Abstract

Avoidance is an adaptive response to actual or perceived threat. However, persistent avoidance despite low likelihood of threat can become maladaptive and prevent effective psychological treatment. To examine behavioural avoidance, in-person, lab-based threat learning paradigms are typically used with relatively small sample sizes. However, such methods pose issues when in-person testing is difficult. The aim of the current study was therefore to adapt a validated lab-based threat and avoidance conditioning paradigm into an online avoidance learning task to investigate threat expectancy and avoidance remotely during the COVID-19 pandemic. An online fear and avoidance learning task was developed and administered to 119 participants who differed in the opportunity to avoid a safe stimulus. Fear and avoidance conditioning were successful and the opportunity to avoid a known safe stimulus increased threat expectancy and fear for the experimental group, relative to the control group. Such remote delivery paradigms may therefore be useful when evaluating changes in fear and avoidance.

Keywords: online avoidance learning task, remote delivery, anxiety, threat, safety

1. Introduction

Avoidance is an adaptive response to actual or perceived threat (i.e., learning to avoid harmful foods or animals). However, persistent maladaptive avoidance when the likelihood of threat is low is a hallmark diagnostic symptom of numerous psychiatric disorders that is targeted by behavioural therapies (Craske et al., 2014; Dymond, 2019; Penninx et al., 2021). Avoidance can be either active or passive. Active avoidance is where a response must be made to prevent delivery of an aversive unconditioned stimulus (US). Passive avoidance is where a response must be suppressed to prevent delivery of an aversive US. The aversiveness of the US can be specific (e.g., fear or a spider) or general (e.g., pain; loud noise). Avoidance is different to escape behaviour where a response is made to avoid an aversive US whilst it is present. To examine the mechanisms of avoidance a wide range of experimental methods have been used (e.g., behavioural, self–report and physiological). However, the United States National Institute of Mental Health (NIMH) Research Domain Criteria (RDoC) workgroup (NIMH, 2016), recommend using threat learning paradigms (i.e., behavioural methods), as a validated negative valence system for assessing acute, potential, and sustained threat as they provide a more objective behavioural measure relative to self-report methods. In threat-learning, a previously neutral stimulus (i.e., conditional stimulus, CS+) comes to predict an aversive unconditional stimulus (US; e.g., electric shock) while another stimulus (i.e., CS-) reliably predicts the absence of the US. Active avoidance learning is studied by modifying the threat learning paradigm and adding a discrete response (e.g., a button press) made in the presence of the danger cue (CS+) to cancel the upcoming US. Withholding US deliveries on all trials and permitting avoidance allows for investigation of the persistence of avoidance in extinction (that is, will participants continue to respond even though the US is withheld in the absence of avoidance?).

Avoidance learning is assumed to be a key component of anxiety disorders. For instance, an individual with social anxiety may avoid (or escape) otherwise benign social settings because of the potential catastrophic consequences that they fear may follow (e.g., blushing or being conversed with). As a result, they lack disconfirming opportunities about the presence or absence of the feared event. In this way avoidance insulates individuals from acquiring new experiences whilst simultaneously preserving the threat value of perceived aversive stimuli. Evidence from laboratory-based treatment studies has conclusively shown maladaptive and excessive avoidance behaviour in those with high levels of anxiety (Dymond, 2019). However, further research is needed on the mechanisms which govern avoidance learning and their real-world relevance.

To date, multiple studies have used a wide range of experimental preparations (van Meurs et al., 2014; Zuj et al., 2020) and measures (e.g., self-report, behavioural, physiological) to examine how maladaptive avoidance is acquired, maintained, and extinguished (Dymond, 2019; Krypotos, 2015; Krypotos et al., 2018). Most studies are, however, conducted in-person, in the laboratory, with relatively small sample sizes and methodological heterogeneity. To address study heterogeneity and power, Purves et al. (2019) and McGregor et al. (2021) developed a smartphone app-based threat learning and extinction task for remote administration with large samples. The authors validated the app against lab-based versions and found that it did not differ in outcomes or within-subject associations. Such an approach has, to date, not been attempted with avoidance learning (where a discrete response option is provided in the presence of the danger cue to cancel the upcoming US) and extinction. Delivering an active avoidance learning task remotely would permit the examination of patterns of impaired performance commonly found in mental disorders, such as anxiety (Endrass et al., 2011; Zuj et al., 2016; Zuj & Norrholm, 2019) whilst enabling participants to be tested in their own preferred environment (e.g., at home).

This is important as the standard laboratory conditions used to examine behavioural avoidance might well produce anxiety and result in participants avoiding behavioural studies. For instance, disorders such as agoraphobia and social anxiety are characterised by individuals avoiding environments in which they do not feel safe or where there is risk of encountering others. If laboratory testing provokes these fears, it is possible that such conditions may inadvertently confound the phenomena under study (i.e., avoidance behaviours). Online avoidance tasks may be less susceptible to such potential confounds and increase both power and sample heterogeneity in the empirical study of avoidance and real-world anxiety.

Delivering an avoidance learning task remotely would also enable research to be conducted during times where in-person laboratory research go against public health restrictions, such as during the COVID-19 pandemic. Moreover, these tasks may also hold value for investigating fear, threat perception (expectancy of the aversive event), and avoidance that arise *because* of the COVID-19 pandemic and associated restrictions. Parallels can be drawn between COVID-19-related fear and clinical disorders (e.g., OCD) where avoidance is a hallmark symptom, namely compulsive checking, fear of contamination, and behavioural avoidance. However, reminders of the threat posed by COVID-19, such as social distancing measures, face masks and hand sanitiser stations are likely to remain for some time and while these steps are protective in reducing transmission, they may trigger sustained levels of anxiety, fear, and avoidance (Ford et al., 2021; Renard, 2016; Van de Veer et al., 2012) and prevent resumption of day-to-day activities in at-risk people. Remote delivery paradigms may therefore be useful when evaluating changes in fear and avoidance as restrictions are eased while reminders of potential threat remain in place, in the form of protective measures (e.g., social distancing, face-coverings, and the general availability of social avoidance as a potentially adaptive response of preventing infection).

1.1. Aim of this study

The aim of the current study was therefore to investigate threat expectancy and avoidance using an online active avoidance learning task, based on the shrieking lady paradigm (Lau et al. 2008), that could be administered remotely for instances of complex real-world avoidance. The task was adapted from validated lab-based threat and avoidance conditioning paradigms (Engelhard et al., 2015; Xia et al., 2019) where an experimental group were given the opportunity to avoid a safe stimulus and a control group were not, following threat and avoidance learning. For example, Xia et al. (2019) first presented an image of a face (A+) which reliably predicted electric shock, while two other stimuli did not (i.e., B-, C-). In a subsequent avoidance learning phase, performing a specific response (i.e., a spacebar press) during the presentation of the A+ danger cue reliably cancelled upcoming shock. Then, the cue denoting the availability of avoidance was also presented with a safety stimulus, C-, for participants in the experimental group but not the control group. In a subsequent test phase, the experimental group reported significantly higher threat expectancy for the previously safe C- stimulus, compared to the control group. That is, providing an opportunity to perform avoidance in the presence of C, increased its threat-relevance (Vervliet et al., 2015; Vervliet et al., 2017). In the current study, we administered an online avoidance learning task that conceptually replicated the Xia et al. design during COVID-19 lockdown restrictions in the UK. For the crucial test phase, we hypothesised significantly increased threat expectancy and fear ratings in the Experimental Group for a previously safe cue now presented with the opportunity to avoid.

2. Method

2.1. Participants

Participants were recruited via Prolific Academic (an online participant panel; www.prolific.co), and the undergraduate psychology student community at Swansea

University using the Psychology Department's Participant Pool. Inclusion criteria included being 18 years or older, currently residing in the UK, not pregnant, and with no reported neurological, hearing or vision difficulties. Student participants received either course credits or a £6 Amazon voucher on completion, while participants recruited via Prolific received between £8 and £16 depending on date of completion. The total sample consisted of 119 participants across the Experimental (n = 58) and Control groups (n = 61), respectively. The mean age of participants in the Experimental group was 29.59 (SD = 10.86). The mean age of participants in the Control group was 30.82 (SD = 11.69). There were 52 females, 4 males and 2 who did not provide a gender in the Experimental group. In the Control group there were 57 females and 4 males.

Sample size was based on an a priori power calculation using *G*Power 3.1* (Faul et al., 2007), with an effect size of Cohen's f = .14, alpha of $\alpha = .05$, Power $(1 - \beta) = .80$, based on 2 groups (experimental and control groups), and 2 within-subjects measurements during the critical test phase. Results indicated that a total sample size of 104 participants would be needed, with 52 participants per group. Data collection commenced on November 25th 2020 and was completed on January 28th 2021. Ethical approval was provided by the Swansea University Psychology Research Ethics Committee.

2.2. Apparatus and Stimuli

The task was administered online using the Gorilla Experiment Builder (Anwyl-Irvine et al., 2020). Participants were required to use a desktop or laptop computer to access the study. Three face stimuli were retrieved from the NimStim set of facial expressions and served as CSs (Tottenham et al., 2009). The delivery of a 95dB sound of a shrieking scream which was presented alongside a Caucasian female face depicting a fearful expression served as the US. The task therefore constituted a modified version of the screaming lady paradigm developed by Lau et al. (2008). The use of sound as an aversive US has also been validated by previous studies (see Neumann et al., 2006). To hear the scream US, participants were asked to wear headphones, to turn their devices volume up to its highest setting, and to keep their headphones on for the duration of the task. They were also required to complete a sound calibration check before the experiment began. Three words ("cat", "house" and "jump") were played automatically three times each and the participant was required to enter the correct word into a text box. On avoidance trials, an unlit image of a light bulb was presented following threat expectancy ratings. When the light bulb appeared illuminated this signalled the possibility of avoiding the shock by pressing the "ENTER" key on the keyboard.

2.3. Design and Procedure

Participants first received access to a link (via Prolific or Participant Pool) which directed them to the information sheet and consent form which they were required to complete before beginning the task. The task consisted of five phases: *habituation*, *threat conditioning*, *avoidance learning*, *avoidance shift learning* and *test* (see Table 1 and Figure 1). Participants were randomly assigned to either the experimental or control group. Task contingencies were similar for both groups except for important differences during the critical *avoidance shift learning* phase (see Table 1 and Figure 1).

Table 1. Experimental design.

Group	Phase				
	Habituation	**Threat Conditioning**	**Avoidance Learning**	**Avoidance Shift Learning**	**Test**
Experimental	A (x1) B (x1) C (x1)	A+ (x4) B- (x4) C- (x4)	A+ (x1) A* (x6) B- (x2) C- (x2)	A+ (x2) B- (x2) C* (x6)	A (x4) B (x4) C (x4)
Control	A (x1) B (x1) C (x1)	A+ (x4) B- (x4) C- (x4)	A+ (x1) A* (x6) B- (x2) C- (x2)	A* (x6) B- (x2) C- (x2)	A (x4) B (x4) C (x4)

Note: A, B and C refer to the three face CSs; + and – refers to presence or absence of the US; * refers to the presence of the avoidance cue; numbers in parentheses indicate the number of trials.

At the outset of the task participants were instructed that on each trial one of three male faces (that is, the CSs) would be presented and to pay attention to which one was followed by the loud scream. CSs were counterbalanced across participants. On all trials the CS was presented on screen for a duration of 2s, followed by threat expectancy ratings, which were obtained in all phases and remained on screen for a duration of 5s. An intertrial interval of 3s followed by a black fixation cross in the centre of the screen for a duration of 250ms was presented on every trial. The threat expectancy scale consisted of the question, *'How likely is it that this face will be followed by the scream?'* displayed above a slider bar ranging from *0 = "highly unlikely a scream*" to *100 = "highly likely a scream*". Fear ratings of each face were also measured at the end of the habituation, threat conditioning, avoidance shift learning and test phases and consisted of the text, "*Please rate how afraid you are of this face*" ranging from 0 ("*unafraid*") to 10 ("*afraid*").

In habituation, participants viewed each of the three faces (A, B, and C) presented once in the absence of the US and made threat expectancy ratings on every trial. The purpose of this phase was to familiarise participants with the experimental stimuli and allow them to practice providing ratings.

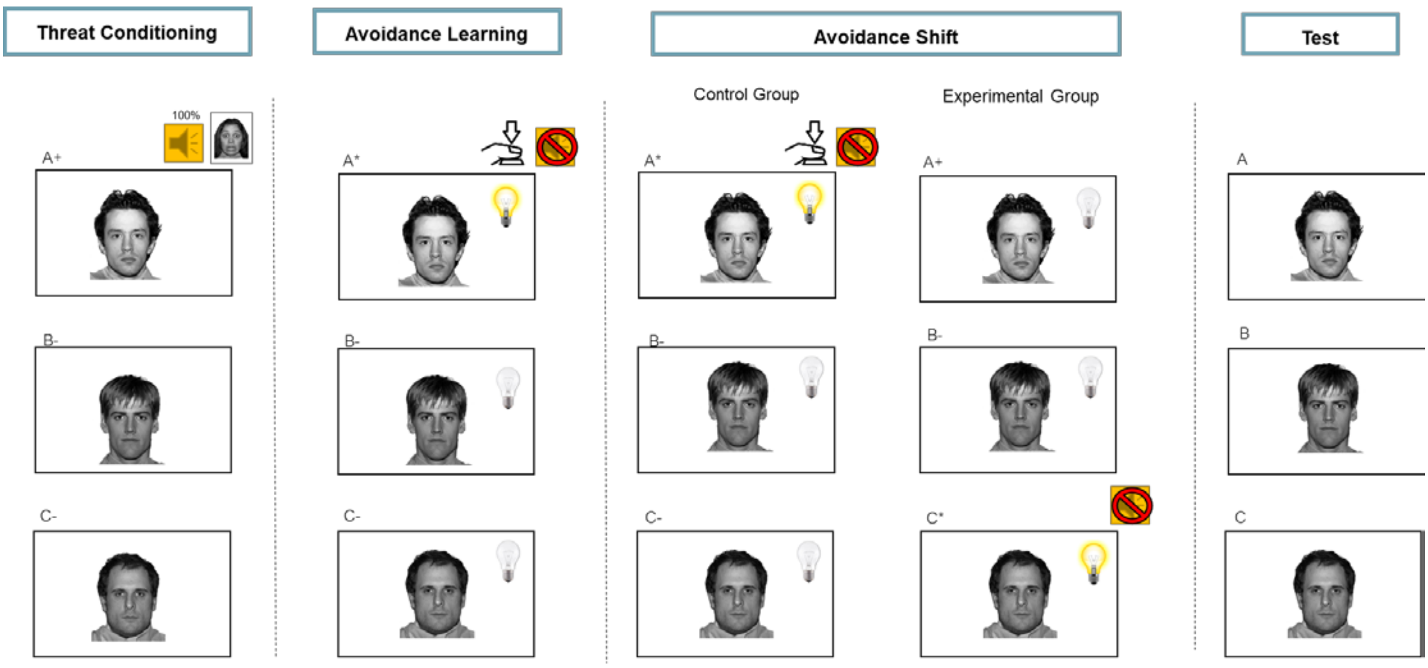
In threat conditioning, each face was presented 4 times, with A+ followed by the US (i.e., a shrieking scream of 2s) on 100% of trials while B- and C- were never followed by the US. The purpose of threat conditioning was therefore to establish A+ as a danger cue and B- and C- and safe cues.

In avoidance learning, brief instructions were first given about making the avoidance response (i.e., pressing the ENTER key on the keyboard, which always cancelled the scheduled US) when the avoidance cue was presented (i.e., an illuminated light bulb presented in the top right corner of the screen). On trials where the avoidance cue was presented, on offset of the expectancy rating, the cue appeared and remained on screen for a duration of 3s. If participants did not make an avoidance response the US followed. For both groups the availability of avoidance was presented on 6 of 7 presentations of A+ (i.e., A*), while B- and C- continued to be presented in the absence of the US. The avoidance cue (i.e., the illuminated lightbulb) was never presented on B- and C- trials (2 trials of each). The purpose of this phase was to train avoidance of the US in the presence of A+ but not in the presence of B- and C-.

In avoidance shift learning, participants in the experimental group received 6 presentations of C with the availability of avoidance now signalled for this previously safe face (denoted C* in Table 1), while the control group received 6 presentations of A with the option to avoid (denoted A*). The US was not delivered on any trial, irrespective of whether participants made an avoidance response. Both groups received the same number of B- presentations (2 trials of each), in the absence of the US. However, participants received a greater number of trials with stimulus C (6) in the experimental group than the control group (2). The purpose of this phase was to provide participants with equal opportunity to make an avoidance response for a previously safe stimulus (i.e., Stimulus C) in the Experimental Group relative to a previously threatening stimulus (i.e., Stimulus A), in the Control Group.

In the test phase, both groups received 4 presentations of each face in the absence of the signal for avoidance and with all US deliveries withheld (A, B and C). The purpose of this phase was to test the combined impact of the previous phases on threat expectancy and fear ratings for all stimuli in extinction. Median task completion time was 29.35 minutes.

Figure 1: Schematic of the trials for each phase of the online avoidance task following habituation.



2.4. Data analysis

Responses were omitted if participants did not fully complete the task or if they indicated that they had not heard the loud scream. Sixteen participants did not progress beyond the sound check and were not included in the sample. In total there were 61 participants in the Control group and 58 in the Experimental group. There was no difference between the groups in age $t(117) = -.60$; $p = .55$ or gender $\chi^2(2, N = 119) = 2.16$, $p = .34$).

Participants in both the Experimental (*M* = 6.31; *SD* = 4.38) and Control group (*M* = 5.82; *SD* = 4.65) also reported comparable levels of anxiety as measured by the Generalised Anxiety Disorder Assessment (GAD-7) *t*(117) = .59; *p* = .55. Learning criteria was set at four successful avoidance responses out of six trials during the *avoidance learning* phase. Participants were excluded from subsequent analysis if they did not meet criterion during this phase. A total of four participants were removed based on this criterion, three from the experimental group and one from the control group. Thus, there were 60 participants in the Control group following the avoidance learning phase and 55 for the Experimental group.

Separate analyses were performed for threat expectancy and fear ratings across phases and for avoidance during the *avoidance learning* and *avoidance shift learning* phases. For cues presented at least twice, trial by trial threat expectancy responses were binned per 2 trials from threat conditioning onwards, except for the test phase. Avoidance was measured as the proportion of trials avoided and ratings for each stimulus were averaged within phases. In cases where the proportion of avoidance data were categorical (that is due to the inclusion criteria whereby a minimum of 4 and a maximum of 6 successful avoidance trials) non-parametric Mann Whitney U tests were performed. While two-way repeated-measures ANOVAs for each phase compared within- and between-subject differences for threat expectancy ratings and fear ratings, with stimulus type (A+, B-, C-, and where relevant, A* and C*) as the within-subjects measure, and group (Experimental and Control) as the between-subjects measure. Separate 2 factor (group) repeated-measures ANOVAs were used for trial-by-trial analysis of A* during *avoidance learning*. Where sphericity was not met, Huynh-Feldt corrections were applied, while Bonferroni correction was applied to all planned and post-hoc comparisons.

Repeated-measures Bayesian ANOVA and paired-samples Bayesian t-tests were also undertaken using default priors to estimate the Bayes Factor (BF) (Rouder et a., 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 evidence for neither hypothesis, respectively (Lee & Wagenmakers et al., 2013). All analyses were conducted using JASP version 14.1 (Love et al., 2015) and the alpha level was set at $\alpha = .05$.

3. Results

3.1. Habituation

Threat expectancy. Both the experimental group ($M = 47.41$; $SD = 27.31$) and the control group ($M = 43.06.41$; $SD = 29.74$) had similar threat expectancy at the outset (Fs <0.75, ps $>.39$), as expected.

Fear. Both groups also had similar fear ratings at the outset (Fs<0.34, ps $>.71$). Fear ratings can be seen in Table 2.

3.2. Threat Conditioning

Threat expectancy. Here, significant main effects of stimulus, and trial, were superseded by a significant stimulus × trial interaction, $F_{5.002, 510.25}=37.538$, $p <.001$, $\eta_p^2= .269$, $BF_{10}=4.360e+60$. Post-hoc tests showed that threat expectancy increased significantly from the first to last A+ trial ($p <.001$) but decreased across trials for both B- ($p <.001$) and C- ($p =.04$), see Figures 2 and 3. No significant between-group differences were found, $F_{1, 102}=0.307$, $P=.58$, $\eta_p^2 =.003$, $BF_{10}=0.138$.

Fear. A significant main effect of stimulus was found, $F_{1.4, 224}=103.367$, $p <.001$, $\eta_p^2 = .480$, $BF_{10} = 7.940e+31$. Post-hoc comparisons confirmed higher fear ratings for A+ compared to B- and C- irrespective of group (all ps $<.001$). The group main effect was not significant, $F_{1, 112}=0.058$, $p =.81$, $\eta_p^2 < .001$, $BF_{10}=1.742e-33$.

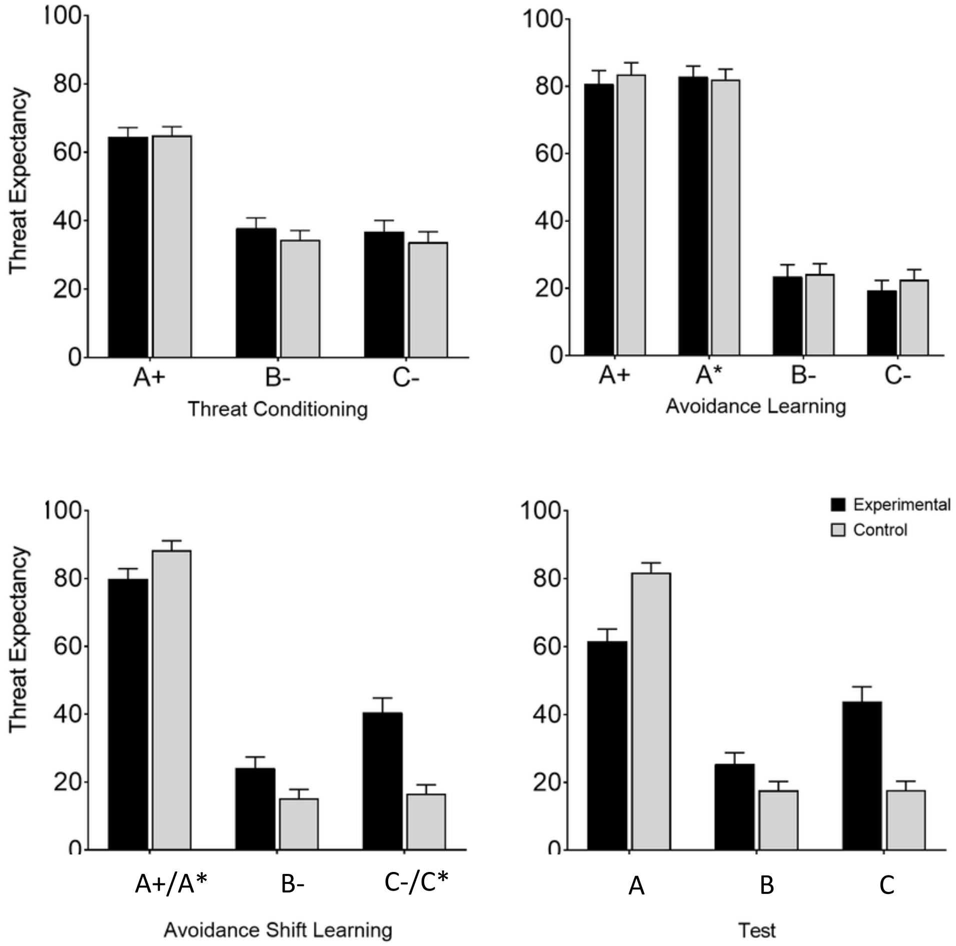


Figure 2. Mean threat expectancy during A+, A*, B-, C- and C* presentations for both Experimental and Control groups during threat conditioning, avoidance learning, avoidance shift learning, and test. Error bars indicate SEM. A+ refers to the face which was followed by the US. B - and C- refer to the faces not followed by the US; * refers to the presence of the avoidance cue.

3.3. Avoidance Learning

Threat expectancy. Expectancy differed across stimuli, $F_{1.48, 162.63} = 271.06$, $p < .001$, $\eta_p^2 = .711$, $BF_{10} = 3.82e+92$, with a linear increase in ratings of A* over trials, $F_{3, 320} = 9.652$, $p < .001$, $\eta_p^2 = .083$, $BF_{10} = 1.977e+6$, which did not differ between groups, $F_{1, 107} = .369$, $p = .55$, $\eta_p^2 = .003$, $BF_{10} = .340$. Further, there was no significant group main effect, $F_{1, 110} = .246$, $p = .62$,

η_p^2=.002, BF_{10}=.122, or interaction with group, $F_{1.48, 162.63}$=.369, p =.63, η_p^2=.003, BF_{10}=6.054e+95. Post-hoc comparisons revealed equivalent threat expectancy for A+ and A* (p =.84), which were significantly higher than expectancy for B- and C- (ps < .001), which did not differ (p =.61).

Avoidance. Proportion of avoidance responses made in the presence of A* did not differ between the experimental group (*M* =94.24%*; SD* = 12.51%) and the control group (*M* = 95.28%*; SD* = 8.72%), as confirmed by a Mann-Whitney U test, *U* = 1645.50, p = .97

3.4. Avoidance Shift Learning

Threat expectancy. There was a significant group × stimulus interaction, $F_{1.67, 189.13}$=15.094, p <.001, η_p^2=.118, BF_{10}=7.657e+65. Threat expectancy for C* in the experimental group was significantly higher than for C- in the control group (p <.001), see Figures 2 and 3, with no significant differences between A+ and A* (p =.84) or B- (p =.63) when examined by post-hoc tests. Within the experimental group, ratings were significantly higher for A+ compared to B- (p < .001) and C* (p < .001). However, ratings for C* were also significantly higher than B- (p =.002) indicating a successful shift in threat expectancy. The control group, however, did not significantly differentiate between B- and C- (p =.61), but did rate A* significantly higher than both B- (p <.001) and C- (p <.001).

Fear. There was a significant group × stimulus interaction, $F_{2, 226}$=10.379, p <.001, η_p^2=.084, BF_{10}=4.365e+29. Fear ratings in the experimental group were significantly higher for A+ compared to B- (p <.001) and C* (p <.001) and ratings for C* were significantly higher than B- (p =.002). On the other hand, the control group rated A* significantly higher than both B- (p <.001) and C- (p <.001), which did not differ (p =1.00).

Avoidance. The proportion of avoidance was significantly higher for A* (*M* = 96.94%); *SD* = 11.21%) in the control group compared to C* in the experimental group (*M* =

60.30%; *SD* = 45.97%). A Mann-Whitney U test confirmed these results, $U = 970.50$, $p < .001$.

3.5. Test

Threat expectancy. There was a significant group × stimulus interaction, $F_{1.55, 170.61}=32.925$, $p <.001$, $\eta_p^2=.230$, $BF_{10}=1.248e+171$. Post-hoc tests showed higher threat expectancy for C in the experimental group compared to control, while ratings of A remained higher in the control group (*p*s <.001), see Figures 2 and 3, with no significant between-group differences on B trials. Within the experimental group, threat expectancy was significantly higher for A than C ($p <.001$), which were, in turn, significantly higher than B ($p <.001$). While the control group had higher threat expectancy for A than B and C (*p*s <.001), ratings of B and C were equivalent ($p = 1.00$).

Fear. There was a significant group × stimulus interaction, $F_{1.73,193.58}=8.557$, $p <.001$, $\eta_p^2=.071$, $BF_{10}=8.486e+19$. Post-hoc comparisons revealed higher fear of C in the experimental group compared to control ($p =.003$), but no significant between-group differences for A or B (*p*s =1.00). For the experimental group, A was rated significantly higher than B ($p <.001$) and C ($p =.012$), with C also rated higher than B ($p =.003$). The control group rated A significantly higher than both B ($p <.001$) and C ($p <.001$), and as expected there was no significant difference between B and C ($p =1.00$).

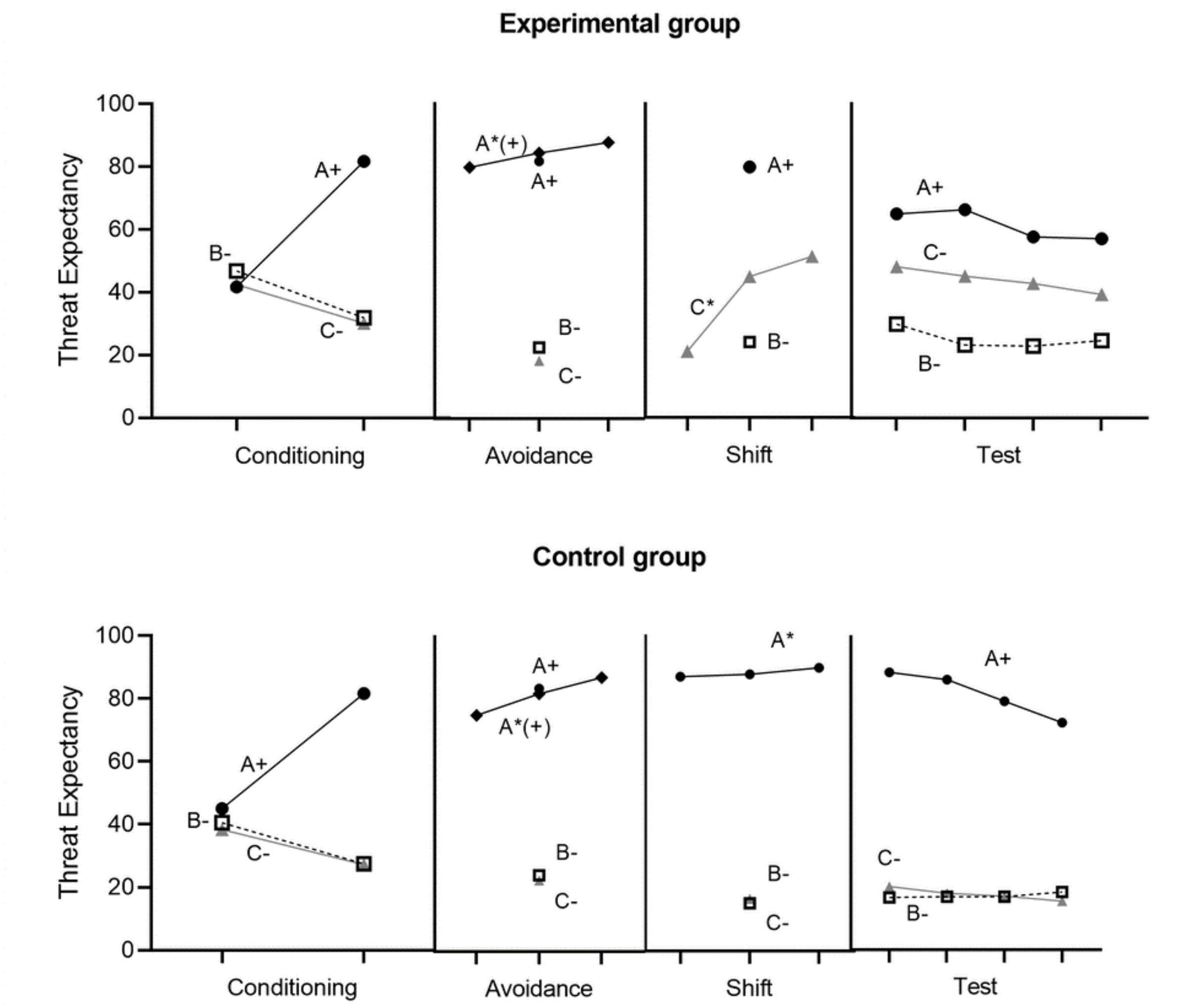


Figure 3. Mean threat expectancy during A+, A*, B-, C- and C* presentations for the Experimental group (upper panel) and Control group (lower panel) across all phases. A+ refers to the face which was followed by the US. B - and C- refer to the faces not followed by the US; * refers to the presence of the avoidance cue.

Table 2. Mean fear ratings and standard deviation for each phase fear ratings were provided

Group	Stimuli	Phase			
		Habituation	Threat conditioning	Avoidance shift	Test
		M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
Experimental	A	3.85 (2.64)	6.91 (3.30)	6.47 (2.91)	5.29 (3.21)
	B	4.1 (3.12)	3.07 (2.83)	2.15 (2.71)	2.21 (2.88)
	C	3.69 (3.06)	2.77 (2.66)	4.31 (3.75)	3.89 (3.37)
Control	A	3.55 (2.90)	6.89 (3.07)	6.98 (3.23)	5.83 (3.41)
	B	3.67 (2.77)	2.73 (2.55)	1.85 (2.49)	1.98 (2.76)
	C	3.57 (2.58)	2.48 (2.49)	1.73 (2.32)	1.83 (2.55)

Note. *M* refers to the mean rating provided to each cue type, whilst *SD* stands for standard deviation of the mean for each rating

4. Discussion

The purpose of the current study was to examine threat expectancy and active avoidance using an online task adapted from established lab-based paradigms (Engelhard et al., 2015; Xia et al., 2019). We hypothesised that the availability of avoidance in the presence of a previously safe stimulus would result in increased threat expectancy relative to a control group where avoidance was unavailable. Our findings demonstrated, as expected, that the option to engage in avoidance in the presence of a previously safe stimulus leads to elevated threat expectancy. These results conceptually reproduced the findings of Xia et al. (2019) and Engelhard et al. (2015), and therefore converge with findings from previous laboratory studies. These findings show that remote online avoidance learning paradigms could be used to examine patterns of impaired performance commonly found in psychiatric disorders (Endrass et al., 2011; Zuj et al., 2016; Zuj & Norrholm, 2019) when in-person testing may well produce anxiety and avoidant behaviours or is not possible. It also holds value for investigating fear, threat perception (expectancy), and avoidance that arise in relation to the COVID-19 pandemic.

In line with previous associative fear learning literature (Engelhard et al., 2015; Xia et al., 2019) the current online study successfully conditioned increased threat expectancy ratings to a threatening stimulus paired with an aversive US (A+), relative to safe stimuli that were not paired with the US (B- and C-). In addition, an avoidance response designed to cancel the impending US was also successfully conditioned, with participants in both groups avoiding at least four trials out of six that were paired with the US (A+). The crucial test phase also revealed that the experimental group reported significantly higher threat expectancy ratings to a stimulus that had not been paired with the US but where avoidance was available (C-), than a safe stimulus that had not been presented with the avoidance cue (B-). Meanwhile, the control group reported significantly higher threat expectancy ratings to the threatening stimulus (A+) compared to the safe stimuli (B- and C-), which did not differ. These findings indicate that providing an opportunity to perform avoidance in the presence of a previously safe stimulus increased its threat relevance, demonstrating convergence with findings from in-person laboratory studies.

The experimental design did differ to Xia et al. (2019) and Engelhard et al. (2015) during some phases of the task. For instance, in the current experiment the avoidance trials with the threatening stimulus (i.e., A*) were carried over into the avoidance shift phase for the Control group to ensure that the presence of avoidance was comparable for both groups. This creates a discrepancy in the treatment of A+ between the two groups which could account for the elevated threat expectancy for C. The inability to avoid A+ in the experimental group, however, did not produce higher ratings than those for the control group, which might have been expected given the inability to engage in avoidance with A+. In this way the availability or otherwise of avoidance for A was not sufficient to cause participants' threat expectancy to increase. In the Experimental group there were also more presentations of the safe stimulus that participants were able to avoid which provides participants with an opportunity to habituate to C and to learn that it is not paired with the US, thus this discrepancy between the two groups would be expected to mitigate the effect.

This methodological feature, combined with the design differences with previous research (Engelhard et al., 2015; Xia et al., 2019), may have afforded an alternative interpretation of the findings based on the transfer of excitatory value signalled by the avoidance cue. Consider the following: the avoidance cue was present on all trials from *avoidance learning* but was only illuminated, first on A* trials, and then subsequently on C* and A* shift learning trials for the experimental and control group, respectively. The compounding of the illuminated avoidance cue with avoidance responses (leading to omission of the US) may therefore have prompted a generalization of excitatory value rather than a shift in avoidance learning per se (Haddad et al., 2012). However, the avoidance cue was not present on test trials and a clear increase in expectancy was predicted for C- in the experimental relative to the control group. Despite this, further research that tests these and other assumptions of associative learning processes in avoidance as alternative interpretations of the data is warranted (Laing & Harrison, 2021; Wong et al., 2022).

The learning criteria employed in this experiment also differed to the criteria employed by both Xia et al. (2019) and Engelhard et al. (2015). In Xia et al. participants were required to make four correct responses out of six in both the *avoidance learning* and *shift* phases, whilst Engelhard et al. employed different criteria across phases. Here, participants were required to perform the avoidance response on four out of six trials during the *avoidance learning* phase only. These different criteria could potentially account for the between-group differences during the *shift* and *test* phases. However, we elected to adopt a single learning criterion for avoidance due to the online task administration format and the need to retain sufficient power. The impact of learning criteria applied during these phases warrants further investigation. It is also possible that avoidance was reinforced as making an avoidance response reduced the trial duration. However, this would not explain why higher threat expectancy ratings were provided for the CSs where an avoidance response could be made. Further studies would also benefit from exploring the role of uncertainty and its potential impact on participants' ratings (in relation to in-person and online studies). This is an important point to consider as it could be that participants' ratings are elevated for stimuli which they are uncertain about, therefore resulting in them using the centre of rating scales. Subsequent studies could explore this by requiring participants to provide certainty ratings in addition to threat and fear rating. Additionally, future studies could examine the possibility that fear may generalise from the avoidance cue to during presentations of A to presentations of C.

Due to the online nature of the study, we were unable to ensure appropriate engagement in the study and sound delivery of the US. That is, we were unable to perform manipulation checks of whether the US was delivered via headphones or speakers, or indeed the decibel (dB) level of the sound, which has been delivered at 95 dB in previous research (Lau et al., 2008). However, the current study did include a manipulation check at the beginning of the task to ensure participants were able to hear the US, where participants were required to listen to several words and type them in a text box before proceeding. If they did not type the correct words, they would be unable to progress. Additionally, participants were also asked whether they had heard a scream at the end of the experiment and the learning criteria also ensured that participants who did not meet the learning criteria were excluded. Future research would benefit from including a manipulation check and ongoing sound checks throughout the task and following completion of the task to monitor engagement. Nevertheless, the conditions under which participants completed the task is a source of between-participant variability that could still impact the results and is difficult to control for when using online tasks.

Due to the online nature of the study, we were also unable to collect commonly used psychophysiological measures of threat responding (Davis et al., 2001; Xia et al., 2019). The platform (i.e., Prolific) used to recruit participants may also limit the generalisability of the findings as the sample will consist of those who will have experience with completing online studies for incentives. However, a recent study by Eyal et al. (2021) found that Prolific provided high quality data compared to alternatives (e.g., Amazon Mechanical Turk and CloudResearch) and allowed us to reach an online audience. Prolific also has a greater number of female than male users which resulted in females primarily taking part in this study. Notably, females also report higher levels of anxiety than males (Remes et al., 2016) and might be more likely to engage in avoidance. These limitations and alternative explanations notwithstanding, the current findings provide evidence of an effective online avoidance learning task that can be administered remotely.

4.1. Conclusions

In summary, the current study provides evidence from an online avoidance learning task that converges with the findings from previous in-person research. This supports the utility of remote avoidance learning experiments to examine patterns of impaired performance commonly found in psychiatric disorders (Endrass et al., 2011; Zuj et al., 2016; Zuj & Norrholm, 2019) when in person testing is not possible. These findings also hold value for investigating fear, threat perception (expectancy), and avoidance in relation to the COVID-19 pandemic.

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