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Online counterconditioning with COVID-19-relevant stimuli in lockdown: Impact on threat expectancy, fear, and persistent avoidance

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ABSTRACT

Background and objectives: In counterconditioning, a conditioned aversive stimulus (CS) is paired with an appetitive stimulus to reduce fear and avoidance. Findings are, however, mixed on the relative impact of counterconditioning versus standard extinction, where the CS is presented in the absence of the aversive event. This analogue treatment study investigated the impact of counterconditioning relative to standard extinction on threat expectancy, fear, and persistent avoidance with an online fear-conditioning task conducted with COVID-19-relevant appetitive stimuli during the pandemic.

Methods: Following *habituation*, in which two CSs (male faces wearing face-coverings) were presented in the absence of the unconditioned stimulus (US; a loud female scream), participants (n = 123) underwent *threat-conditioning* where one stimulus (CS+) was followed by the US and another (CS-) was not. In *avoidance learning*, the US could be prevented by making a simple response in the presence of the CS+. Next, participants received either counterconditioning in which trial-unique positively rated images of scenes from before the COVID-19 pandemic and its associated restrictions (e.g., hugging others and holding hands) were presented with the CS+ or no-counterconditioning (i.e., extinction). In the final *test* phase, avoidance was available, and all US deliveries were withheld.

Results: Counterconditioning led to diminished threat expectancy and reduced avoidance relative to no-counterconditioning. Fear ratings did not differ between groups.

Limitations: No physiological measures were obtained.

Conclusions: Implemented online during the pandemic with COVID-19-relevant appetitive stimuli, counterconditioning was effective at reducing persistent avoidance and threat expectancy.

1. Introduction

Overcoming learned fear and avoidance is a defining feature of therapy for anxiety-related disorders. Exposure therapy, for instance, incorporates standard Pavlovian extinction procedures to reduce maladaptive behaviour. Standard extinction involves experiencing the feared situation or event in the absence of threat; yet extinction is often temporary, and relapse is common (Craske et al., 2014; Dymond, 2019). As a result, interest is growing in alternative methods of reducing learned patterns of maladaptive fear and avoidance such as using counterconditioning procedures. Counterconditioning has a long history in the associative learning of emotion, having first been proposed by Jones (1924) in a case study of the treatment of a young boy with a fear of rabbits (Hermans et al., 2019). In that study, the boy was allowed to eat his favourite food in the presence of the feared stimulus as it was gradually brought closer and closer. Jones (1924) reported that by the last session, the boy's fear "was entirely absent" (p.314). Since then, a small but growing empirical literature (Keller et al., 2020) and clinical extension studies (Wolpe & Plaud, 1997) have been devoted to the study of counterconditioning.

Counterconditioning studies make use of human threat (fear) conditioning paradigms in which a neutral stimulus (i.e., conditional stimulus, CS+) first becomes a predictor of an aversive unconditional stimulus (US; e.g., electric shock) and another stimulus (i.e., CS-) comes to reliably predict its absence (Lonsdorf et al., 2017; Vervliet & Boddez, 2020; Zuj & Norrholm, 2019). Withholding US deliveries on all CS trials

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then permits investigation of the effects of extinction on the persistence of fear. Counterconditioning, on the other hand, involves presentations of stimuli with opposing valence (usually appetitive) to counter or overcome the learned, aversive behaviour (Bouton, 2002; Keller et al., 2020). For instance, following threat conditioning in which a visual CS predicts shock, participants undergoing counterconditioning receive presentations of appetitive visual USs such as positively rated images or scenes (Kang et al., 2018; Keller et al., 2020). Tests for counterconditioning then involve presentations of the CSs in the absence of all USs. In this way, it is possible to compare the impact of counterconditioning with standard extinction on reducing learned fear.

Raes and De Raedt (2012) found that counterconditioning of a learned CS-aversive US (100 dB white noise) contingency through either appetitive counterconditioning (with a baby laugh US) or neutral conditioning (with a simple tone US) was no more effective than standard extinction on measures of CS valence, US threat expectancy, and fear ratings. Both forms of counterconditioning however were effective at reducing negative evaluative responses when tested in a separate affective priming task (cf. Hughes et al., 2020). Keller and Dunsmoor (2020) found that more CS category exemplars were remembered following counterconditioning than extinction and that CC reduced the renewal of conditioned fear, while other studies have produced mixed results of similar aversive-to-appetitive counterconditioning methods on the renewal of fear (Kang et al., 2018; Meulders et al., 2015; van Dis et al., 2019).

Counterconditioning has proven consistently more effective than standard extinction at reducing fear and avoidance of phobic stimuli in children (e.g., Newall et al., 2017; Reynolds et al., 2018). Within the threat conditioning paradigm, avoidance may then be modelled by adding a response made in the presence of the CS+ (e.g., a button press) to cancel the upcoming US (Krypotos et al., 2018). To date, most studies of counterconditioning in adults have not examined the impact on avoidance behaviour directly. Instead, studies like those reviewed above have focused on assessing changes in self-reported valence, fear, US expectancy, and physiology because it is assumed that fear is a significant motivator of avoidance. Interestingly, this remains a relatively untested assumption in the context of counterconditioning with, to our knowledge, only one prior study having sought to indirectly investigate this issue. In that study, Hendrikx et al. (2021) tested whether an imagery-based counterconditioning procedure, where participants were instructed to imagine as vividly as possible a positive sound US after every CS + presentation, during extinction and response-prevention (ExRP) would reduce avoidance. Results showed that there was no difference between the counterconditioning group and standard ExRP group on avoidance and only a short-lived reduction in self-reported distress (see also, Zenses et al., 2021). Thus, it remains to be determined whether a non-imagery-based counterconditioning procedure implemented under conditions of standard extinction (without prior response prevention) is effective at reducing *avoidance* in adults. Doing so may have important implications for clinical treatment development aimed at overcoming maladaptive behavioural avoidance and promoting positive behaviour change (Dymond, 2019; Pittig et al., 2020).

It is notable that most studies conducted to date on aversive-to-appetitive counterconditioning have employed generic examples of positively valenced static visual stimuli or film clips to diminish the threat relevance of CSs. These stimuli have tended to emphasise broadly opposing stimulus functions (e.g., positively valenced images of people smiling or of preferred items) that contrast with the learned aversiveness of the CS rather than counterposing presentations of CS-specific appetitive functions (e.g., in the context of spider phobia, examples of positive interactions with or displays of spiders). Although a thorough analysis of counterconditioning stimuli remains to be conducted (but see Keller et al., 2020, for a recent review), it is likely that the nature and type of stimuli employed may impact the perceived salience of the CS and the resulting contrast in effects with standard extinction. Moreover, an important issue in determining the therapeutic relevance of counterconditioning studies concerns the role of contextual factors, or the background conditions in place in an individual's life when counterconditioning occurs, on subsequent reduction of fear and avoidance. For example, in the application of counterconditioning to treat social anxiety, stimuli illustrating positive social interactions, perhaps featuring the individual concerned, may exert an enhanced effect on subsequent fear and avoidance and promote further opportunities for therapeutic change.

The ongoing global pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and the resulting highly infectious spread of the COVID-19 disease represents a unique opportunity to study aversive-to-appetitive counterconditioning with salient images of activities that the population are prevented from doing (e.g., hugging family and friends) while national lockdown restrictions are in place. In a between-groups design, the present study sought to address this issue by administering an online avoidance learning and extinction task with groups of participants that either received counterconditioning or standard extinction. Data collection for the present study occurred during a period of national lockdown in the United Kingdom (UK) with the population required to stay at home and with schools, retail shops and international travel borders closed (Institute for Government, 2021). Against this background, we aimed to investigate whether pilot-tested counterconditioning stimuli depicting scenes from pre-pandemic life (e.g., hugging others and holding hands) and which the population were prevented from doing, would impact on fear and avoidance. We expected that the potential aversive effects of the counterconditioning stimuli (i.e., signifying behaviours that might contribute to the spread of COVID-19) would be mitigated by their perceived appetitive value or desirability during lockdown.

The aim of the present analogue treatment study was therefore to investigate the impact of counterconditioning relative to standard extinction on US threat expectancy, fear ratings, and avoidance using COVID-19 relevant stimuli during an online task conducted during national lockdown restrictions. It was expected that counterconditioning and no-counterconditioning (i.e., standard extinction) groups would not differ on all measures during habituation, threat conditioning, and avoidance learning. Following the counterconditioning intervention, we expected a greater reduction in fear ratings, threat expectancy, and avoidance in the counterconditioning group relative to the standard extinction group.

2. Method

2.1. Participants

Participants were recruited via Prolific Academic (https://www.prolific.co/). Inclusion criteria included being 18 years or older, currently residing in the UK, not being pregnant, and with no reported neurological, hearing or vision difficulties. A total of 155 respondents initiated the study; three (1.94%) did not progress beyond the information sheet, while a further two (1.29%) left at the consent form stage. Four respondents (2.48%) left during the initial questionnaire measures, while nine (5.81%) completed the questionnaires but did not progress beyond the sound check stage. A further four (2.48%) participants left at varying stages of the task, while a final ten participants (6.45%) did not proceed beyond the final sound check. Thus, the final sample consisted of 123 participants, $n = 67$ in the Counterconditioning (CC) group (38 males, 29 females, $M_{age} = 32$ years, SD = 9.2) and $n = 56$ in the No-counterconditioning (No-CC) group (27 males, 29 females, $M_{age} = 35$ years, SD = 10.76). Sample size was calculated using G*Power (Erdfelder et al., 2007), (Cohen's f 0.25) based on a 2 × 2 repeated measures ANOVA with stimulus type as the within-subjects factor and group (counterconditioning and no-counterconditioning) as the between-subjects factor. Ethical approval was obtained from the School of Psychology Research Ethics Committee, Swansea University and all participants provided informed consent. Participants received £5 on completion.

2.2. Stimuli

Conditional stimuli consisted of two male faces selected from the NimStim database (Tottenham et al., 2009), displayed in black and white, and counterbalanced to serve as CS+ and CS-, respectively. Faces were edited to show them wearing face-coverings (disposable surgical masks; see Fig. 1). The US was a compound visual-auditory stimulus consisting of a facial photograph of a female paired with a 2 s shrieking scream of approximately 90 dB (Cameron et al., 2022; Lau et al., 2008; Neumann & Waters, 2006).

Eight images obtained from www.unsplash.com depicting positive activities (e.g., couples hugging) served as the counterconditioning stimuli. The images were pre-rated for valence on a scale from 1 ("*not at all pleasant*") to 10 ("*extremely pleasant*") prior to the present study with a separate sample (N = 21, Mean valence = 7.95, SD = 0.40). Those stimuli which received high valence scores were selected as our counterconditioning stimuli. All study materials are available from https://osf.io/3fhgc/.

2.3. Procedure

The experiment was hosted online in Gorilla (Anwyl-Irvine et al., 2020) and data collection occurred between March 5th and May 6th, 2021. Participants were first instructed to wear headphones, to ensure the device volume was set to its highest setting, and to keep headphones on for the duration of the task. They then completed a US-calibration ('sound check') to ensure they could hear the US. Three words (e.g., "cat", "house" and "jump") were played automatically three times each and participants were required to enter the correct word into a text box. They were then instructed that on each trial one of the male faces will be followed by the loud scream and 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*"). The scale appeared below the CS 3 s after trial onset and remained onscreen for 5 s (i.e., CS duration 8 s). Each trial was followed by an inter-trial interval (ITI) of a white screen for 5 s and a black fixation cross for 500 ms. At the end of each phase, each CS was presented again, uninterrupted, and participants were asked to rate how afraid they were of the image shown on a scale ranging from 0 ("*unafraid*") to 100 ("*afraid*"). Stimulus presentation was pseudo-randomized throughout, with no more than two consecutive trials of each CS. All participants took part in five phases: *habituation*, *threat conditioning*, *avoidance learning*, *counterconditioning* (or no counterconditioning), and *test* (Fig. 1).

During *habituation*, the CS+ and CS- were each presented twice separately in the centre of the screen in the absence of the US. Threat expectancy ratings were made on both trials. In *threat conditioning*, the CS+ and CS- trials were each presented 8 times (16 trials in total). The US was presented immediately upon CS + offset on 6/8 trials (i.e., a 75% CS-US reinforcement schedule), and never following the CS-. During the *avoidance learning* phase, both groups were informed that they could now prevent the scream from occurring, but only when an illuminated lightbulb appeared at the top right-hand corner of the screen, by pressing the ENTER key on their keyboard. The CS+ and CS- were each presented 8 times in a block of 16 trials. Availability of avoidance was signalled on all trials (CS+ and CS-), but when the ENTER key was pressed in the presence of the CS+, the upcoming US was cancelled. As in *threat conditioning*, the US occurred immediately following CS + -offset unless the avoidance response was made. The US never followed any CS− presentations irrespective of avoidance.

For the Counterconditioning (CC) group, the CS+ and CS- were each presented 8 times (16 trials in total) during the *counterconditioning* phase. At CS+ offset, one of the eight positive images was presented (i.e., a trial-unique positive image for each CS+ presentation) for a duration of 3 s, while a blank screen was presented on CS- trials. For the No-Counterconditioning (No-CC) group, the blank screen appeared on both CS+ and CS- offset. Avoidance was not signalled and therefore unavailable on all trials across both groups. The US was not presented throughout the *counterconditioning* phase. For both groups, the *test* phase continued uninterrupted from the *counterconditioning* phase, and the CS+ and CS- were each presented 8 times for a total of 16 trials. The availability of avoidance was signalled on all trials and US deliveries were withheld.

2.4. Data analysis

Separate analyses were performed for threat expectancy and fear ratings across phases and for avoidance during the *avoidance learning* and *test* phases. A combination of two-way and three-way mixed model

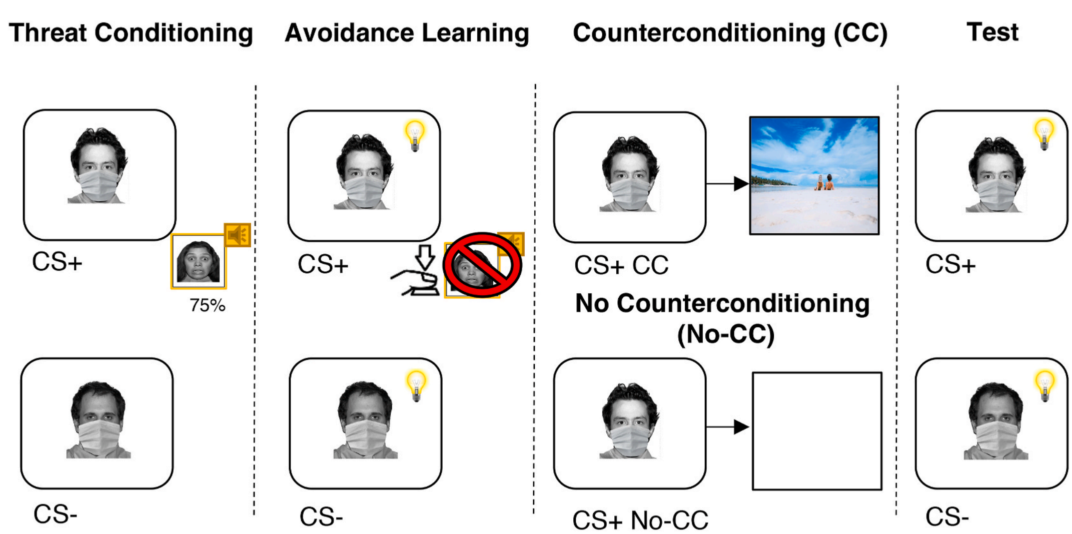

Fig. 1. Overview of phases and experimental design. In *threat conditioning*, one of two masked faces (CS+) was followed by the loud scream + female face unconditioned stimulus (US) on 75% of trials, while another (CS-) was not. During *avoidance learning*, an illuminated light bulb signalled the availability of avoidance (i.e., pressing the 'enter' key) whereby responding in the presence of the CS + cancelled upcoming US deliveries. Avoidance was not necessary in the presence of the CS-. Next, participants assigned to the *counterconditioning group* received presentations of the CS + followed by pre-rated appetitive stimuli depicting scenes the population were currently prevented from doing in lockdown, while participants in the *no-counterconditioning group* received presentations of the CS+ in the absence of the US (i.e., standard extinction). Finally, in the *test* phase, avoidance was again available, and all US deliveries were withheld.

ANOVAs for each phase compared within- and between-subject differences for threat expectancy ratings and, where relevant, avoidance behaviour, with stimulus type (CS+ and CS-) and individual trial-by-trial numbers as within-subjects variables (from *threat conditioning* onwards), and group (CC and No-CC) as the between-subjects variable. Interactions are reported where significant. Huynh-Feldt corrected *F*-ratios and degrees of freedom are reported where the assumption of Sphericity was not met, Bonferroni corrections were applied to all planned and post-hoc comparison, and partial eta squared effect sizes (η_p^2) are reported. All analyses were conducted using JASP version 14.1 (JASP Team, 2020) and $\alpha = 0.05$.

Repeated-measures Bayesian ANOVA and paired-sample *t*-tests were also undertaken using default priors to estimate the Bayes Factor (BF; Rouder et al., 2012). We evaluated the weight of evidence for the alternative hypothesis over the null (BF_{10}), whereby values greater than 1, less than 1, and equal to 1 represent increasing evidence for the alternative hypothesis, increasing evidence for the null hypothesis, and no evidence for either hypothesis, respectively (Lee & Wagenmakers, 2013).

3. Results

3.1. Habituation

Threat expectancy did not differ between stimuli, $F(1, 118) = 0.082$, $p = .775$, $\eta_p^2 < 0.001$, $BF_{10} = 0.15$, or groups, $F(1, 118) = 1.739$, $p = .190$, $\eta_p^2 = 0.015$, $BF_{10} = 0.37$ (Fig. 2). Similarly, fear ratings did not differ between CSs, $F(1, 112) = 0.039$, $p = .84$, $\eta_p^2 < 0.001$, $BF_{10} = 0.14$, or groups, $F(1, 112) = 1.311$, $p = .255$, $\eta_p^2 = 0.012$, $BF_{10} = 0.33$.

3.2. Threat conditioning

Threat expectancy was higher for the CS+ than the CS- across the combined groups, $F(1, 116) = 236.511$, $p < .001$, $\eta_p^2 = 0.671$, $BF_{10} = 4.267e + 169$ (Fig. 2). No significant between-group differences were found, $F(1, 116) = 1.026$, $p = .313$, $\eta_p^2 = 0.009$, $BF_{10} = 0.139$. Post-hoc comparisons revealed significantly higher threat expectancy to the CS + compared to CS- in the CC ($p < .001$; $BF_{10} = 9.065e{+}11$) and No-CC groups ($p < .001$; $BF_{10} = 0.1.835e{+}15$) Increasing levels of threat expectancy indicated a significant main effect of trial, $F(5.994, 695.30) = 19.040$, $p < .001$, $\eta_p^2 = 0.141$, $BF_{10} = 2.202e + 5$ (Fig. 5). A significant interaction between CS and Trial, $F(6.025, 698.87) = 52.644$, $p < .001$, indicated successful conditioning of the CS + across trials with a linear trend.

Fear was significantly higher for CS + than for CS-, $F(1, 119) = 73.674$, $p < .001$, $\eta_p^2 = 0.38$, $BF_{10} = 5352e\ {+}13$, and comparable across groups, $F(1, 119) = 0.022$, $p = .884$, $\eta_p^2 < 0.001$, $BF_{10} = 0.15$.

3.3. Avoidance learning

For threat expectancy, a significant main effect of stimulus type was found, $F(1, 120) = 260.534$, $p < .001$, $\eta_p^2 = 0.69$, $BF_{10} = {>}3$, with elevated expectancy for CS + compared to CS- (Fig. 3). This effect did not differ across groups, $F(1, 120) = 0.048$, $p = .827$, $\eta_p^2 < 0.001$, $BF_{10} = 0.086$, and nor was there a significant main effect of trial, $F(4.721, 566.535) = 1.602$, $p = .162$, $n_p^2 = 0.01$, $BF_{10} = 4.163e\text{-}5$ or any interactions (Fig. 5).

Fear ratings for the CS+ were higher than to the CS- $F(1, 121) = 83.096$, $p < .001$, $\eta_p^2 = 0.41$, $BF_{10} = 1.331e{+}15$, but again did not differ between groups $F(1, 121) = 0.009$, $p = .924$, $\eta_p^2 < 0.001$, $BF_{10} = 0.154$

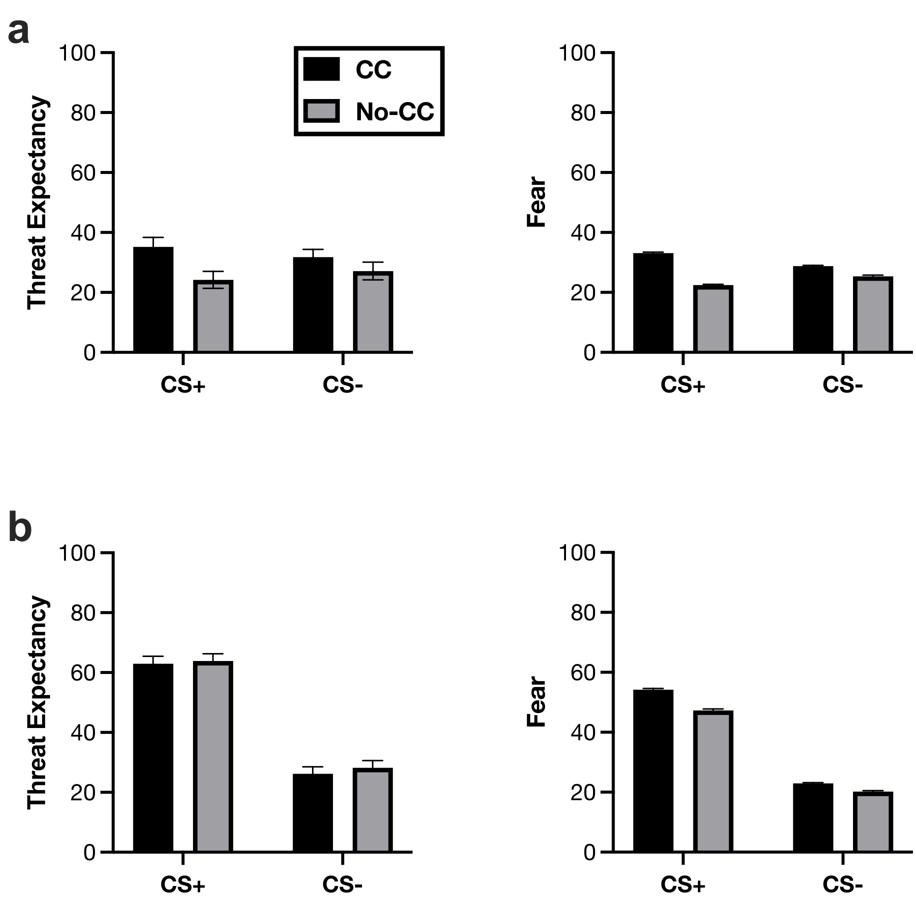

Fig. 2. Mean threat expectancy and fear ratings per CS during (a) habituation and (b) threat conditioning for both groups. Error bars show SEM.

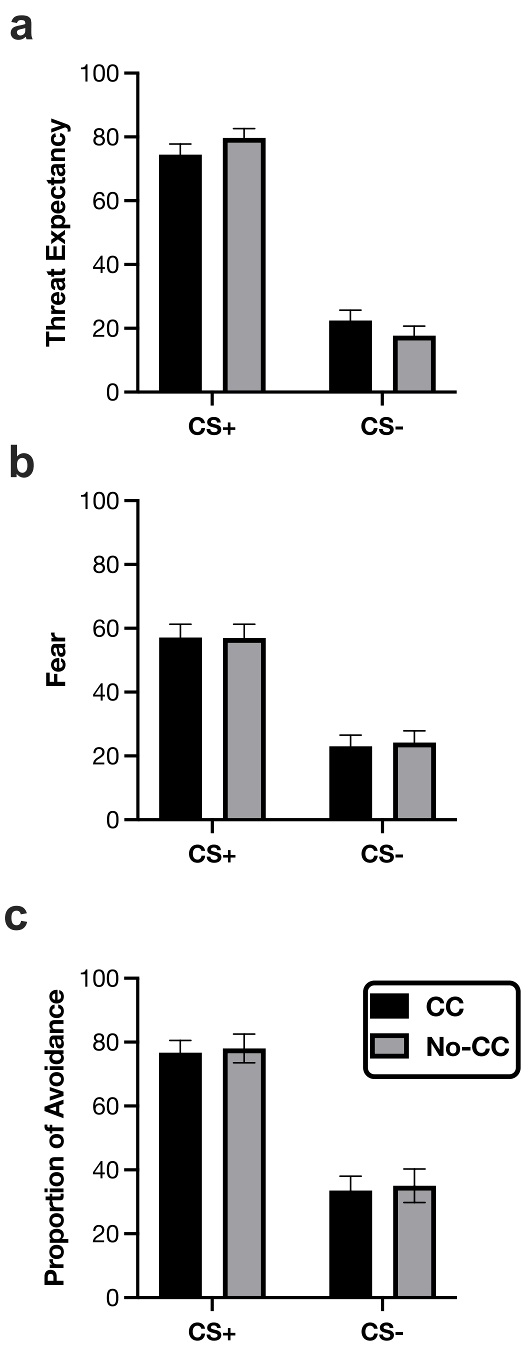

Fig. 3. Mean threat expectancy (a), fear ratings (b), and proportion of avoidance (c) per CS during avoidance learning for both groups. Error bars show SEM.

(Fig. 3).

Analysis of the proportion of avoidance revealed a significant main effect of stimulus type, $F(1, 116) = 142.680, p < .001, \eta_p^2 = 0.55$, BF_{10} = 1864e+165, with proportion of avoidance higher for CS + than for CS-. Groups did not differ, $F(1, 116) = 0.00, p = .97, \eta_p^2 < 0.001$, $BF_{10} = 0.14$, indicating similar levels of avoidance (Figs. 3 and 6)

3.4. Counterconditioning: CC and No-CC group

Significant main effects of stimulus type on threat expectancy, $F(1, 121) = 198.839$, $p < .001$, $\eta_p^2 = 0.62$, BF_{10} = 2.047e+193, trial, F (0.3.097, 0.374.693) = 31.130, $p < .001$, $\eta_p^2 = 0.21$, BF_{10} = 1.244e +11, and group $F(1, 121) = 22.02, p < .001, \eta_p^2 = 0.154$, BF_{10} = 884.193, were found. Significant interactions were also found between stimulus type and group $F(1, 121) = 17.25, p < .001, \eta_p^2 = 0.125$, BF_{10} = 3.567e+216, trial and group F(3.097,374.693) = 7.256, $p < .001$, $\eta_p^2 = 0.057$, BF_{10} = 2.461e+13, and stimulus type and trial F(4.811, 582.113) = 22.995, $p < .001$, $\eta_p^2 = 0.16$, BF_{10} = 1.248e+228 (Fig. 5). Post-hoc comparisons revealed significantly higher threat expectancy to the CS+ in the No-CC group compared to CC group ($p < .001$; BF_{10} = 111430.446), which decreased linearly across trials ($p < .001$) (Fig. 5).

Fear ratings differed by stimulus, $F(1, 120) = 51.819, p < .001, \eta_p^2 = 0.30$, BF_{10} = 3217e+7, and between groups, $F(1, 120) = 9.86$ $p = .002$, $\eta_p^2 = 0.08$, $BF_{10} = 6.119$. A significant interaction was found between stimulus and group, $F(1, 120) = 17.578$, $p = .001$, $\eta_p^2 = 0.128$, BF_{10} = 1.956e+11-. Post-hoc tests revealed fear did not differ for CS- between groups, ($p = .996$), while ratings of CS+ were significantly higher in the No-CC group compared to the CC group ($p = .002$) (Fig. 4).

3.5. Test

Threat expectancy differed by stimulus type, $F(1, 121) = 76.32, p < .001, \eta_p^2 = 0.39$, BF_{10} = 4.855e+125, group, $F(1, 121) = 5.013, p = .027$, $\eta_p^2 = 0.04$, $BF_{10} = 1.593$, and there was a significant interaction between the two, $F(1, 121) = 8.42$, $p = .004$, $\eta_p^2 = 0.065$, BF_{10} = 2.438e+142. Post-hoc tests revealed that threat expectancy differed across groups, with lower threat expectancy to the CS + for the CC group compared to No-CC ($p = .002$; $BF_{10} = 16.394$) (Fig. 4). A main effect of trial was also observed based on frequentist analyses, F (3.99, 483.286) = 3.61, $p = .007$, $\eta_p^2 = 0.029$, BF_{10} = 5.793e – 4, however, this conflicted with the Bayes factor and the effect size was small.

Fear ratings differed by stimulus, $F(1, 121) = 41.81, p < .001, \eta_p^2 = 0.26$, BF_{10} = 5.872e + 6, but not between groups, $F(1, 121) = 0.184, p = .668$, $\eta_p^2 = 0.002$, $BF_{10} = 0.181$. Overall, fear was higher for CS + compared to CS- in both groups (Fig. 4).

Avoidance significantly differed by stimulus, $F(1, 120) = 25.321$, $p < .001$, $\eta_p^2 = 0.174$, BF_{10} = 5.499e + 35, but not between groups, $F(1, 120) = 0.848$, $p = .36$, $\eta_p^2 = 0.007$, $BF_{10} = 0.349$. However, this unpredicted finding was superseded by a significant stimulus × group interaction, $F(1, 120) = 6.28$, $p = .014$, $\eta_p^2 = 0.05$, BF_{10} = 3.821e+44. These effects also persisted when controlling for the total combined (i.e., CS+ and CS-) proportion of avoidance responses made during the initial avoidance learning phase by stimulus, F (1, 119) = 10.691, $p < .001$, $\eta_p^2 = 0.08$, BF_{10} = 6.345e+35), group, F (1, 119) = 0.88, $p = .35$, $\eta_p^2 = 0.007$, $BF_{10} = 0.354$) and stimulus × group F (1, 119) = 6.36, $p < .05$, $\eta_p^2 = 0.05$, BF_{10} = 3.970e+44, respectively. Post-hoc tests revealed a significantly higher proportion of avoidance of CS + relative to CS- in both the No-CC group ($p < .001$; $BF_{10} = 341.544$), and the CC group ($p = .018$; $BF_{10} = 1.997$), however, the size of the difference was reduced in the CC group and the BF provided evidence in support of the alternative hypothesis.

4. Discussion

We investigated counterconditioning relative to standard extinction using COVID-19 relevant appetitive stimuli in an online task conducted during UK lockdown restrictions. In the crucial test phase, we found that the CC group had lower threat expectancy for CS+ than CS- compared to the No-CC group. Fear was, however, rated the same between groups, while the proportion of avoidance was higher for CS + than CS- in the No-CC group with no differences between CSs in the CC group, indicating more successful extinction in the group that received counterconditioning. These findings add to the growing literature on counterconditioning of fear and avoidance in humans and demonstrate, for the first time, a reduction in avoidance following a COVID-19-related counterconditioning procedure (Keller et al., 2020).

Our findings revealed a reduction in threat expectancy in the CC group relative to the No-CC group during the test phase in a manner

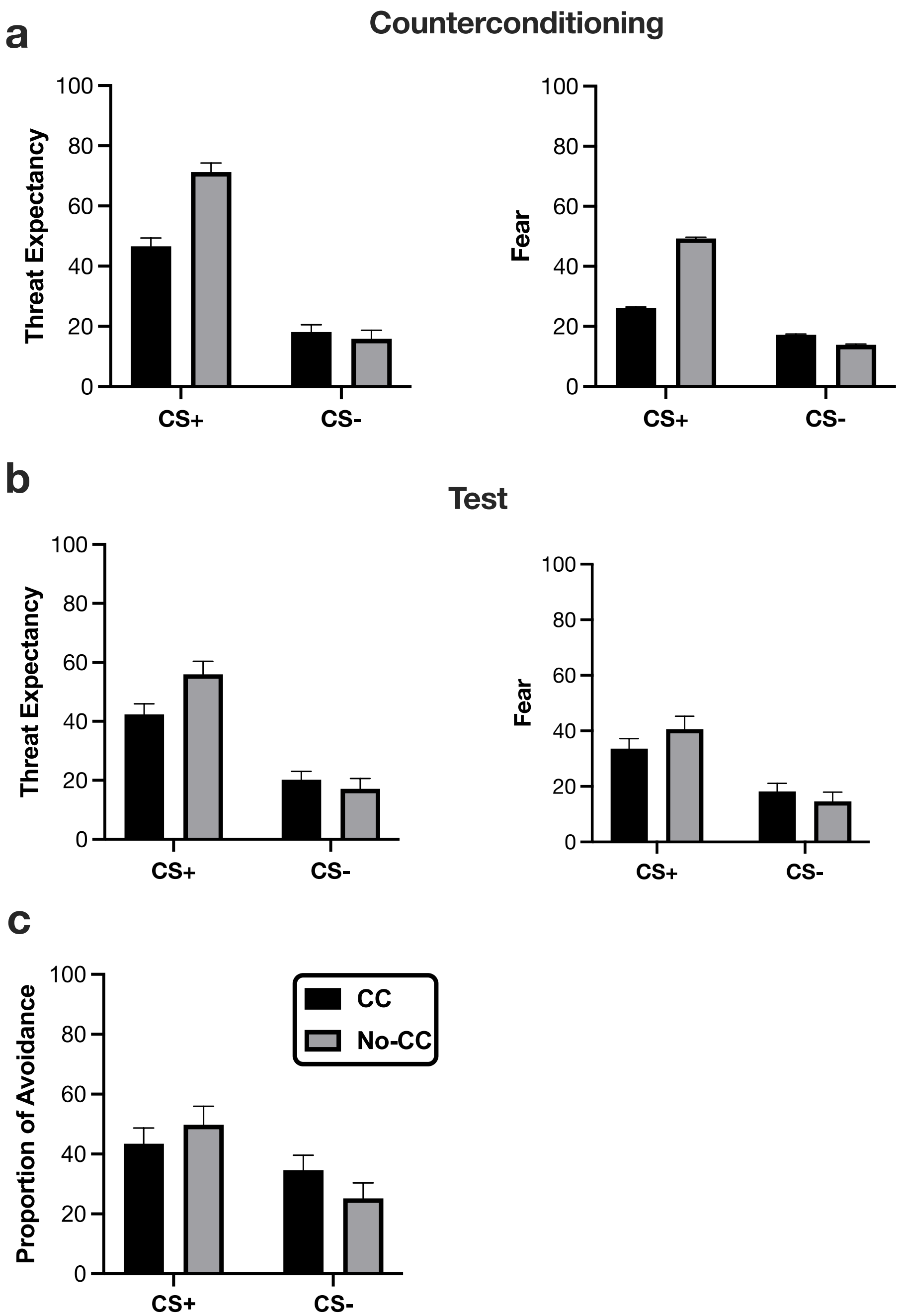

Fig. 4. Mean threat expectancy and fear ratings during (a) counterconditioning and (b) test, and (c) proportion of avoidance per CS for both groups. Error bars show SEM.

consistent with trends shown during the counterconditioning phase. That is, the counterconditioning procedure was clearly more effective than standard extinction at reducing threat expectancy and ratings remained low during the test phase for the CC group. While expectancy for the CS+ gradually extinguished as predicted between counterconditioning and test phases, there was substantial and sustained differential reduction for the group that received COVID-19-relevant counterconditioning. Threat expectancy measures are commonly employed in research on counterconditioning and the present findings add to this literature by demonstrating a differential impact of a specific counterconditioning procedure implemented online relative to standard extinction.

Counterconditioning differentially reduced self-reported fear ratings relative to extinction, but groups did not differ during the post-test. Similar findings were observed in studies of pain-related fear (Meulders et al., 2015) and in human fear-conditioning paradigms (Raes & De Raedt, 2012). The present findings complement this literature by showing an absence of an effect of counterconditioning with COVID-19-relevant appetitive stimuli on fear ratings. The absence of between-group differences at *test* indicates that fear ratings, which were the only measure obtained offline at the end of each phase, were sensitive to the impact of test trials presented in the absence of the US. That is, the extinction trials may have reduced or temporarily negated the impact of counterconditioning and may not have extinguished the original conditioning when subsequently assessed offline. It is noteworthy that mixed findings on the effects of counterconditioning have been obtained with procedures either presenting all measures offline (i.e., at the end of trial-blocks; Raes & De Raedt, 2012) or a combination of

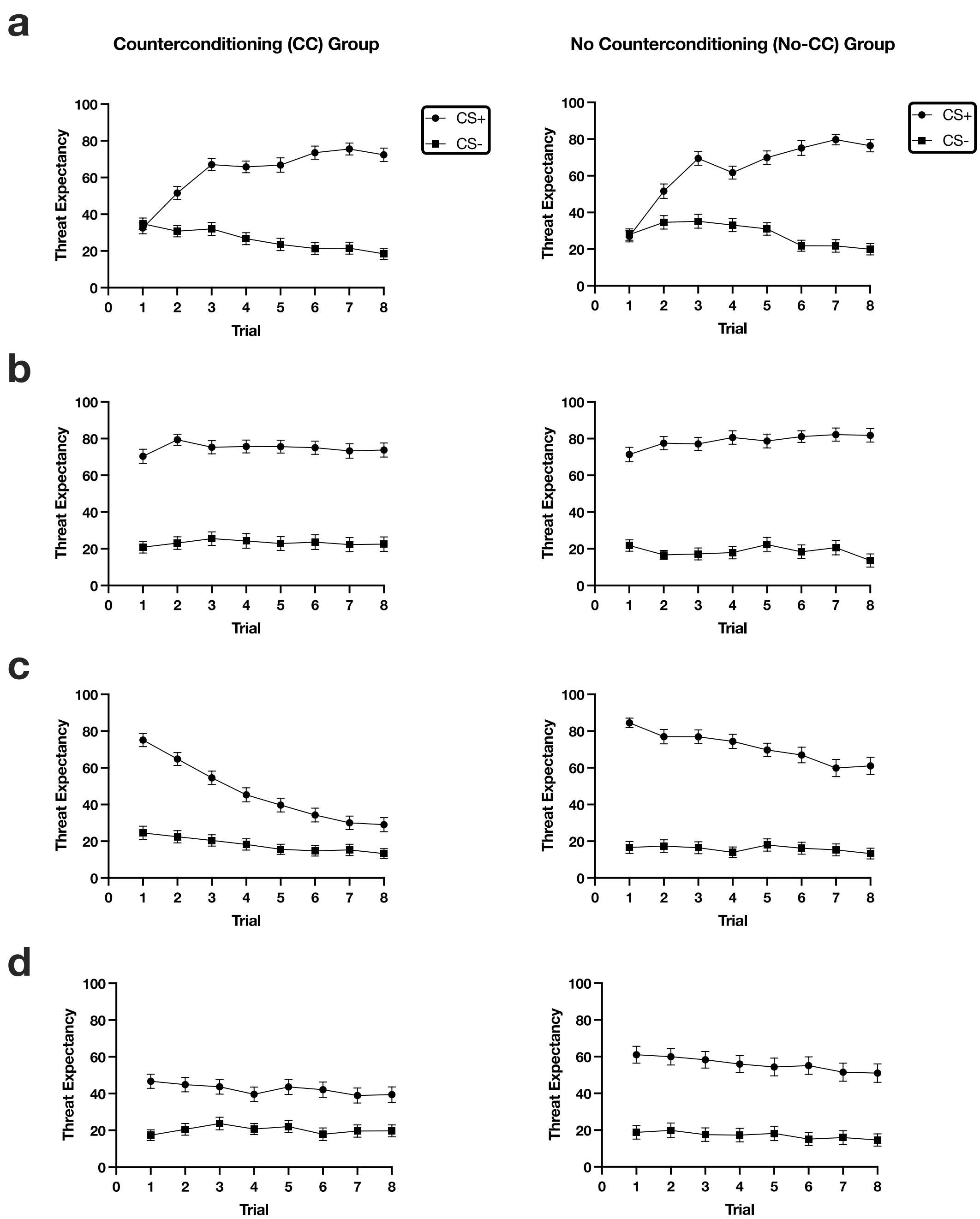

Fig. 5. Trial by trial mean threat expectancy during (a) threat conditioning, (b) avoidance learning, (c) counterconditioning and (d) test per CS for both groups. Error bars show SEM.

offline and trial-by-trial (Hendrikx et al., 2021). Further research on the differential sensitivity of online and offline measurement of threat expectancy on counterconditioning is therefore warranted.

To our knowledge, only one previous study has investigated the impact of counterconditioning on avoidance behaviour (Hendrikx et al., 2021). That study found no significant difference in avoidance between counterconditioning and extinction groups. Here, follow-up tests indicated a a reduction in the proportion of avoidance after counterconditioning compared to standard extinction. Like Hendricks et al., however, the impact of counterconditioning on avoidance appeared initially to be rather subtle and possibly transient. Further investigations of the impact of counterconditioning on avoidance may wish to consider the role of prior level of avoidance responding in facilitating the persistence or otherwise of any subsequent intervention effects. This is particularly important as most avoidance learning research tends not to employ predetermined acquisition criteria (Dymond, 2019). Notwithstanding this, it would have been valuable here to conduct further testing of the persistence of avoidance when responding was prevented (i.e., in the absence of the signalled availability of avoidance). Doing so would allow us to determine whether the availability of avoidance on all trials may have increased the threat value of the CS-, leading to the relatively sustained level of avoidance for these cues from *avoidance learning* to *test* in both groups. Importantly, Hendrikx et al. employed an imagery-based counterconditioning procedure while the present study adopted in vivo visual presentations of pre-tested appetitive stimuli depicting scenes that the UK general population were currently prevented from doing during COVID-19 lockdown. It is possible therefore that the present findings were at least in part determined by the combined effects of the

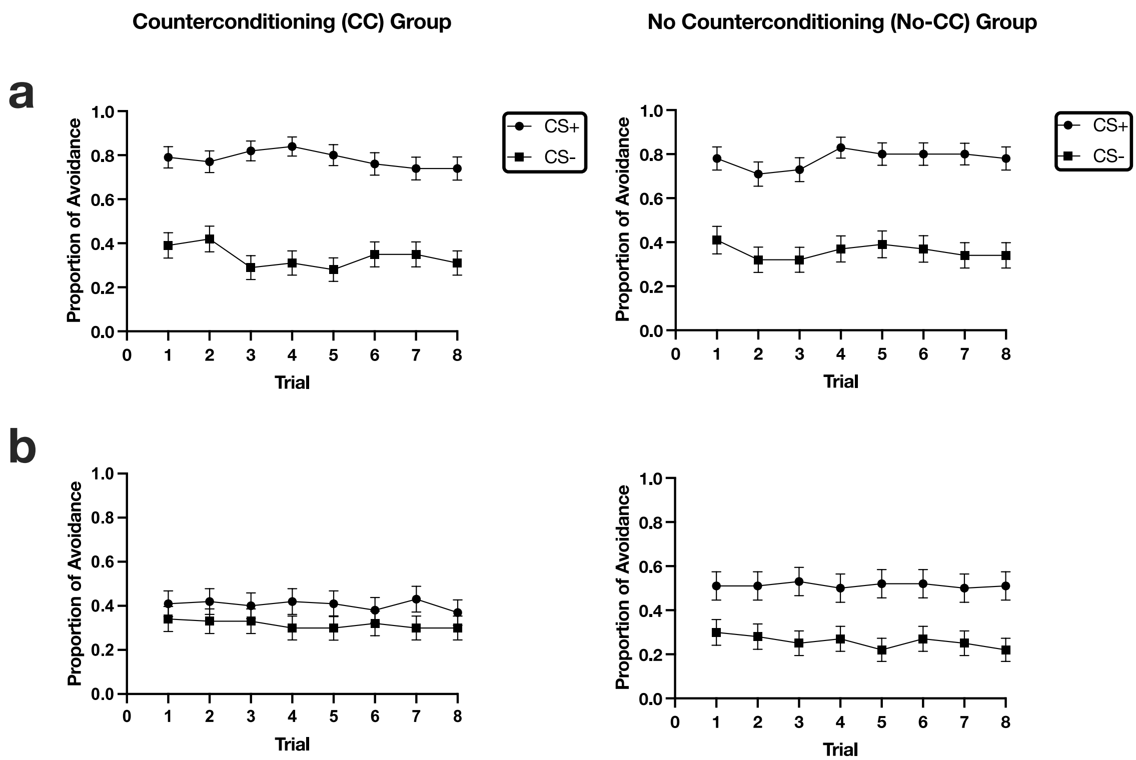

Fig. 6. Trial by trial mean proportion of avoidance during (a) avoidance learning and (b) test per CS for both groups. Error bars show SEM.

motivational significance of the CSs and counterconditioning stimuli (Bouton & Peck, 1992), as well as the background contextual factors of COVID-19 lockdown rules in place at the time. Further research should therefore investigate the persistence of avoidance following in vivo counterconditioning with and without salient background contextual factors and under conditions of avoidance availability and response prevention, respectively.

Despite early promise (Jones, 1924), the clinical application of counterconditioning procedures for the treatment of anxiety and related disorders has not progressed to the same extent as research on the application of standard extinction learning (Craske et al., 2014; Keller et al., 2020; Zuj et al., 2016; Zuj & Norrholm, 2019). Indeed, mixed findings from the relatively small number of analogue treatment studies contrast with those from studies of phobic fear and avoidance in children and with the present counterconditioning of COVID-19-relevant fear and avoidance. The impact of counterconditioning relative to standard extinction may be enhanced therefore through the combined motivational significance of the present CSs (male faces wearing face-coverings, which participants had likely encountered prior to the study and had at least some prior threat value in the context of COVID-19) and the counterconditioning stimuli which depicted experiences and situations that participants were currently prevented from experiencing. In this way, while the motivational significance of the CS remained intact, it now prompted competing responses with those associated with pre-pandemic living at greater strength than those associated with the US. As a result, counterconditioning reduced threat expectancy and avoidance relative to standard extinction. This account, while speculative, indicates that similar motivational properties may be at work in counterconditioning studies of phobic fear and avoidance. Clearly, a great deal of further empirical research is needed to understand the role of motivational significance in the application of counterconditioning to the treatment of fear and avoidance in anxiety and related disorders. It may be, for instance, that counterconditioning could supplement existing therapeutic interventions such as low-intensity CBT to reduce symptoms of anxiety and depression during COVID (Egan et al., 2021).

The present study has several methodological limitations. The test phase was relatively brief (8 presentations of each CS) and did not test for renewal (van Dis et al., 2019) or when avoidance was actively prevented (Hendrikx et al., 2021). Moreover, we employed a one-day conditioning paradigm which did not permit assessment of spontaneous recovery after a 24-hr delay (Keller & Dunsmoor, 2020) and our online task administration format did not allow for collection of physiological data (Keller et al., 2020). We did not assess our compound CSs (consisting of neutral male faces with superimposed face coverings) prior to the study and hence each CS may have evoked unexpected emotional responses. Finally, data collection occurred between March and May 2021 when further easing of lockdown restrictions was announced in the UK and which may have influenced responses.

In conclusion, the present study was designed to investigate the impact of counterconditioning relative to standard extinction using COVID-19 relevant stimuli in a novel online task conducted during the pandemic. Findings showed that threat expectancy, avoidance, but not fear ratings, differed between counterconditioning and no-counterconditioning groups.

CRediT authorship contribution statement

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

Declaration of competing interest

The authors have no interests to declare.

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