Renewal of instrumental avoidance in humans

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Gonzalo P. Urcelay[1], Kadell Symmons[2], Bethany Amos[2], Hazem Toutounji[3], & Arthur Prével[4]

[1] School of Psychology, University of Nottingham, UK.

[2] School of Psychology and Vision Sciences, University of Leicester, UK

[3] Department of Psychology, University of Sheffield, UK

[4] SCALab, University of Lille, France.

Corr. author: Gonzalo P. Urcelay
School of Psychology
University of Nottingham
University Park. Nottingham, NG7 2RD, UK
TEL: +44 (0115) 9515319
E-mail: gonzalo.urcelay@nottingham.ac.uk

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Abstract

The renewal effect, which occurs when extinguished behaviour is tested outside of the extinction context, has been proposed as a model of contextual control that has relevance for the understanding of relapse following exposure therapy. Notably, there are multiple mechanisms by which the renewal effect can be explained. In two experiments, we used within-subjects designs in which participants learned to avoid a loud noise signalled by two discrete visual stimuli (CSs+), by pressing the space bar on the computer keyboard. Each CS+ was trained along with a CS- in a different 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 vs ABB comparison. In both experiments, participants increased avoidance responses during training, and decreased responding during extinction, although Experiment 2 revealed less extinction. During test, responding was higher when CS+ stimuli were tested in the training (ABA) vs the extinction context (ABB), thus showing renewal of instrumental avoidance in humans. Additional analyses in Experiment 2 showed a remarkable similarity between avoidance responses and expectancy ratings. This study shows renewal of instrumental avoidance in humans, and the results suggest the operation of a modulatory role for the context in renewal, similar to occasion setting of extinction learning by the context.

Key Words: Instrumental avoidance; extinction; renewal; context

Renewal of instrumental avoidance in humans

Anxiety disorders and post-traumatic stress disorder (PTSD) are a group of disabling disorders, which result from individuals showing disproportional fear to objects or situations, and excessive active avoidance of potential threats (Pittig, Treanor, LeBeau, & Craske, 2018). These symptoms are apparently irrational and lead to considerable distress and social isolation. Much like anxiety disorders and PTSD, obsessive-compulsive disorder (OCD) also shows excessive avoidance along with other symptoms such as checking (which itself can be characterized as avoidance). Across all these conditions, excessive avoidance behaviour is a behavioural manifestation, a diagnostic criterion, and sometimes a predictor of successful treatment (Aderka, McLean, Huppert, Davidson, & Foa, 2013). In addition, recent dimensional attempts to overcome the categorical nature of DSM-V (American Psychiatric Association, 2013) have identified Research Domain Criteria (RDoC: Insel et al, 2010), and in this scheme avoidance is a behavioural element of aversively motivated behaviours. Despite the prevalence and clinical relevance of avoidance behaviour, it is only recently that interest in, and studies investigating avoidance have re-emerged (Cain, 2019; Dymond, 2019; Gillan, Urcelay & Robbins, 2016; LeDoux et al., 2016; Pittig, Treanor, LeBeau, & Craske, 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 behaviour. Interest in avoidance behaviour however has resurged in the last decade, leading to numerous reviews on avoidance, and two specialized volumes (see Beckers & Craske, 2017; Servatius, 2016 for introduction by editors; also see LeDoux, Moscarello, Sears & Campese, 2016). The resurged interest for avoidance behaviour may be due in part to the finding that avoidance behaviour itself can prevent fear extinction from happening (Lovibond, Mitchell, Minard, Brady & Menzies, 2009), which is central to exposure-based therapies. It is thought that this can sometimes result in persistent fear and avoidance behaviours (Williams & Levis, 1991).

Extinction learning has inspired exposure-based therapies, in part because of the striking parallels between the two. One of the cardinal features of extinction learning is that, rather than erasing the original memory, it results in new inhibitory learning, which is context dependent (Bouton, 1993; 2004). This is supported by behavioural evidence showing at least eight phenomena documenting 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 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 (renewal). Whilst these three phenomena have been widely documented following extinction of fear and appetitive conditioning, there is a dearth of studies investigating recovery from extinction of instrumental avoidance behaviour (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, AAB) result in recovery from extinction (Bouton, 2004; Urcelay, 2012). Renewal of avoidance has been documented in rodents (Nakajima, 2014), and there are two recent reports with human participants (Schlund et al., 2019; Cobos et al., 2023), although both can be explained by either context inhibition (during extinction) or context summation (during 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 CS and that of a modulator of memory expression (Urcelay & Miller, 2010; 214). 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, the context B acquires inhibitory associative strength during extinction, thus resulting in disinhibition when testing is conducted in A. Second, because the context A was also present during acquisition, it could contribute to responding to the target stimulus at test by summation. Either alone or together, these two mechanisms can account for ABA renewal and both appeal to the context functioning like any other discrete CS which 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 extinction phenomena). An alternative way to explain ABA 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 highly context dependent and therefore any change in context from extinction to test results in recovery from extinction. Extinction is thus seen as new learning which is highly context dependent.

One way to distinguish between these explanations of the ABA renewal effect is to run the experiment using multiple CSs and contexts, and a within-subjects design in which the associative history of the context of acquisition and extinction is matched. In this case, the observation of ABA renewal can only be explained by Bouton's explanation. 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 context 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 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 can only be accounted for by Bouton's explanation. In order to fulfil these objectives, we adapted the task pioneered by Flores and her colleagues (Flores, López, Vervliet, & Cobos, 2018) and used a within-subjects design (Rescorla, 2008). The unique advantage of this design is that it matches the two contexts for their overall history of reinforcement during acquisition and non-reinforcement during extinction, and the conditioned stimuli (CSs) in terms of histories of reinforcement and non-reinforcement. In addition to reducing the number of participants needed, this design renders any differences observed at test attributable to modulatory effects of the context, which is consistent with the best-developed explanation for the context-dependence of extinction (Bouton, 1993, 1994).

Experiment 1

Method

Participants

The participants were 30 undergraduate students from the University of Leicester that completed the study in exchange for course credit. Twenty-five identified themselves as female and 5 as males, 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 2x2 within-subjects interaction (at renewal). We estimated the sample size based on prior experience. The experiments were not preregistered.

Apparatus and Materials

The experiments were run in three separate rooms, each containing a chair and desk with a computer. Three Helwet-Packard PCs 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 1280 x 1024 resolution), placed roughly 60 cm in front of the participants. Avoidance responses were made through a keyboard by pressing the spacebar. Four fractals (10 x 8.5 cm) were used as stimuli (CS1, CS2, CS3, CS4) and these were randomized across participants by the program. A 3-second tone of 1100 Hz (95 ± 4dB) 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 these the loud noise was reduced to 90 dB. Before starting the experiment, participants completed Spielberger's State-Trait Anxiety Inventory for adults (Spielberger, Gorsuch, Lushene, Vagg, Jacobs, 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 colour 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 vs ABA comparison (where A is the context of acquisition and B the context of extinction).

Procedure

Upon arriving in the laboratory, participants signed a consent form informing them that there will 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 4 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 seconds. Following this, one of the four images (CS1, CS2, CS3, and CS4) was displayed in the centre of the screen in front of the context background for 20 seconds. In this and all other phases, the CSs were always presented for 20 seconds, regardless of whether participants avoided the loud noise or not. The onset of the noise was programmed according to a variable time schedule with a mean of 9 seconds (from the onset of the CSs+), which followed a rectangle distribution with range of 15 seconds. This way, the aversive sound could appear randomly at any second between 2 and 16 seconds from the onset of a CS+. The Pavlovian learning phase consisted of 4 trial blocks each including 2 presentations of each CS, the order in which each CS was presented within a block was randomised (as was the case throughout) as well as the specific images that triggered the aversive sound also being randomised. Each CS was presented 8 times during this 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 4 trial blocks each including 2 presentations of each CS that was randomised, therefore having 8 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 2 CSs+ were presented against the opposite context background as was the case with the 2 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 8 blocks of randomised CS presentations, therefore each CS was presented 16 times during this phase. Lastly, all stimuli were tested in both contexts, with the order of context counterbalanced across participants. This phase consisted of blocks in which there were 2 presentations of each CS per context.

Data Analysis

The main dependent measure in this study was the number of presses per stimulus in each block (each block containing 2 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 2 presentations of each CS, and averaged the two CSs+ and the two CSs- in each block (4 blocks). The same was done for the 8 extinction blocks, and each test block. Space bar presses were analysed with within-subjects ANOVAS with stimulus identity (CSs+ vs CSs-) and blocks (1-4 during training, and 1-8 during extinction) as within-subjects variables. During test, we used within subjects ANOVAS and compared stimuli (CSs+ vs CSs-) and context of Test (Extinction vs Acquisition). 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 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 paper are available at DOI 10.17605/OSF.IO/V4D3B. Data were analyzed using IBM SPSS Statistics (Version 27). This study's design and its analysis were not pre-registered. 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 1A depicts the acquisition of instrumental avoidance (frequency of space bar presses) for both CSs+ (CS1 and CS3) and both CSs- (CS2 and CS4) across 4 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-) x 4 (Block: 1-4) within-subjects ANOVA, that revealed a main effect of Stimulus, F (1, 29) = 42.81, $p < .001$, $\eta p^2 = 0.596$, 90% CIs [.37, .70], an effect of Block, F (1.47, 42.85) = 10.69, $p < .01$, $\eta p^2 = 0.26$, 90% CIs [.08, .40], and a Stimulus x Block interaction, F (1.44, 41.85) = 8.89, $p < .01$, $\eta p^2 = 0.23$, 90% CIs [.05, .38]. Analyses of simple effects revealed a large effect of block for CSs+, F (1.44, 41.95) = 9.97, $p < .01$, $\eta p^2 = 0.25$, 90% CIs [.07, .40], but only a marginal effect for CSs- F (1.36, 39.59) = 3.45, $p = .058$, $\eta p^2 = 0.10$, 90% CIs [.00, .24]. Thus, the interaction suggests that acquisition was observed for CSs+, but not for CSs-.

Extinction

Figure 1B shows the frequency of spacebar presses during 8 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. These impressions were supported by the following statistical analyses. A 2 (Stimulus: CS+ vs CSs) x 8 (Block: 1-8) within-subjects ANOVA revealed a main effect of Stimulus, F (1, 29) = 21.81, p < .001, ηp^2 = 0.42, 90% CIs [.18, .57], a main effect of Block, F (1.49, 43.24) = 10.56, p < .01, ηp^2 = 0.26, 90% CIs [.08, .40], and a Stimulus x Block interaction, F (1.75, 50.81) = 8.52, p < .01, ηp^2 = 0.22, 90% CIs [.06, .35]. To follow up the Stimulus x 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, ηp^2 = 0.28, 90% CIs [.10, .41], but only a marginal change for CSs-, F (1.12, 32.58) = 3.07, p = .085, ηp^2 = 0.09.

Test

Figure 1C 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 analysed with a 2 (Stimulus: CS+ vs CS-) x 2 (Context: Acquisition vs Extinction) within-subjects ANOVA, which revealed an effect of Stimulus, F (1, 29) = 21.36, p < .001, ηp^2 = 0.42, 90% CIs [.18, .57], and effect of Context, F (1, 29) = 9.71, p < .01, ηp^2 = 0.25, 90% CIs [.05, .43], and a Stimulus by Context interaction, F (1, 29) = 9.15, p < .01, ηp^2 = 0.24, 90% CIs [.04, .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, ηp^2 = 0.24, 90% CIs [.04, .42], but no differences were observed for CSs-, F (1, 29) = .96, p = .33, ηp^2 = 0.03. 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 the associative strength of both contexts, we did not observe any differences in responding to the CSs- based on test context.

Experiment 2

Experiment 1 revealed convincing evidence for 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, 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 for expectancy in human avoidance (Lovibond, 2006).

Method

Participants

The participants were 30 undergraduate students from the University of Leicester that completed the study in exchange for course credit. Twenty-seven identified themselves as female and 3 as males, 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.

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 GAD-7 (Spitzer, Kroenke, Williams & Lowe, 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 4 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 9 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 2A). This pattern changed as training progressed, so that the differences became larger. These impressions were confirmed by a 2 (Stimulus: CSs+ vs CSs-) x 4 (Block: 1-4) within-subjects ANOVA. The analysis revealed a main effect of Stimulus, F (1, 29) = 61.02, p < .001, ηp^2 = 0.678, 90% CIs [.48, .76], an effect of Block, F (1.78, 51.64) = 24.45, p < .001, ηp^2 = 0.457, 90% CIs [.27, .56], and a Stimulus x Block interaction, F (1.73, 50.18) = 17.7, p < .001, ηp^2 = 0.379, 90% CIs [.19, .50]. Analyses of simple effects revealed an effect of block for CSs+, F (1.8, 52.22) = 24.25, p < .001, ηp^2 = 0.455, 90% CIs [.37, .56], but a nonsignificant effect for CSs- F (1.44, 41.81) = 3.29, p = .062, ηp^2 = 0.102. 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 block, F (2.36, 68.58) = 14.82, p < .001, ηp^2 = 0.327, 90% CIs [.16, .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 2B, which reveal little extinction of responding to the CSs+ in comparison to what was observed in Experiment 1. These impressions were supported by a 2 (Stimulus: CS+ vs CSs) x 8 (Block: 1-8) within-subjects ANOVA revealed a main effect of Stimulus, F (1, 29) = 7.54, p = .011, ηp^2 = 0.20, 90% CIs [.02, .38], but no effect of Block, F (2.44, 70.87) = 1.42, p = .24, ηp^2 = 0.047, 95%, and no Stimulus x Block interaction, F (2.82, 82.00) = 0.478, p = .68, ηp^2 = 0.016. Given the absence of an interaction, we did not assess the change for each pair of CSs separately.

Test

Participants during 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 2C). These observations were corroborated with a 2 (Stimulus: CS+ vs CS-) x 2 (Context: Acquisition vs Extinction) within-subjects ANOVA, which revealed an effect of Stimulus, F (1, 29) = 29.69, p < .001, ηp^2 = 0.50, 90% CIs [.26, .63], and effect of Context, F (1, 29) = 4.92, p < .05, ηp^2 = 0.145, 90% CIs [.00, .33], and a Stimulus by Context interaction, F (1, 29) = 8.08, p < .01, ηp^2 = 0.218, 90% CIs [.03, .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, ηp^2 = 0.251, 90% CIs [.05, .43], but no differences were observed for CSs-, F (1, 29) = 2.39, p = .13, ηp^2 = 0.076.

Analysis of the expectancy ratings collected after the test of instrumental responding revealed a similar pattern as that observed with instrumental responses (Figure 2D). A 2 (Stimulus: CS+ vs CS) x 2 (Context: Acquisition vs Extinction) within-subjects ANOVA, revealed an effect of Stimulus, F (1, 29) = 70.45, p < .001, ηp^2 = 0.70, 90% CIs [.51, .78], and effect of Context, F (1, 29) = 9.37, p < .01, ηp^2 = 0.244, 90% CIs [.04, .42], and a Stimulus by Context interaction, F (1, 29) = 13.12, p < .001, ηp^2 = 0.312, 90% CIs [.09, .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, ηp^2 = 0.359, 90% CIs [.12, .52], but no differences were observed for CSs- expectancy ratings in the different contexts, F (1, 29) = 1.12, p = .29, ηp^2 = 0.037. Thus, expectancy ratings paralleled the findings observed in instrumental responses. The average rating of noise intensity was 6.63 (SD = 1.47) suggesting that participants perceived the noise as somewhere in between Loud (5) and Very Loud (9).

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 and colleagues (Flores, López, Vervliet & Cobos, 2018) that introduces uncertainty concerning when the aversive outcome is to occur. This results in high levels of avoidance behaviour, 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 that noticed the change in contingency began responding to the previously non-reinforced 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 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-.

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 non-reinforced 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 by the context during extinction learning (Cobos et al., 2023). Similarly, it could be argued that in an ABA vs ABB comparison, the differences in responding observed at test are due to 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 behaviour 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 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 best explained by Bouton's model that assumes that extinction is context-dependent new learning (Bouton, 1993).

In addition to discriminating between different explanations of the renewal effect, the within-subjects design offers increased sensitivity to renewal, perhaps superior to that seem 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 test would not have been observed. The differences at 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 of the avoidance behaviour 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, Urcelay & Miller, 2009).

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 of recovery from extinction in human avoidance behaviour has been somewhat contradictory. In rodents, Nakajima (2014) conducted a thorough set of experiments investigating different forms of renewal following extinction, and Tapias-Espinosa and colleagues (Tapias-Espinosa, Kadar, & Segura-Torres (2018) investigated spontaneous recovery following extinction, both using of 2-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 extinction of targets (CS+ and CS-) and generalized stimuli, Cameron Schlund and Dymond (2015) presented 3 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 afterwards they administered 3 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 behaviour. Krypotos and colleagues (Krypotos, Effting, Arnaudova, Kindt & Beckers, 2014) investigated the effect of fear extinction on avoidance tendencies (as distinct from instrumental avoidance responses, avoidance tendencies rely on automatic tendencies acquired through Pavlovian conditioning). Using an ABA design, they observed a trend towards 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 (as an attempt to model exposure with response prevention; ERP) and observed that extinction with response prevention resulted in recovery at 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 lead 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, Roman-Ruiz, Montesinos-Cartagena, & Quirk, 2015). Finally, the two reports mentioned above (Cobos et al., 2023; Schlund et al., 2020) have documented renewal of avoidance behaviour in humans, and both of those reports can be explained by standard associative theories.

Given that avoidance is a hallmark of anxiety, PTSD and OCD, and renewal models return of fear (or relapse) that occurs when patients leave the therapist 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, Vurbic & Bouton, 2014). This means that much of what we know about extinction of fear can also be applied to avoidance behaviour, 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 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 behaviours provide relief, and safety signals reinforce avoidance behaviour (Fernando, Urcelay, Mar, Dickinson & Robbins, 2014; Vervliet, Lange & Milad, 2017), but conditioned inhibitors also prevent extinction of fear (Lovibond, Mitchell, Minard, Brady & Menzies, 2009; Volders, Meulders, De Peuter, Vervliet & Vlaeyen, 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 return of fear (i.e., relapse) outside of the extinction context. Finally, a clear renewal design allows to investigate ways of conducting extinction to attenuate recovery from extinction of instrumental avoidance, as it has been done in Pavlovian extinction paradigms (Urcelay, 2012). For example, studies in rodents investigating extinction of fear (Urcelay, Wheeler, & Miller, 2009) and avoidance (Tapias-Espinosa, Kadar, & Segura-Torres, 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 provides unique support for Bouton's proposal (1993; 1994). Overall, we believe that this task and design have potential to develop basic research on extinction of human avoidance, with an emphasis of 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 towards the development of such basic knowledge.

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Author Notes

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Table 1

Context	Pavlovian Conditioning	Instrumental Acquisition	Instrumental Extinction	Tests CTX A	CTX B
A	CS1+ CS2-	CS1+:R CS2-:R	CS3-:R CS4-:R	CS1-:R CS2-:R	CS1-:R CS2-:R
B	CS3+ CS4-	CS3+:R CS4-:R	CS1-:R CS2-:R	CS3-:R CS4-:R	CS3-:R CS4-:R

Table 1: Design of Experiments 1 and 2. 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 vs ABA renewal design.

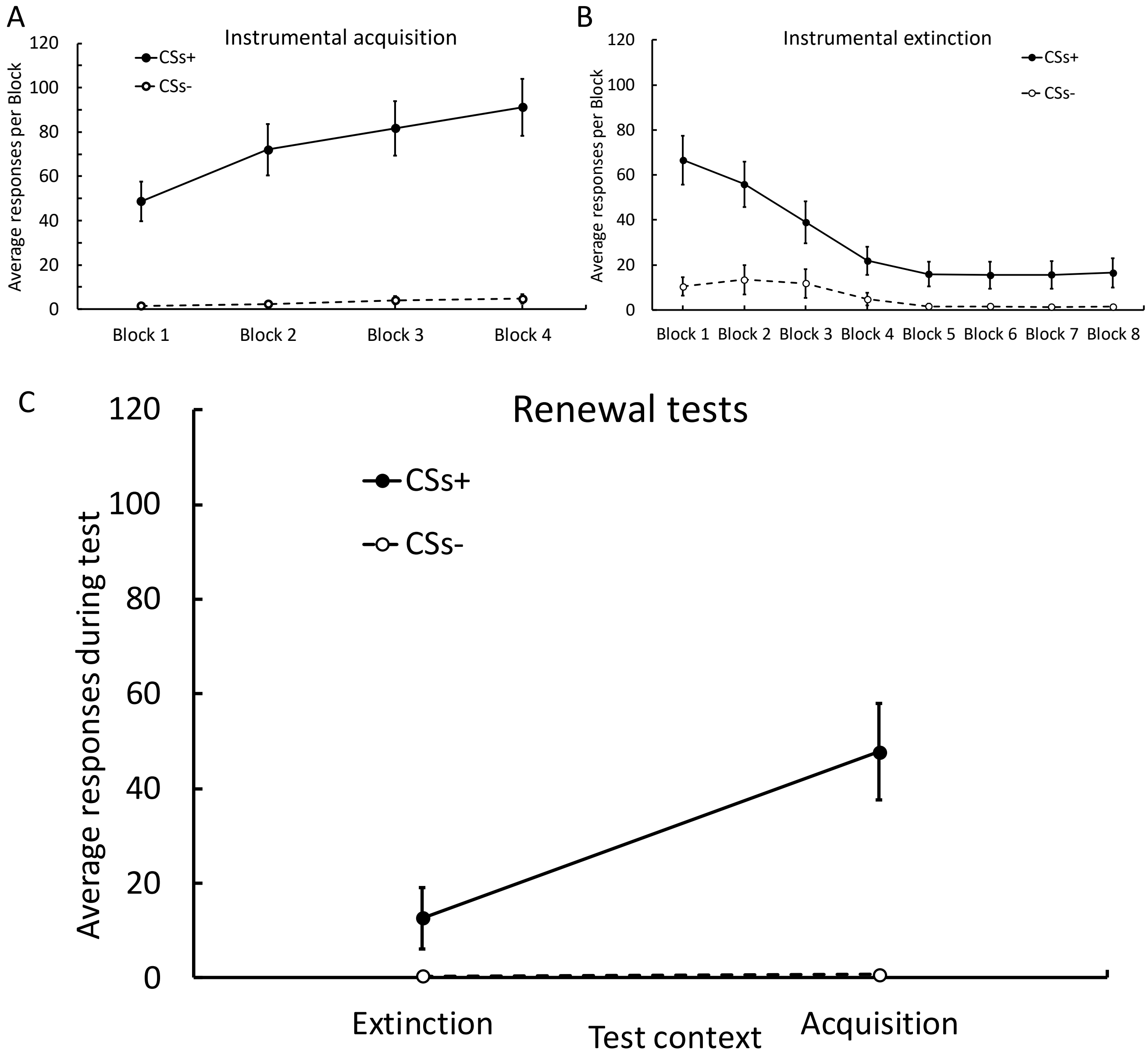

Figure 1. Results of Experiment 1. A) Average responses per block during acquisition. There was an increase of avoidance responses upon presentation of CSs+, but not when CSs- were presented. B) Responses during extinction. There was clear extinction of responding during presentations of the CSs+, but a marginal change during presentations of CSs- C) Results of Renewal tests. 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 context of test were observed for CSs-. Error bars represent SE of the mean.

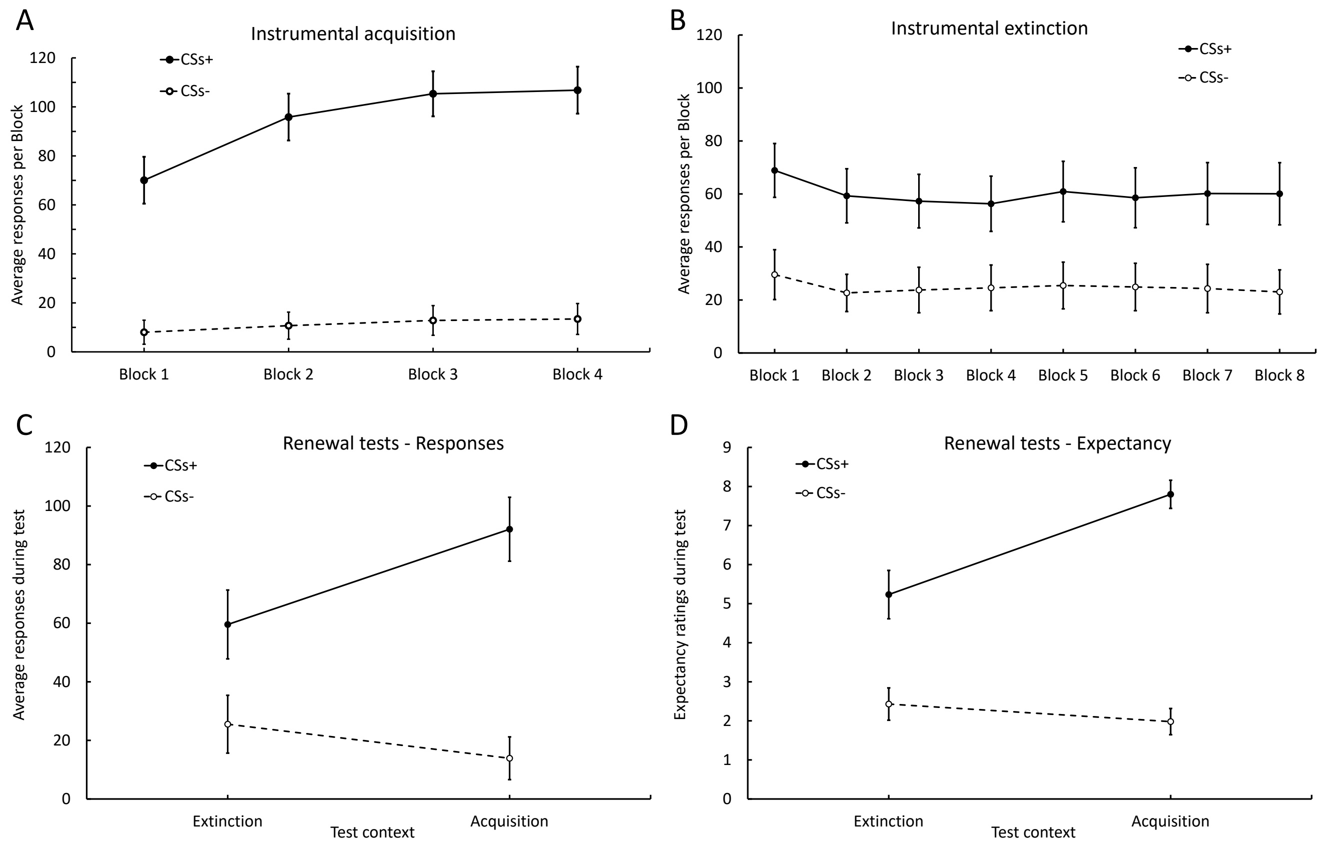

Figure 2. Results of Experiment 2. A) Average responses per block during acquisition. There was an increase of avoidance responses upon presentation of CSs+, but not when CSs- were presented. B) Responses during extinction. There was no extinction of responding during presentations of the CSs+ (although 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 context of 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 context of test were observed for CSs-. Error bars represent SE of the mean.