Article:

Urcelay, G.P. orcid.org/0000-0003-4717-0181, Symmons, K., Amos, B. et al. (2 more authors) (2024) Renewal of instrumental avoidance in humans. Journal of Experimental Psychology: Animal Learning and Cognition, 50 (3). pp. 197-209. ISSN 2329-8456

https://doi.org/10.1037/xan0000383

Journal of Experimental Psychology: Animal Learning and Cognition

ISSN: 2329-8456

2024, Vol. 50, No. 3, 197–209
https://doi.org/10.1037/xan0000383

Renewal of Instrumental Avoidance in Humans

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The ABA renewal effect occurs when behavior is trained in one context (A), extinguished in a second context (B), and the test occurs in the training context (A). Two mechanisms that explain ABA renewal are context summation at the test and contextual modulation of extinction learning, with the former being unlikely if both contexts have a similar associative history. In two experiments, we used within-subjects designs in which participants learned to avoid a loud noise (unconditioned stimulus) signaled by discrete visual stimuli (conditioned stimuli [CSs]), by pressing the space bar on the computer keyboard. The training was conducted in two contexts, with a different pair of CSs (CS+ and CS−) trained in each context. During extinction, CS+ and CS− stimuli were presented in the alternative context from that of training, and participants were allowed to freely respond, but no loud noise was presented. Finally, all CSs were tested in both contexts, resulting in a within-subjects ABA versus ABB comparison. Across experiments, participants increased avoidance responses during training and decreased them during extinction, although Experiment 2 revealed less extinction. During the test, responding was higher when CS+ were tested in the training context (ABA) versus the extinction context (ABB), revealing the renewal of instrumental avoidance. Experiment 2 also measured expectancy after the avoidance test and revealed a remarkable similarity between avoidance responses and expectancy ratings. This study shows the renewal of instrumental avoidance in humans, and the results suggest the operation of a modulatory role for the context in renewal, similar to the occasion setting of extinction learning by the context.

Keywords: instrumental avoidance, extinction, renewal, context

Anxiety disorders and posttraumatic stress disorder (PTSD) are a group of disabling disorders, which result from individuals showing disproportional fear of objects or situations, and excessive active avoidance of potential threats (Pittig et al., 2018). These symptoms are apparently irrational and lead to considerable distress and social isolation. Much like anxiety disorders and PTSD, obsessive-compulsive disorder also shows excessive avoidance along with other symptoms such as checking (which itself can be characterized as avoidance). Across all these conditions, excessive avoidance behavior is a behavioral manifestation, a diagnostic criterion, and sometimes a predictor of successful treatment (Aderka et al., 2013). In addition, recent dimensional attempts to overcome the categorical nature of *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; American Psychiatric Association, 2013) have identified research domain criteria (Insel et al., 2010), and in this scheme avoidance is a behavioral element of aversively motivated behaviors.

Despite the prevalence and clinical relevance of avoidance behavior, it is only recently that interest in, and studies investigating avoidance have re-emerged (Cain, 2019; Dymond, 2019; Gillan et al., 2016; LeDoux et al., 2017; Pittig et al., 2018; Urcelay & Prével, 2019) after three decades with little research on this area. This may be due to a long-standing overemphasis on studying and treating fear itself instead of avoidance behavior. Interest in avoidance behavior however has resurged in the last decade, leading to numerous reviews on avoidance, and two specialized volumes (see Beckers

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Part of these findings was presented by Gonzalo P. Urcelay, Kadell Symmons, and Arthur Prével at the International Meeting of the Sociedad Española de Psicología Comparada held in Málaga, Spain (September 2019). Experiment 1 was submitted by Kadell Symmons and Experiment 2 by Bethany Amos in partial fulfillment of the requirements for an undergraduate dissertation at the University of Leicester. The authors wish to thank Alice Welham, José Alcalá, and Peter Lovibond for their helpful comments on a previous version of this article and Richard Kirkden for technical assistance. The data reported in this article are available at https://doi.org/10.17605/OSF.IO/V4D3B. Materials are available upon request.

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& Craske, 2017; Servatius, 2016 for introduction by editors; also see LeDoux et al., 2017). The resurgence of interest in avoidance behavior may be due in part to the finding that avoidance behavior itself can prevent fear extinction from happening (Lovibond et al., 2009), which is central to exposure-based therapies. It is thought that this can sometimes result in persistent fear and avoidance behaviors (Williams & Levis, 1991).

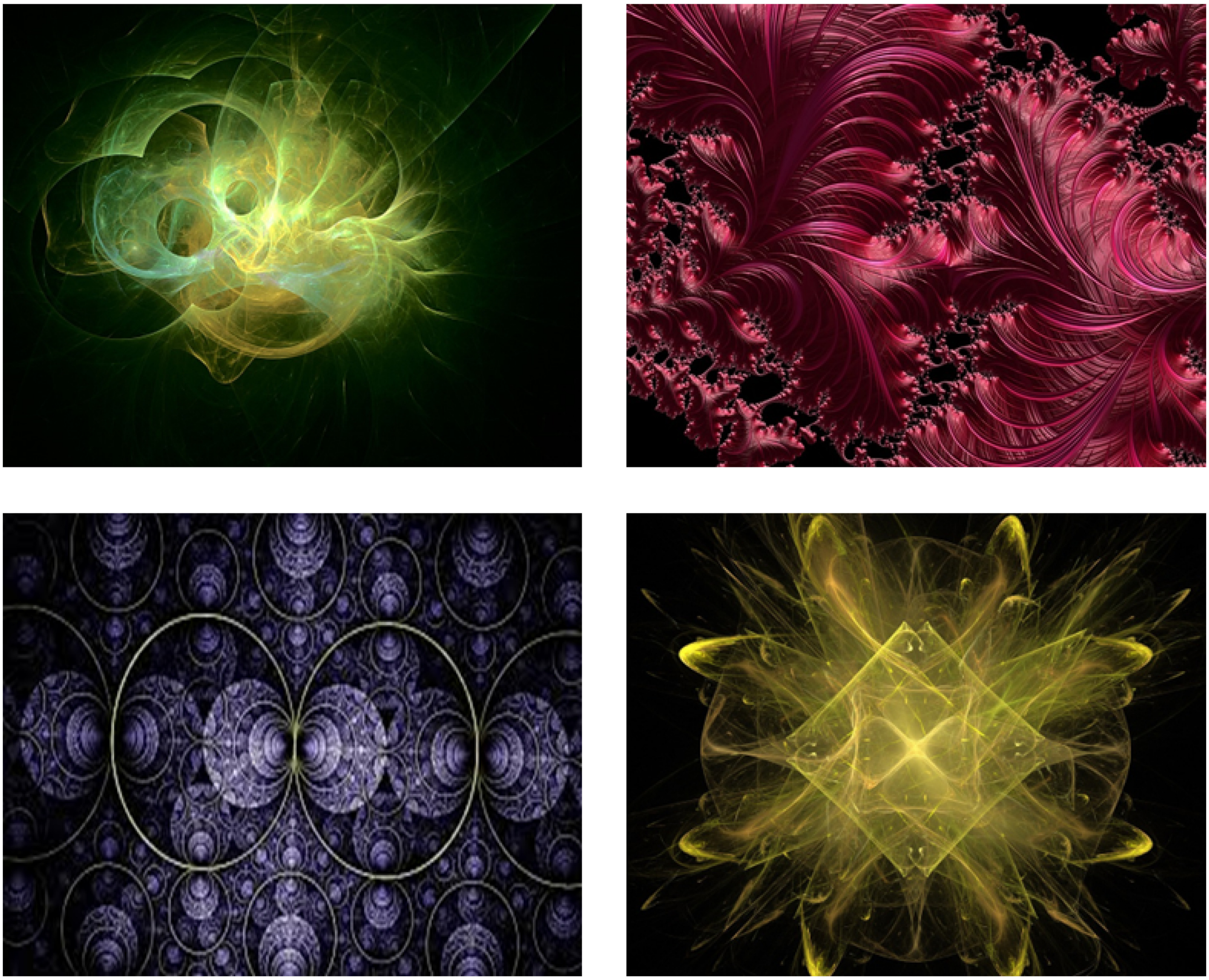
Extinction learning has inspired exposure-based therapies, in part because of the striking parallels between the two. One feature of extinction learning is that it does not involve the total erasure of original learning, and it results in new inhibitory learning, which is context-dependent (Bouton, 1993, 2004). This is supported by behavioral evidence showing eight phenomena documenting some recovery from extinction (Urcelay, 2012). Three of these phenomena, namely spontaneous recovery, reinstatement, and renewal, have been widely studied in humans and other animals (Bouton, 1993, 2004; Urcelay, 2012). Following conditioning and extinction, spontaneous recovery is the return of excitatory learning that is observed when a retention interval is interposed between extinction and testing. Reinstatement is a similar recovery that results from re-exposure to the aversive event. Finally, renewal is the recovery from extinction that is typically observed when participants are tested outside of the context in which extinction took place. These three phenomena have gained attention because they parallel the return of fear following exposure-based therapies, which happens with the passage of time (spontaneous recovery), upon re-exposure to feared stimuli and stress (reinstatement), and when patients leave the therapist's office (ABA renewal). Whilst these three phenomena have been widely documented following the extinction of fear and appetitive conditioning, there is a dearth of studies investigating recovery from the extinction of instrumental avoidance behavior (Urcelay & Prével, 2019).

As mentioned, the renewal effect happens when, following extinction learning, participants are tested in a context different from that of extinction learning. Assuming that excitatory learning happens in Context A, extinction can occur in the same (A) or a different context (B), and testing can occur in the same context as acquisition and extinction (AAA), in the context of extinction learning (ABB), in the context of acquisition when extinction was conducted in a different context (ABA), or when test happens in a context different from that of acquisition and extinction (AAB or ABC). All three conditions in which testing is conducted outside of the context of extinction (ABA, ABC, and AAB) result in recovery from extinction, although the amount of recovery differs between the three renewal procedures (Rescorla, 2008). Renewal of extinguished avoidance behavior has been documented in rodents (Nakajima, 2014), and there are two recent reports with human participants (Cobos et al., 2023; Schlund et al., 2020; also see Papalini et al., 2021, although they only extinguished fear in the absence of avoidance behavior). Schlund et al. (2020) used a gamified task in which participants experienced training trials in one context (A). During these trials, a monetary reward was presented along with signals about escalating threats of monetary loss, and participants had to choose whether to approach for a monetary gain at the risk of monetary loss. With increasing threats, participants successfully learned to avoid these threats. Extinction was conducted in a second context (B), in which no monetary losses occurred, and hence extinction of avoidance behavior was observed. During the test in the context of acquisition (A), participants resumed avoiding the threats consistent with the phenomenon of ABA renewal. In the report by Cobos et al. (2023), participants experienced pairings of two visual cues with an aversive outcome (i.e., a mild shock) and also a third cue that was not paired with the aversive outcome—all presented in Context A. In the same Context A, participants then learned that pressing a button resulted in the absence of the shock—that is avoidance behavior—and hence during avoidance training participants increased their avoidance behavior. Extinction was conducted in a second Context B. Participants experienced repeated presentations of all cues but in the absence of the shock, which resulted in a decrease in avoidance behavior. A third phase was conducted in Context C, and participants showed more avoidance responses in this context relative to responses at the end of extinction, consistent with ABC renewal. Thus, both of these studies have revealed renewal of avoidance behavior, although both can be explained by either context inhibition (during extinction) or context summation (during the test) and do not distinguish between different explanations of the renewal effect (see below and General Discussion).

Although numerous different associative mechanisms can account for ABA renewal (see Nelson et al., 2011; Figure 1 and text for elaboration on these), they can be classed into two general categories that map on the notion that contexts can play two fundamental functions, that of a discrete conditioned stimulus (CS) and that of a modulator of memory expression (Urcelay & Miller, 2010, 2014). If the context is assumed to play the role of a discrete CS that enters into an association with the outcome, then ABA renewal can be explained in two ways. First, Context B acquires inhibitory associative strength during extinction, and that inhibitory strength is no longer present when testing is conducted in Context A or an alternative Context C. This mechanism can explain the ABC renewal effect that was observed by Cobos et al. (2023). Second, because Context A was also present during acquisition, it could acquire associative strength and contribute to responding to the target stimulus at test by summation, and this explains the ABA renewal effect observed by Schlund et al. (2020). Either alone or together, these two mechanisms can account for ABA and ABC renewal, and both appeal to the context functioning like any other discrete CS that enters into (excitatory or inhibitory) associations with the US. These mechanisms are consistent with standard associative theories like the Rescorla–Wagner model (Rescorla & Wagner, 1972; also see Delamater & Westbrook, 2014 for an elaboration on how it can account for recovery from extinction phenomena). An alternative way to explain ABA (and ABC) renewal is offered by Bouton's model (1993, 1994) which assumes—in line with the context functioning like an occasion setter or modulator—that second-learned associations, such as those learned during extinction, are context-dependent and therefore any change in context from extinction to test results in recovery from extinction. Extinction is thus seen as new learning that is context-dependent, so testing outside of the extinction context results in recovery from extinction.

One way to potentially distinguish between these explanations of the ABA renewal effect is to run the experiment training multiple CSs and contexts, using a within-subjects design in which the associative histories of the contexts of acquisition and extinction are matched. In this case, the observation of ABA renewal is less likely to be explained by the explanation that the context is functioning like a discrete CS (Rescorla & Wagner, 1972). Such a design was proposed by Rescorla (2008; Experiment 1a). In this design, two different CSs (CS1 and CS2) are trained each in a different Contexts A and B, respectively (CS1 is trained in Context A and CS2 is trained in Context B). Following training, CS1 is extinguished in Context B

Figure 1
The Four Fractals Used as CSs in Experiments 1 and 2



Note. For each participant, the fractals were randomly allocated as CS1, CS2, CS3, and CS4 (see Table 1). CSs = conditioned stimuli. See the online article for the color version of this figure.

whereas CS2 is extinguished in Context A. Finally, both CSs are tested in both contexts. Because both contexts received excitatory training during acquisition and both received inhibitory training during extinction, the associative histories of the contexts are the same, and hence no renewal is anticipated. If, however, renewal results from second-learned associations being context dependent (Bouton, 1993, 1994), then renewal is anticipated despite the associative histories of the contexts being the same.

In these experiments, the objective was to document ABA renewal of instrumental avoidance in humans, as this would increase the generality of the phenomenon. A second objective was to disambiguate different explanations of the ABA renewal effect, by adopting a within-subjects design developed by Rescorla (2008), which is consistent with a modulatory account of contextual control in ABA renewal. In order to fulfill these objectives, we adapted the task pioneered by Flores et al. (2018). Unlike other instrumental avoidance tasks in which participants are only required to emit one press to successfully avoid the aversive outcome, in the task developed by Cobos et al. (2023) the aversive outcome occurs at variable times during the presentations of the CS+, and participants have to emit the avoidance response 1 s before the presentation of the aversive outcome for avoidance to be successful. This adds uncertainty to the task and results in participants vigorously emitting the avoidance response. We implemented a variation of this task in which we trained pairs of CSs in two different contexts and assessed renewal using a within-subjects design (Rescorla, 2008). The advantage of this design is that it matches the two contexts for their overall history of reinforcement during acquisition and nonreinforcement during extinction, and the CSs in terms of histories of reinforcement and nonreinforcement. Whilst this has been occasionally done in between-subject designs (Urcelay et al., 2009; Experiment 2), in the current experiment we sought to exploit the benefit of a within-subjects design. In addition to reducing the number of participants needed, this design renders any differences observed at the test attributable to modulatory effects of the context, in line with a modulatory explanation for the context-dependence of extinction (Bouton, 1993, 1994; although see the General Discussion section for alternative accounts).

Experiment 1

Method

Participants

The participants were 30 undergraduate students from the University of Leicester who completed the study in exchange for course credit. Twenty-five identified themselves as female and five as male, their ages ranged from 18 to 25 years ($M = 20.43$, $SD = 1.41$). Participants were recruited via an online system where they signed up in return for course credits. The University of Leicester Ethics Review Committee approved the study, in accordance with the Code of Ethics of the World Medical Association. Because the report on which we based the task (Flores et al., 2018) was conducted between-subjects, we did not have a proper reference to estimate the sample size needed to achieve power in a 2 × 2 within-subjects interaction (at renewal). A recent study that documented ABA renewal using avoidance as a measure during the test in a between-subjects design (Papalini et al., 2021) employed 42 participants per group. Assuming that a within-subjects design requires fewer participants, we estimated that 30 participants would be sufficient to detect a significant interaction at the test. The experiments were not preregistered. State anxiety scores ranged from 20 to 53 ($M = 35.43$, $SD = 7.51$), whereas trait anxiety scores ranged from 26 to 64 ($M = 43.93$, $SD = 9.46$).

Apparatus and Materials

The experiments were run in three separate rooms, each containing a chair and desk with a computer. Three Helwet–Packard personal computers with Windows operating system were used to run the task, which was programmed in MATLAB using the Psychtoolbox interface. The stimuli were presented using 19.0″ Neovo F-419 monitors (SXGA 1,280 × 1,024 resolution), placed roughly 60 cm in front of the participants. Avoidance responses were made through a keyboard by pressing the spacebar. Four fractals (10 × 8.5 cm) were used as stimuli (CS1, CS2, CS3, and CS4; see Figure 1) and these were randomized across participants by the program. A 3-s tone of 1,100 Hz (95 ± 4 dB) was presented bilaterally through dynamic stereo headphones and served as the aversive outcome. A few participants mentioned that the noise was too loud, and for them, the loud noise was reduced to 90 dB. Before starting the experiment, participants completed Spielberger's State-Trait Anxiety Inventory (STAI) for adults (Spielberger et al., 1983), which consists of 40 items, 20 of these assessing state anxiety and the remaining 20 assessing trait anxiety. Items are rated on a Lickert scale ranging from 1 to 4.

Design

This study was run using a within-subjects design (see Table 1), adapted from the design used by Rescorla (2008). Two contexts were created by changing the color of the background (green or pink) of the screen where the stimuli were presented. In Context A, CS1 was always (i.e., continuous reinforcement) paired with the loud tone, whereas CS2 was never paired with the loud tone. In Context B, CS3 was similarly paired with the tone whereas CS4 was not. Following Pavlovian conditioning and instrumental acquisition phases, CS1 and CS3 were presented in the alternative context (CS1 was presented in Context B, and CS3 in Context A), and participants were allowed to press the spacebar but the loud tone was never presented (extinction). During this phase, CS2 and CS4 were also presented in the alternative context, in the absence of the loud tone. All stimuli were tested in the acquisition and extinction contexts, with the order counterbalanced between participants. Thus, all stimuli were tested (test phase) in the same context in which extinction took place, or in the context where acquisition took place, resulting in a within-subjects ABB versus ABA comparison (where A is the context of acquisition and B is the context of extinction).

Table 1
Design of Experiments 1 and 2

Context	Pavlovian conditioning	Instrumental acquisition	Instrumental extinction	Test
A	CS1+ CS2−	CS1+: R CS2−: R	CS3−: R CS4−: R	CS1−: R CS3−: R CS2−: R CS4−: R
B	CS3+ CS4−	CS3+: R CS4−: R	CS1−: R CS2−: R	CS3−: R CS1−: R CS4−: R CS2−: R

Note. All participants received Pavlovian training in Contexts A and B. During instrumental acquisition, CS1+ and CS2− were trained in Context A, whereas CS3+ and CS4− were trained in Context B. Stimuli CS1 and CS3 were extinguished in the alternative context from that of training (B and A, respectively), and all stimuli were tested in both contexts (counterbalanced), resulting in a within-subjects ABB versus ABA renewal design. CS = conditioned stimulus; R = response.

Procedure

Upon arriving in the laboratory, participants signed a consent form informing them that there would be images that may be paired with a loud noise as part of the experiment, and they would eventually have the opportunity to avoid the loud noise by using the keyboard. After giving informed consent, participants completed the STAI questionnaires and then started the experiment. The experiment itself was divided into four phases: a Pavlovian learning phase, an instrumental learning phase, an extinction phase, and a test phase. Participants began by wearing the headphones given and reading the instructions pertaining to the first, Pavlovian phase. The instructions read:

> In this experiment, you will see different fractal images on the screen. Some of these will be followed by an aversive sound (that will be played through the headphones), but some will not. At this stage, your task is to determine which images are followed by the annoying sound, and which ones are not. Note that there will also be changes in the background colour of the screen. In addition, you should try to determine when the sound is to appear. Press the SPACE bar to continue.

During each trial, the context background was the first thing presented for 3 s, and hence this was the duration of the intertrial interval during all phases of the experiment. The background context was always present during the inter-trial interval. Following this, one of the four images (CS1, CS2, CS3, and CS4) was displayed in the center of the screen in front of the context background for 20 s. In this and all other phases, the CSs were always presented for 20 s, regardless of whether participants avoided the loud noise or not. In other words, successful avoidance did not terminate the CS presentation. Only one noise could be presented during CSs+ trials, and the onset of the noise was programmed according to a variable time schedule with a mean of 9 s (from the onset of the CSs+), which followed a rectangle distribution with a range of 15 s. This way, the aversive sound could appear randomly at any second between 2 and 16 s from the onset of a CS+. The Pavlovian learning phase consisted of four blocks each including two presentations of each CS, the order in which each CS was presented within a block was randomized (as was the case throughout) as well as the specific images that triggered the aversive sound also being randomized. Each CS was presented eight times during this phase, and trials (with their respective contexts) were intermixed. During the Pavlovian and instrumental phases, there was 100% contingency between CS and US (if participants did not avoid during the instrumental phase).

After the Pavlovian phase, participants read the instructions for the instrumental phase.

> This phase is identical to the previous phase, except you can now avoid the sound by pressing the space bar. Critically, for a press to be successful, it has to be emitted within one second before the sound is presented. You can press the space bar as many times as you wish nevertheless, but only those presses within one second of the appearance of the noise will prevent the noise from happening. Your task it to try to avoid as many presentations of the noise as possible. Press the SPACE bar to continue.

The instrumental phase also consisted of four blocks each including two presentations of each CS that was randomized, therefore having eight presentations for each CS during this phase. After the instrumental phase, participants began the extinction phase which did not have any instructions beforehand, so the transition from the instrumental to the extinction phase was seamless. During this phase, however, the two CSs+ were presented against the opposite context background as was the case with the two CS− (see Table 1). During this and the test phases, the aversive sound was never presented, but spacebar responses were still permitted. The extinction phase consisted of eight blocks of randomized CS presentations, therefore each CS was presented 16 times during this phase. Finally, all stimuli were tested in both contexts, with the order of context counterbalanced across participants. This phase consisted of blocks in which there were two presentations of each CS per context.

Data Analysis

The main dependent measure in this study was the number of presses (i.e., avoidance behavior) per stimulus in each block (each block containing two stimulus presentations) across both CSs+ and both CSs−. The reasoning for collapsing across CSs is that these always received the same training across all phases. Thus, during acquisition, we summed the avoidance responses across the two presentations of each CS and averaged the two CSs+ and the two CSs− in each block (four blocks). The same was done for the eight extinction blocks and each test block. Space bar presses were analyzed with within-subjects analyses of variance (ANOVAs) with stimulus identity (CSs+ vs. CSs−) and blocks (1–4 during training and 1–8 during extinction) as within-subjects variables. During the test, we used within-subjects ANOVAs and compared stimuli (CSs+ vs. CSs−) and the context of the test (extinction vs. acquisition). In Experiment 2 we also collected expectancy ratings after the test of behavioral responses, and these were also analyzed with a 2×2 ANOVA. When sphericity was violated, we used the Huynh–Feldt adjustment. In all cases, we report partial-eta squared as a measure of the unbiased, effect size (Cohen, 1992). Confidence intervals (CIs) on partial-eta squares (90%) were computed using software available in Nelson (2016).

Transparency and Openness Statement

We report how we determined our sample size, and explain all data exclusions (if any), all manipulations, and all measures in the study. The data reported in this article are available at DOI https://doi.org/10.17605/OSF.IO/V4D3B. Data were analyzed using IBM SPSS Statistics (Version 27). This study's design and its analysis were not preregistered. The task was programmed using MATLAB using the Psychophysics Toolbox V. 3 extensions (Kleiner et al., 2007), and the materials are available upon request.

Results

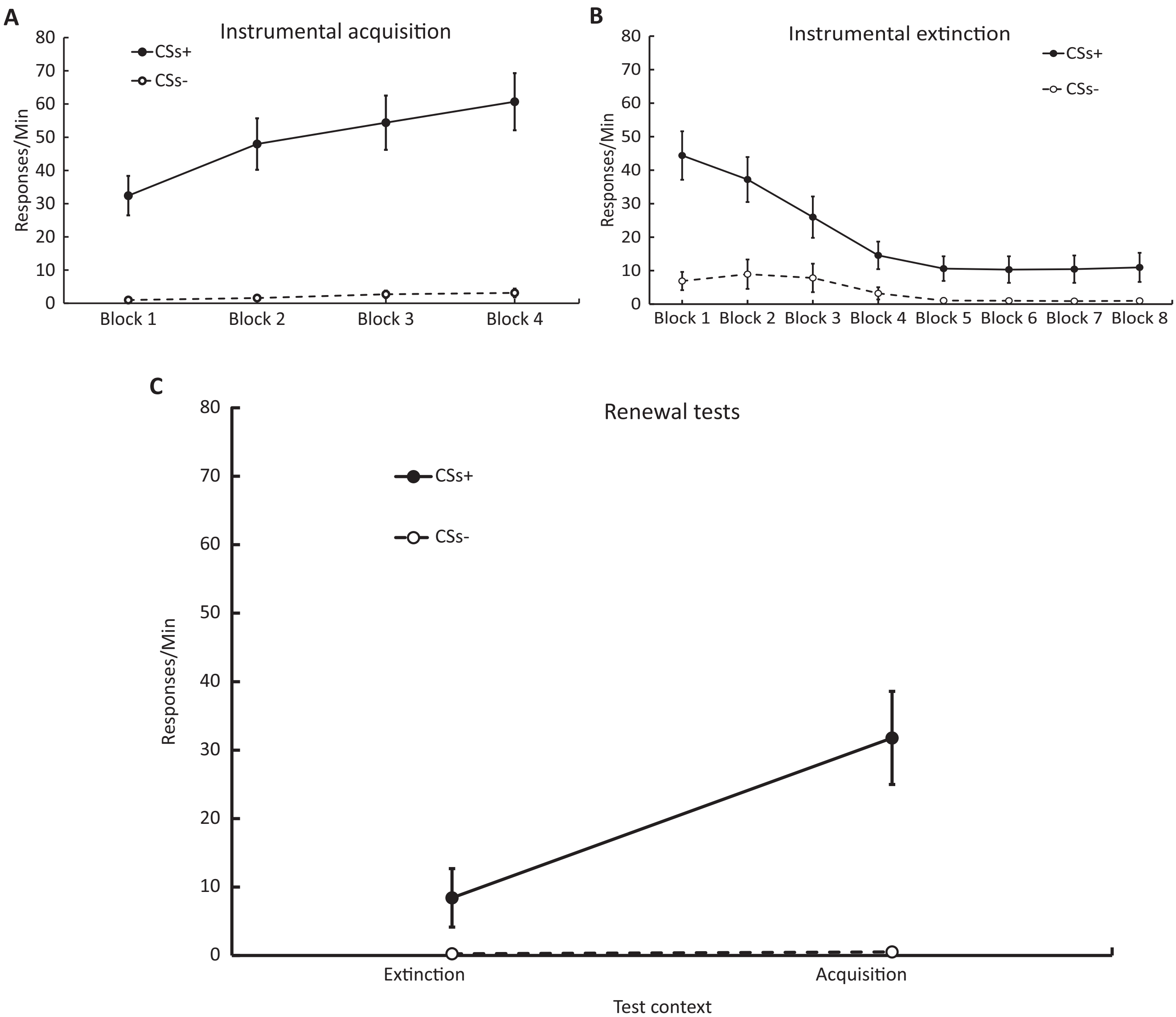
Acquisition

Figure 2A depicts the acquisition of instrumental avoidance (frequency of space bar presses) for both CSs+ (CS1 and CS3) and both CSs− (CS2 and CS4) across four blocks of training. All participants learned to avoid during CSs+ presentations. Avoidance responses increased across blocks for CSs+, but not for CSs−. These impressions were supported by a 2 (stimulus: CSs+ vs. CSs−) × 4 (block: 1–4) within-subjects ANOVA, that revealed a main effect of stimulus, $F(1, 29) = 42.81$, $p < .001$, $\eta_p^2 = .596$, 90% CIs [0.37, 0.70]; an effect of block, $F(1.47, 42.85) = 10.69$, $p < .01$, $\eta_p^2 = .26$, 90% CIs [0.08, 0.40]; and a Stimulus × Block interaction, $F(1.44, 41.85) = 8.89$, $p < .01$, $\eta_p^2 = .23$, 90% CIs [0.05, 0.38]. Analyses of simple effects revealed a large effect of block for CSs+, $F(1.44, 41.95) = 9.97$, $p < .01$, $\eta_p^2 = .25$, 90% CIs [0.07, 0.40], but only a marginal effect for CSs− $F(1.36, 39.59) = 3.45$, $p = .058$, $\eta_p^2 = .10$, 90% CIs [0.00, 0.24]. Thus, the interaction suggests that acquisition was observed for CSs+, but not for CSs−.

Extinction

Figure 2B shows the frequency of spacebar presses during eight blocks of extinction for CSs+ and CSs−. As can be appreciated in the figure, extinction was observed for CSs+, whilst CSs− only showed a small change early during the extinction session, perhaps reflecting the uncertainty produced by the extinction contingency and the changes in context. Finally, a visual comparison of levels of avoidance responding at the end of instrumental acquisition with those observed in the first block of extinction suggests lower responses during the first block of extinction, which likely resulted from the change in context from acquisition to extinction. These impressions were supported by the following statistical analyses. A 2 (stimulus: CSs+ vs. CSs−) × 8 (block: 1–8) within-subjects ANOVA revealed a main effect of stimulus, $F(1, 29) = 21.81$, $p < .001$, $\eta_p^2 = .42$, 90% CIs [0.18, 0.57]; a main effect of block, $F(1.49, 43.24) = 10.56$, $p < .01$, $\eta_p^2 = .26$, 90% CIs [0.08, 0.40]; and a Stimulus × Block interaction, $F(1.75, 50.81) = 8.52$, $p < .01$, $\eta_p^2 = .22$, 90% CIs [0.06, 0.35]. To follow up the

Figure 2
Results of Experiment 1



Note. (A) Rate of responses/min in each block during acquisition. There was an increase in avoidance responses upon presentation of CSs+, but not when CSs− were presented. (B) Rate of responses/min. There was a clear extinction of responding during presentations of the CSs+, but a marginal change during presentations of CSs−. (C) Results of renewal tests. The response rate was higher when participants were tested in the presence of CSs+ in the acquisition context relative to the extinction context, but no changes based on the context of the test were observed for CSs−. Error bars represent standard error of the mean. Min = minutes; CSs = conditioned stimuli.

Stimulus × Block interaction, we tested if there was a change across blocks for each pair of stimuli separately. These analyses revealed a clear effect of block for CSs+, $F(1.65, 47.96) = 11.53$, $p < .001$, $\eta_p^2 = .28$, 90% CIs [0.10, 0.41], but only a marginal change for CSs−, $F(1.12, 32.58) = 3.07$, $p = .085$, $\eta_p^2 = .09$. In order to assess the context dependency of instrumental avoidance, we compared responses to presentations of the CSs+ during the last block of acquisition with those during the first block of extinction, and this comparison was significant, $F(1, 29) = 9.42$, $p < .01$, $\eta_p^2 = .24$, 90% CIs [0.04, 0.42].

Test

Figure 2C shows the results during the test sessions. As is clear from the figure, participants responded more to the CSs+ when these were tested in the acquisition context relative to the extinction context. On the contrary, no effect of context change was observed for CSs−. The test data were analyzed with a 2 (stimulus: CS+ vs. CS−) × 2 (context: acquisition vs. extinction) within-subjects ANOVA, which revealed an effect of stimulus, $F(1, 29) = 21.36$, $p < .001$, $\eta_p^2 = .42$, 90% CIs [0.18, 0.57]; effect of context,

$F(1, 29) = 9.71$, $p < .01$, $\eta_p^2 = .25$, 90% CIs [0.05, 0.43]; and a Stimulus × Context interaction, $F(1, 29) = 9.15$, $p < .01$, $\eta_p^2 = .24$, 90% CIs [0.04, 0.42]. A comparison of avoidance responses during CSs+ in both contexts revealed more responding in the acquisition context, $F(1, 29) = 9.44$, $p < .01$, $\eta_p^2 = .24$, 90% CIs [0.04, 0.42], but no differences were observed for CSs−, $F(1, 29) = .96$, $p = .33$, $\eta_p^2 = .03$. Thus, consistent with the expectations, we observed a significant renewal effect when testing was conducted in the acquisition context relative to the extinction context. In addition, because this within-subjects design equates to the associative strength of both contexts, we did not observe any differences in responding to the CSs− based on the test context.

Experiment 2

Experiment 1 revealed convincing evidence for the renewal of instrumental avoidance in humans. The purpose of Experiment 2 was twofold. First, we wanted to replicate the main findings observed in Experiment 1. Second, in Experiment 1 we asked participants to fill out an STAI questionnaire, but we did not detect any meaningful relationships between trait or state anxiety levels and the behavioral measures that we took. Thus, a second objective was to collect additional data and assess these relationships. Finally, we wanted to collect self-report measures in addition to instrumental responding to assess whether there is consistency between avoidance responses and measures of expectancy because cognitive models of avoidance assign an important role to expectancy in human avoidance (Lovibond, 2006; Seligman & Johnston, 1973).

Method

Participants

The participants were 30 undergraduate students from the University of Leicester who completed the study in exchange for course credit. Twenty-seven identified themselves as female and three as male, their ages ranged from 18 to 39 years ($M = 19.7$, $SD = 3.71$). Participants were recruited via an online system where they signed up in return for course credits. State anxiety scores ranged from 21 to 59 ($M = 35.4$, $SD = 9.48$), whereas trait anxiety scores ranged from 24 to 63 ($M = 40.67$, $SD = 10.99$). Finally, general anxiety disorder-7 questionnaire scores ranged from 0 to 15 ($M = 6.50$, $SD = 4.05$).

Apparatus and Materials

The apparatus and materials were the same as those described in Experiment 1. In addition to recording responses and expectancy (see below), the program also recorded the number of loud noises (USs) experienced during training. We also asked participants to complete the general anxiety disorder-7 questionnaire (Spitzer et al., 2006).

Procedure

The procedure was the same as in Experiment 1, except for the addition of an expectancy test which was given immediately after the renewal tests. In the expectancy test, participants saw each of the four CSs in each of the two contexts and had to rate the extent to which they expected that the loud noise would appear. Before the expectancy test, they received the following instructions.

> Now we wish to know your expectation that the loud noise will appear following different stimuli and backgrounds. To indicate your expectation, with the help of the computer mouse you will have to make choices on a scale between nine responses. 1 = *no expectation*, 5 = *moderate expectation*, 9 = *very high expectation*.

Immediately after, participants saw all possible combinations of CSs and contexts and gave a rating for each. Following the expectancy test, participants were asked to rate how loud they thought the noise was (scale; 1 = *not loud*, 5 = *loud*, 9 = *very loud*).

Results

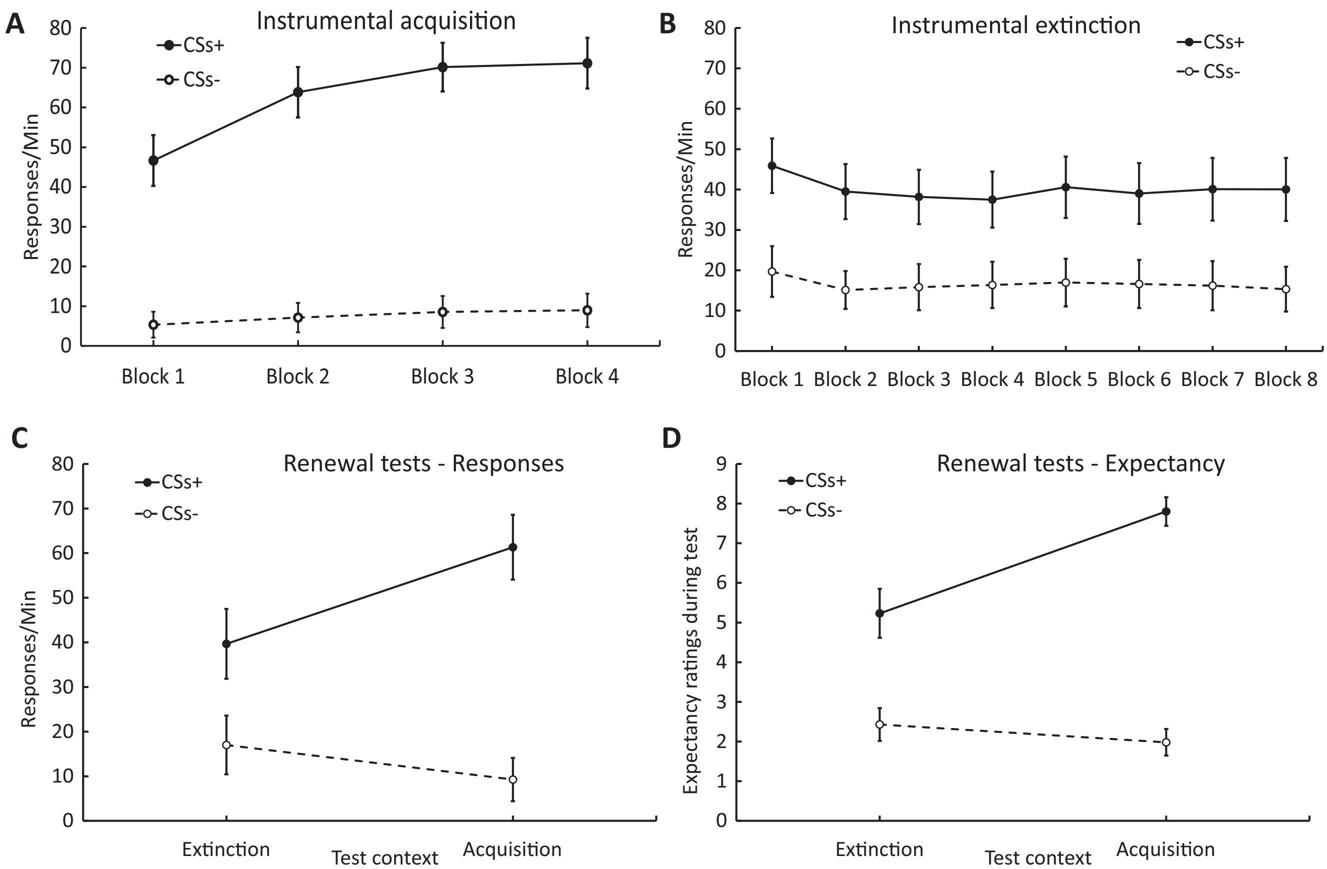
Acquisition

Instrumental acquisition proceeded as expected, with participants pressing the space bar more in the presence of the CSs+ than in the presence of the CSs− (see Figure 3A). This pattern changed as training progressed, so that the differences became larger. These impressions were confirmed by a 2 (stimulus: CSs+ vs. CSs−) × 4 (block: 1–4) within-subjects ANOVA. The analysis revealed a main effect of the stimulus, $F(1, 29) = 61.02$, $p < .001$, $\eta_p^2 = .678$, 90% CIs [0.48, 0.76]; an effect of the block, $F(1.78, 51.64) = 24.45$, $p < .001$, $\eta_p^2 = .457$, 90% CIs [0.27, 0.56]; and a Stimulus × Block interaction, $F(1.73, 50.18) = 17.7$, $p < .001$, $\eta_p^2 = .379$, 90% CIs [0.19, 0.50]. Analyses of simple effects revealed an effect of block for CSs+, $F(1.8, 52.22) = 24.25$, $p < .001$, $\eta_p^2 = .455$, 90% CIs [0.37, 0.56], but a nonsignificant effect for CSs− $F(1.44, 41.81) = 3.29$, $p = .062$, $\eta_p^2 = .102$. Thus, the interaction suggests that an increase in responding was observed for CSs+, but not for CSs−. Consistent with the increase in CSs+ responses reflecting avoidance learning, the number of loud noises experienced in each block decreased, as revealed by one-way within-subjects ANOVA that revealed an effect of the block, $F(2.36, 68.58) = 14.82$, $p < .001$, $\eta_p^2 = .327$, 90% CIs [0.16, 0.43]. During Blocks 1, 2, 3, and 4 participants experienced on average 1.1 ($SD = .99$), 0.47 ($SD = .81$), 0.2 ($SD = .55$), and 0.17 ($SD = .37$) loud noises, respectively.

Extinction

The results of the extinction phase are presented in Figure 3B, which revealed little extinction of responding to the CSs+ in comparison to what was observed in Experiment 1. Similar to Experiment 1, we observed that avoidance responding was lower during the first block of extinction relative to the last block of acquisition. These impressions were supported by a 2 (stimulus: CS+ vs. CSs) × 8 (block: 1–8) within-subjects ANOVA that revealed a main effect of stimulus, $F(1, 29) = 7.54$, $p = .011$, $\eta_p^2 = .20$, 90% CIs [0.02, 0.38], but no effect of block, $F(2.44, 70.87) = 1.42$, $p = .24$, $\eta_p^2 = .047$, 95%, and no Stimulus × Block interaction, $F(2.82, 82.00) = 0.478$, $p = .68$, $\eta_p^2 = .016$. Given the absence of an interaction, we did not assess the change for each pair of CSs separately. Finally, in order to assess the context dependency of instrumental avoidance, we compared responses to presentations of the CSs+ during the last block of acquisition with those during the first block of extinction, and this comparison was significant, $F(1, 29) = 12.11$, $p < .005$, $\eta_p^2 = .29$, 90% CIs [0.08, 0.47].

Figure 3
Results of Experiment 2



Note. (A) Rate of responses/min in each block during acquisition. There was an increase in avoidance responses upon presentation of CSs+, but not when CSs− were presented. (B) Responses during extinction. There was no extinction of responding during presentations of the CSs+ (although a tendency towards a decrease), and no change in responding during presentations of CSs−. (C) Renewal tests of avoidance responses. Responding was higher when participants were tested in the presence of CSs+ in the acquisition context relative to the extinction context, but no changes based on the context of the test were observed for CSs−. (D) Renewal tests of expectancy ratings. Ratings were higher when participants were tested in the presence of CSs+ in the acquisition context relative to the extinction context, but no changes based on the context of the test were observed for CSs−. Error bars represent standard error of the mean. Min = minutes; CS = conditioned stimulus.

Test

Participants during the test responded more to the CSs+ when these were tested in the acquisition context than in the extinction context, a finding that reveals renewal of instrumental avoidance. No differences were apparent in responding to the CSs−, in line with Experiment 1 (see Figure 3C). These observations were corroborated with a 2 (stimulus: CS+ vs. CS−) × 2 (context: acquisition vs. extinction) within-subjects ANOVA, which revealed an effect of stimulus, $F(1, 29) = 29.69$, $p < .001$, $\eta_p^2 = .50$, 90% CIs [0.26, 0.63]; effect of context, $F(1, 29) = 4.92$, $p < .05$, $\eta_p^2 = .145$, 90% CIs [0.00, 0.33]; and a Stimulus × Context interaction, $F(1, 29) = 8.08$, $p < .01$, $\eta_p^2 = .218$, 90% CIs [0.03, 0.40]. A comparison of avoidance responses during CSs+ in both contexts revealed more responding in the acquisition context, $F(1, 29) = 9.73$, $p < .01$, $\eta_p^2 = .251$, 90% CIs [0.05, 0.43], but no differences were observed for CSs−, $F(1, 29) = 2.39$, $p = .13$, $\eta_p^2 = .076$.

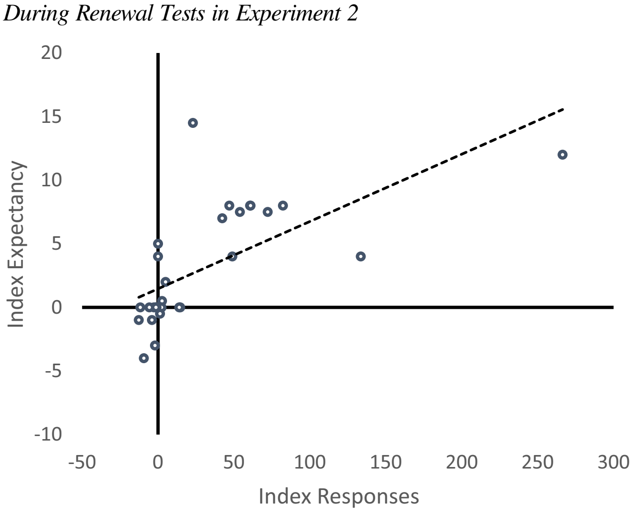
Analysis of the expectancy ratings collected after the test of instrumental responding revealed a similar pattern as that observed with instrumental responses (Figure 3D). A 2 (stimulus: CS+ vs. CS) × 2 (context: acquisition vs. extinction) within-subjects ANOVA, revealed an effect of stimulus, $F(1, 29) = 70.45$, $p < .001$, $\eta_p^2 = .70$, 90% CIs [0.51, 0.78]; effect of context, $F(1, 29) = 9.37$, $p < .01$, $\eta_p^2 = .244$, 90% CIs [0.04, 0.42]; and a Stimulus × Context interaction, $F(1, 29) = 13.12$, $p < .001$, $\eta_p^2 = .312$, 90% CIs [0.09, 0.48]. A follow-up comparison of expectancy ratings to the CSs+ in both contexts also revealed more responding in the acquisition than in the extinction context, $F(1, 29) = 16.26$, $p < .001$, $\eta_p^2 = .359$, 90% CIs [0.12, 0.52], but no differences were observed for CSs− expectancy ratings in the different contexts, $F(1, 29) = 1.12$, $p = .29$, $\eta_p^2 = .037$. Thus, expectancy ratings paralleled the findings observed in instrumental responses. In order to assess the correlation between avoidance responses and expectancy measures, we computed a single score for each measure that reflected the 2 × 2 interaction observed during the renewal test. By definition, an interaction is the difference between differences, so we calculated a score by subtracting responses to the CSs+ in the extinction context from those in the acquisition context. A similar differential was computed for CSs− responses and subtracted from the CSs+ differential. In other words, we computed a single score that captured the CS × Context interaction, for both behavioral and expectancy measures. The Pearson correlation between these two scores was significant, $r(28) = .657$, $p < .001$, 90% CIs [0.40, 0.79] (see Figure 4). The average rating of noise intensity was 6.63 ($SD = 1.47$) suggesting that participants perceived the noise as somewhere in between 5 (*loud*) and 9 (*very loud*). We did not detect any meaningful relationships between anxiety scores and behavioral outcomes.

General Discussion

The purpose of this study was to assess in a within-subjects experimental paradigm the renewal of instrumental avoidance in humans. Both experiments revealed convincing evidence of renewal, and Experiment 2 in addition revealed a striking parallel between renewal of avoidance responses and expectancy ratings. We adopted a within-subjects design proposed by Rescorla (2008) and used a task based on that developed by Flores et al. (2018) that introduces uncertainty concerning when the aversive outcome is to occur. This results in high levels of avoidance behavior, as opposed to requiring a single response for successful avoidance as often used in these paradigms. In both experiments, during instrumental training, we observed good discrimination between CSs+ and CSs−, and an increase in responding across blocks of training that was selective to the CSs+, as suggested by the interaction between stimuli and block during training. During extinction, Experiment 1 revealed a selective decline in responding to the CSs+ without large changes in responding to the CSs−. There was a small increase in responding to the CSs− that occurred during early blocks of extinction, perhaps because participants who noticed the change in contingency began responding to the previously nonreinforced CSs−, a finding that is also observed in Pavlovian fear extinction experiments (e.g., Haesen & Vervliet, 2015). Experiment 2 did not reveal much evidence of extinction, although numerically there was a decline in responding. This could be due to a number of reasons, the most relevant being that the data was collected during February 2020 when the COVID pandemic was imminent and stress levels were high—for it has been documented that stress attenuates extinction in human participants (Schwabe & Wolf, 2011). Critically, during the test both experiments revealed higher levels of avoidance responding when CSs+ were tested in the acquisition context relative to testing in the extinction context, whilst no differences were observed in responding to the CSs−. Finally, in both experiments, we observed a decrease in avoidance responses with a context change from acquisition to extinction, in line with suggestions that instrumental behavior tends to be more context-dependent than Pavlovian conditioning (Thrailkill & Bouton, 2015).

Figure 4

Correlation Between Avoidance Responses and Expectancy Measures During Renewal Tests in Experiment 2



Note. For each measure, we computed a single score that captured the interaction between responses to the two CSs (CSs+ and CSs−) in the two contexts (extinction and acquisition). The correlation between the two measures was large ($r = .657$). CS = conditioned stimulus. See the online article for the color version of this figure.

As described in the introduction, there are several explanations of the renewal effect (see Delamater & Westbrook, 2014; Nelson et al., 2011; for detailed reviews), and these broadly align with two fundamental roles played by contexts (Urcelay & Miller, 2010, 2014). When the context is assumed to function like any other discrete CS, ABA (and ABC) renewal can be explained by positing that the extinction B context became inhibitory during extinction (because of nonreinforced presentations of the excitor during extinction), and such a release from inhibition when subjects are tested in the A (or C) context results in renewal. A recent report using a task similar to the one used in the present experiments has revealed ABC renewal that can be explained by inhibitory learning in the context during extinction learning (Cobos et al., 2023). Similarly, it could be argued that in an ABA versus ABB comparison, the differences in responding observed at the test are due to the excitatory associative strength of the A context summating with responding to the extinguished CS (such excitation should not be present in the extinction Context B) and again that can provide an explanation for the observation of renewal. Consistent with this explanation, there is a report that has documented ABA renewal of avoidance behavior and can be explained by the training context (A) acting as a cue and contributing to responding during the test (Schlund et al., 2020). Finally, it is possible that during training the combination of the context and the CS became configured (as a unique cue; see Wagner & Rescorla, 1972). During extinction of the CS in a different Context B, the unique/configural cue is not present and therefore undergoes little extinction (but presentations of the CS alone may disintegrate the configuration) and recovery is observed when the unique/configural cue is presented again during the test–although this explanation does not easily explain AAB renewal. As an alternative to these explanations, Bouton (1993, 1994) proposed that extinction is best conceived as new (inhibitory) learning which is highly context-dependent. That is, during extinction, the CS becomes associated with the absence of the US and this CS → NoUS association depends on the extinction context for its expression, which means that testing in any other context from that of extinction should result in some recovery from extinction. Because the current within-subjects design equates the associative history of contexts and CSs, that is, all contexts and cues have similar excitatory and inhibitory training, the current results are consistent with Bouton's model that assumes that extinction is context-dependent new learning (Bouton, 1993).

Whilst we have advocated for an explanation in terms of context-dependent interference, the results may be accommodated by mechanisms other than those proposed by interference. For example, although undoubtedly conditioned inhibition transfers to excitors other than those used to train conditioned inhibition, there is evidence that such transfer is incomplete. That is, Rescorla (1982; Experiment 2) trained two different conditioned inhibitors, each with its excitor, and then tested them in a summation test with the excitor that was used during training and the alternative excitor. Inhibition was evidenced with both excitors, but negative summation was stronger with the excitor that each inhibitor was trained with. Applied to the current experiments, it could be possible that the inhibition learned in the context of extinction failed to transfer to the context of acquisition and that is why evidence of renewal was observed. Similarly, Wagner's sometimes opponent processes model (Wagner, 1981) provides a way of accommodating the current results by assuming that the CSs+ are more strongly associated with the extinction context than with the acquisition context, despite a similar number of trials in each context before test. The key assumption is that presentations of the US—which only occurred in the acquisition context—disrupted context-CSs+ associations (Rescorla, 1981), and hence at the test the extinction context was better capable of priming the CSs+ into A2 than the acquisition context was. Thus, with more CS+ available in A1 to respond in the acquisition context, renewal is predicted by this account.

A notable feature of the within-subjects design is that it offers increased sensitivity to renewal, perhaps superior to that seen in a between-subjects design. In Experiment 2, for example, there was little evidence that participants decreased responding during extinction, yet testing revealed a strong renewal effect—participants responded less when tested in the extinction context relative to the acquisition context. This suggests that participants did learn something about the extinction phase, otherwise, such differences at the test would not have been observed. The differences at the test observed in responding were also observed in expectancy ratings for each CS and context combination. Although in the expectancy tests, we did not manipulate the possibility of responding—that is we asked participants to provide an expectancy rating, but we did not allude to whether the avoidance response was made or not—the overall pattern of results had a remarkable similarity to the pattern observed in responses. The expectancy data thus provides some support to the proposal that cognitive expectations form a strong basis for the avoidance behavior observed during the avoidance test (Lovibond, 2006; Seligman & Johnston, 1973). Of course, it is difficult to properly determine what came first. In Experiment 2, participants were first tested on avoidance responding, so it is possible that what they did during the avoidance tests carried over to (or formed the basis of) the expectancy tests. Ultimately, associative and cognitive explanations of the phenomena should not necessarily be seen as incompatible with each other but instead complementary, with associative processes providing the building blocks for cognitive expectations (Witnauer et al., 2009).

Related to the last point above, a question that remains unanswered in the current experiments is whether we observed the extinction (and renewal) of avoidance responses or the extinction (and renewal) of Pavlovian associations. Whilst participants in these experiments were given the opportunity to avoid during extinction, renewal has been documented even when participants were not allowed to respond during extinction (Papalini et al., 2021). The extent to which the avoidance responses are relevant during extinction is a burgeoning issue as most therapeutic approaches prevent participants from avoiding during exposure therapy. This is predicated on the assumption that avoidance responses during extinction prevent fear extinction, which has been demonstrated empirically (Lovibond et al., 2009). There is also evidence (summarized recently by Urcelay, 2024) that avoidance responses can increase fear to neutral CSs. Whilst response prevention during extinction (which models exposure with response prevention; ERP) results in recovery once participants are allowed to respond again at the test (Gatzounis & Meulders, 2020; Vervliet & Indekeu, 2015), this finding has not always been replicated (Papalini et al., 2021). Unfortunately, none of these studies included all the necessary control conditions to determine what is being extinguished (Pavlovian association or the instrumental avoidance association), and therefore these questions remain unanswered. It is only once we understand these questions that we will better define what is being extinguished and renewed in these situations.

As previously noted, research on extinction of instrumental avoidance has been growing steadily in the last decade (see Dymond, 2019; Urcelay & Prével, 2019 for reviews), however, the scarce literature on recovery from extinction in human avoidance behavior has been somewhat contradictory. In rodents, Nakajima (2014) conducted a thorough set of experiments investigating different forms of renewal following extinction, and Tapias-Espinosa et al. (2018) investigated spontaneous recovery following extinction, both using two-way shuttle-box avoidance. Both studies revealed clear evidence of recovery from extinction in rodent avoidance. In humans, most studies have observed recovery from extinction assessed by expectancy ratings and skin conductance responses, but only a few reports have observed recovery from extinction as measured by avoidance responses. For example, following the extinction of targets (CS+ and CS−) and generalized stimuli, Cameron et al. (2015) presented three unsignaled shocks and observed a moderate reinstatement of avoidance, but to a CS−. Similarly, Krypotos and Engelhard (2018) conducted fear extinction following instrumental avoidance, and afterward, they administered three unsignaled shocks to the participants. This resulted in reinstatement of shock expectation but because they did not measure avoidance responses during extinction, they could not measure the extent to which this manipulation resulted in reinstatement of avoidance behavior. Krypotos et al. (2014) investigated the effect of fear extinction on avoidance tendencies (characterized as distinct from instrumental avoidance responses, avoidance tendencies rely on automatic tendencies acquired through Pavlovian conditioning). Using an ABA design, they observed a trend toward more avoidance tendencies in the training context (A) but the specific comparison with avoidance tendencies in the extinction context (B) did not achieve statistical significance. Vervliet and Indekeu (2015) tested extinction of instrumental avoidance without the possibility of responding (ERP) and observed that extinction with response prevention resulted in recovery at the test when the response was again available, regardless of whether extinction prevention was experienced (i.e., the response was not available during extinction) or informed (i.e., participants were told not to respond during extinction). This finding, which in itself is problematic for ERP (because of the recovery) and expectancy theory (because participants avoided at test despite showing low—extinguished—expectancy ratings), can be interpreted as renewal. That is, renewal can be assumed following the logic that avoidance acquisition occurred in a context (A) with the presence of the response, removing the response during extinction created a distinct context during extinction (B), which led to recovery when participants had again the opportunity to avoid during test (A). This finding replicated a study using a platform-avoidance task in rats (Bravo-Rivera et al., 2015). Finally, the two reports mentioned above (Cobos et al., 2023; Schlund et al., 2020) have documented renewal of avoidance behavior in humans, and both of those reports can be explained by CS-based accounts of the context.

Given that avoidance is a hallmark of anxiety, PTSD, and obsessive-compulsive disorder, and renewal models return of fear (or relapse) that occurs when patients leave the therapist's office, the current findings have a number of implications. First, a clear demonstration of renewal in human instrumental avoidance suggests that the principles governing extinction of human instrumental avoidance obey similar principles to those of human fear extinction, and of course extinction (Pavlovian and instrumental) in other animals (Todd et al., 2014). This means that much of what we know about the extinction of fear can also be applied to avoidance behavior, and this is relevant given recent suggestions that considering avoidance as part of the treatment (or as an adjunct to exposure therapy) can be beneficial (Hofmann & Hay, 2018; Treanor & Barry, 2017). Second, a design that provides a clear demonstration of renewal in human instrumental avoidance will enable studies investigating the effectiveness of ERP upon changes in contextual background. Given that the availability or not of the response can create different contexts, changes in physical background can help to determine whether these effects are additive or not, hence illuminating the interactions between these different factors. Third, safety signals and safety behaviors provide relief, and safety signals reinforce avoidance behavior (Fernando et al., 2014; Fisher & Urcelay, 2024; Vervliet et al., 2017), but conditioned inhibitors also prevent the extinction of fear (Lovibond et al., 2009; Volders et al., 2012), and hence their use in therapeutic settings is poorly understood. Assessing their role using a powerful renewal design will enhance our understanding of these interactions on a design that better models the return of fear (i.e., relapse) outside of the extinction context. Finally, a clear renewal design allows us to investigate ways of conducting extinction to attenuate recovery from extinction of instrumental avoidance, as has been done in Pavlovian extinction paradigms (Urcelay, 2012). For example, studies in rodents investigating extinction of fear (Urcelay et al., 2009) and avoidance (Tapias-Espinosa et al., 2018) have found that spacing extinction trials (or sessions) attenuates recovery from extinction, but little is known about this factor in the extinction of human instrumental avoidance.

In summary, in two experiments we observed a clear, within-subjects demonstration of renewal in human instrumental avoidance, using a design that we interpret as consistent with Bouton's proposal (1993, 1994). Overall, we believe that this task and design have the potential to develop basic research on the extinction of human avoidance, with an emphasis on translating basic findings to clinical practice. Whilst there is more research needed in these areas, we believe that this is a first and important step toward the development of such basic knowledge.

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Received December 13, 2023
Revision received May 22, 2024
Accepted May 22, 2024 ■