Stimulus-NoEvent association formed during preexposure could interfere with the formation (Revusky, 1971), or expression (Miller & Matzel, 1988) of the CS-US association trained during subsequent conditioning. This second mechanism would complement the effects of CS-associability reduction and could explain the contextual dependence of the phenomenon. If the CS-NoEvent association established in preexposure hinders the acquisition and/or expression of the CS-US association acquired during conditioning, a context switch between the two phases could attenuate these effects by hindering the retrieval of that association.

Bouton (1993) extensively examined various conditioning procedures, such as extinction and latent inhibition. Through his comprehensive review of the literature, he noted that certain factors like physical context switches and delay intervals influenced conditioned performance in a way that contradicted traditional associative models. According to ideas proposed by Bouton, when a CS is reinforced, it forms a strong association with the US, leading to the acquisition of a CS-US memory. On the other hand, when the CS is presented without reinforcement, it results in the formation of a CS-noUS association, representing the absence of the US. These two associations, CS-US and CS-noUS, then compete with each other for expression in subsequent testing. Bouton's model attributes LI and HPNT to proactive interference, wherein the CS-noUS/small US memory established during pre-exposure or initial conditioning, respectively, interferes with the retrieval or expression of the CS-US memory formed during later conditioning. In other words, the presence of a conflicting association acquired during pre-exposure hinders the effective expression of the association between the CS and the US during conditioning. Context becomes important by enabling the retrieval of the later-learned information, disambiguating the meaning of the stimulus (Bouton, 1993).

LI and extinction are well-documented effects. Each has been shown across a variety of stimulus modalities in both appetitive and aversive conditioning processes, as well as in a variety of animal species, including people. Latent inhibition and extinction, procedurally, are similar phenomena (Westbrook & Bouton, 2010). Extinction stages suppose a reversal of the key stages in LI studies. In extinction, two groups of animals are exposed to a relation between a CS and a US. Then, animals in one group but not another, are exposed to the CS in the absence of any other outcome.

The responding elicited by the CS in animals just exposed to the pairing is depressed in those that received the CS-alone exposures.

Furthering the parallel, parameters that influence LI, and discussed above, have been found to regulate extinction in similar ways (Holmes & Harris, 2010). For example, the number of extinction trials enhance the effect (e.g., Sandoz & Pham-Delegue, 2004); the changes in CS duration are directly proportional to the effect (e.g., Haselgrove & Pearce, 2003), also the total extinction time (e.g., Shipley, 1974), CS intensity (e.g., Taylor & Boakes, 2002), and interval between presentations (e.g., Cain et al., 2003) affect extinction as occur with LI.

As commented earlier, extinction of a response is rarely permanent. A CR may be recovered by means of the mere passage of time (spontaneous recovery; e.g., Aguado et al., 1994), by unsignaled presentations of the US (reinstatement; e.g., Bouton, 1991), or when the animal is tested out of the extinction context (renewal; e.g., Bouton & Bolles, 1979). In these phenomena, the organism relapses into a previous state with the loss of the new learning that took place in extinction. Together, these effects indicated 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 (e.g., Bouton, 1993, 2004).

In the case of LI, some authors supported that LI is “renewed” if pre-exposure and conditioning are conducted in different contexts and testing occurs in the context of pre-exposure. For example, Bouton and Swartzentruber (1989) pre-exposed rats to a CS in context B, while also exposing the rats to Context C alone. The rats then received CS-shock pairings in context A and tested for conditioned suppression in either B or C, between subjects. Bouton and Swartzentruber found evidence for what they suggested was a restoration of latent inhibition, because there was less conditioned suppression to the CS in the preexposure context (B) than in the other context (C). Nevertheless, there was also a loss of responding when the pre-exposed and conditioned CS were tested in Context C, which was not associated with either conditioning or pre-exposure. Thus, the learning that took place in Context A after pre-exposure was contextually controlled. Though clearly implied by the result, it is not clear is whether the greater loss of response in Context B was because the LI had been recovered or whether it simply was a greater loss of CR due to the context switch back to the pre-exposure context. Second-learned associations are particularly sensitive to the effects of a context change (e.g., Bouton, 1993; Nelson, 2002). Thus, the effect that they observed is consistent with an interference account suggesting that something was learned in the pre-exposure context that resulted in the contextual control of the later learning in Context A. What is not clear is whether LI, as a deficit in the ability to acquire a response, was truly recovered in the pre-exposure context.

If LI is the result of interference, then like interference produced by extinction, it should be subject to a “renewal” effect. LI may be proactive interference between the learning in pre-exposure and the subsequent conditioning, while conditioning produces retroactive interference with the learning in the earlier pre-exposure phase in the same way that extinction interferes with conditioning. Miller et al. (2015) reported two experiments in which potential parallels between the context specificity of the effects of extinction and latent inhibition treatments were directly compared in a lick suppression preparation with rats. Experiment 1 revealed that when conditioning and nonreinforcement occurred in the same context, both extinction and LI treatments reduced test performance. Similarly, Experiment 2 showed that when conditioning was administered in one context and nonreinforcement was administered in a second context, the effects of both extinction and latent inhibition treatments were attenuated when testing occurred in a neutral context. Based on the results, the authors proposed a single interference mechanism for both effects because both LI and extinction were specific to the context of non-reinforcement, although they recognized that there were alternative explanations that may well have arisen from different mechanisms.

Mechanisms apart from outcome interference, CAD mechanisms for example, also predict a recovery of LI. A return to context A after conditioning in context B should return the stimulus to a state associated with that context (e.g., an A2 state). That return to A2 should both produce a deficit in further learning, and a performance decrement as A2 is assumed to be less effective in generating responses. In the attentional model of Schamjuk et al, (1996), which also incorporates context-stimulus associations, the return to context A could reduce novelty and then reduce the strength of the internal representation of the stimulus, recovering LI properties.

Interference-based models face a challenge with the contextual specificity of latent inhibition (LI) itself, as it appears to contradict the findings from simple Pavlovian conditioning (e.g., Bouton & Swartzentruber, 1986; 1989). Rodriguez and Hall (2008), and others such as Hall (1991) and Bouton (1993), have suggested that LI is a result of learning a CS- "No Event" or "No US" association. However, if LI were merely about acquiring a simple association, its expression should not be context-specific (e.g., Bouton & King, 1983; Bouton & Peck, 1989). The context-specific nature of latent inhibition and conditioning following pre-exposure raises questions about the content of what is learned during pre-exposure.

The observation that latent inhibition is context-specific is addressed by Hall and Rodriguez (2010). Hall and Rodriguez's model emerged as a reformulation of Pearce and Hall's (1980) model, whose central tenet, as discussed previously, was that the associability of a CS decreases when it is reliably followed by a given consequence. Hall and Rodriguez proposed that nonreinforced stimulus presentations in latent inhibition should theoretically be handled similarly to those included in an extinction procedure (i.e., inhibitory learning or the development of a CS-no US association, generated by the omission of the expected US; Westbrook & Bouton, 2010). Hall and Rodriguez predict that a novel salient stimulus will unconditionally elicit the anticipation of a general consequence or “Event.” Then, inhibitory learning may take place, establishing a stimulus-NoEvent association with enough training, that would take the place of the anticipation that some event would occur. The stimulus also loses its associability as it improves at precisely predicting its outcome, or lack thereof. As the “NoEvent” association is the second-learned association, it would become context dependent (Nelson, 2002).

Theories (e.g., Bouton, 1993; Hall & Rodriguez, 2010; Wagner, 1981) that can cope with the context specificity of LI also predict that the LI properties of a CS should be recovered when the CS is returned to the context of pre-exposure. While this has been suggested (e.g., Westbrook et al., 2000), the evidence is not clear. As discussed earlier, a recovery of LI as a reduced ability to *acquire* a response, has not been demonstrated. Testing has not involved the acquisition of a response, but only the response presently elicited by the CS, and any reduction confounds the potential recovery of LI with the context specificity of conditioning that might result from a pre-exposure treatment. The experiments in this chapter were designed to address that confound.

Three experiments were conducted with a method presented in chapter 2. The main procedural difference was that, due to the COVID-19 pandemic and its lasting impact on being able to conduct in-person studies, the research was conducted with online participants through the Prolific platform (www.prolific.com). The first of the experiments was to confirm that the online participants and methods produced the same effects as in the procedures in face-to-face experiments in chapter 2.

Experiment 2 added contextual changes to assess whether the LI and HPNT phenomena would recover with a change of context. The addition of a new outcome (e.g., !) following conditioning with "+" allows the assessment of whether the LI effect, expressed as an acquisition deficit with !, is recovered with a return to the conditioning context along with demonstrating the context specificity of the + response. Four groups used AAA, ABA, AAB and ABB context change protocols, where A and B correspond to different contexts along the pre-exposure, conditioning, and testing stages.

To foreshadow, the experiment unexpectedly showed no effects of context change on the expected latent inhibition and negative-transfer effects. Such a lack of effect could be due to the stimulus acquiring conditioned-inhibition properties, which are not context specific (e.g., Nelson, 2002; Nelson & Bouton, 1997). Although pre-exposure with this method has not been shown to produce conditioned inhibition (Nelson et al., 2021), Nelson et al., (2022) have shown that what is learned during pre-exposure may be affected by individual differences, specifically suggesting that a form of inhibition (response inhibition or conditioned inhibition) may be learned when demand characteristics are high. As the online experiments use a different demographic of participants, are conducted in vastly different settings and conditions, and involve monetary payments to the participants, demand characteristics may be different, facilitating the use of a conditioned inhibition mechanism. Experiment 3 was conducted with a summation test after a conditioning phase in order to address if the stimulus acquired inhibitory properties consistent with conditioned inhibition.

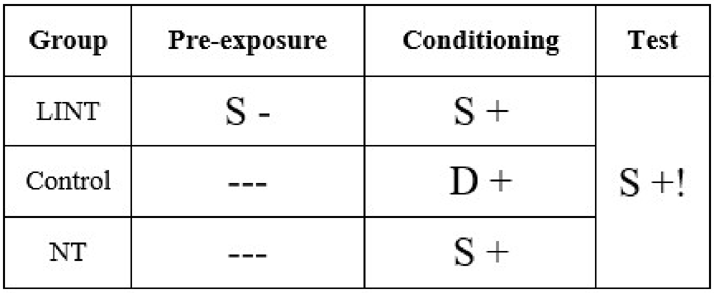
Experiment 1 (C3E1)

Behavioral research has increasingly used online platforms in recent years for participant recruiting, experiment design, and testing (Sauter et al., 2020). Internet-based participant recruitment is simple and convenient, making it a typical technique for gathering vast and varied data sets quickly (Chetverikov & Upravitelev, 2016). It has been reported that the number of online studies has increased at least tenfold to such an extent that, by 2016, the number of studies published in major journals using only online recruitment platforms (such as Amazon Mechanical Turk or Prolific) had begun to surpass those using traditional methods (e.g., Lu et al., 2022; Walter., 2019).

A variety of probable reasons, including increased access to technology, more knowledge of the benefits that remote testing offers, and the development of tools designed to enable online research, have likely contributed to the fast acceleration in the use of online techniques for research. Online research tools are now available for several traditional research methods, such as response time studies, user experience studies, user interface studies, AI model training, multiplayer studies, consumer behavior studies, and gamified studies, in addition to more conventional research methods like surveys (Tomczak et al., 2023). The Covid-19 epidemic in the beginning of 2020, which forced many researchers to completely abandon lab-based recruitment, has also had a substantial effect in this increased use (e.g., De Man et al., 2021; Rashid & Yadav, 2020). Recent work found no statistical difference between online and in-person testing (Sauter et al., 2022).

Here, the limitations caused by the pandemic made it necessary to consider the use of Prolific as a tool for recruitment and online experimentation. The instrument chosen for the experiments reported in this chapter was designed by Nelson et al., (2014) and is a near-exact replication of the methodology described in Nelson et al., (2014; 2021) and used in Chapter 2. The design is summarized in Table 5. The weapons, sensor colors, and spacecraft were as described in Chapter 2. New, more colorful and potentially distinctive, background skyboxes were used as contexts. The goal of this experiment was to demonstrate that the same effects obtained in the face-to-face procedures were also evident in online procedures via the Prolific platform. Group LI was removed from this experiment because no effect was found in the original experiment, and the effects I wished to investigate in this chapter dealt with the recovery of LI following conditioning.

Table 5.
Design of Experiment 1, Chapter 3.



Group	Pre-exposure	Conditioning	Test
LINT	S -	S +	S +!
Control	---	D +	
NT	---	S +	

Note: Design of Experiment 1 in which “S” and “D” were two sensors serving as CSs (red and green colored, counterbalanced). “-” indicates no US or nor enemy attack while “+” and “!” indicates the appearance of the enemy spaceships or US (Learian or Stellarian, counterbalanced). Finally, “---” indicates nor CS or US (pre-exposure to the context).

Method

Subjects

One hundred fifty-one participants were recruited from Prolific platform. The experiment was conducted entirely in English and the requirements established in the platform were a reported fluency in English, and English as a primary language. Participants were recruited from USA, England, Wales, Scotland, Ireland, Australia, and New Zealand. Participants were assigned randomly to the counterbalancing conditions constituting each group without replacement until each condition had equal assignments before being put back into the selection pool. Being conducted online, there were participants which might be assigned to a task and the assignment record updated at that point, but they did not complete the task which led to the random assignment of a new subject, which produced some minor differences in Ns. Group LINT had 50 participants, Group NT had 51 participants, and Group Control had 50 participants. Ten participants were removed from experiment because they did not show a sufficient trained response to the presence of the outcome spaceship itself (less than an average 3 responses per second in the last three conditioning trials). Three responses per second were what was required for the weapon to be activated and fire. All procedures were approved by the relevant institutional review board.

Apparatus

The video game used was nearly identical to that described of Nelson et al. (2014; 2021), and detailed earlier. Participants were registered in the Prolific platform and accessed the experiment with the language requirements explained above. In addition, the experiment program tested their computer to verify that the graphics were capable of at least 20 frames per second. Participants were aware of the requirements and that if these requirements could not be met, they could not participate.

Environment contexts were visible through the view screen. The first was a "training environment," as described in Chapter 2, 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", contained a large spiral-shaped rotating space station and a colorful, predominately orange, star-system consisting of a small ringed planet to the right of the station surrounded by stars and a yellow/orange gaseous nebula with a sun radiating light from the left of the station.

There were minor changes between the face-to-face procedure (detailed in Chapter 2) and the online procedure. The name of the context (i.e., Nicholosia) appeared in the top of the viewscreen, the themes and elements of the contexts were similar but the images used as contexts were new. The details not mentioned of this section were as those mentioned in Chapter 2.

Procedure

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 male voice.

Response training. The response training occurred as in Chapter 2. The four weapons and places where they appear were the same. However, in order to accommodate different keyboards, participants were required to choose the key to use associated with each weapon from what was available on their keyboard (system keys, e.g., “Win”, were excluded as were the shift keys whose rapid pressing can activate windows “sticky keys” feature during the game). The identity of the key choices was not recorded, instead the data output provided information on the position of the weapon used (top left, TL; top right, TR; low left, LL; and low right, LR) to which a key was assigned. The criterion for repelling enemy ships during training was also to fire eight shots. The wording of the instructions varied slightly to shorten them, but conveyed the same content and message as the original. The instruction voice was male instead of female. Only two spaceships (the “Learian” and the “Stellarian”) were used in the remainder of the experiment, counterbalanced as + and !.

Phase 1. During Phase 1, Group LINT received six pre-exposure trials with stimulus S alone. S was either a red or a green light, counterbalanced. Group NT and Group Control were simply exposed to the context during this period. On each pre-exposure trial, the CS (or its absence in Group Control and Group NT) was presented for 20 s. 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. During Phase 2, Group LINT and Group NT received twelve conditioning trials with S while Group Control received conditioning trials with D. For all groups there were three randomly intermixed conditioning trials with a blue sensor (B) followed by the two USs. These trials were used to allow practice in simultaneously responding to the two outcomes.

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.

Test. All groups received eight conditioning trials with S and both USs. Participants could respond independently to both USs, using both their right and left hand independently. Timing parameters were the same as Phases 1 and 2.

Results and Conclusions

Phase 1. Pre-exposure

The entire trial (20-seconds each) was analyzed, as there was no outcome during this phase. Responding was averaged across the entire 20s. Figure 23 shows the mean presses per second during each trial by group. Although the response rate per second was low (overall 0.24 responses per second), participants in Group LINT, which experienced the presence of the CS, responded more (0.4 per second) than participants who simply patrolled the galaxy (0.17 and 0.15 responses per second for Group Control and Group NT, respectively). Due to the low responding, the data were analyzed with nonparametric tests.

The Kruskal-Wallis test confirmed that significant differences existed between groups in both trial 1 (p = .008) and trial 6 (p = .044). However, there were no differences in the other trials (*ps* ≥ .147) and no differences between Group NT and Group Control groups (*ps* ≥ .146). Some small response was elicited by the sensor for Group LINT as compared to the groups simply patrolling. Within each group (Friedman tests) found no effect in Group NT, p = .168, or Group Control, p = .415. However, in Group LINT Friedman test showed differences across trials, p = .012. After comparing the means, it was observed that trial 1 ($\bar{x}$ = .73) was different from trials 2, 3, and 4, *p*s ≤ .04. Trial 1 did not differ from trials 5 and 6, *p*s ≥ .08 and no differences were found among the remaining trials, *p*s ≥ .39.

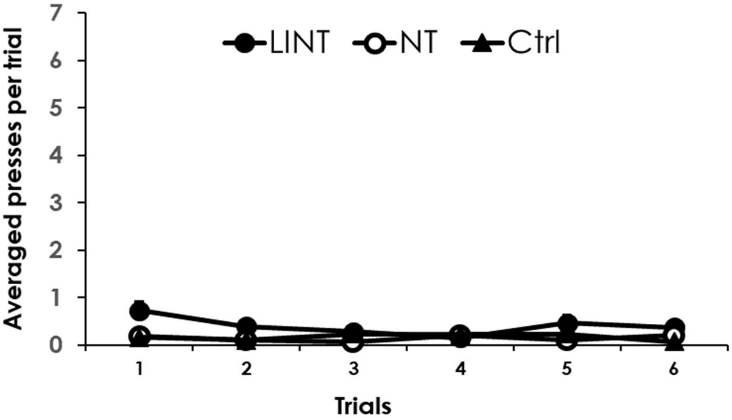


Figure 23: Responses averaged (1-20 seconds) on each trial (± SEM) by group during pre-exposure.

Phase 2. Conditioning

As in the previous chapter, the responses per second on each of the first 5-seconds of the sensor, prior to the arrival of the outcome, were analyzed. The data are shown in Figure 24. During conditioning, a lower response rate in Group LINT was observed. As in the original experiment pre-exposure entailed a decrease in responding during conditioning. Effects were analyzed by a Group (LINT, NT, Control) × Trials × Seconds ANOVA. Findings revealed an effect of Group, *F*(2, 148) = 6.49, $p = .002$, $\eta^2_p = .08$, Trials *F*(11, 1628) = 67.14, $p < .001$, $\eta^2_p = .31$, Seconds *F*(4, 592) = 349.59, $p < .001$, $\eta^2_p = .7$, and a three-way interaction of Group × Trials × Seconds, *F*(88, 13024) = 1.39, $p = .009$, $\eta^2_p = .02$. No other effects, not superseded by the interaction, were significant.

As in Chapter 2, the effect of seconds and its interactions were clearly predominately due to the low responding on the first second. To determine the asymptotic responding, seconds were eliminated beginning at second 1 until the effects of seconds disappeared. That elimination process identified the last 2 seconds as the stable responding on the trials (no effects of seconds, $p = .194$). Simple effects investigating the effect of Group on the average of these last seconds showed that there were differences between groups, *F*(2, 148) = 6.75, $p =.002$, $\eta^2_p = .08$. Simple effects of Trials were found, $F(11, 1628) = 7.13$, $p < .001$, $\eta^2_p = .27$; but the Group × Trials interaction, $p = .134$, was not significant.

Seconds (4-5) were collapsed and trials dropped, beginning at trial 1, until no effect of trials was observed in order to investigate differences in the learning asymptotes. No effect of Trials were found after trial 6 in a Group (LINT, NT, Control) × Trials (7-12) ANOVA with seconds collapsed, $p = .168$, nor Trials × Group interaction, $p = .184$. The ANOVA demonstrated an effect of Group $F(2, 148) = 3.65$, $p = .028$, $\eta^2_p = .05$. Group LINT differed from Group NT, $F(1, 99) = 5.054$, $p = .027$, $\eta^2_p = .049$, and Control, $F(1, 98) = 6.62$, $p = .02$, $\eta^2_p = .05$. No differences were found between Group NT and Group Control, $p = .993$. Group LINT differed from the others, showing that the asymptotes reached were different between Group LINT and the other groups.

Online results in conditioning are consistent with those obtained in face-to-face. An overall acquisition deficit was evident in Group LINT. Group LINT did not reach the learning asymptote of the other groups, which is consistent with Wagner account, and contradicts the prediction of attention-based models (e.g., Mackintosh, 1975). It also contradicts interference accounts where the interfering information acquired in phase 1 contributes to the overall error in prediction in the conditioning phase (Hall & Rodriguez, 2010). Group Control and Group NT behaved in the same way as expected, rapid learning was shown. In summary, the results obtained in this phase are in line with those obtained in the original experiment.

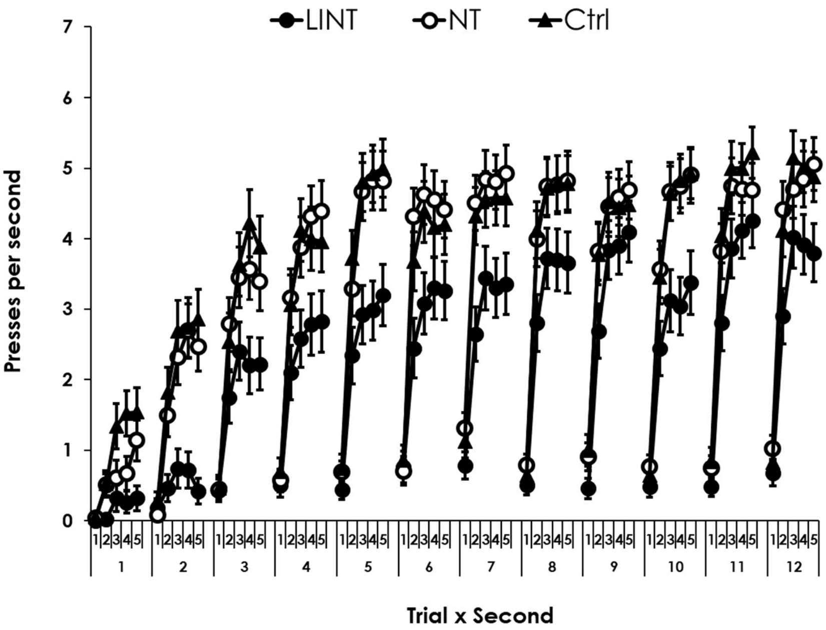


Figure 24: Responding by second on each trial (± SEM) by group during conditioning.

Test with "+"

The + key, which had been conditioned phase 2, was examined first in this stage (see Figure 25). Group LINT and Group NT experienced another conditioning trial; nothing changed between the last trial of phase 2 and the first appearance of S, prior to both outcomes, in the first trial of test. Therefore, the responses are a continuation of those observed in the previous phase. Group LINT showed a lower response rate compared to NT, as occurred in the previous experiment. On the other hand, because it was the first experience with S for Group Control, the response in trial 1 is low. Group Control quickly acquired the response.

The differences on trial 1 are obvious and reflect what was observed at the end of phase 2. Trials 2 through 8 were analyzed with a Group (LINT, NT, Control) × Trials (2 to 8) × Seconds (1-5) ANOVA and showed an effect of Group $F(2, 148) = 3{,}72$, $p = .027$, $\eta^2_p = .05$. There was an effect of Seconds, $F(4, 592) = 369.32$, $p < .001$, $\eta^2_p = .71$, and Seconds × Group interaction, $F(8, 1184) = 2.62$, $p = .008$, $\eta^2_p = .03$. There was no effect of Trials, nor any interactions with Trials, $ps \geq .289$.

The response was established during the last two seconds (4-5), *p* = .146. After collapsing seconds, Group LINT showed less response than Group Control, *F*(1, 98) = 6.87, *p* = .010, η^2_p = .07, but the difference with Group NT was marginal, *F*(1, 99) = 3.72, *p* = .057, η^2_p = .04. Group NT and Group Control did not differ, *p* = .575, and Group LINT differed from Group NT and Group Control combined, *F*(2, 148) = 3,72, *p* = .027, η^2_p = .05.

The learning deficit in Group LINT persisted through 20 conditioning trials of conditioning, as in the original experiment from Chapter 2. Some learning from phase 1 persisted after the contradictory conditioning in phase 2, and it was expressed in test performance.

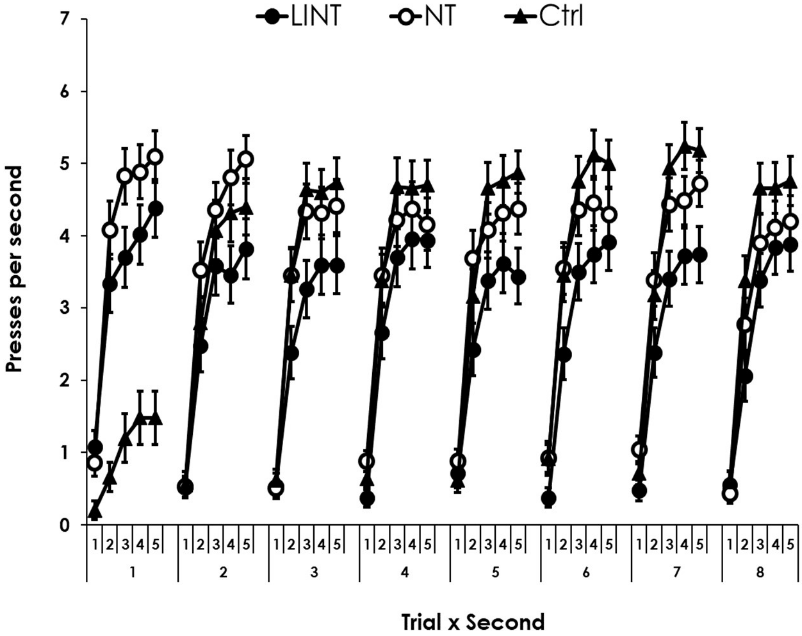


Figure 25: Responding by second on each trial (± SEM) by group on the + response during the test phase.

Test with "!"

Group LINT continued to show an attenuated + response during test, and also showed difficulties in acquiring the new ! response (see Figure 26). This result is consistent with that obtained in the original experiment (C2E1). However, the effect in Group LINT was not greater than that observed in Group NT. The latter group showed a larger effect than that shown by Group NT in the in-person experiments. Group NT, showed a significant delay in acquisition only on Trial 2 of the original experiments (C2E1 & E3). Here, performance of group NT and LINT was the same. The delay in acquisition was evident in Trials 2 and 3, and after learning was established, the asymptote reached was on a par with that of Group LINT.

A Group (LINT, NT, Control) × Trials × Seconds ANOVA revealed an effect of Group $F(2, 148) = 7.31$, $p < .001$, $\eta^2_p = .09$. It also revealed simple effects of Trials $F(7, 1036) = 92.57$, $p < .001$, $\eta^2_p = .39$, and Seconds $F(4, 592) = 297.68$, $p < .001$, $\eta^2_p = .67$. Of most interest, Trial × Group × Seconds three-way interaction was significant $F(56, 8288) = 2.17$, $p < .001$, $\eta^2_p = .03$.

Seconds were dropped until second 4 (4-5), where the effects of Seconds disappeared, $p = .8$. After collapsing seconds (4-5), the delay in acquisition was very evident in early trials (trials 2 and 3). Further analyses of Group (LINT, NT, Control) on the asymptotic seconds confirmed an overall effect of Group, $F(2, 148) = 19.72$, $p < .001$, $\eta^2_p = .21$, in trial 2. Group LINT differed to Group Control, $F(1, 98) = 20.37$, $p < .001$, $\eta^2_p = .2$, and Group Control differed to NT $F(1, 99) = 33.58$, $p < .001$, $\eta^2_p = .25$. Group NT and Group LINT behaved the same, $p = .463$. In trial 3, an overall effect of Group was also reliable, $F(2, 148) = 9.59$, $p < .001$, $\eta^2_p = .12$. LINT differed to Group Control $F(1, 98) = 15.98$, $p < .001$, $\eta^2_p = .14$, and Group Control differed to Group NT $F(1, 99) = 15.31$, $p < .001$, $\eta^2_p = .13$. Group NT and Group LINT behaved the same, $p = .898$.

The effects of Trials persisted $F(7, 1036) = 88.98$, $p < .001$, $\eta^2_p = .38$. Trials were dropped until trial 6 (6-8), where the effect of Trials was no longer reliable, $p = .112$. A Group (LINT, NT, Control) × Trials (6-8) confirmed that asymptotes were reached in trial 6, but an effect of Group $F(2, 148) = 3.85$, $p = .024$, $\eta^2_p = .05$, indicated that there were different asymptotes. Group LINT and Group NT did not differ $p = .714$, but both differed from Group Control $F(1, 98) = 6.65$, $p = .011$, $\eta^2_p = .06$, and $F(1, 99) = 5.65$, $p = .019$, $\eta^2_p = .05$, respectively. No differences were found between LINT and NT performance during ! responses. Both groups responded the same. Moreover, LINT and NT reached the same asymptote, and a lower one than in Group Control.

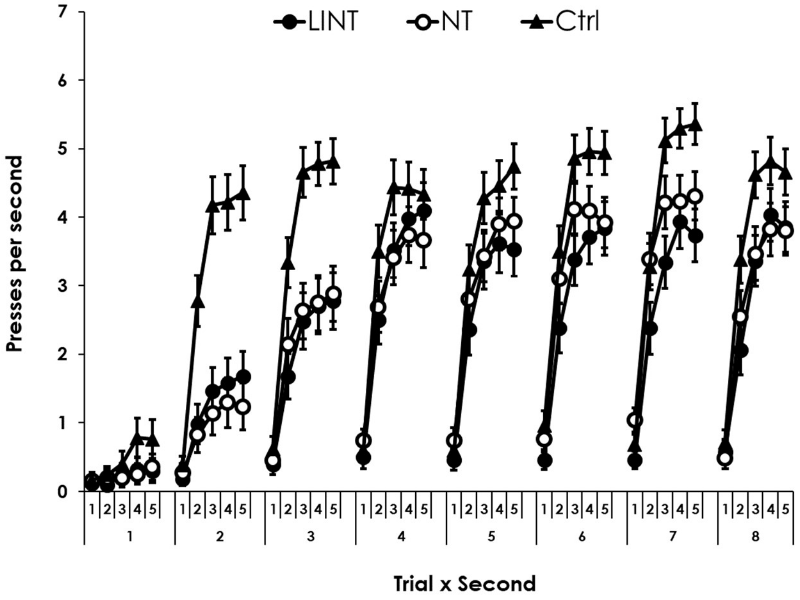


Figure 26: Responding by second on each trial (± SEM) by group on the ! response during the test phase.

Results reported here were consistent with a Hall-Pearce negative transfer effect and were largely consistent with those obtained in the original experiment. In this case, the negative transfer effect is more evident in Group NT. Groups LINT and NT behaved in a similar way.

Experiment 2 (C3E2)

The present experiment was designed to examine the context specificity and recovery of Latent Inhibition and Hall-Pearce Negative Transfer effects. As with Latent Inhibition (e.g., Lubow et al., 1976), the HPNT effect is context-specific. For example, Swartzentruber and Bouton (1986) found the effect in an experiment with rats. When phase 2 occurred in the same context as phase 1, a group that had received prior tone-weak shock pairings (Group AT) acquired less additional tone suppression than did a group that had received a similar prior treatment with the light (Group AL). However, they also found that context plays a role in HPNT. When Phases 1 and 2 occurred in different contexts (Groups BT and BL), the effect was not obtained (see also Ayres, et al., 1984). On the other hand, experiments demonstrating an effect of HPNT in human participants are limited (for an example see Griffiths et al., 2011) and assessing contextual specificity in the effect in humans is novel.

In the case of LI, if the first and second phases occur in different contexts, a return to the phase 1 context can lead to a recovery of phase 1 performance (Bouton & Swartzentruber, 1989). This phenomenon implies the potential recovery of latent inhibition after conditioning. However, when testing occurs in a third context, different from both the pre-exposure and conditioning contexts, it results in a decrease in the learned response (Westbrook et al., 2000). This finding suggests that post-pre-exposure learning is also influenced by the context. As discussed earlier, the reduction in response observed during testing in the pre-exposure context remains open to interpretation. It could be attributed to the conditioning being context-specific (Nelson, 2002), or it might be due to a recovery of the "latent inhibition" acquired during pre-exposure. The method in this experiment allows for a recovery of a learning deficit to be observed by incorporating the acquisition of a new response, while maintaining the old one, during the test to evaluate both a loss of responding to the original outcome and a recovery of LI, as acquisition of the new outcome, independently.

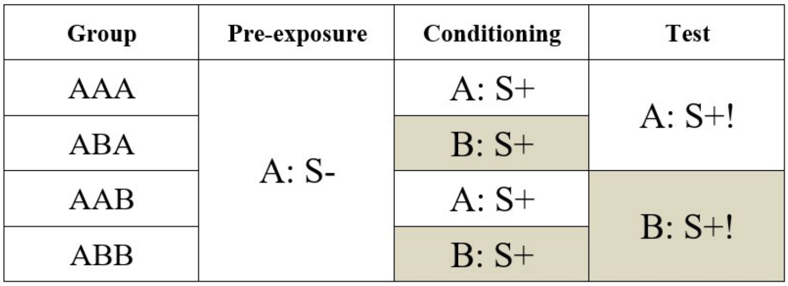
The design is summarized in Table 6. Group AAA group corresponds to the LINT treatment of the previous experiments and did not undergo any critical contextual changes for the treatment. The contexts were balanced and all groups had experiences in both contexts as will be detailed below. Group AAA, after non-reinforced pre-exposure in phase 1 with the S stimulus, is expected to have slow response acquisition in phase 2 during S+ trials. Finally during the ! test it is expected that this group will show the LI effect and a HPNT effect after learning that S is a good predictor of + during phase 2.

Group ABA underwent a contextual change during phase 2 (conditioning in context B) relative to the first Group AAA group. Group ABA, after S pre-exposure in context A, is expected to rapidly acquire the S+ response in context B, due to the contextual specificity of LI (e.g., Lubow, 1989). After such learning is established, Group ABA will undergo a return to context A during testing. Based on the findings of Westbrook and colleagues (2000), we should see a drop in the + response, whose responsible mechanism is ambiguous. However, if slow learning occurs during the acquisition of ! on the ! test, it should be explained by a recovery of LI. A HPNT effect is not expected since the effect is context specific (e.g., Swartzentruber & Bouton, 1986) and its influence should be lost in the contextual change between phase 2, and the test.

For Group AAB, a delay was expected during conditioning after pre-exposure and subsequent conditioning in context A. Despite some possible loss in responding to the + key, recovery of that response and the acquisition of the new ! response were expected to be rapid as both effects of pre-exposure and conditioning should be attenuated in context B. Overall, this group was expected to perform better than Group ABA during the + test, and above Group AAA in the ! test.

Finally, in Group ABB we expected to find no effect of non-reinforced pre-exposure either during conditioning or during either test. The effect of LI should be reduced due to the contextual change between pre-exposure (A) and conditioning and test (B). However, it is expected to find a simple effect of HPNT on the ! test during learning with the new outcome.

Table 6.
Design of Experiment 2, Chapter 3.



Group	Pre-exposure	Conditioning	Test
AAA	A: S-	A: S+	A: S+!
ABA		B: S+	
AAB		A: S+	B: S+!
ABB		B: S+	

Note: Design of Experiment 2 in which A and B were markedly different contexts (Boutonia or Nicholosia, counterbalanced). “S” was a sensor served as CS (red and green colored, counterbalanced). “-” indicates no enemy attack while “+” and “!” indicates the appearance of the enemy spaceships or US (Learian or Stellarian, counterbalanced).

Method

Subjects

Two hundred thirty-five participants from Prolific platform were randomly assigned to one of four groups. Group AAA had 62 participants, Group ABA had 55 participants, Group AAB had 60 participants, and Group ABB had 58 participants. Seventeen participants were removed from the experiment because they did not show a sufficiently trained response to the outcomes (same criterion as Experiment 1). The same language criteria were used and participants were collected from the countries mentioned above. All procedures were approved by the relevant institutional review board.

Apparatus

A second experimental setting was included in this experiment and was part of the design. In addition to "Nicholosia" explained above, participants experienced "Boutonia"; the skybox galaxy was predominately blue and composed of various images of the "Pillars of Creation" portion of the Eagle 1 nebula. "Boutonia" was also called the context used during Chapter 2. It shares the name with the one used here but the background was different. The rest of the apparatus section was the same as in Experiment 1.

Procedure

Conditions, as Experiment 1, were randomly assigned until all counterbalances (CSs, USs, contexts, and orders) were completed and then re-entered into the pool. When the subject was ready to start, a press on the "B" key initiated the experiment. Instructions were delivered to the participant as in the previous experiment.

Response training. Response training occurred as Experiment 1.

Phase 1. During Phase 1, all groups received two blocks of three pre-exposure trials with stimulus S without consequences in context A. S was either a red or a green light, counterbalanced. Contexts A and B were Boutonia or Nicholosia backgrounds, counterbalanced. To equalize the time participants experienced each context, all groups experienced equal time in context B with the order of blacks counterbalanced (ABAB or BABA).

On each trial, the CS (or its absence in context B) was presented for 20-s. 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. The appearance of the spaceship was signaled by the appearance of a colored (red or green, counterbalanced as in the prior experiment) flashing sensor light (S). During Phase 2, Group AAA and Group AAB groups received two blocks of three trials of conditioning with S in context A. On the other hand, Group ABA and Group ABB received the same treatment but in context B. For all groups there was one conditioning trial with a blue sensor (B) followed by the two USs in the conditioning context inside each of these blocks to allow practice in simultaneously responding to the two outcomes.

Exposure to the contexts was equated by having the trials (with the CS or empty trials) in blocks of four (3 with the target CS, 1 with Blue) in each context. The order between conditioning or context exposure blocks repeated the pre-exposure sequence. The ITI was as in Phase 1.

Test. All groups received six conditioning trials with S and both USs. Group AAA and Group ABA groups in context A, while Group AAB and Group ABB in context B. Timing parameters were the same as Phases 1 and 2. Context exposure was not equated on test.

It is important to note that the number of conditioning and test trials were reduced compared to that of previous experiments. We feared that the added length of the experiment by the introduction of context exposure would fatigue participants and affect their overall attention to the task, which lasted an average of 36 min.

Results and Conclusions

Phase 1. Pre-exposure

With no outcome on the trial, the entire trial (20-seconds each) was averaged. The Kruskal-Wallis test confirmed that significant differences existed between the four groups in trial 2 ($p = .009$). However, there were no differences in the other five trials ($ps \geq .052$). Friedman tests showed within-subject effects of trials for groups Group AAA ($p = .014$), Group ABA ($p = .001$), and Group ABB ($p = .018$). However, no effect of Trials was found in Group AAB group ($p = .177$). As shown in Figure 27, any differences in the tendency to respond to the sensor were minor, and would not be reliable if corrected for the 6 tests, (no $ps \leq .008$). The average response rate per trial (0.75) was larger than those obtained in previous experiments using this method (0.4). The context changes used to balance exposure to the contexts may have been arousing in some manner, producing this slightly increased tendency.

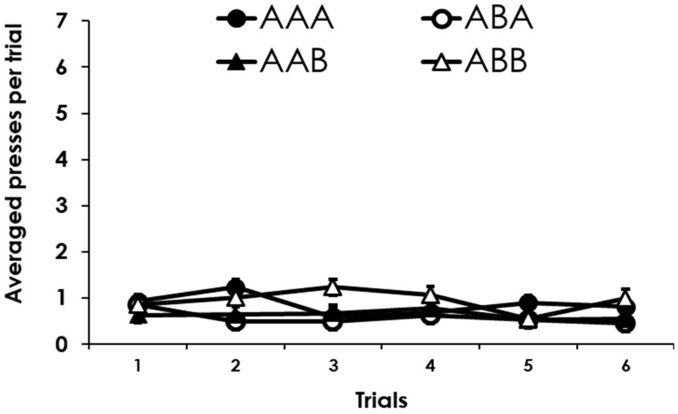


Figure 27: Responses averaged collapsing seconds (1-20) on each trial (± SEM) by group during pre-exposure.

Phase 2. Conditioning

During conditioning, it was expected to find results consistent with a latent inhibition effect for groups that experienced pre-exposure and conditioning in the same context (Group AAA and Group AAB) compared to groups that experienced a contextual change between phases (Group ABA and Group ABB). Both treatments were collapsed (AA vs AB) in further analysis. The context specificity of latent inhibition is well documented (e.g., Hall & Channel, 1985; Lubow et al., 1976; for a revision see Lubow, 1989, 2010), but, as seen in Figure 28, no strong differences were evident between groups during conditioning. A Conditioning Context (AA, AB) × Trials × Seconds confirmed no effect of Conditioning Context, $F(1, 233) = .99$, $p = .32$, $\eta^2_p = .004$. Effects of Trials $F(5, 1165) = 70.89$, $p < .001$, $\eta^2_p = .23$, Seconds $F(4, 932) = 246.03$, $p < .001$, $\eta^2_p = .51$, and Trial × Seconds interaction, $F(20, 4660) = 33.78$, $p < .001$, $\eta^2_p = .13$, were reliable. However, despite a trend in the samples for the AB condition to show slightly greater responding on some seconds, no interactions with Conditioning Context were reliable, $F(20, 4660) = 1.53$, $p = .06$, $\eta^2_p = .007$.

The effect of Seconds persisted until second 4, $p = .65$. During the last two seconds, the response was established. After collapsing the last two seconds, trials were dropped in order to find the asymptote. The effect of Trials persisted during the entire conditioning phase as confirmed a Trials effect between trials 5 and 6 in a

Conditioning Context (AA, AB) × Trials (5-6) analysis, $F(1, 233) = 10.17, p < .001$, $\eta^2_p = .08$. There remained no effect of Conditioning Context, $F(1, 233) = .72, p = .398, \eta^2_p = .003$, nor interaction, $F(1, 233) = 2.29, p = .13, \eta^2_p = .1$.

In this phase of the experiment, a context-change effect between the pre-exposure phase and conditioning was expected. AA treatment participants were expected to acquire the S+ response more slowly than AB treatment participants. Figure 28 shows that the AB sample did show some higher responding than the AA sample, but the minor increase was far from being indicative of a population difference. The lack of effect here is indicative that the participants learned something other than traditional "latent inhibition" during pre-exposure. As conditioned inhibition is not context specific (Bouton & Nelson, 1994; Nelson, 2002; Nelson & Bouton, 1997), these participants may have associated the CS with the absence of the ships that might be expected from the initial response-training phase. In addition to finding no context effect, when the context specificity of latent inhibition is a well-established effect, the data confirmed that a learning asymptote was not reached at the end of six conditioning trials and the overall response rate (1.8 presses per second) was lower than Experiment 1 (2.12). It is, of course, uncertain, what the outcome would be if the number of trials was extended to those used earlier.

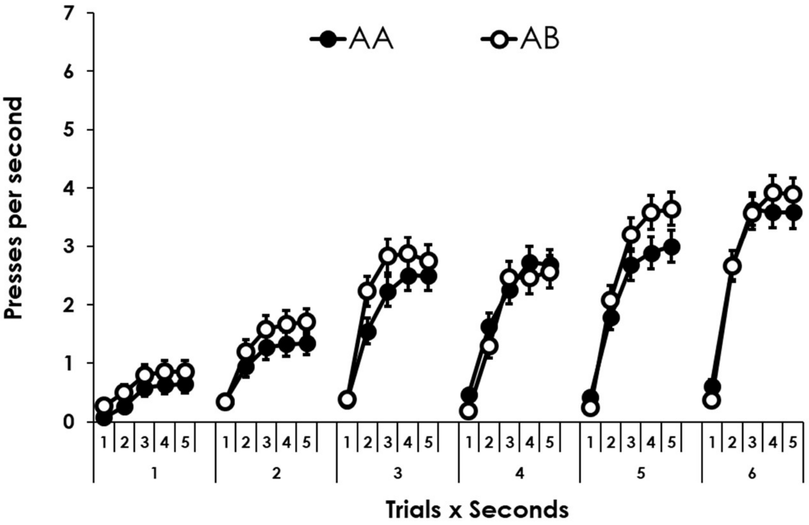


Figure 28: Responses averaged across seconds on each trial (± SEM) by treatment (AA vs. AB) during conditioning.

Test with "+"

The context change between conditioning and test produced small changes in the + response (see Figure 29). Group AAA should show strong responding, as should Group ABB as neither experience a context change from conditioning to test. However, Group ABA and Group AAB should show a loss of the + response as it was based on a second-learned association, assuming the conditioning occurred after acquiring either latent inhibition (e.g., Westbrook et al., 2000) or conditioned inhibition (Nelson, 2002; Sissons & Miller, 2009).

A Conditioning Context (AA, AB) × Test Context (A, B) × Trials (1-6) × Seconds (1-5) ANOVA of the entire phase showed no main effects of Conditioning Context, $p = .944$; or Test Context, $p = .789$, or their interaction, $p = .09$. Simple effects of Trials, $F(5, 1155) = 8.84$, $p < .001$, $\eta^2_p = .037$, and Seconds , $F(4, 472) = 385.68$, $p < .001$, $\eta^2_p = .63$, were reliable as was their interaction, $F(20, 4620) = 1.84$, $p = .013$, $\eta^2_p = .01$. However, of most interest, findings revealed a four-way interaction of Conditioning Context × Test Context × Trials × Seconds, $F(20, 4620) = 1.714$, $p = .025$, $\eta^2_p = .007$. No other effects, not superseded by the interaction or already reported, were significant.

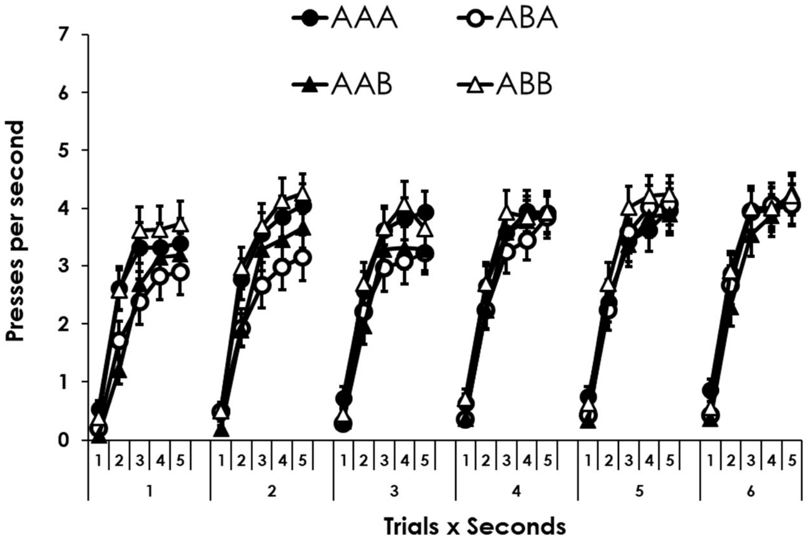


Figure 29: Responses averaged across seconds on each trial (± SEM) by group during + responses in the test phase.

The four-way interaction suggests differences among the groups on some trials of some seconds. The patterns of responding on the first three trials in the sample match what would be expected. Responding in Group ABA (open circles) was less than in Group ABB (open triangles). Responding in Group AAB (solid triangles) was less than in Group AAA (solid circles). These results in the sample are consistent with a loss of conditioned responding with a context switch when conditioning follows either simple pre-exposure or learning conditioned inhibition (e.g., Nelson, 2002). No differences were found between the two groups undergoing a context switch at test (ABA and AAB groups) $ps \geq .67$. No differences were found between the groups that were not undergoing a context switch (AAA and ABB groups, $ps \geq .88$). Interactions with Conditioning Context x Test Context crosses the same/different nature of the context change between the conditioning and test context identities. Coding the data based on a contextual change from conditioning to test (ABA & AAB combined vs AAA and AAB combined) showed differences during the first three trials, averaged over seconds for simplicity (see Figure 30). A Context (Switched/Same) × Trials (1-3) ANOVA, confirmed an effect of Context $F(1, 233) = 6.03$, $p = .015$, $\eta^2_p = .03$, and an effect of Trials, $F(2, 466) = 5.06$, $p = .007$, $\eta^2_p = .02$, and no interaction, $p = .63$.

Results are consistent with a loss of conditioned responding after a contextual change when conditioning was second learned (e.g., Nelson, 2002; Westbrook et al., 2000). The lack of effect of the context change between pre-exposure and conditioning is inconsistent with a latent inhibition account of what was learned in the first phase, but more consistent with the idea that conditioned inhibition was learned. Conditioned inhibition has not been demonstrably context-specific (e.g., Bouton & Nelson, 1994; Miguez et al., 2018; Nelson, 2002; Nelson & Bouton, 1997).

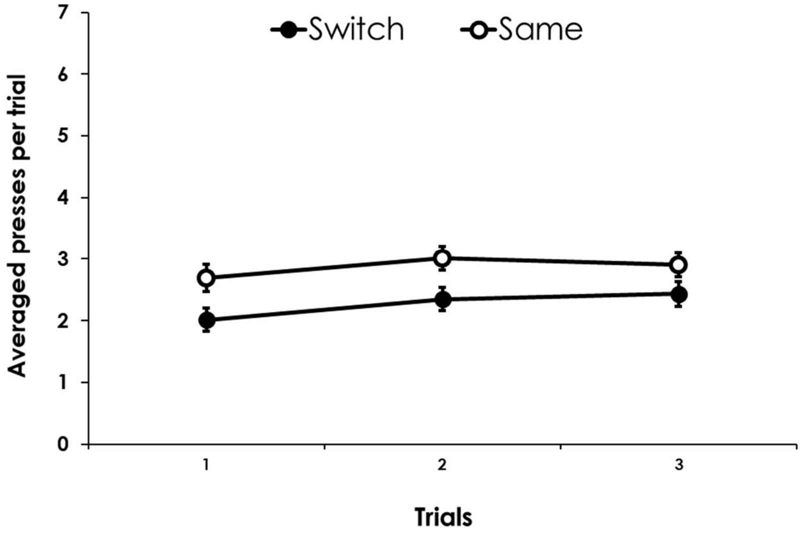


Figure 30: Responses averaged collapsing seconds (1-5) on the first three trials (± SEM) by group during + responses in the test phase.

Test with "!"

Data associated with ! are shown in Figure 31. For Group AAA, a delay in the acquisition of the ! response was expected due to S pre-exposure (i.e., LI) in phase 1 and HPNT from the S+ experience in conditioning 2. That is, to the extent that LI and HPNT are responsible for its performance it should be showing both effects in the acquisition of the ! response and be the slowest of the four conditions.

Group AAB experiences conditioning with ! outside of both the contexts of exposure and conditioning, where LI and HPNT each should have been acquired, and show less of each. Thus, acquisition of the ! response in group AAB should be the most rapid of the four groups.

Group ABA should show an attenuated HPNT effect, as it is outside the context where the NT training occurred. But, it is in the context where LI training occurred. Thus, their acquisition should be more rapid than that of the AAA condition (having lost HPNT), but less rapid than AAB (if LI is recovered). The final group, ABB, is in the context of HPNT training, but outside the context of LI training, thus they should show the effects of HPNT and their acquisition should be more rapid than that of the AAA condition, but less rapid than AAB. Comparison of the ABA and ABB conditions allow a comparison of the LI and HPNT effects, assuming the effects of context change on each are similar.

The results from the conditioning phase, where the context change had no effect, suggests that the effect of pre-exposure in this experiment may not have produced latent inhibition. Rather, it may have produced conditioned inhibition. That possibility is consistent with the previous experiment where the LINT and NT conditions were both equally slow in acquiring the + response in conditioning. The presence of strong inhibition might obscure any effect of HPNT. If the S stimulus acquired conditioned inhibition (i.e., expectations of the absence of any of the four ships used in response training), then that inhibition for ! should be more or less equally present regardless of the context, and there would be no group differences.

The results supported the latter pattern. All groups responded the same. A Conditioning Context (A**A**, A**B**) × Test Context (A, B) × Trials × Seconds ANOVA demonstrated no effect of Conditioning Context, $p = .894$. Nor effect of Test Context, $p = .827$. Simple effects of Trials, $F(5, 1155) = 96.83$, $p < .001$, $\eta^2_p = .295$, and Seconds, $F(4, 472) = 343.65$, $p < .001$, $\eta^2_p = .598$, were found, and also their interaction, , $F(20, 4620) = 31.07$, $p < .001$, $\eta^2_p = .12$. However, no interactions involving Conditioning Context or Test Context were reliable $ps \geq .091$.

Effects of Seconds persisted until the last two seconds (4-5), $p = .119$. After collapsing seconds (4-5) and dropping trials, the asymptote was found after trial 3 in a Conditioning Context (AA, AB) × Test Context (A, B) × Trials (4-6) ANOVA, in which effect of Trials was not found, $p = .081$. Findings revealed no effect if Conditioning Context, $p = .749$, Test Context, $p = .798$, nor any interactions, $ps \geq .222$.

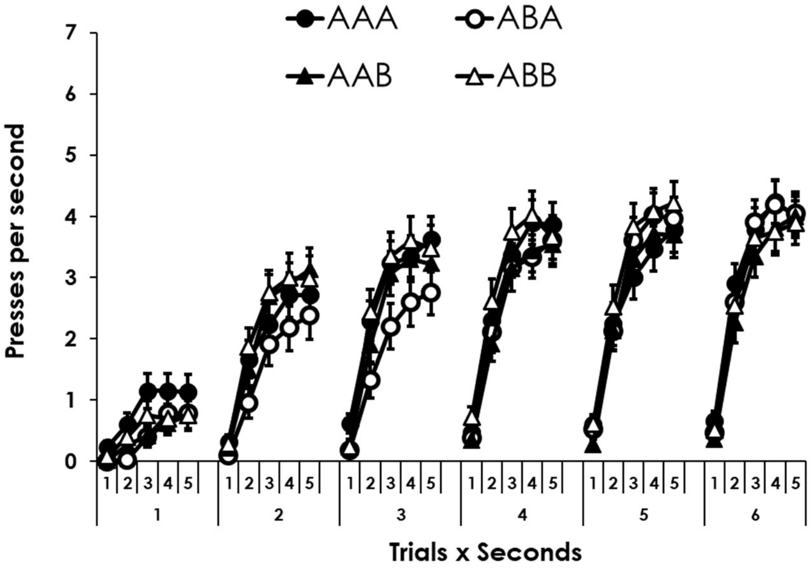


Figure 31: Responses averaged across seconds on each trial (± SEM) by group during ! responses in the test phase.

Experiment 3 (C3E3)

The lack of context effects on the learning presumed to occur during the first phase, combined with the context switch effects on the learning about + in phase two, suggests that the pre-exposure phase resulted in the acquisition of conditioned inhibition, rather than context-specific latent inhibition. Conditioned inhibition (e.g., Rescorla, 1969) is typically discussed as the learned potential of a stimulus to suppress the retrieval of some outcome expectation. Operationally, subjects are typically trained with an A+ / AX- procedure. In this procedure, the CS A is reinforced with a US on some trials, but is not reinforced when presented in compound with the intended inhibitor (X), on other trials. The absence of the outcome, whose expectation is produced by A, allows X to acquire inhibitory properties.

One of the main characteristics of CI, contrary to many assumptions of LI, is that a conditioned inhibitor passes a summation test (Rescorla, 1971). A summation test is based on the simple idea that conditioned inhibition counteracts or inhibits conditioned excitation. To observe conditioned inhibition, one has to measure how the presentation of the CS- inhibits or suppresses the response that would normally be elicited by a CS+. Thus, the typical observation is less responding by the subject to a test excitor (B) when is presented in compound with the conditioned inhibitor (i.e., BX) than if it was presented alone or in compound with a neutral stimulus.

CI is learning about the absence of something specific rather than general, and has been shown to be insensitive to context changes (e.g., Bouton & Nelson, 1994; Nelson, 2002). Nelson (2002) used a retardation test where the inhibitor was reinforced in either the same context as training or a different context and showed no differences between the contexts when a simple inhibitor was tested. A prior conclusion that inhibition transferred perfectly to another context was based on only a single trial in Bouton and Nelson (1994) and was based on an average of the first two trials of the summation test in Nelson and Bouton (1997). Nelson's (2002) conclusion that conditioned inhibition is not affected by a context switch is somewhat stronger because it was based on a within-subjects analysis of six trials. Nelson concluded that associations construed as either excitatory or inhibitory, are relatively insensitive to context change when they are first-learned, as opposed to second-learned.

Interestingly, Hall and Rodriguez (2010) assume that the mechanism behind latent inhibition, the formation of a “No Event” association, is the same as that behind conditioned inhibition. Clearly, a latent inhibitor "passes" the retardation test; but its efficacy in the summation test procedure is more debatable (e.g., Reiss and Wagner, 1972; Rescorla, 1971; Solomon et al., 1974). Failures of pre-exposed stimuli to pass summation tests have been attributed to the inhibition formed simply through pre-exposure being not strong enough to affect the response of another CS (Liberal et al., 2020).

Liberal et al. (2020) predicted that in situations where several things are occurring during pre-exposure, a stronger event expectancy will be generated, resulting in a stronger association with the non-event being formed. If the association with the non-event is strong enough, the pre-exposed CS could pass a summation test (Rescorla, 1969). Liberal and colleagues tested this idea by manipulating the number of different stimuli occurring during pre-exposure. In one of their experiments, rats were pre-exposed to a signaling light (A) 32 times, and each time it was accompanied by a different novel sound (NDs), or not, between groups. With each presentation of NDs, the expectation that some event will occur should rise since each novel stimulus should cause some expectation of something happening. In the case that nothing happens after that, the NDs cause A to develop a stronger connection with nothing happening. After pre-exposure, a different key light (X) was conditioned to serve as a target in a summation test in which the two key lights were presented together.

There was less response to compound XA than to X alone in conditions where A had been accompanied by ND. The pre-exposed CS passed the summation test, and this was assumed to be the result of the acquisition of a strong non-event association.

The result demonstrated by Liberal et al. (2020) indicates that a latent inhibitor can acquire some form of inhibitory potential perhaps by eliciting a non-event representation. When that representation is relatively weak, it only affects acquisition (retardation test; Rescorla, 1969). When it is relatively strong, it should affect both acquisition and expectations elicited by other stimuli on summation trials. Those data support the hypothesis that, at least part of the latent inhibition effect, comes from interference as predicted by Hall and Rodriguez (2010). However, according to the theorizing of Hall and Rodriguez that inhibition is still a second-learned type of association, conflicting with the “Event” expectation and should be context specific, which conflicts with studies of traditional conditioned inhibition where context specificity has not been observed (Bouton & Nelson, 1994; Nelson, 2002; Nelson & Bouton, 1997). Additionally, where inhibition may have been acquired, as in the prior experiment, the effects of pre-exposure on acquisition were not affected by a context change.

There are additional data to be considered as to whether latent inhibition is a weaker form of conditioned inhibition. One of the features of CI is that it is outcome-specific (e.g., Delamater et al., 2003; Holland, 1989; Rescorla, 1969). For example, Holland (1989), found that CI did not transfer across different USs with qualitatively different motivational characteristics. However, LI following simple pre-exposure to a CS does not appear to suppress learning about specific USs. That is, LI slows learning between stimuli generally, while CI is a mechanism by which one stimulus, relatively specifically, predicts the absence of another. Moreover, CI has been shown to be affected by pre exposure (e.g., Killcross & Balleine, 1996; Rescorla, 1971). That effect would not necessarily be expected if a pre-exposed stimulus has a head start on acquiring inhibition, unless it is a HPNT type of effect. Conditioned inhibition has been shown to be little affected by context change (Bouton & Nelson, 1994; Nelson, 2002; Nelson & Bouton, 1997), yet the type of second-learned no-event learning that takes place during pre-exposure to account for latent inhibition is. Overall, CI appears to be different than the type of inhibition imagined by Hall and Rodriguez (2010) which is more general.

The next experiment was designed to evaluate whether the stimuli used in the previous experiment could have acquired context-inspecific conditioned inhibition. The design is summarized in Table 7. All groups were pre-exposed to the S-sensor in context A, and then conditioned with a new sensor (W) in context A or B. Finally, a summation test was conducted in the conditioning context for each group with the S-sensor (for experimental groups, Group AAA and Group ABB) or a different sensor D for control groups, AAActrl and ABBctrl. As W was a novel sensor for which no group had experience, rapid acquisition of the response was expected during conditioning. The goal was to assess CI and its context specificity. If S acquires inhibitory properties during pre-exposure, the response towards the SW compound during the test will be lower than that obtained during the DW control for which only some external inhibition/generalization decrement should operate. Prior results have indicated that CI is not context specific, so no effect of context is expected.

Table 7.
Design of Experiment 3, Chapter 3.

Group	Preexp	Cond	Test
AAA	**A: S-**	**A: W+**	**A: SW-**
ABB	**A: S-**	**B: W+**	**B: SW-**
AAActrl	**A: S-**	**A: W+**	**A: DW-**
ABBctrl	**A: S-**	**B: W+**	**B: DW-**

Note: Design of Experiment 3 in which A and B were markedly different contexts (Boutonia or Nicholosia, counterbalanced). “S” and “D” were the red or green sensors (counterbalanced), used in the prior experiments. “W” was a white sensor used as the transfer excitor. “-” indicates no US or nor enemy attack while “+” indicates the appearance of the enemy spaceships or US (Learian or Stellarian, counterbalanced).

Method

Subjects

Two hundred ninety participants from the Prolific platform were randomly assigned to one of four groups, Group AAA (n= 84), Group ABB (n= 71), Group AAActrl (n= 68), and Group ABBctrl (n= 67). Twenty three participants were removed from experiment because they did not show adequate trained responses to the presence of the outcome spaceship itself (less than an average 3 responses per second in the last three conditioning trials). The same language criteria were used and participants were collected from the countries mentioned above. All procedures were approved by the relevant institutional review board.

Apparatus

The apparatus used was the same as in Experiment 2.

Procedure

Conditions were randomly assigned until all counterbalances (CSs, USs, contexts, and orders) were completed and then re-entered into the pool, though subject attrition slightly affected final values as in Experiments 1 and 2. When the subject was ready to start, a press on the "B" key initiated the experiment. Instructions were delivered to the participant as in the previous experiment.

Response training. Response training occurred as Experiment 1 and 2.

Phase 1. During Phase 1, all groups received two blocks of three pre-exposure trials with stimulus S without consequences in context A. S and D were either red or green flashing sensors, counterbalanced. Context A was Boutonia or Nicholosia backgrounds, counterbalanced.

As in the previous experiment, groups experienced six presentations without the CS or US in context B (Boutonia or Nicholosia, counterbalanced) in blocks of three in a row. The order between A and B block presentation were counterbalanced as in the previous experiment.

On each trial, the CS (or its absence) was presented for 20-s. 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. The appearance of the spaceship (the same two as used in the prior chapters were used here, counterbalanced) was signaled by the appearance of a colored flashing sensor light (W) located on the control panel just below the pre-sensor S. During Phase 2, Group AAA and Group AAActrl received six trials of conditioning with W in context A. On the other hand, Group ABB and Group ABBctrl received the same treatment but in context B. In this experiment, the filler trials (B+!) were removed because participants did not need practice simultaneously responding to the two outcomes. The ITI was the same as Phase 1.

Summation Test. Groups received a nonreinforced trial with sensor W in combination with S (Group AAA) or D (Group AAActrl) in context A, or S (Group ABB) or D (Group ABBctrl) in context B. Timing parameters were the same as Phases 1 and 2.

Results and Conclusions

Phase 1. Pre-exposure

Responding was averaged across the entire 20s as there was no outcome during this phase (see Figure 32). Kruskal-Wallis tests confirmed that no differences existed between groups on any trial, *ps* $\geq$ .193. Because there were no group differences, groups were collapsed for a Friedman test, which showed an overall effect of Trials, $p < .001$. There were no differences between trials 1 and 2, $p = .13$. In both trials (1.1 and .98, respectively) the response was larger than trials 3 (.69) 4 (.89), 5 (.88), and 6 (.84), *ps* < .03. There were no differences between trials 3 - 6, $p \geq .085$.

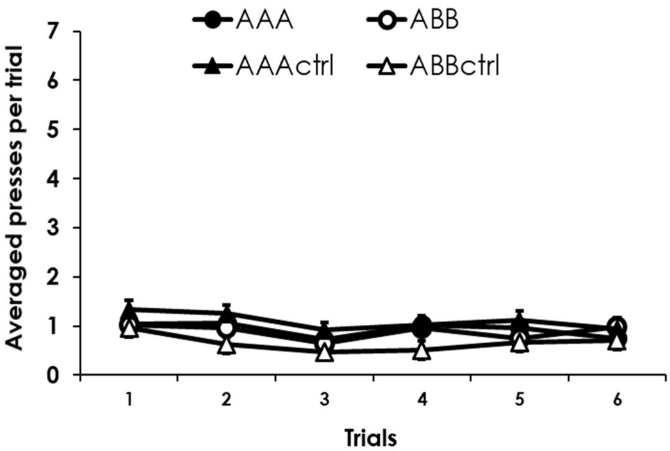


Figure 32: Responses averaged (1-20 seconds) on each trial (± SEM) by group during pre-exposure

Phase 2. Conditioning

Data from conditioning are shown in Figure 33. A Group × Trials × Seconds ANOVA confirmed no pre-existing differences associated with Group assignment, $p = .306$. Simple effects of Trials, $F(5, 1430) = 148.05$, $p < .001$, $\eta^2_p = .34$, Seconds, $F(4, 1144) = 486.05$, $p < .001$, $\eta^2_p = .63$, and Trial × Seconds interaction, $F(20, 5720) = 39.34$, $p < .001$, $\eta^2_p = .12$, were reliable. However, no interactions with Group were observed, *ps* $\geq$ .069.

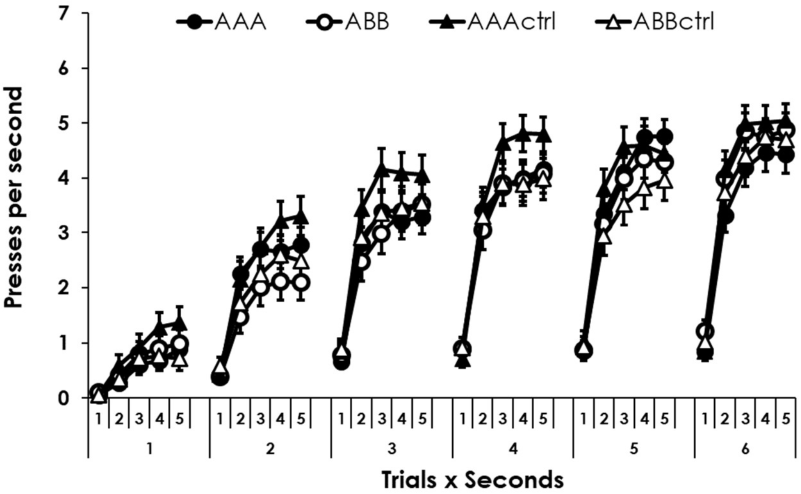


Figure 33: Responses averaged across seconds on each trial (± SEM) by group during conditioning.

Summation Test

The summation test consisted of presenting W and S (experimental groups) or W and D (control groups) at the same time on the trial. Because there was no outcome in this test, the entire 20-seconds of the test were analyzed. A Context Change (AA, AB) × Exposure (S, D) × Seconds ANOVA confirmed no effect of Context Change, $p = .291$. Neither the interaction of Context Change with Seconds, $p = .381$, Exposure, $p = .111$, nor the three-way interaction, $p = .712$, were found. However, of most interest, the effect of Exposure, $F(1, 286) = 7.7, p = .006, \eta^2_p = .03$, and the Exposure × Seconds interaction were reliable, $F(19, 5434) = 4.1, p = .01, \eta^2_p = .01$. The effect of pre-exposure is presented in Figure 34, where groups were collapsed across the insignificant context effect to show the effect of testing with the same stimulus that was pre-exposed (S) or a different (D) novel one.

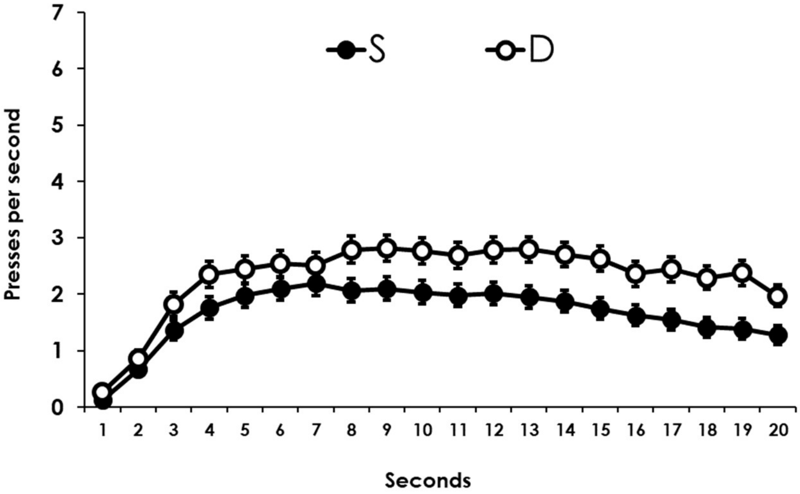


Figure 34: Responses averaged across seconds (± SEM) by stimulus during ! responses (Trial 1) in the summation test (SW- or DW-).

This result suggested that the stimulus used in pre-exposure acquired some inhibitory properties consistent with conditioned inhibition, which inhibited the response to W. In summary, the pre-exposed S inhibited the response to the excitor W in comparison to the novel D. This result is consistent with conditioned inhibition passing a summation test. In addition, the effect of context change was not found, which is consistent with the context in-specificity of conditioned inhibition (e.g., Bouton & Nelson, 1994).

Discussion

The experiments presented here used a different procedure due to the COVID-19 pandemic. Three experiments were conducted through the Prolific platform. The first served to confirm that the same effects obtained in the in-person procedures were found through the online platform. The second incorporated contextual changes to its design to assess whether both the latent inhibition effect and the Hall-Pearce negative transfer effect were recoverable with a contextual change. The addition of a new outcome that was responded to independently allowed us to assess reliably whether the LI was retrieved and the typical loss of the response conditioned after pre-exposure (e.g., Westbrook et al., 2000) was more than simply second learning being context-specific (e.g., Nelson, 2002). Finally, the third experiment reported the possibility of having obtained conditioned inhibition during Experiments 1 and 2.

The results obtained in Experiment 1 were largely consistent with those obtained during Chapter 2. An LI effect (in the LINT Group) was observed during the first conditioning phase. During the test associated with the + responses, it was observed that the LINT Group obtained a lower response rate compared to the other two groups. Regarding acquisition of the new ! response, an HPNT effect was observed for the LINT and NT groups which was consistent with what was observed during Chapter 2 and the pioneering human studies by Griffiths et al. (2011). Observing the HPNT effect also further alleviated the doubts proposed by Le Pelley et al., (2016) who stated that the attempts to replicate the negative effect of Griffiths et al. (2011) have been mixed. However, the effect was larger in this experiment than those previously conducted in-person in the laboratory, which questions whether the mechanism being demonstrated is the same across the chapters.

Latent inhibition is a highly context-specific phenomenon (e.g., Bouton & Swartzentruber, 1986; Gordon & Weaver, 1989; Gray et al., 2001; Hall & Channel, 1985; Lovibond et al., 1984; Nelson & Sanjuan, 2006; Westbrook et al., 2000), yet, in Experiment 2 context specificity was not observed. All groups, pre-exposed in the same or a different context as that of conditioning, responded the same during conditioning. Nor was an effect observed with HPNT insofar as contextual change also did not attenuate its effect (e.g., Swartzentruber & Bouton, 1986).

Nevertheless, after conditioning a context-switch effect was observed. Groups that received testing with the initially conditioned + response showed less of that response when tested in a different context. That loss of responding is consistent with Nelson (2002) and could reflect the simple contextual control of second-learning, or some recovery of the learning from phase 1. The test with !, however, showed no effects of context. Regarding pre-exposure's ability to affect acquisition, whether it was of the + response immediately after pre-exposure, or the ! response after acquisition of the + response, there was no effect of a context change. This aspect of the finding suggests that these participants may have treated the pre-exposed cue as a conditioned inhibitor, which should be minimally affected by context change.

Nelson (2002) among others (see for example Harris et al., 2000) reported that second learning about a cue that contradicted the first learning was contextually controlled. The results obtained during the test associated with the + responses were consistent with the findings of Nelson (2002). The learning acquired during conditioning was contextually controlled. That is, groups that underwent a contextual change between conditioning and test (i.e., ABA & AAB) responded less than groups in which the context was not changed (i.e., AAA & ABB).

Experiment 3 included a summation test to assess whether the groups in Experiment 2 might be learning conditioned inhibition (e.g., Rescorla, 1969) during exposure to the S sensor in the absence of the spaceships which might be expected from the response-training phase and instructions. The results obtained confirmed that the sensor S had acquired inhibitory properties, consistent with conditioned inhibition.

The data in all three experiments using the online method are consistent with the idea that S became a conditioned inhibitor. In E1, Groups LINT and NT behave in the same way. In E2, no effect of context on the pre-exposure effect was found, but an effect on the second-learned association was demonstrated. Finally, in E3, stimulus S passed a summation test.

However, finding CI in this series of experiments is not consistent with the results of Chapter 2. In in-person experiments using the same methods and procedures Nelson et al., (2021) ruled out that pre-exposure produced CI, and C2E2 ruled out that that a CI effect was mediating the results of the NT group. The smaller HPNT effect seen in Chapter 2 is also consistent with different mechanisms operating between the chapters.

Online participants are a different demographic from in-person studies with students. Features of an older sample of participants (40 years old on average in online experiments), combined with the nature of the platform from which they are being paid to participate, and demand characteristics (e.g., Orne, 2009) may produce motivations to perform "correctly," however an individual may define that, that systematically influence learning. For example, Nelson et al., (2022) observed that the contextual specificity of LI was reversed, showing more LI with a context change, when participants were eye-tracked, and suggested that eye-tracking may be producing demand characteristics that affect the learning in pre-exposure. In this case, demand characteristics to perform could maintain better expectations from the instructions and response training phase into the pre-exposure phase, contributing to the formation of conditioned inhibition.

The retardation produced by CS pre-exposure is probably multiply determined and this chapter introduces new variables that might drastically affect the cause. These variables and the questions that this chapter suggests may be at play go beyond the scope of the initial research objectives and open interesting avenues for continued research.

General Discussion

General Discussion

The project was to determine the impact of various mechanisms proposed to explain the LI phenomenon. As discussed in the introduction, LI is an effect that is empirically demonstrated as a delay in the acquisition of a CR during CS-US pairings due to pre-exposure to the CS alone (e.g., Lubow & Moore, 1959). More conceptually, it delays the acquisition or expression of a CS-US association. It is established that CS pre-exposure affects both excitatory (e.g., Bouton, 1993) and inhibitory (e.g., Killcross & Balleine, 1996) learning.

Most theories point to latent inhibition as a decrease in attention or associability to the CS (e.g., Le Pelley, 2004; Mackintosh, 1975; Pearce & Hall, 1980). Simply put, attention to the stimulus would decrease during pre-exposure making it more difficult to learn about in a later stage compared to a group for which that stimulus is novel.

Other authors have proposed LI as a deficit in the behavioral expression of the CS-US association (e.g., Bouton, 1993; Hall, 1991). According to these models, during pre-exposure subjects learn that the CS is followed by no consequence (e.g., CS-“noUS”, Bouton, 1993; CS-“No Event”, Hall & Rodriguez, 2010). Subsequent learning of the CS-US association proceeds normally, but the relationship is not well expressed due to the interference produced by the initial learning. Once the CS has been pre-exposed and conditioned, its presentation may activate two different types of information, which interfere with each other.

A main feature of LI is that it is context specific. Many studies have reported that the LI effect, present when subjects are pre-exposed, conditioned, and tested in the same context, is attenuated when the pre-exposure is in one context but the conditioning and test are in different contexts (e.g., Hall & Honey, 1989; Nelson & Sanjuan, 2006). This issue is not directly accommodated by attention-based models (e.g., Le Pelley, 2004; Mackintosh, 1975; Pearce & Hall, 1980) as they make no explicit assumptions about context change restoring attention (but see, Schmajuk, Lam & Gray, 1996). However, the effect is consistent with the interference model of Hall and Rodriguez (2010) who assume that latent inhibition produces new learning (i.e., “no Event”) that interferes with current expectations (i.e., “Event”), resulting in it becoming context specific.

A third class of models that explain LI and its context-specificity I labeled as Contextual Association Dependent (CAD) in this work. With their differences, the three that are encompassed by the acronym (i.e., McLaren & Mackintosh, 2000; Schmajuk et al., 1996; Wagner, 1981) all share an emphasis on context forming associations with the pre-exposed stimulus that hinders subsequent learning about that stimulus.

In the first chapter, bidirectional associations between a CS and an outcome were used with the goal of differentiating attention and interference-based accounts of the LI effect. A secondary goal in chapter one was to convincingly demonstrate the effect in humans without having to resort to masking tasks. The use of masking tasks in LI experiments has been widely criticized for being not being able to excluded other phenomena such as negative priming (e.g., Graham & McLaren, 1998) or learned irrelevance (e.g., Le Pelley & Schmidt-Hansen, 2010). Byrom et al. (2018) raised many of the same doubts about whether the psychological mechanisms underlying the LI phenomenon are the same in animals and humans. Despite subsequent demonstrations of LI without using masking tasks (e.g., Nelson & Sanjuan, 2006) it has been debated that the mechanisms are still unclear by alluding to the use of instructions that guide the task and other factors (e.g., Nelson et al., 2021).

Experiment 1 in Chapter 1 (C1E1) alleviated doubts about LI in humans by using a method without instructions or masking tasks. Participants were unaware of the purpose of the experiment and were simply instructed to watch a short video. Furthermore, C1E1 results were consistent with a context-specific LI effect, which would move the result away from attention-based theories that do not include a role for context in their explanation of LI. The results were explainable by an interference account and CAD theories.

However, results from C1E2 align more consistently with theories attributing the observed effect to the attention or processing of the cue that depend on the context (CADs models), rather than interference-based accounts. The results in C1E2 which tested for Glowing Hands→Moon (outcome→Cue) associations preclude the possibility that any association formed to the Moon during pre-exposure could produce interference. In this case, the deficit would be better described as arising from a change in the way the Moon was processed.

The new method was successful. Nevertheless, the implementation was time consuming, involving the creating of 108 videos from slides to fully counterbalance stimuli and sequences. Moreover, the extensive preparation leaves many places for error and is not presently an efficient means of investigation.

The goal of Chapter 2 was to better distinguish interference and attention accounts from CAD mechanisms by paying attention to the asymptotic response. Some theories predict no difference (e.g., Mackintosh, 1975; Pearce & Hall, 1980) in asymptotic learning, while others (e.g., Wagner, 1981) are able to predict asymptotic differences after pre-exposure.

Chapter 2 used a video game method (e.g., Nelson et al., 2014; 2021) in which participants learned the relationship between a cue (e.g., a colored sensor) and an outcome (e.g., enemy spaceship). The method also allows the use of two simultaneous and different outcomes at the same time. Participants could respond independently to both outcomes, using both their right and left hands. The additional outcome allowed assessing the persistence of LI, as an acquisition deficit. Introduction of an outcome, particularly a new outcome, should be effective in restoring attention according to attention-based models, while context-cue associations responsible under CAD models should be unaffected.

The assessment of the persistence of LI as an acquisition deficit was also important for Chapter 3, where I would be investigating LI's persistence after context switches. Assessments of LI after conditioning could involve the Hall-Pearce Negative Transfer effect (HPNT; Hall & Pearce, 1982), an effect that has received little investigation in humans, thus its assessment was included through the NT group. This latter group, and the use of two outcomes, allowed for the potential comparison of LI and HPNT, which have been assumed by theories of LI to result from the same mechanism.

Chapter 2 findings for Group LINT were in line with Wagner's (1981) model, as it predicted the persistence of the LI effect and variations in the asymptotic response during both conditioning and testing phases (both + and !) as observed in C2E1 and C2E3. However, based on the same mechanism it would be anticipated that the LI and NT results should also be manifest at asymptote when compared to Group Control, which did not occur. The LI and NT effects were transient and reflected differences in the rate of acquisition only. Nevertheless, Group LINT had more the exposure to S (pre-exposure and conditioning) and more opportunity to form the Context-Stimulus associations necessary to produce asymptotic differences.

Results consistent with a HPNT effect were obtained in C2E1 and C2E3. A HPNT effect (Group NT) in human participants was demonstrated, which in addition to a lack of presence in the literature (but see Griffiths et al., 2011), Le Pelley et al., (2016) had questioned its replicability. C2E2 confirmed that the HPNT effect was consistent with change in CS processing (e.g., Pearce & Hall, 1980) but not conditioned inhibition, which the two-outcome nature of the design could have permitted to be learned in the first phase of conditioning with only one outcome. As with other demonstrations, the HPNT was incompatible with the attention model proposed by Mackintosh (1975). Moreover, the result was inconsistent with interference accounts (e.g., Bouton, 1993), since the first outcome, +, still present in phase 2, should not interfere with the second, !.

Data obtained in C2E1 and C2E3 provided another observation of LI during conditioning (Group LINT). One of the most interesting observations is that the learning deficit of Group LINT appeared during the conditioning trials of phase 2, and continued during the +! trials of phase 3. The presence of the stimulus in phase 2 phase, even though it is being conditioned, in some way maintained the effect. However, the absence of the stimulus during this phase (Group LI) attenuated the effect. Group LI (in C2E1) was expected to suffer retarded acquisition because of the pre-exposure in phase 1. However, no evidence for delayed or attenuated acquisition was found. Group LI behaved in the same way as Group Control. It possible that inserting the conditioning phase with a different CS could have attenuated the latent-inhibition effect for Group LI as the effect is very sensitive to context changes and the passage of time (e.g., Aguado et al., 1994; Channel & Hall, 1983).

Maintaining the deficit in group LINT after conditioning raises the question as to what mechanism maintains it. Apart from the cue suffering a change in its representation, altering its ability to enter into associations and elicit performance (e.g., Wagner, 1981), there could be some retrieval and rehearsal of the learning from phase 1. Rehearsal refers to a maintenance process involved in keeping information available (e.g., Oberauer, 2019). Overall, many theories of working memory (e.g., Atkinson & Shiffrin, 1968; Oberauer & Lewandowsky, 2011) assume that some form of rehearsal plays an important role in maintaining and learning information, including the memory model proposed by Wagner (1978) which laid the framework for Wagner's 1981 theory.

In the case of the experiments described, even though the cue is being paired with an outcome, recall and rehearsal of the phase 1 learning could affect subsequent performance, without necessarily affecting learning (e.g., factoring into a prediction error). In the absence of that rehearsal, the LI group which had a phase of conditioning with a different stimulus inserted between pre-exposure and conditioning may have been unable to successfully retrieve the phase 1 experience. Or, the introduction of the conditioning in phase 2 could be viewed as a context change, as the recent events (Bouton, 1997) prior to conditioning in phase 3 were different than during pre-exposure. Another possibility, consistent with Wagner, involves the extinction of context-cue associations. As the intervals suspected to be responsible for the failure to observe LI were spent in the pre-exposure context, extinction of the context-CS associations (see for example Baker & Mercier, 1982) could have occurred, removing the stimulus from the A2 state. It would be necessary to compare Group LI in C2E1 and a version similar to C2E3 (i.e., R- | -- | R+! vs. -- | R- | R+!, respectively) in order to assess the role of the interval. Eliminating the phase 2 conditioning should eliminate any potential context change caused by recent events. To assess context-cue extinction's contribution, the interval could be spent in the same context where extinction could occur, or a different one.

However, there is still an issue of the LI effect being transient in C2E3. Participants received conditioning in phase 1 with a different CS, then experienced a pre-exposure of the CS in phase 2, and showed LI in phase 3. But, the effect of LI was smaller than that shown by the LINT group in phase 2, when at this point the two groups had had the same number of context-CS associations (one pre-exposure phase, 6 trials).

Two ideas emerged to explain this difference. In the first one, it was suggested that the LI group had more experience with the type of conditioning in phase 3 than the LINT group in phase 2. This was due to the fact that in the first phase the LI Group had experience with 12 conditioning trials, so the difference could reflect a learning-to-learn effect (e.g., Balea et al., 2018). In the second, possibly the conditioning with +! was a larger change in context (e.g., Bouton, 1997; Hall & Channel, 1985; for a discussion see Holmes & Harris, 2010) for the LI group in phase 3 than for the LINT group in phase 2. So, the LI group in phase 3 benefits from both that bigger context change produced by two USs compared to LINT phase 2, and learning-to-learn.

In summary, the results showed a pre-exposure effect that persisted beyond conditioning. Results failed to show a simple pre-exposure effect when conditioning with another stimulus was inserted between the pre-exposure and conditioning phases, but they did show a pre-exposure effect when the two phases were contiguous. An effect consistent with HPNT was also observed, and it likewise disappeared when a phase was inserted between phase 1 and the phase where the cue was paired with a second outcome. Overall, the results are most consistent with the theorizing of Wagner (1981). During pre-exposure context-cue associations form that change the representation of the cue to one for which it is difficult to acquire new associations. That representation interferes both with the acquisition and expression of new learning, which can produce a consistent deficit as was observe in the LINT groups. The LI and HPNT groups showed smaller deficits, which may be due to having less opportunity overall to form context-cue associations. Inserting a phase between pre-exposure and testing appeared to eliminated both the LI and NT effects, which is consistent with extinction of the Context-CS associations thought responsible for them. Future work should directly compare groups that receive LINT training to those that simply receive the same number of exposures, non reinforced, to the cue in order to further delineate the cause of the asymptotic differences reached in the LINT condition.

Due to the COVID-19 pandemic, the studies in Chapter 3 were conducted with online participants through the Prolific platform (www.prolific.com). It was an adaptation of the instrument used in Chapter 2 with minor changes detailed earlier. Chapter 3 was included to examine whether what is learned during pre-exposure can be re-expressed in the correct context. Chapter 2 shows that the pre-exposure effect persists through conditioning. The question asked by Chapter 3 is whether, once lost due to a context change (e.g., Bouton & Swartzentruber, 1986), is the deficit-producing mechanism recovered when tested in the pre-exposure context, or is the conditioning acquired in phase 2 simply context-specific itself (e.g., Nelson, 2002) and lost. While the recovery of LI has been suggested (e.g., Westbrook et al., 2000), the evidence is not clear. The type of test used (a non-reinforcement test where the same CR learned during conditioning was tested; e.g., Westbrook et al., 2000) was not able to answer the question of whether the response loss was a consequence of the LI being retrieved or of second-order learning being context-specific (e.g., Nelson, 2002).

Interference accounts predict that CS-NoUS (Bouton, 1993) or CS-NoEvent (Hall & Rodriguez, 2010) associations are learned during pre-exposure. This learning would compete with the association learned during conditioning and context would play an important role. In addition to attenuating the effect if the change occurs between pre-exposure and context, the contexts would control both learning episodes, which could be expressed in the correct context. The CAD mechanisms (e.g., Wagner, 1981) also predict a recovery. A return to context A after conditioning in context B should return the stimulus to a contextually-controlled state (e.g., A2). That state return should both produce a deficit in further learning, and a performance decrement as that state, at least the A2 state described by Wagner, is assumed to be less effective in generating responses. Attentional accounts (e.g., Schmajuk et al., 1996) that assume a role for context-CS associations in affecting attention can also predict a recovery of LI.

Although a similar instrument was used, the characteristics of the sample and the user experience were different so Experiment 1 (C3E1) was conducted with the objective of evaluating whether the same effects obtained in face-to-face participants were the same as those found online. The findings of C3E1 were mainly in line with Chapter 2. During the first conditioning phase (phase 2), there was an evident LI effect (Group LINT). In terms of learning the new response (!) in phase 3, the LINT and NT groups showed a HPNT effect, which was highly in line with findings from Chapter 2 and the landmark human research by Griffiths et al. (2011). However, the HPNT effect was larger in this experiment than those previously conducted in-person in the laboratory, which questions whether the mechanism being demonstrated is the same. No behavioral differences were found between the LINT and NT groups during response acquisition, which was observed in Chapter 2, again questioning the mechanism.

Experiment 2 in Chapter 3 (C3E2) incorporated contextual changes that would allow the assessment of LI persistence in an ABA procedure, where LI learned during pre-exposure could be expressed when the test consisted of a return to the pre-exposure context. As discussed above, the method used allowed the test to consist of an acquisition test with a novel outcome. No context-dependent LI effect was observed, which is a well-documented effect (e.g., Hall & Channel, 1985; Nelson &

Sanjuan, 2006) that has been observed with this method (Nelson et al., 2021, 2022). It did not matter whether there was a contextual change between pre-exposure and conditioning (AB) or not (AA). All groups acquired the same response during conditioning. The results suggests that perhaps the participants learned conditioned inhibition during pre-exposure. If participants had a strong expectancy of the four ships to which they had previously been trained to respond, the pre-exposure cue could become an inhibitor for those outcomes. Conditioned inhibition does not appear to be context specific (e.g., Bouton & Nelson, 1994).

If CI is learned in phase 1 then that would make +, a second-learned association, context specific on test. The patterns of responding on the first three non-asymptotic trials match what would be expected based on a conditioned-inhibition account. Responding in Group ABA was less than in Group ABB. Responding in Group AAB was less than in Group AAA. These results with + are consistent with a loss of responding due to the second learning becoming context-specific (e.g., Nelson, 2002), and consistent with the effects observed by Westbrook et al., (2000) examining contexts changes after pre-exposure and conditioning. On the other hand, the changes of context should not affect learning the ! outcome. The ! outcome remained absent in phase 2 so, despite becoming excitatory for +, the cues should still be inhibitory for ! and there should be no effect because CI is not context-specific.

Finally, in C3E3 a summation test was run to evaluate whether, during pre-exposure, participants learned that the CS (i.e., S) was a conditioned inhibitor. The results obtained indicated that the pre-exposed CS had acquired sufficient inhibitory strength to inhibit the response of an elicitor (i.e., W) during a non-reinforced test in which both stimuli were presented in combination, and were compared to a control in which the elicitor was presented as a novel stimulus (i.e., D).

Overall, the results obtained during Chapter 3 were different from those obtained in Chapter 2. In Chapter 2, the influence of CI was ruled out as an alternative explanation for HPNT with the same procedure. In addition, in recent work, Nelson et al., (2021) ran summation tests with the same method and parameters in a face-to-face laboratory setting to conclude that CI was not sufficient to explain the pre-exposure effect. However, the results of the 3 experiments in Chapter 3 were consistent with CI. In C3E1, no differences were found between the NT and LINT groups indicating that same mechanism was affecting both groups. In C3E2 all groups respond the same and no attenuated LI effect was obtained due to a contextual change between pre-exposure and conditioning, which is well established in the literature (e.g., Hall & Channel, 1985; Nelson & Sanjuan, 2006; Nelson et al., 2021, 2022). Responding to + acquired after the presumed inhibitory conditioning was context specific, consistent with having learned inhibition first (Nelson, 2002). Finally, in C3E3 a summation test showed that S acquired inhibitory properties consisted with CI in phase 1.

Hall and Rodriguez (2010) propose that what is experienced during latent inhibition is similar to what is experienced during an extinction phase with similar inhibitory learning. Therefore, for Hall and Rodriguez, latent inhibition and conditioned inhibition would be the same effect resulting from inhibitory learning. It is important to note that the CI they propose would necessarily have to be unspecific to the US (e.g., No-Event) when there are demonstrations that show that CI is US specific (for a review see Rescorla, 1979). Hall and Rodriguez predict that CI should be context-specific, as is extinction. However, context-specificity of CI is not easily observed, as in C3E3, if it occurs at all (e.g., Bouton & Nelson, 1994).

As explained earlier, Hall and Rodriguez (2010) suggest that the ability of novel stimuli to evoke an expectation that something is going to happen is an intrinsic property of these stimuli and, second, that it is produced (and/or enhanced) by generalization. In this sense, Hall and Rodriguez suggest that when an organism is confronted with a stimulus for the first time, this stimulus is never totally new, and its presence elicits an expectation of something. This expectation is countered by learning “no event” during pre-exposure. The inhibition that is learned should contradict “Event” in some way, leading to context specificity, unless “No Spaceship from training” is also considered an “Event.” “Event” requires further definition. Based on the same analysis, a “Spaceship” should be just as different from “Event” as “No Spaceship” is from “NoEvent.” The question is what constitutes an “Event.” The problems regarding CI and its insensitivity to context could be resolved by assuming that the absence of a strongly expected specific event (e.g., No-Spaceship) would be important or salient enough to be considered an "Event."

The observation of conditioned inhibition in C3E3, and the differences with the other published experiments (Nelson et al., 2021), and those reported here (e.g., the size of the NT result) are interesting. The results of the summation test in C3E3 were contradictory to those reported in Nelson et al., (2021). Using the same method, their work concluded that CI did not play a role in this method by conducting summation tests. The main difference between the experiments conducted in Chapter 3 of the dissertation and those conducted in the prior chapters, or that by Nelson and colleagues, is the type of sample and the procedure used to collect the data. The main difference being whether they were in person, or online.

Conditioned inhibition (Rescorla, 1969; Miller et al., 1991) can be described as a mechanism through which a stimulus predicts the absence of an expected outcome. To form this expected absence, a specific result should be expected. The initial response training used during chapters 2 and 3 involved an experience with four different outcomes. During the training, the participant learns to shoot at enemy spaceships, which are presented on multiple occasions individually and in pairs. Instructions introduce the possibility that these ships might attack during the experimental phase. It is plausible to think that the training may have influenced the expectation that something specific (or some specific things) was/were going to occur during the presence of the sensor. That “specificity” may vary between in-person and online samples. Under potentially greater motivation to learn and perform, online participants may have had a better memory and expectation of the four ships during pre-exposure, allowing their absence during the pre-exposure to make the sensor specifically inhibitory for each.

Continuing work on the topics investigated in Chapter 3 should involve manipulating the demand of the experiment itself (e.g., participants' attention, rewards for "correct" performance etc.). In this regard, in a recent report, Nelson et al., (2022) suggested that the context-specificity of latent inhibition was affected by whether participants were being eye-tracked. In experiments where participants were not being eye tracked (e.g., Nelson et al., 2021), normal context-specificity of LI was observed. But, in experiments with eye tracking (e.g., Nelson et al., 2022), the effect was reversed; *More* LI overall was observed *with* a context switch. They then separated the participants by whether they were predominately sign trackers (i.e., preferring to look at the signal predicting the upcoming spaceship), or goal trackers (i.e., preferring to look for the appearance of the predicted ship) at the end of training. Sign-tracking occurs when conditioned response is directed toward the CS, but goal-tracking appears as reacting to the position of the expected outcome delivery. In Nelson et al.’ work, among sign trackers, the change of context reduced the effect of pre-exposure. It was a result similar to Nelson et al. (2021). Among goal trackers, the change of context increased the effect of pre-exposure.

Those authors speculated that with demand characteristics (e.g., Orne, 2009), which could reasonably be produced by participants knowing that their eyes and attention are being actively monitored, could shift their strategies from sign to goal tracking. With a focus on the outcome, participants may be more likely to recall the specific outcomes from training and learn some type of response inhibition (e.g., McLaren et al., 2021) during pre-exposure. If that inhibition acted like conditioned inhibition, it should not be context specific (e.g., Nelson, 2002), and may even be increased with a context change if context changes boost attention to the stimuli.

Characteristics of an older, potentially more mature, sample of participants (40 years old on average in online experiments), combined with the nature of the platform from which they are paid to participate, may produce motivations to perform "correctly" that systematically influence their learning. For example, during the first phase of the online experiment, participants who are assumed to be motivated to be able to achieve the goal might better remember what happened during the training than college students who participated in the face-to-face experiment. Improved recall would be the result of motivation and would make a difference with respect to the generation of expectations. These more specific expectations, in terms of the absence of specific vessels, could predispose them to form some kind of conditioned inhibition, or response inhibition in terms of a specific expectation to emit any of the four responses.

This account could also explain, for example, why the LINT and NT effects observed in Chapter 3 were equivalent. During conditioning participants knew, through response training, four different spaceships could be available. Thus, as tested in the in-person experiment (Experiment 1 of Chapter 2), when S signalled one ship, it may have become a conditioned inhibitor for the other in Chapter 3. It becomes necessary to re-assess CI in the NT condition online, and investigate effective ways to manipulate motivation in order to determine its impact on these phenomena.

The results obtained during Chapter 3 agree with Nelson (2002) in demonstrating how excitatory second learning (i.e., the + response) becomes context specific. The experiments in Chapter 3, despite incorporating a novel test that did not interfere with the original during testing, could not answer the question posed in the introduction regarding the recovery of latent inhibition. Finding CI instead of LI made it impossible to assess the persistence of what was learned in LI and its retrieval in the pre-exposed context. The results of Chapter 3 highlight the over-arching concern addressed by Byrom et al., (2018). Care must be taken when inferring the mechanism by which supposedly simple "pre-exposure" operates to affect conditioning. Online studies of these phenomena will require explorations as to how training, instructions, and participant expectations affect the learning and expression of associative mechanisms.

Several other avenues for future work have arisen from the experiments conducted here. Group LINT had more exposure during pre-exposure and conditioning to S. Whereas Group LINT experienced 18 trials in which the sensor appeared before testing, Groups NT, LI, and Control had fewer opportunities to form Context-Stimulus associations necessary to produce asymptotic differences (12, 6, and 0, respectively). Moreover, despite finding simple effects of HPNT and LI throughout Chapter 2, inserting a phase between pre-exposure and testing appeared to eliminate both the LI and NT effects, which is consistent with extinction of the Context-CS associations thought responsible for them. These differences open several avenues of research into the effects of context-cue associations on learning by manipulating the strength to which they are established or evident at the time of testing. The results reported here, together with some recent ones (e.g., Nelson et al., 2022), point to the need to investigate processes (e.g., motivation, expectations) linked to individual differences and how they might be manipulated by study demand and affect the processes under study.

Briefly, the experiments used here have demonstrated a context-specific latent inhibition effect that was not dependent on instructions or the use of masking tasks in human participants, alleviating doubts that some authors have proposed (e.g., Byrom et al., 2018; Le Pelley & Schmidt-Hansen, 2010). They also show a latent-inhibition effect that persists across conditioning, latent-inhibition and HPNT effects that are of comparable size, and that sometimes the same pre-exposure procedure which produces a latent-inhibition type effect can produce conditioned inhibition, pointing to the continued importance of considering the issues raised by the authors cited earlier in this paragraph.

In general, formal attention accounts are not able to explain LI because they do not predict either a role for context (C1E1) or asymptotic differences (C2E1, C2E3). Interference accounts also cannot explain the findings because they are incompatible with bidirectional formation of CS-US associations (C1E2). The interference is also incompatible with the effect of HPNT, which has been demonstrated in humans (C2E1, C2E3) where information learned during conditioning (e.g., +) does not behaviorally interfere with the additional new outcome (!). Wagner's (1981) model is able to successfully predict the results reported here by alluding to Context-CS associations. Finally, it has been shown that pre-exposure can produce conditioned inhibition (C3), which is predicted by Hall and Rodriguez (2010). However, their model predicts that CI is context-specific, which is inaccurate as it is well established that CI is context-unspecific (e.g., Bouton & Nelson, 1994; Nelson, 2002; Nelson & Bouton, 1997), which is also consistent with the findings here (C3).

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