



Renewal of threat expectancy in an online contextual avoidance paradigm

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ABSTRACT

Extinction of fear and avoidance is not permanent and can return following contextual changes (termed *renewal*). The aim of the current study was to investigate the renewal of avoidance, threat expectancy, and fear ratings in an online avoidance task administered during the COVID-19 pandemic. One-hundred and two participants completed a task consisting of habituation, threat conditioning, avoidance conditioning, extinction with response prevention, and renewal. Tests for renewal occurred either in the original conditioning context (ABA, $n = 52$) or the extinction context (ABB, $n = 50$). Images of a quiet and a busy street served as relevant contexts. Renewal was evident whereby the ABA group showed a significant increase in threat expectancy when tested in the conditioning context, which had not been extinguished. This effect was not found for avoidance or fear ratings, nor for the ABB group who underwent the renewal test in the extinction context. The current study demonstrated differential renewal of threat expectancy in an online contextual avoidance paradigm.

1. Introduction

Avoidance behaviours aim to increase the perceived or actual distance between individuals and dangerous stimuli (Dymond, 2019; Pittig et al., 2018; Wong et al., 2022). Often, avoidance is driven by the motivation for safety, although in many clinical disorders the behaviours can be disconnected from their adaptive function and are performed to reduce uncomfortable thoughts and feelings. As a result, avoidance behaviours can—via negative reinforcement mechanisms—prevent the extinction of fear and anxiety (Dymond, 2019) and are considered the primary barriers to effective treatment for anxiety disorders (Craske et al., 2018).

During the COVID-19 pandemic, many avoidance-related behaviours associated with infection control may have become normalised. While behaviours such as hand hygiene and social distancing are healthy behaviours to promote safety and prevent contagion, they also serve as reminders of threat and may maintain maladaptive avoidance alongside fear and anxiety (Cameron et al., 2022; Kesim et al., 2024; Xia et al., 2019). Persistent maladaptive avoidance is particularly pernicious and associative learning theories hold that learned safety behaviours are moderated, at least in part, by context (Bouton & Moody, 2004; Papalini et al., 2021).

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The role of context in the acquisition and extinction of conditioned threat associations is well established. Early rodent research identified that conditioned fears acquired in one context (context A) that are ‘successfully’ extinguished in another context (context B) may return if the rodents are returned to context A, even in the absence of the unconditioned stimulus (US; Bouton & Bolles, 1979). This effect, termed contextual fear renewal, has been replicated numerous times in rodents (Bouton & King, 1983; Orsini et al., 2011), humans (Hermann et al., 2016; Sjouwerman & Lonsdorf, 2023; Wang et al., 2024), and in clinical populations with posttraumatic stress disorder (Milad et al., 2005). It is commonly accepted that extinction learning does not re-consolidate, override, or replace the original conditioned memory, but undergoes consolidation and storage as a *new* inhibitory memory trace that is retrieved in competition with the original conditioned memory (Bouton & Moody, 2004; Craske et al., 2014). In short, the fear extinction memory traces are bound by the context in which learning occurred.

Relative to renewal of fear and threat, little is known about the impact of context on the renewal of avoidance. Recently, Papalini et al. (2021) used a contextual renewal paradigm to investigate the learning, extinction, and renewal of avoidance behaviours. In their study, participants first underwent Pavlovian threat conditioning in context A, after which they learned that an avoidance cue predicted the opportunity to prevent the US (a mild electric shock) in the same context. Avoidance learning was followed by extinction with response prevention in context B, after which groups of participants completed an avoidance renewal test in either conditioning context A (ABA) or extinction context B (ABB). Papalini et al. (2021) found that avoidance was greater for participants tested in the conditioning context compared to the extinction context, suggesting that avoidance learning is also subjected to the same—or similar—contextual modulation as fear.

Since the COVID-19 pandemic, the conceptualisation and empirical investigation of factors modulating fear and avoidance has greatly expanded. The remote delivery of fear conditioning paradigms via smartphone apps or online platforms confers numerous advantages such as easier recruitment of large sample sizes and the potential to replicate and extend lab-based experiments using real-world settings and stimuli (Ney et al., 2023). For instance, smartphone apps have been validated to study fear conditioning and extinction in large samples (Lambert et al., 2021; McGregor et al., 2021; McGregor et al., 2023; Purves et al., 2019, 2021), while web-based tasks have been developed involving high degrees of experimental control (Berg et al., 2022; Plog et al., 2023). Berg et al., for example, employed individualised US calibration procedures by adjusting participants’ headphone volume settings and found it effective at generating fear conditioning effects in an online task. We recently developed and evaluated the feasibility of a novel online fear conditioning task to study avoidance learning during the COVID-19 pandemic (Cameron et al., 2022, 2023; see also, Dymond et al., 2024). We instructed participants to wear headphones and to turn the volume setting to maximum and used a compound US consisting of a loud female scream and a fearful female face (Lau et al., 2008; Neumann and Waters, 2006). Clear evidence of differential fear conditioning was found using trial-by-trial expectancy ratings and end-of-phase fear ratings, while we further showed that the task could record the acquisition and extinction of avoidance behaviour by pressing a keyboard key to cancel upcoming US presentation (Cameron et al., 2022, 2023). Another study showed that the task was sensitive to fear generalisation involving multiple, graded real-world fearful images from the pandemic (Dymond et al., 2024).

In the current study, we investigated the renewal of avoidance, threat expectancy and fear in our adapted online task with data collection conducted during the 2020/21 UK COVID-19 lockdown period. Images of a quiet and crowded street with many mask-wearing individuals served as context A and B, counterbalanced. These stimuli were deemed to be sufficiently salient and representative of the prevailing public health conditions in the UK at the time, to be equally likely of eliciting pre-experimental appetitive and non-appetitive functions, and to illustrate the then-novel presence of face coverings worn by people engaging in otherwise familiar activities (i.e., walking on a popular shopping street). As before, a fearful female face accompanied by a loud shrieking scream served as the aversive US (Cameron et al., 2022).

We expected that renewal of avoidance behaviour, US threat expectancy and fear ratings would be significantly greater in the conditioning context (context A). In addition, we predicted that renewal would be greater for the busy street compared to the quiet street, irrespective of whether this context served as the acquisition or extinction context. We expected this due to the salient threat value likely imbued by the busy street image at the time of data collection (i.e., during national pandemic lockdowns).

2. Method

2.1. Participants

One-hundred-and-two participants were recruited via Prolific. The sample age ranged between 18–70 ($M = 31.2$ years, $SD = 10.6$ years), with 50 females, 51 males, and 1 participant who preferred not to say. Participants were randomly allocated to the ABA group ($n = 52$) or the ABB group ($n = 50$) with the acquisition context (quiet vs. busy) counterbalanced between participants (i.e., $ABA_{\text{quiet}} = 27$; $ABA_{\text{busy}} = 25$; $ABB_{\text{quiet}} = 24$; $ABB_{\text{busy}} = 26$). A post-hoc sensitivity analysis using *G*Power 3.1* (Faul et al., 2007) calculated that we should expect to find an effect size of Cohen’s $f = 0.15$ and a critical $F = 2.15$ (numerator $DF = 6$, denominator $DF = 196$) in the analysis of the renewal test.

Inclusion criteria consisted of being 18 years or older, currently residing in the UK, not pregnant, and no reported neurological, hearing or vision difficulties. Participants were reimbursed £6. Data collection occurred between the 9th and 11th of April 2021. The study was approved by Swansea University’s School of Psychology Research Ethics Committee.

2.2. Design and procedure

The online contextual avoidance renewal task was developed and administered using the Gorilla Experiment Builder (Anwyl-Irvine

et al., 2020). The contextual images consisted of a photograph of Queen Street, Cardiff, Wales (a popular shopping precinct), which was modified to appear *quiet* (original image) or *busy*, containing individuals wearing face-coverings (see Fig. 1). These images were further modified such that the colour of a carousel structure in the background acted as the conditional stimuli (CS); when illuminated white, it was assigned the CS-, and when illuminated green or blue, the CS+ (counterbalanced as the avoidable CS+ (CS_{AV}) and unavoidable CS+ (CS_{UNAV}), respectively (Fig. 1). The compound US was a fearful female face (Tottenham et al., 2009) accompanied by a loud shrieking scream presented at CS-offset for 2 s (Lau et al., 2008). The avoidance cue was a small image of a hand holding a computer-mouse presented in the top left corner.

Participants were required to use a desktop or laptop computer and instructed to wear headphones with the volume set to the highest setting for the duration of the study. A sound manipulation check was completed at the outset, where three words (“cat”, “house”, and “jump”) were played three times each and the participant was required to enter the correct words into an onscreen textbox.

During each trial, the CS was presented onscreen for 3 s, followed by the threat expectancy scale presented below for 5 s (see Fig. 2). Participants were instructed to rate their expectancy of the US using the computer mouse on a sliding scale ranging from 0 (“*highly unlikely a scream*”) to 100 (“*highly likely a scream*”). At scale offset, the CS remained onscreen for a further 3 s either with or without the

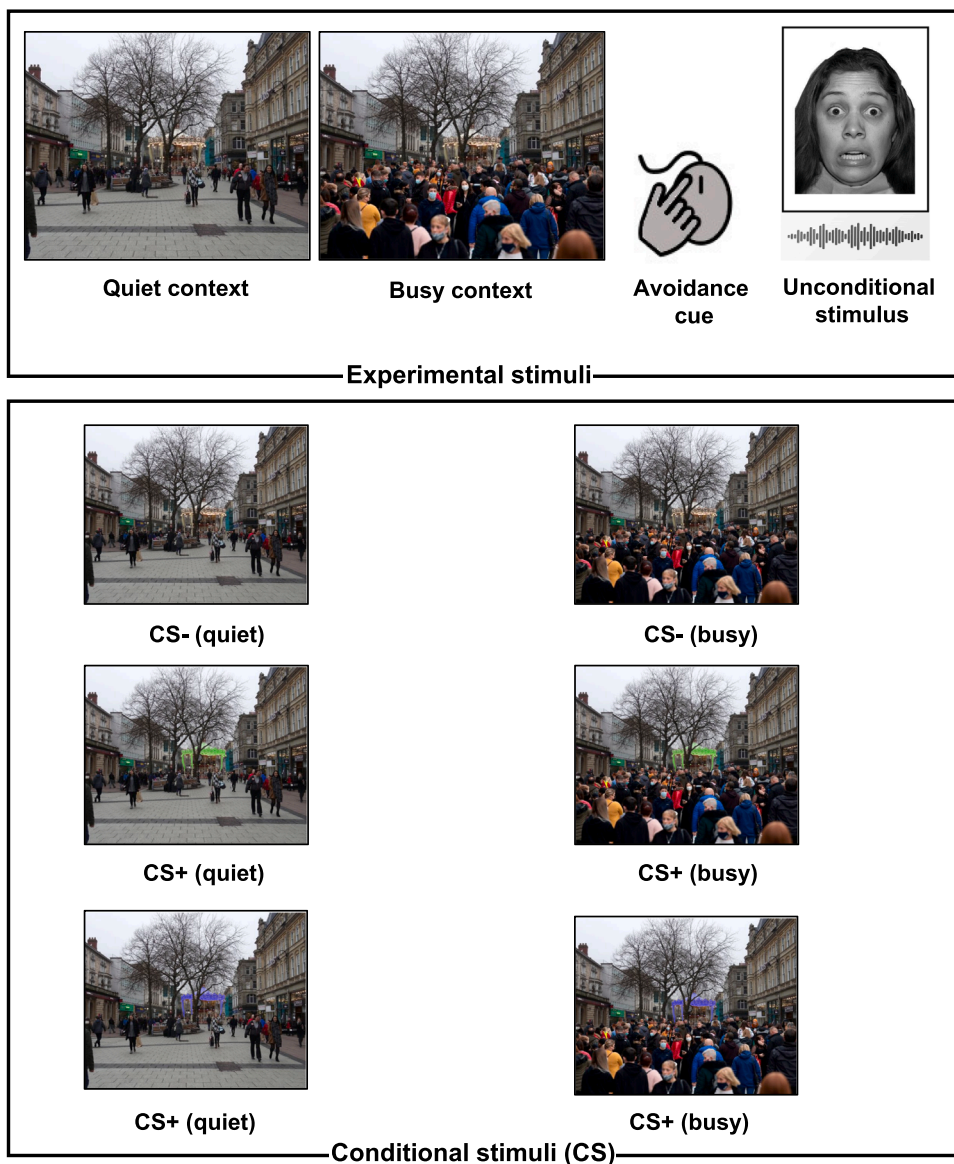


Fig. 1. Top panel: experimental stimuli (quiet and busy contexts), avoidance cue and illustration of compound US employed in the study. Bottom panel: conditional stimuli (CS) representing CS-, CS+(avoidable and unavoidable) across each of the two contexts (quiet and busy) employed in the study. CSs were distinguished by the background colour of the carousel (i.e., white, blue or green).

avoidance cue present (i.e., a total trial duration of 11 s). At the end of each phase, each CS was presented again, and participants were instructed to rate how afraid they were on a scale ranging from 0 (“unafraid”) to 100 (“afraid”).

The online contextual avoidance renewal task consisted of six phases: *habituation* (context A), *threat conditioning* (context A), *avoidance conditioning* (context A), and *extinction with response prevention* (context B). We then included two counterbalanced renewal test phases. For half of the participants, renewal test 1 and renewal test 2 occurred in context B and context A, respectively, while the remaining participants experienced renewal test 1 and renewal test 2 in context A and context B, respectively (only the first test phase was included in analyses).

Prior to *habituation*, participants were informed that they would be shown three images of a high street and that two of these images would be accompanied by a loud female scream and one would not. Their task was to rate each image on how likely they thought the scream would occur and to rate how afraid they were of each image. Crucially, they were instructed to keep their headphones on throughout the experiment. Prior to *avoidance conditioning*, participants were informed that they would now be able to prevent the scream from occurring by pressing the ENTER key on trials with an image of hand clicking a mouse. Prior to *extinction*, participants were informed that the ENTER key would no longer be available (see [Supplementary materials](#) for the full instructions).

During *habituation*, participants experienced one trial each of the CS+_{AV}, CS+_{UNAV}, and the CS- in randomised order. During *threat conditioning*, participants were exposed to 8 trials of each stimulus, with 24 trials in total. The CS+_{AV} and CS+_{UNAV} were followed by the US immediately upon CS+ offset on 6 trials each (75 % reinforcement schedule). Similarly, *avoidance conditioning* included 8 trials of each stimulus (24 trials in total). During this phase, the avoidance cue appeared on all trials for the final 3 s of stimulus presentation. The avoidance response was a single spacebar press, and this cancelled upcoming US delivery on the CS+_{AV} trials, but not the CS+_{UNAV} trials. During *extinction with response prevention*, each stimulus was presented 8 times each, however neither the avoidance cue nor the US were delivered on any trial. Importantly, the *extinction with response prevention* phase occurred in context B, whereby participants who underwent threat and avoidance conditioning during the quiet context underwent extinction in the busy context, and vice versa.

Following *extinction with response prevention*, participants underwent the renewal test 1 and test 2 phases. Each phase consisted of 8 trials of each stimulus, with the avoidance cue presented on all trials; however, the US was not presented on any trial irrespective of whether an avoidance response was made.

2.3. Statistical analyses

Mixed repeated measures analyses of variance (ANOVAs) were conducted separately per phase of the experiment to assess threat expectancy ratings, fear ratings and avoidance responses. For threat expectancy ratings, we used 2 (context) $\times$ 3 (CS) $\times$ 8 (trial)



Fig. 2.. The online contextual avoidance task. Conditioning and extinction context was counterbalanced, such that the ABA_{quiet} and ABB_{quiet} groups underwent threat conditioning in the quiet context, while the ABA_{busy} and ABB_{busy} groups underwent threat conditioning in the busy context. The avoidance cue was present on all trials during avoidance conditioning.

ANOVAs for all experimental phases except *habituation*, which did not include the within-subjects trial factor. For fear ratings, which were taken at the end of each experimental phase, we used 2 (context) $\times$ 3 (CS) ANOVAs. For analyses of habituation, threat conditioning, avoidance conditioning and extinction learning, we used the context variable with two levels (quiet/busy). Only the first renewal test phase was analysed to avoid carryover effects (Papalini et al., 2021) using a 2 (group: ABA, ABB) $\times$ 2 (time: end of extinction, beginning of test) $\times$ 3 (CS) mixed ANOVA (Vervliet et al., 2013). As trial-by-trial ratings were collected for threat expectancy, this dependent variable allowed for the direct comparison of the final trial of the extinction with response prevention phase, whereas fear ratings compared whole phase extinction vs. renewal test as the time variable.

Avoidance responses were recorded as a dichotomous response of 1 or 0, representing that an avoidance response was made or not made, respectively. For analyses, avoidance responses were calculated as the proportion of trials within a phase for which an avoidance response was made. Proportional avoidance was analysed using a 3 (CS) $\times$ 2 (context: quiet, busy) mixed ANOVA in the avoidance learning phase, and a 3 (CS) $\times$ 4 (group: ABA_{quiet}, ABA_{busy}, ABB_{quiet}, ABB_{busy}) mixed ANOVA was used for the renewal test phase. An avoidance learning criterion was applied (Dymond, 2019), whereby participants were excluded if they did not avoid the CS+AV on at least 50 % of trials during the avoidance learning phase. We elected to adopt such a criterion to ensure there were sufficient levels of conditioned avoidance prior to subsequent extinction and renewal testing. Analyses were conducted both with and without the excluded participants ($n = 20$), which showed no change to statistical significance or effect direction, with negligible changes to effect size. Greenhouse-Geisser-corrected degrees of freedom and Epsilon values (ϵ) are reported where sphericity was violated. Significant interaction effects were followed up with Sidak-corrected tests of simple main effects. Effect sizes are reported as partial eta-squared (η_p^2) with 0.01, 0.06 and 0.14 as small, medium and large effects, respectively.

Bayesian repeated measures ANOVAs were conducted using default priors to estimate Bayes Factors (BF; Rouder et al., 2012). Bayes Factors were evaluated as the weight of evidence for the alternative hypothesis over the null hypothesis (BF₁₀), where values greater than 1, less than 1, and equal to 1 represent greater evidence for the alternative hypothesis, greater evidence for the null hypothesis, and no evidence for either hypothesis, respectively (Lee & Wagenmakers, 2013). The inclusion Bayes Factor across matched models (BF_{incl}) is reported for interaction terms. Bayesian analyses were conducted using JASP v0.16.1 (JASP Team, 2022).

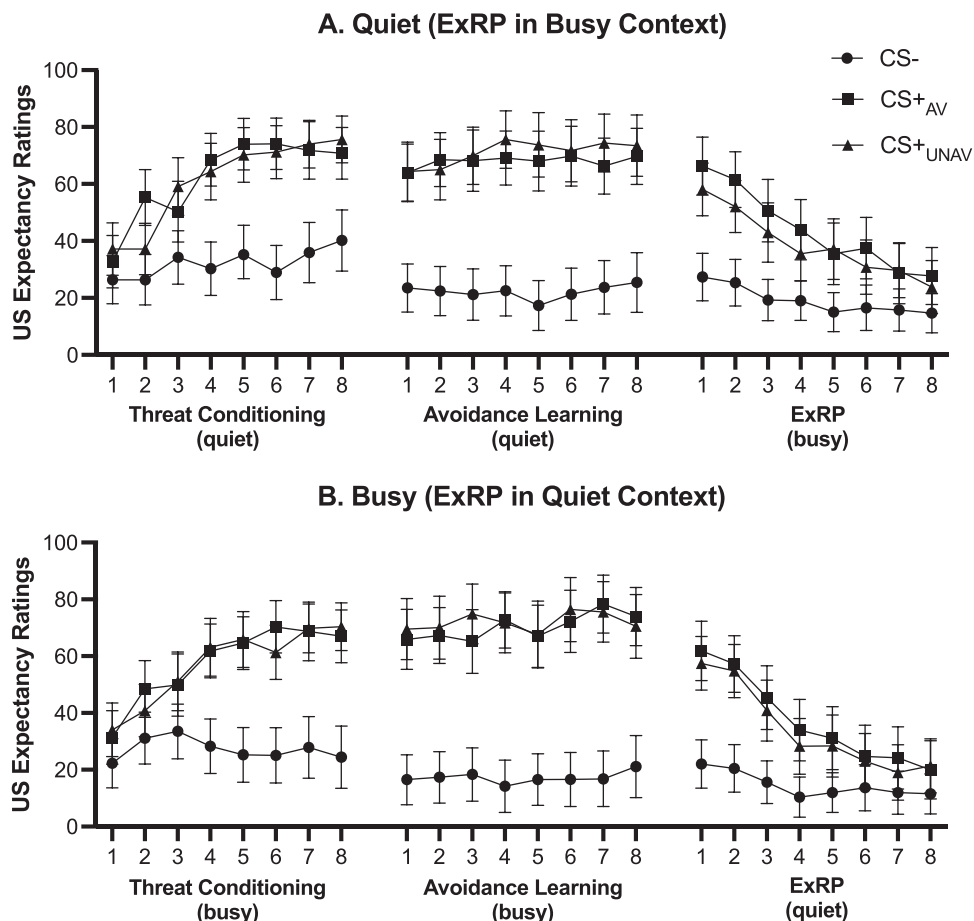


Fig. 3. Threat (US) expectancy ratings to the CS-, CS+AV and CS+UNAV across threat conditioning, avoidance learning and extinction with response prevention (ExRP) for participants who underwent initial threat conditioning in the (A) quiet context or (B) busy context. Error bars represent 95 % confidence intervals.

3. Results

3.1. Habituation

3.1.1. Fear ratings

Almost half of the sample ($n = 42$) failed to provide a US expectancy response to the habituation stimuli and therefore threat expectancy ratings for the habituation phase were not analysed.

Unexpectedly, the 3 (CS) $\times$ 2 (context) ANOVA revealed a significant main effect of CS, $F(1.78, 103.37) = 4.82, p = .013, \eta_p^2 = .077, \varepsilon = .891, BF_{10} = 8.20$, showing that fear ratings were highest for the unavoidable CS+_{UNAV} ($M = 2.59, SE = 0.37$), followed by the CS+_{AV} ($M = 2.42, SE = 0.39$), with lowest fear ratings to the CS- ($M = 1.70, SE = 0.31$). It is worth noting that the means are low for each CS and, based on the low trial numbers and randomised presentation order, unlikely to represent a meaningful effect. The main effect of context was not significant, $F(1, 58) = 0.04, p = .844, \eta_p^2 = .001, BF_{10} = 0.74$, nor was the CS $\times$ context interaction, $F(1.78, 103.37) = 1.25, p = .290, \eta_p^2 = .021, \varepsilon = .891, BF_{incl} = 0.09$.

3.2. Threat conditioning

3.2.1. Threat expectancy

Threat (US) expectancy ratings showed a significant main effect of CS, $F(1.25, 99.88) = 62.69, p < .001, \eta_p^2 = .439, \varepsilon = .624, BF_{10} = 1.62$. Simple main effects revealed equivalent threat expectancy for the CS+_{UNAV} and CS+_{AV} ($p = .902$); however, both CS+ stimuli were rated significantly higher than the CS- ($ps < .001$). The main effect of trial was also significant, $F(4.68, 374.04) = 32.77, p < .001, \eta_p^2 = .291, \varepsilon = .668, BF_{10} = 4.88$, with a generally increasing pattern of threat expectancy over the *threat conditioning* phase (Fig. 3). These main effects were superseded by a significant CS $\times$ trial interaction, $F(8.43, 674.65) = 10.46, p < .001, \eta_p^2 = .116, \varepsilon = .602, BF_{incl} = 6.32$. Fig. 2 shows that expectancy increased throughout the phase for the CS+_{UNAV} and the CS+_{AV}, with ratings to the CS- remaining relatively low. This pattern of effects is suggestive of successful differential threat conditioning to the CS+ stimuli relative to the CS-. Main effects and interactions involving context were not significant ($ps > .138$).

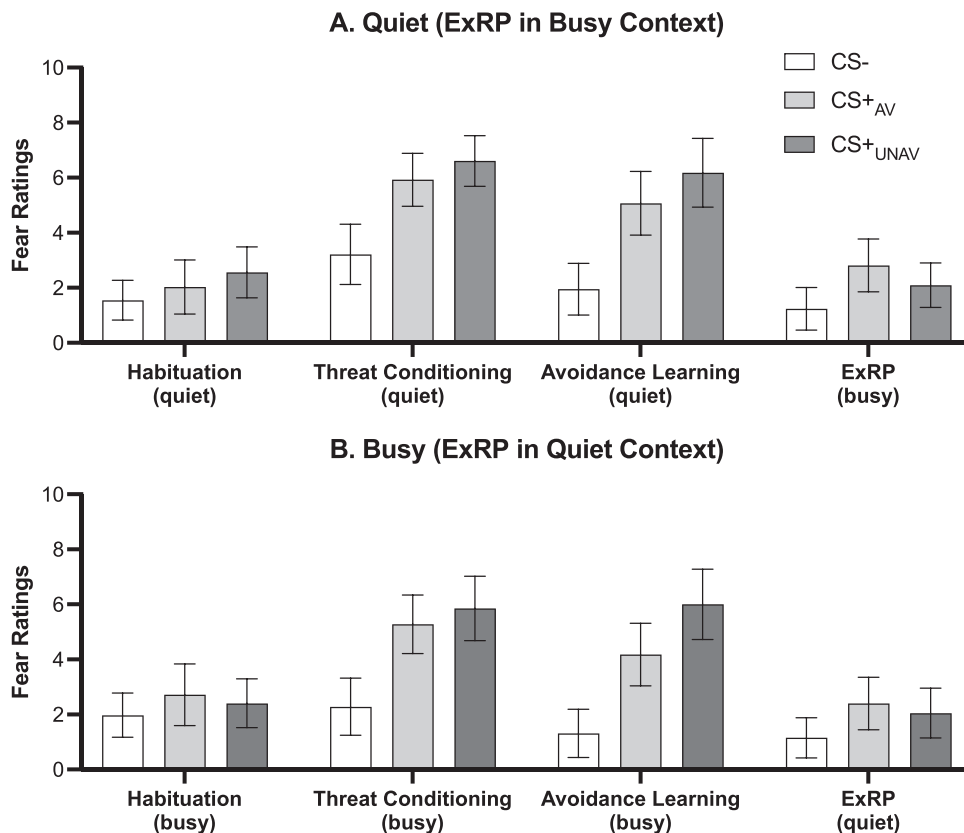


Fig. 4. Fear ratings to the CS-, CS+_{AV} and CS+_{UNAV} across habituation, threat conditioning, avoidance learning and extinction with response prevention (ExRP) for participants who underwent initial threat conditioning in the (A) quiet context or (B) busy context. Error bars represent 95 % confidence intervals.

3.2.2. Fear ratings

During *threat conditioning* there was a significant main effect of CS, $F(1.51, 114.74) = 33.94, p < .001, \eta_p^2 = .309, \varepsilon = .755, BF_{10} = 7.56$. Simple main effects showed that, while fear ratings did not significantly differ between the CS+_{UNAV} and the CS+_{AV} ($p = .165$), fear ratings to both CS+ stimuli were significantly higher than to the CS- ($ps < .001$) (see Fig. 4). The between-subjects main effect of context was not significant, $F(1, 76) = 1.84, p = .179, \eta_p^2 = .024, BF_{10} = 0.34$, and there was no significant CS $\times$ context interaction, $F(1.51, 114.74) = 0.33, p = .934, \eta_p^2 < .001, \varepsilon = .755, BF_{incl} = 0.07$.

3.3. Avoidance learning

3.3.1. Avoidance responses

A mixed ANOVA found there was a significant main effect of CS, $F(1.86, 148.68) = 71.75, p < .001, \eta_p^2 = .473, \varepsilon = .929, BF_{10} = 1.84$. Sidak-correct simple main effects revealed that there was a significantly higher proportion of avoidance to the CS+_{AV} ($M = 83.05, SE = 1.89$) than the CS+_{UNAV} ($M = 71.08, SE = 3.43, p = .004$). Both CS+ stimuli had significantly higher proportion of avoidance than the CS- ($M = 35.68, SE = 4.28, ps < .001$). There was no significant main effect of context or interaction involving context ($ps > .763$). This pattern suggests differential avoidance conditioning was not impacted by context (see Fig. 4).

3.3.2. Threat expectancy

During *avoidance conditioning* participants continued to have higher threat expectancy to the CS+_{UNAV} and CS+_{AV} compared to the CS- ($ps < .001$) with no significant difference between CS+ stimuli ($p = .644$), $F(1.32, 93.43) = 98.79, p < .001, \eta_p^2 = .582, \varepsilon = .658, BF_{10} = 3.40$. There was also a significant main effect of trial, $F(5.40, 383.41) = 2.44, p = .030, \eta_p^2 = .033, \varepsilon = .771, BF_{10} = 1.35$. Fig. 3 shows that elevated threat expectancy to the CS+ stimuli was maintained throughout *avoidance conditioning*, with little change in responding to the CS-. No further main effects or interactions were significant, including those involving context (all $ps > .364$).

3.3.3. Fear ratings

The main effect of CS remained significant in *avoidance conditioning*, $F(1.75, 131.29) = 42.84, p < .001, \eta_p^2 = .364, \varepsilon = .875, BF_{10} = 1.07$, with tests of simple effects showing that the CS+_{UNAV} was rated significantly more fearfully ($M = 5.99, SE = 0.45$) than the CS+_{AV} ($M = 4.47, SE = 0.41, p < .001$), which was also rated significantly higher than the CS- ($M = 1.61, SE = 0.33, p < .001$) (see Fig. 4). There was no significant main effect of context, $F(1, 75) = 1.41, p = .240, \eta_p^2 = .018, BF_{10} = 0.17$, or CS $\times$ context interaction, $F(1.75, 131.29) = 0.32, p = .700, \eta_p^2 = .004, \varepsilon = .875, BF_{incl} = 0.08$.

3.4. Extinction with response prevention

3.4.1. Threat expectancy

During *extinction with response prevention* there were significant main effects of CS, $F(1.19, 94.91) = 41.54, p < .001, \eta_p^2 = .342, \varepsilon = .593, BF_{10} = 7.76$, and trial, $F(2.87, 229.54) = 43.87, p < .001, \eta_p^2 = .354, \varepsilon = .410, BF_{10} = 7.77$. These main effects were superseded by a significant CS $\times$ trial interaction, $F(8.34, 667.08) = 9.90, p < .001, \eta_p^2 = .110, \varepsilon = .596, BF_{incl} = 2.02$, which showed a clear pattern of reducing threat expectancy to the CS+_{UNAV} and CS+_{AV} with low expectancy remaining stable for the CS- (Fig. 3). There were no significant main effects or interactions involving context (all $ps > .206$).

3.4.2. Fear ratings

As shown in Fig. 4, there continued to be a significant main effect of CS during the *extinction with response prevention* phase, $F(1.58, 126.71) = 11.78, p < .001, \eta_p^2 = .128, \varepsilon = .792, BF_{10} = 683,360.35$. Sidak-corrected simple main effects revealed there continued to be significant differences between all three CS types (all $ps < .039$), with fear ratings highest to the CS+_{AV} ($M = 2.61, SE = 0.34$), followed by the CS+_{UNAV} ($M = 2.07, SE = 0.30$), and the lowest fear ratings to the CS- ($M = 1.19, SE = 0.26$). As with previous experimental phases, there was no significant main effect of context, $F(1, 80) = 0.13, p = .717, \eta_p^2 = .002, BF_{10} = 0.61$, or CS $\times$ context interaction, $F(1.58, 126.71) = 0.23, p = .742, \eta_p^2 = .003, \varepsilon = .792, BF_{incl} = 0.36$.

3.5. Renewal test

3.5.1. Avoidance responses

A 3 (CS) $\times$ 4 (group) mixed ANOVA revealed a significant main effect of CS, $F(1.32, 102.79) = 10.87, p < .001, \eta_p^2 = .122, \varepsilon = .659, BF_{10} = 9484.95$. Sidak-corrected simple effects showed significantly lower proportion of avoidance to the CS- ($M = 24.01\%, SE = 4.18$) than to the CS+_{AV} ($M = 36.42\%, SE = 4.37; p = .002$) and the CS+_{UNAV} ($M = 37.75\%, SE = 4.71; p = .003$), which did not significantly differ ($p = .843$). Further, there was no significant main effect of group, $F(3, 78) = 0.81, p = .491, \eta_p^2 = .030, BF_{10} = 0.67$, or CS $\times$ group interaction, $F(3.95, 102.79) = 0.65, p = .627, \eta_p^2 = .024, \varepsilon = .659, BF_{incl} = 0.06$. These results indicate greater avoidance behaviour to CS+ stimuli relative to the CS-, although context had no effect on avoidance at test.

3.5.2. Threat expectancy

A 2 (group) $\times$ 2 (time) $\times$ 3 (CS) mixed model ANOVA revealed that a significant main effect of CS remained, $F(1.28, 102.67) = 40.50, p < .001, \eta_p^2 = .336, \varepsilon = .642, BF_{10} = 1.77$, with ongoing elevated expectancy to the CS+ stimuli (CS+_{AV}: $M = 34.35, SE = 2.95$; CS+_{UNAV}: $M = 36.18, SE = 3.00$) relative to the CS- ($M = 12.87, SE = 2.08$). As with previous phases, there were no significant

differences between expectancy ratings to the CS+ stimuli ($p = .507$), however these stimuli were rated higher than the CS- ($ps < .001$). There was also a significant main effect of time, $F(1, 80) = 27.48, p < .001, \eta_p^2 = .256, BF_{10} = 4.78$, showing a significant increase in expectancy from the end of extinction ($M = 19.80, SE = 2.60$) to the beginning of test ($M = 35.80, SE = 2.67$). These main effects were superseded by a significant CS $\times$ time interaction, $F(1.90, 151.61) = 22.16, p < .001, \eta_p^2 = .217, \varepsilon = .948, BF_{incl} = 14,291.78$. Tests of simple main effects showed there was no significant change in expectancy between extinction and test for the CS- ($M_{DIFF} = 0.36, SE = 3.02, p = .906$), but there was a significant increase from extinction to test for both the CS+_{AV} ($M_{DIFF} = 21.24, SE = 4.46, p < .001$) and the CS+_{UNAV} ($M_{DIFF} = 27.13, SE = 4.22, p < .001$).

Additionally, there was a significant between-subjects main effect of group, $F(1, 80) = 11.51, p = .001, \eta_p^2 = .126, BF_{10} = 8.87$, with significantly higher expectancy for the ABA group compared to the ABB group ($M_{DIFF} = 14.54, SE = 4.28, p = .001$). The group $\times$ time interaction was significant, $F(1, 80) = 14.68, p < .001, \eta_p^2 = .155$, which showed that there was no significant difference in average expectancy ratings on the last trial of the extinction phase ($M_{DIFF} = 2.84, SE = 5.19, p = .585$). However, the ABA group reported significantly higher expectancy on the first trial of the test phase, relative to the ABB group ($M_{DIFF} = 26.23, SE = 5.33, p < .001$).

Finally, there was a significant group $\times$ time $\times$ CS interaction, $F(1.90, 151.61) = 3.41, p = .038, \eta_p^2 = .041, \varepsilon = .948, BF_{incl} = 9.42$. Sidak-corrected tests of simple interaction effects showed that neither the ABA group or the ABB group had a significant change in expectancy to the CS- from extinction to test ($ps > .185$). From extinction to test, the ABB group showed no significant change in responding to the CS+_{AV} ($M_{DIFF} = 8.47, SE = 6.53, p = .185$) or the CS+_{UNAV} ($M_{DIFF} = 10.37, SE = 6.19, p = .098$). The ABA group, on the other hand, showed a significant increase in expectancy from the extinction phase to the test phase for both the CS+_{AV} ($M_{DIFF} = 34.00, SE = 6.07, p < .001$) and the CS+_{UNAV} ($M_{DIFF} = 43.89, SE = 5.75, p < .001$). These results demonstrate a differential context-

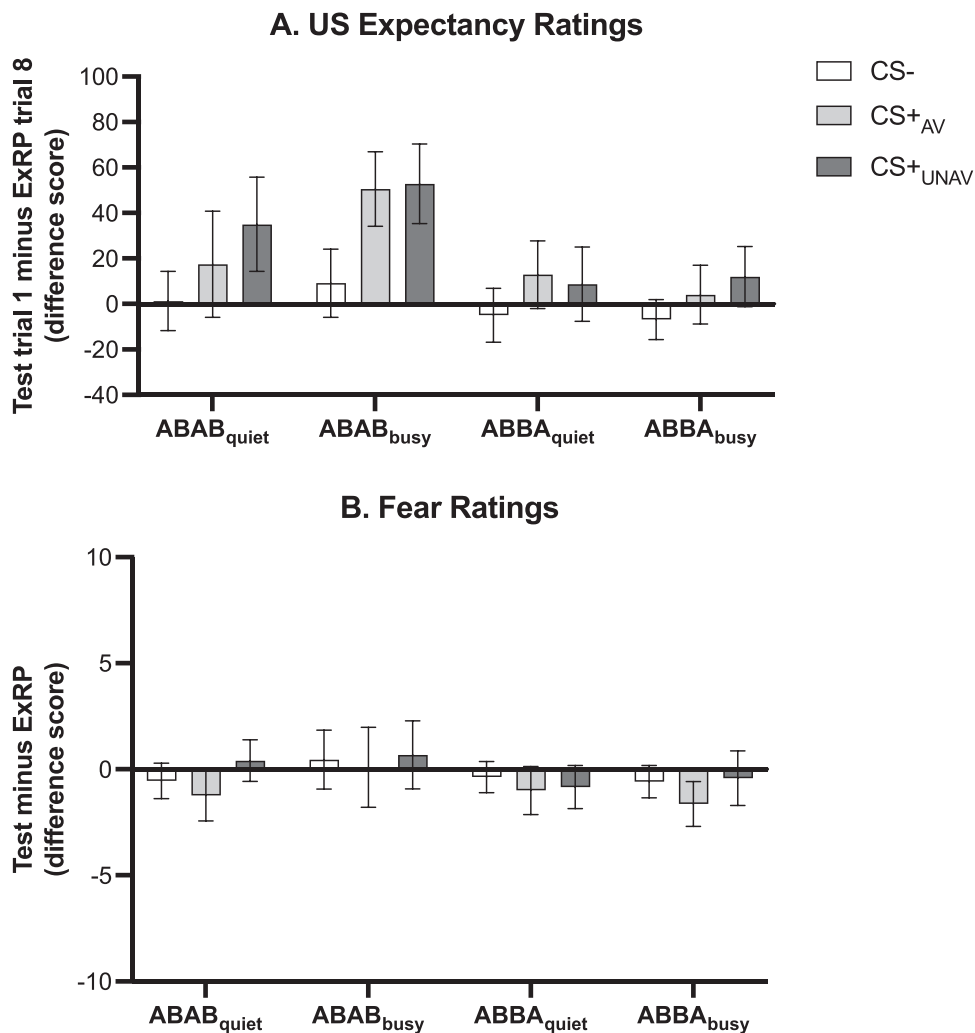


Fig. 5. Extinction with response prevention (ExRP) and renewal test differences scores for (A) US expectancy ratings and (B) fear ratings by condition and CS-type. Positive values represent an increase in expectancy and fear ratings from ExRP to test, and negative values represent a decrease in expectancy and fear ratings from ExRP to test. Error bars represent 95 % confidence intervals.

based renewal effect (Fig. 3).

Sidak-corrected tests of simple interaction effects showed that there were no significant differences between groups for any CS on the last trial of *extinction with response prevention* (all p s > .426). On the first trial of the test phase, however, the ABA group had significantly higher expectancy than the ABB group for the CS- ($M_{DIFF} = 13.39$, $SE = 5.32$, $p = .014$), the CS+_{AV} ($M_{DIFF} = 31.30$, $SE = 7.57$, $p < .001$), and the CS+_{UNAV} ($M_{DIFF} = 34.01$, $SE = 7.92$, $p < .001$). These results demonstrate a differential context-based renewal effect.

Further between-subjects pairwise comparisons were conducted that focused on the CS+ stimuli to determine whether the acquisition and test context—as either a quiet or busy street—modulated renewal effects (Fig. 5). For the CS+_{AV}, the ABA_{quiet} group had significantly higher threat expectancy than the ABA_{busy} group at the end of extinction learning ($M_{DIFF} = 19.89$, $SE = 9.23$, $p = .036$), suggesting that extinction learning was more effective in the quiet context relative to the busy context. There were no significant differences between the ABA_{quiet} and ABA_{busy} groups on the first trial of the test phase ($M_{DIFF} = 9.19$, $SE = 10.17$, $p = .371$). For the CS+_{UNAV}, there were no significant differences between the ABA_{quiet} or ABA_{busy} groups at the end of extinction learning ($M_{DIFF} = 8.11$, $SE = 8.52$, $p = .346$) or the beginning of the test phase ($M_{DIFF} = 10.49$, $SE = 10.84$, $p = .338$). Mean difference scores are presented in Fig. 5A.

3.5.3. Fear ratings

A 2 (group) $\times$ 2 (time) $\times$ 3 (CS) ANOVA revealed a significant main effect of CS, $F(1.50, 119.77) = 14.86$, $p < .001$, $\eta_p^2 = .157$, $\epsilon = .749$, $BF_{10} = 1.24$. This main effect was superseded by a significant time $\times$ CS interaction, $F(1.81, 144.97) = 4.73$, $p = .013$, $\eta_p^2 = .056$, $\epsilon = .906$, $BF_{incl} = 1.36$ (see Fig. 4). Sidak-corrected simple main effects showed that fear ratings for the CS+_{AV} were significantly lower at the end of test, relative to the end of extinction ($M_{DIFF} = -0.94$, $SE = 0.34$, $p = .007$). There were no significant differences between extinction and test for the CS- ($M_{DIFF} = -0.26$, $SE = 0.24$, $p = .285$) or the CS+_{UNAV} ($M_{DIFF} = -0.04$, $SE = 0.30$, $p = .886$). No further main effects or interactions were significant (all p s > .085). These results suggest that context did not result in the renewal of fear ratings (Fig. 5B).

4. Discussion

The aim of the current study was to investigate the renewal of avoidance, threat expectancy and fear ratings using our validated online task. We predicted that renewal would be significantly greater when tested in the conditioning context, relative to the extinction learning context. We found partial support for this hypothesis, whereby expectancy ratings were greater if participants were tested in the conditioning context, which differed from the extinction context. This effect was not observed for avoidance responses or fear ratings. Further, we hypothesised greater renewal to the busy street compared to the quiet street, however renewal of threat expectancy ratings showed the same pattern irrespective of which image served as the conditioning, extinction, or test context. Post-hoc analyses further showed that the quiet context appeared to facilitate extinction learning while the busy context hindered extinction. The primary finding of the current study is that renewal was apparent for threat expectancy but not for avoidance behaviours or fear ratings. Further replication and extension of these findings with online and lab-based tasks is required to identify the necessary and sufficient conditions for renewal of avoidance and fear (Wang et al., 2024).

There is a wealth of evidence demonstrating the renewal of threat expectancy ratings (e.g., Eftting & Kindt, 2007; Neumann & Kitlertsirivatana, 2010; Vansteenwegen et al., 2005) and the current study demonstrates that renewal tasks can be conducted in an online environment. Indeed, there is a growing interest in the online investigation of conditioning tasks (Cameron et al., 2022, 2023; Dymond et al., 2024; Green et al., 2021; Luck & Lipp, 2020; Ney et al., 2023). The current study extends this expanding collection of effects that can be examined in online tasks to renewal, however for reasons stated above, results may be limited to self-reported expectancy ratings. Nevertheless, this affords researchers further opportunity to explore the mechanisms and boundary conditions of different associative learning phenomena. In the current study, we were unable to collect psychophysiological recordings of electrodermal activity or acoustic startle due to the online nature of recruitment and data collection. Electrodermal activity is known to be a psychophysiological indicator of cognitive threat expectancy (Lovibond, 2004; Weike et al., 2007) and acoustic startle responses can provide an index of subcortical fear network activity (Davis & Whalen, 2001; Kindt & Soeter, 2013). Future research that can encompass the psychophysiological indices of threat responses alongside behavioural avoidance responses, threat expectancy ratings, and self-reported emotional expression of fear would provide a more comprehensive indication of associative learning processes.

Unlike Papalini et al. (2021), who found evidence for higher renewal of avoidance in the acquisition context relative to the extinction context at test, the current study found no evidence of avoidance renewal. However, our study differed from Papalini et al. by the online nature of the task and the use of a visual-auditory US rather than an electro-tactile US. Nevertheless, pairing a fearful female expression with a loud scream has been used effectively as a US (Cameron et al., 2022, 2023; Lau et al., 2008), but is subjectively less aversive compared to an electric shock (Glenn et al., 2012) and therefore may be one explanation for the absence of avoidance renewal in the current study. Other potential explanations include the relative salience of the CSs which may have been diminished by their presence within a compound street image (LePelley et al., 2016), generalisation across CSs, and a likely role for preparedness given the COVID-19 relevant street scenes and the fact that data collection occurred during the pandemic (Dymond et al., 2024).

The current study has some limitations. Although we included a sound manipulation check at study outset to ensure participants could hear the shrieking scream from the compound US, no further sound checks were conducted. While it is possible that participants may have removed their headphones or turned the volume off/down, this was an unlikely outcome as we still detected a stimulus-specific renewal effect (and not a generalised reduction in responding and self-report) and have replicated and expanded similar

effects using variants of this online paradigm (Cameron et al., 2022, 2023; Dymond et al., 2024). In future research, however, it may be helpful to conduct sound checks to ensure stimulus volume is maintained throughout. Similarly, as participants in the current study were recruited and completed the study entirely online, it is plausible that participants may have perceived substantially lower threat from the task (not just the employed US) relative to participants completing an in-person lab-based task. Also, during the extinction with response prevention phase, we did not record whether participants did or did not respond and hence avoidance may not have fully extinguished. It is recommended that future research records and evaluates avoidance responses made in all phases (Dymond, 2019).

In conclusion, the current study demonstrated renewal of threat expectancy in an online task employing pandemic-relevant images of a quiet and busy street serving as the manipulated contexts. While we found that the specific images did not impact upon renewal effects, extinction learning towards a previously avoidable CS+ was significantly facilitated if extinction learning occurred in the quiet context relative to the busy context.

CRedit authorship contribution statement

Simon Dymond: Writing – original draft, Supervision, Funding acquisition, Conceptualization. **Daniel V Zuj:** Writing – review & editing, Funding acquisition, Conceptualization. **Martyn Quigley:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Gemma Cameron:** Writing – review & editing, Software, Formal analysis, Data curation.

Data availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.lmot.2024.102044](https://doi.org/10.1016/j.lmot.2024.102044).

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