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Investigating the relationship between intolerance of uncertainty and threat extinction learning whilst controlling for anxiety-related symptoms

Kane Steggles [a], Nico Biagi [b], Matthew Garner [a], Jayne Morriss [a,*]

[a] School of Psychology, University of Southampton, Southampton, UK
[b] Henley Business School, Business Informatics Systems and Accounting, Informatics Research Centre, University of Reading, UK

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ABSTRACT

Exposure-based therapies operate on principles of threat conditioning and extinction. Previous research has demonstrated that trait-level intolerance of uncertainty (IU) is specifically associated with worsened extinction learning whilst controlling for trait anxiety. Hence, IU may serve as a useful focus for researchers aiming to improve the effectiveness of exposure-based therapies as research suggests that IU can be modified clinically. Yet, little is known as to whether IU is associated with extinction learning whilst controlling for anxiety-related symptoms. A two-day Pavlovian conditioning task was carried out, consisting of threat acquisition, extinction, and extinction retention phases. Participants ($N = 101$) completed IU, trait anxiety, and various disorder-specific questionnaires e.g., panic disorder. before engaging in the conditioning procedure. Skin conductance magnitudes, and behavioural ratings of anxiety and stimulus expectancy were used as indices of conditioned responding, and extinction by extension. Analyses revealed that successful threat conditioning was observed for all three measures during threat acquisition, yet extinction was not observed during the extinction and retention phases. IU was not specifically associated with individual differences in extinction as indexed by differential SCR magnitudes, contradicting prior research. Further, IU was specifically associated with differential stimulus expectancy and anxiety ratings within extinction and retention respectively, whilst controlling for symptom measures. Lastly, IU was not associated with any other extinction measure. Overall, IU failed to predict extinction learning consistently throughout the experiment, although this may be due to experimental artefacts. The authors outline considerations for future research on the relationship between IU and extinction learning.

1. Introduction

Anxiety is a negative affective state characterised by specific behavioural and physiological responses such as avoidance, hypervigilance, and physiological arousal (Gross & Hen, 2004). Anxious responding arises in situations wrought with potential danger; hence such responding is thought to serve the function of enabling the identification of, and escape from, species-specific threats (Gray & McNaughton, 2003). Overall, anxiety is considered a normal and adaptive response allowing one to effectively anticipate, prepare for, and contend with future problems (Davey, 2021). Anxiety disorders, however, refer to psychiatric conditions characterised by frequent and intense bouts of anxiety, fear, and worry, alongside physical symptoms such as heart palpitations, breathlessness, dizziness, and increased muscle tension etc. (Bandelow et al., 2017). Anxiety meets diagnostic thresholds when it produces significant distress and/or impairment in multiple domains of daily functioning e.g., social, occupational, or other important aspects of life (American Psychiatric Association (APA), 2022).

Previous research estimates that anxiety disorders have a global prevalence ranging from 4.05% to 7.3%, with a moderate degree of cross-cultural variation (Baxter, Scott, Vos, & Whiteford, 2013; Vos et al., 2017; Javaid et al., 2023; Kessler et al., 2012; Wittchen et al., 2011). Further, as outlined in the most-recent diagnostic and statistical manual (DSM-V-TR; APA, 2022), the term 'anxiety disorder' encompasses multiple related conditions such as generalised anxiety disorder (GAD), panic disorder (PD), and social anxiety disorder (SD). These conditions are frequently comorbid with one another and other depressive disorders e.g., major depressive disorder (Brown et al., 2001; Goldstein-Piekarski et al., 2016). Interestingly, seemingly distinct

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* Corresponding author. School of Psychology, B44 University Rd, University of Southampton, Southampton, SO17 1PS, UK.
E-mail address: j.morriss@soton.ac.uk (J. Morriss).

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anxiety disorders share similar diagnostic features such as excessive worry and frequent avoidance of feared situations (Herr et al., 2014). Indeed, recent research on transdiagnostic models emphasises the presence of shared underlying mechanisms amongst anxiety disorders e.g., attentional biases to threat, anxiety-sensitivity (Norton & Paulus, 2017). Despite this, individual anxiety disorders are distinguishable from one another in the types of stimuli that induce fear and/or anxiety in each condition. For instance, individuals with SD tend to fear negative social evaluation and ridicule, whereas those with PD tend to fear the prospect of dying or losing one's mind as a result of an impending panic attack (APA, 2022). Therefore, individuals with SD and PD are both likely to experience excessive worry, however the content of said worry is likely to differ significantly with respect to their associated diagnoses.

It has long been argued that an element of exposure to feared, or anxiety-provoking, situations is essential when treating anxiety disorders (Foa & Kozak, 1986). Within exposure-based treatments, the therapist facilitates the voluntary engagement of the patient with a series of objects or situations that they find anxiety or fear inducing. Paradoxically, upon repeated instances of exposure, the previously avoided objects begin to elicit less fear/anxiety which then produces a reduction in anxiety symptomatology (Barlow, 2021). Exposure therapies vary widely in their clinical application, for instance exposure can be graded or non-graded, employed in vivo or with imaginal cues, utilise internal or external cues, and be used with or without relaxation techniques e.g., diaphragmatic breathing (Kaplan & Tolin, 2011). It is now well-established that exposure-based therapies are highly effective for treating anxiety disorders (Kaplan & Tolin, 2011). Indeed, multiple meta-analyses have demonstrated that cognitive behavioural therapy (CBT), of which exposure is a key component, outperforms wait-list control, pill placebo, and psychological placebo groups within clinical trials (Hofmann & Smits, 2008; Norton & Price, 2007; Carpenter et al., 2018). It is thought that exposure may directly and predominantly underpin the effectiveness of CBT in reducing anxiety symptomatology given its centrality within established protocols (Craske et al., 2014; Foa & Kozak, 1986). Indeed, it has been shown that exposure-based therapies produce larger effect sizes than those that do not utilise exposure when treating anxiety disorders (Carpenter et al., 2018). Despite the illustrated efficacy of exposure-based therapies, treatment responses in naturalistic settings are varied with approximately 49% of patients failing to reach clinical remission by the end of treatment (Springer et al., 2018). Similarly, 14% of patients with successful treatment outcomes experience relapse post-treatment (Levy et al., 2021). Although higher relapse rates have been recorded elsewhere in the literature e.g., 23.8% (Lorimer et al., 2021). Such differences are likely due to varying definitions of relapse and follow-up. Additionally, exposure protocols produce high rates of treatment refusal and attrition (Haby et al., 2006; Issakidis & Andrews, 2004). Therefore, it is important to understand the variables that may inhibit the success of exposure-based treatments for the benefit of future patients.

Exposure treatments can be understood via principles of classical conditioning (Boschen et al., 2009). Within human threat-conditioning experiments, and during the 'threat acquisition phase', a neutral stimulus (CS+; conditioned stimulus e.g., a shape) is repeatedly paired with an aversive stimulus (US; unconditioned stimulus e.g., an electric shock). After repeated pairings, the CS+ begins to evoke a response analogous to the unconditioned stimulus i.e., defensive responding, otherwise known as the conditioned response (Lonsdorf et al., 2017). Additionally, conditioning procedures often include a control stimulus (CS-) that is not paired with the US to outline differential responding to conditioned and unconditioned stimuli (Lonsdorf et al., 2017). Typically, this phase is followed by either an immediate or delayed/repeated 'threat extinction' phase. In the threat extinction phase, both the CS+ and the CS- are presented to the participant without the presence of the aversive stimulus which leads to a reduction in the magnitude/frequency of conditioned responding to the CS+, this process is known as 'extinction learning' (Hermans et al., 2006; Lonsdorf et al., 2017). Threat acquisition and extinction tend to be indexed via differential CS+/CS- response measurements in either physiological data e.g., skin conductance responses, or behavioural ratings e.g., expectancy of aversive stimulus presentation or perceived distress (Lonsdorf et al., 2017). Threat acquisition is said to represent the mechanism by which pathological anxiety/fear responses may be acquired (Mineka & Oehlberg, 2008; Mineka & Zinbarg, 2006; Ohman & Mineka, 2001). Whereas threat extinction learning is thought to represent the central mechanism underpinning exposure-based treatments i.e., the unlearning of previously acquired CS+/US associations (Dunsmoor, Campese, et al., 2015; Milad & Quirk, 2012; Rachman, 1989; Vervliet et al., 2013). Multiple explanatory mechanisms of extinction learning have been proposed, however recent research supports the inhibitory learning model (Craske et al., 2012). This model suggests that threat extinction learning leads to the formation of new safety associations in relation to the conditioned stimulus which compete with, but do not erase, the older threat associations (Bouton, 2004; Delamater, 2004).

Interestingly, recent research has demonstrated distinct differences in conditioned responding between those with and without clinical anxiety disorders. Such research has been undertaken to elucidate potential differences in threat conditioning between clinical and non-clinical groups with the hope of improving future treatments (Jacoby & Abramowitz, 2016). For instance, a seminal meta-analysis found that anxiety patients show stronger conditioned responses to the CS-, but not the CS+, during acquisition in comparison to non-clinical controls. Additionally, anxiety patients, vs controls, displayed heightened responding to the CS+, but not the CS-, during extinction (Duits et al., 2015). These results suggest that individuals with anxiety disorders transfer learned threat associations to non-threatening stimuli during threat acquisition, whilst also demonstrating difficulty in extinguishing previously learned CS+/threat associations during extinction. Although utilizing a general anxiety disorder category, most of the studies within Duits et al. (2015) examined patient-control differences in relation to post-traumatic stress disorder (PTSD) hence these effects may be more specific to this disorder. Interestingly, a more recent meta-analysis carried out by Kausche et al. (2025) found heightened patient responses to both the CS+ and CS- throughout the entirety of the conditioning procedure i.e., acquisition, extinction, and retention although this varied on the basis of conditioning index e.g., affect ratings vs physiological measures. Instead, this suggests that anxiety disorders are associated with heightened arousal throughout threat acquisition and extinction, as opposed to showing differences specific to either conditioning phase or stimulus type. Similar results have been found utilizing a sample that includes child and adolescent anxiety patients (Abend et al., 2020). Further, OCD patients also demonstrate heightened responding to the CS+ in extinction compared to controls, however this effect was stronger in studies that utilised delayed extinction protocols (see Cooper & Dunsmoor, 2021 for review). Yet, unlike anxiety disorders in general, individuals with OCD display heightened conditioned responding to the CS+ but not the CS- during threat acquisition, as well as displaying reduced discrimination between CS+ and CS- during retention, compared to controls (Cooper & Dunsmoor, 2021). This may suggest that individuals with OCD acquire stronger, or more rapid, threat associations to the CS+ and reduced extinction retention in comparison to anxiety disorders in general. Further, it appears that individuals with social anxiety do not display much evidence of group-level differences in threat conditioning (Wake et al., 2024). Hence, although patient-control differences in threat conditioning have been found in relation to anxiety disorders as a general category (Abend et al., 2020; Duits et al., 2015; Kausche et al., 2025), there is a high amount of variation in both the presence and/or nature of these effects with respect to specific anxiety disorders (Cooper & Dunsmoor, 2021; Wake et al., 2024).

On another note, disparate lines of academic enquiry have outlined the emerging importance of intolerance of uncertainty (IU) in accounting for both anxiety disorder symptomatology (Mahoney & McEvoy,

2012) and altered threat extinction learning (Morriss, Wake et al., 2021). IU is defined as "an individual's dispositional incapacity to endure the aversive response triggered by the perceived absence of salient, key, or sufficient information, and sustained by the associated perception of uncertainty" (Carleton, 2016a). Essentially, IU represents an aversion to uncertainty similar to the notion of "fearing the unknown"; an experience associated with multiple anxiety disorders (Carleton, 2016b). IU is said to represent a lower-order transdiagnostic factor which is subsumed by neuroticism (Carleton, 2016a, 2016b; Hong & Cheung, 2015; McEvoy & Mahoney, 2012; Paulus et al., 2015), a higher-order personality trait indexed by an increased tendency to experience negative emotion, otherwise known as negative affectivity (Watson & Clark, 1984). IU has been shown to account for unique variance in social anxiety whilst controlling for neuroticism (McEvoy & Mahoney, 2011). Similarly, IU mediates the well-established relationship between neuroticism and various anxiety disorders and depression (McEvoy & Mahoney, 2012). In relation to human threat conditioning, research has revealed mixed findings regarding the relationship between threat acquisition learning and IU with few studies finding positive associations yet most revealing null associations (Morriss, Zuj, & Mertens, 2021). Concerning threat extinction however, a recent meta-analysis revealed that higher IU is associated with poorer threat extinction learning whilst controlling for other measures of trait anxiety that are similar to neuroticism (Morriss, Wake et al., 2021). Therefore, demonstrating a robust link between IU and extinction learning. Indeed, it is posited that those with high IU may find the contingency uncertainty during extinction more distressing than those with low IU, and this, in turn, maintains heighted conditioned responding to the CS+ during extinction (Morriss & van Reekum, 2019). If true, this may suggest that a clinical focus on IU within exposure-based therapies is warranted to enhance extinction learning specifically (Morriss, 2025).

Indeed, there is strong evidence that IU can be clinically altered via evidence-based treatments for anxiety disorders such as CBT (Miller & McGuire, 2023). Pertinently, it appears that CBT interventions which target IU specifically are more effective at reducing IU (Wilson et al., 2023). Such targeted approaches included further psychoeducation about IU, worry awareness training, behavioural experiments aimed at re-evaluating IU-related beliefs etc. (Robichaud et al., 2019; Hebert & Dugas, 2019). However, to fully understand the clinical utility of IU as a transdiagnostic dimension, it is important to address whether IU is associated with extinction learning, over and above anxiety- and depression-related symptomatology as such constructs have not yet been controlled for in prior research. This would allow us to demonstrate whether the predictive effect of IU upon extinction learning is subsumed by anxiety- and depression-related symptomatology or whether it represents an association that may translate across different types of symptomatology.

The current study aimed to investigate IU in relation to threat extinction learning whilst controlling for anxiety- and depression-related symptoms as measured by disorder-specific questionnaire measures. The study employed a two-day classical threat conditioning task consisting of three distinct phases: threat acquisition (acquisition), same-day threat extinction (extinction), and next-day extinction retention (retention). Behavioural ratings of anxiety, stimulus expectancy, and skin conductance responses (SCR) were used as indices of conditioned responding as per standard practice in threat conditioning research (Lonsdorf et al., 2017). Similar to previous research, the specificity of IU was assessed whilst controlling for trait-level anxiety and then whilst controlling for an array of common mental health disorder symptoms e.g., social anxiety disorder, generalised anxiety disorder, depression etc. Considering previous research, we outline the following hypotheses:

1.1. General threat conditioning hypotheses

1. During acquisition, we predicted significantly heightened responding to the CS+, vs the CS-, for both the behavioural ratings (anxiety and stimulus expectancy) and SCR, demonstrating threat acquisition.
2. During extinction, we predicted a continuation of significantly heightened responding (behavioural ratings and SCR) to the CS+, vs CS-, within the first half of the extinction phase. However, within the latter half we predicted equal responding (SCR and behavioural ratings) between the CS+ and CS-, demonstrating extinction learning.
3. During retention, we predicted slightly yet significantly heightened responding to the CS+, vs the CS-, (SCR and behavioural ratings) in the first half of the retention phase demonstrating a 'return of fear' (Lonsdorf et al., 2017). Within the latter half, we predicted equal responding (SCR and behavioural ratings) between the CS+ and CS-, demonstrating extinction retention.

1.2. Primary hypotheses

4. We predicted that high IU will be associated with poorer extinction learning (heightened responding to the CS+ vs the CS-) across all three measures (anxiety, expectancy, and SCR) during both extinction and retention whilst controlling for TA (Morriss, Zuj, & Mertens, 2021). Additionally, we explored the association between IU and threat acquisition learning across all three measures (anxiety, expectancy, and SCR) whilst controlling for TA without making any predictions about the presence and/or direction of the effect.
5. Further, we predicted that the previously detected IU-extinction learning associations will continue to retain their statistical significance whilst controlling for anxiety- and depression-related symptoms separately. Thus, demonstrating an IU-extinction learning association that is specific over both TA, and anxiety- and depression-related symptoms. Similarly, we explored, without making any predictions, whether any previously detected IU-acquisition learning associations will continue to retain their statistical significance whilst controlling for anxiety- and depression-related symptoms.

2. Method

2.1. Participants

An opportunity sample of 101 participants (76 females, 25 males; 54 White, 38 Asian, 6 black, and 3 multi-ethnic; 68 heterosexual, 24 lesbian/gay/bisexual, 9 sexual orientation not reported) was recruited for the study. Participants were between the ages of 18 and 40 (M = 23.13, SD = 5.79). The sample consisted predominantly of students enrolled at the University of Southampton recruited via word of mouth or the University's student research recruitment website (SONA). Each participant was renumerated for their time via the payment of 24 SONA credits (required for those enrolled on an undergraduate Psychology course) or £20 in cash. This study was granted ethical approval by the Psychology ethics sub-committee within the University of Southampton Research Ethics Committee (UREC; Ethical Approval Number: 78272).

2.1.1. Inclusion criteria

The pre-specified age range was between 18 and 40 due to theoretical differences in safety learning and retention in relation to the hormonal profiles and experiences of people above and below this age range (Lonsdorf & Merz, 2017). Additionally, participants were excluded if they had a history of traumatic brain injury due to its effect in producing emotion processing and regulation differences (Salas et al., 2019). Similarly, participants were excluded if they were currently taking psychotropic medications as such treatments are known to alter internal experiences and psychophysiological responsiveness (Siepmann et al.,

2007).

2.2. Power analysis

Although multi-level modelling (MLM) was the main analysis in this study, an a-priori power analysis was carried out to estimate the minimum sample size required to detect IU-differential responding (CS+ - CS-) correlations. This method was employed given the lack of well-established methods for estimating sample sizes for MLMs (Peugh, 2010; Snijders, 2005). The power analysis was carried out using G*Power version 3.1.9.7 (Faul et al., 2007) with an estimated effect size of $r = 0.28$ (the IU-differential responding correlation effect size across 18 studies; Morriss, Wake et al., 2021). The additional parameters used within the analysis were: a two-tailed hypothesis, an alpha value of = 0.05, and Power (1- error probability) = 0.8. This produced a required sample size of $N = 97$. Therefore, the obtained sample size of $N = 101$ is adequate to test the study hypotheses using MLMs.

2.3. Conditioning task

Eprime 3.0 software was used to design and run the conditioning task procedure (Psychology Software Tools Ltd., Pittsburgh, PA). Participants were positioned approximately 60 cm from the computer screen. During the experiment, visual shape stimuli (blue and yellow squares) were presented on the screen with visual angles of 6.16 × 9.07°. The aversive sound stimulus was administered using headphones. The sound stimulus used throughout the experiment was that of a high-pitched female scream at 90 dB. This sound was based on a sample from the International Affective Digitised Sounds Battery (IADS-2; Bradley & Lang, 2007) and has been used in similar research (Morriss et al., 2020). The volume of the aversive stimulus was kept consistent across participants; experimenters used an audiometer to measure the volume prior to each experiment and adjusted as necessary.

The main conditioning task was a differential cue conditioning protocol (Lonsdorf et al., 2017) consisting of three distinct learning phases: threat acquisition (acquisition), threat extinction (extinction), and extinction retention (retention). During acquisition, one of the coloured squares (yellow or blue) was paired with the aversive sound stimulus 50% of the time (CS+), the other coloured square was not paired with the aversive stimulus (CS-). Such partial reinforcement rates are known to prolong extinction learning in human samples therefore are considered optimal for extinction-specific investigations such as the current study (Haselgrove et al., 2004; Lonsdorf et al., 2017). The CS+ stimuli were counterbalanced; an equal number of participants had a blue or yellow square as the CS+ to avoid any potential confounding colour effects. During both extinction and retention, the CS+ was not paired with the aversive stimulus. Participants were not aware that the experiment consisted of different phases, nor did they receive any differing instructions per phase. Additionally, participant instructions did not outline the reinforcement contingencies in any way, hence representing an "uninstructed procedure" (Lonsdorf et al., 2017).

Acquisition consisted of 24 trials (6 CS+ paired, 12 CS-, and 6 CS+ unpaired). Both extinction and retention consisted of 32 trials each (16 CS+ unpaired, and 16 CS-). Experimental trials underwent pseudo-randomisation; this ensured that the first trial of the acquisition phase was a CS+ trial. The shape stimuli were presented for a total of 4000ms, and the aversive sound stimulus was presented for the final 1000ms of the shape stimuli presentation (within paired trials i.e., CS+ paired). This ensured a degree of anticipation and unpredictability. Subsequently, a blank screen was presented for 6000ms to 8800ms after each stimulus presentation (Morriss, Saldarini, et al., 2019; Morriss & van Reekum, 2019). Each experimental phase was split into two equal experimental blocks consisting of the same number of trials per block i.e., the acquisition phase consisted of two blocks of 12 trials whereas the extinction and retention phases consisted of two blocks of 16 trials (Fig. 1). Behavioural rating scales were presented to the participants after each experimental block (see 'Rating Scales'). Pseudo-randomisation ensured that each block had an equal proportion of CS+ and CS- stimuli, and a maximum of 2 CS+ or 3 CS+ unpaired/3 CS- were presented consecutively.

2.4. Questionnaires

The following questionnaires were used to collect construct-specific data per participant.

2.4.1. Intolerance of uncertainty scale (IUS-12; Carleton et al., 2007)

The IUS-12 consists of 12 items measuring trait IU on a 5-point Likert scale (score range: 12 – 60). For instance, example item *"One should always look ahead so as to avoid surprises"* is rated from 1 (Not at all characteristic of me) to 5 (Entirely characteristic of me). The IUS-12 possesses an 'excellent' level of internal consistency ($\alpha = .91$). The IUS-12 does not have an established clinical cut-off.

2.4.2. Trait anxiety shortened (STAI-T; Zsido et al., 2020)

The STAI-T consists of 5 items measuring trait anxiety on a 4-point Likert scale (score range: 5 - 20). For instance, example item *"I worry too much over something that really doesn't matter"* is rated from 1 (Not at all) to 4 (Very much so). This scale possesses a 'good' level of internal consistency ($\alpha = .82$). The STAI-T does not have an established clinical cut-off.

2.4.3. Generalised anxiety disorder questionnaire (GAD-7; Spitzer et al., 2006)

The GAD-7 is a routinely utilised measure for symptoms of GAD. It consists of 7 items measured on a 4-point Likert scale (score range: 0 - 21). For instance, example item *"Over the last 2 weeks, how often have you been bothered by any of the following problems?.. Feeling nervous, anxious or on edge?"* is rated from 0 (Not at all) to 3 (Nearly every day). The internal consistency of the GAD-7 is considered 'excellent' ($\alpha = .92$), and test-

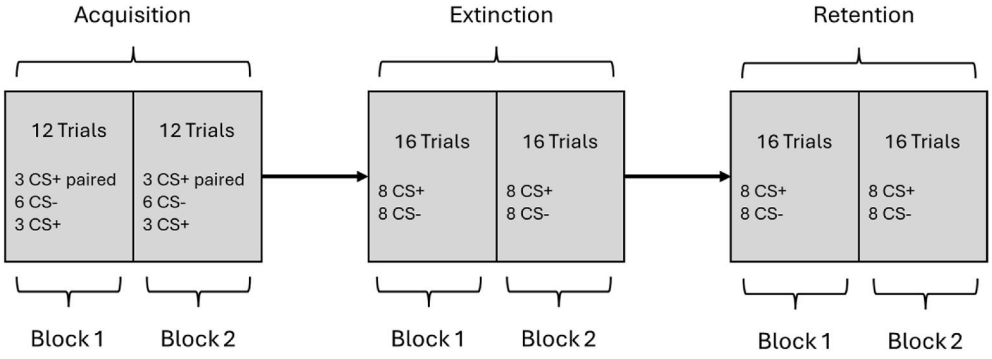

Fig. 1. A diagram depicting progression through the experimental procedure in terms of experimental phases and their constituent blocks.

retest reliability was also 'good' (α = .83). Similarly, the GAD-7 is considered to have good criterion, factorial, construct, and procedural validity. This measure has been validated for use within the general population (Lowe et al., 2008). The GAD-7 has three categorical cut-offs at total scores of 5, 10, and 15 which represent mild, moderate, and severe levels of generalised anxiety respectively. A clinical cut-off score of 10 or above is said to represent a clinical level of GAD.

2.4.4. Patient health questionnaire (PHQ-9; Kroenke et al., 2001)

The PHQ-9 measures symptoms of depression (MDD). It consists of 9 items rated on a 4-point Likert scale (score range: 0 - 27). For instance, *"Over the last 2 weeks, how often have you been bothered by any of the following problems?.. Feeling down, depressed, or hopeless?"* is rated from 0 (not at all) to 3 (nearly every day). The PHQ-9 has demonstrated a 'good' level of internal consistency (α = .89) and satisfies the criteria for construct and criterion validity. This measure has been validated for use within the general population (Kocalevent et al., 2013). The PHQ-9 has four categorical cut-offs at total scores of 5, 10, 15, and 20 which represent mild, moderate, moderately severe, and severe levels of depression respectively. A clinical cut off score of 10 or above is said to represent a clinical level of depression.

2.4.5. Obsessive compulsive inventory - revised (OCI-R; Foa et al., 2002)

The OCI-R measures symptoms of obsessive-compulsive disorder (OCD). It consists of 18 items rated on a 5-point Likert scale (score range: 0 - 72). For instance, example item *"I check things more often than necessary"* is rated from 0 (not at all) to 4 (extremely). The OCI-R has achieved an 'excellent' level of internal consistency (α = .90) as well as a good range for test-retest reliability and convergent validity. This measure has been validated for use within the general population (Hajcak et al., 2004). A clinical cut-off score of 21 or above is said to represent a clinical level of OCD.

2.4.6. Panic disorder severity scale (PDSS-SR; Houck et al., 2002)

The PDSS-SR is a self-report version of the panic disorder severity scale (PDSS) interview measure (Shear et al., 1997) which measures symptoms of panic disorder. It consists of 7 items rated on a 5-point Likert scale (score range: 0 - 28). For instance, example item *"How many panic and limited symptoms attacks did you have during the week?"* is rated from 0 (No panic or limited symptom episodes) to 4 (Extreme: full panic attacks occurred more than once a day, more days than not). The PDSS-SR possesses an 'excellent' level of internal consistency (α = .92), as well as demonstrating 'good' test-retest validity and sensitivity to change. This measure has been tested within a non-clinical sample where it also achieved an 'excellent' level of internal consistency (α = .92) (Plunkett et al., 2025). A clinical cut-off score of 8 or above is said to represent a clinical level of panic disorder (Shear et al., 2001).

2.4.7. Social interaction phobia scale (SIPS; Carleton et al., 2009)

The SIPS measures symptoms of social anxiety disorder. It consists of 14 items rated on 5-point Likert scale (score range: 0 - 56). For instance, example item "*I am tense mixing in a group*" is rated from 0 (not at all characteristic of me) to 4 (entirely characteristic of me). The SIPS has been shown to contain an 'excellent' level of internal consistency (α = .92). This measure has been validated for use within both non-clinical and clinical samples (Menatti et al., 2015). A clinical cut-off score of 21 is said to represent a clinical level of social anxiety.

2.5. Behavioural rating scales

The behavioural rating scales were presented after each experimental block. There were two behavioural rating scales used throughout the experiment that related to both of the shape stimuli presented: expectancy i.e., *"Please rate how much you expect the sound to occur when you see this colour square?"* which was rated on a 101-point Likert scale (0 = Didn't expect it, 100 = Did expect it), and anxiety i.e., *"Please rate how anxious you feel when you see this colour square?"* which was also rated on a 101-point Likert scale (0 = Not at all anxious, 100 = Anxious). These scores were used to calculate the mean score for each stimulus type. For instance, the mean rating for both the CS+ and CS- was calculated for the acquisition phase, and for both experimental blocks within the extinction and retention phases (see Fig. 1). This resulted in a behavioural rating score for acquisition, early extinction (block 1), late extinction (block 1), early retention (block 1), and late retention (block 2) per stimulus (CS+ and CS-), per behavioural construct (expectancy and anxiety ratings), per participant across the experiment.

2.6. Skin conductance responses (SCR)

Skin conductance data was recorded via a BIOPAC MP160 machine (Biopac Systems Inc., Goleta, CA) and processed using Acqknowledge software. The skin conductance data was measured in microsiemens (μS) at a rate of 2000 samples per second. After data acquisition, the data were down-sampled to 20 samples per second. The full skin conductance signal was split into sections that were experiment-relevant and irrelevant. The sections that were relevant were known as epochs; each epoch denoted the signal recorded between 1 and 4s post-stimulus presentation, per trial. Within each epoch, the highest peak was identified and baseline corrected by subtracting the mean value from 1s pre-stimulus (Pineles et al., 2009). To be counted as a valid SCR, the difference between the baseline and peak had to be $\geq$ 0.03 μS (Dawson et al., 2000). Trials with no discernible SCR were given a value of 0.

CS+ trials that were paired with the aversive stimulus were excluded from the analysis to prevent sound-based confounds. Therefore, each participant produced a total of 82 epochs per experiment: 6 CS+ and 12 CS- in acquisition, and 16 CS+ and 16 CS- in both extinction and retention. These epochs were visually inspected to check for movement-based artefacts and total loss of signal. Zero artefacts were detected. The data were square root transformed to normalize the distributions in accordance with previous literature (Braithwaite et al., 2013). Separate SCR magnitudes were then created by calculating the mean number of SCRs per stimulus type, per phase/block. Resulting in an SCR magnitude for acquisition, early extinction (block 1), late extinction (block 1), early retention (block 1), and late retention (block 2) per stimulus (CS+ and CS-), per behavioural construct (expectancy and anxiety ratings), per participant across the experiment.

2.7. Procedure

On the first day of testing (day 1), the experimenter verbally introduced the participant to the outline of the experiment. The participant then read the information sheet and signed the consent form. Participants were given time to ask any questions prior to signing the consent form. Once consent was obtained, the participant was instructed to listen to an example soundbite that was similar in nature and volume to the aversive stimulus used in the experiment. Following this, the experiment began with the participant completing all questionnaires.

Next, participants were instructed to wash their hands with warm water prior to the conditioning task. Participants were instructed not to use soap when washing their hands to prevent excessive removal of surface salt as it can negatively impact skin conductance data (Shaffer et al., 2016). The skin conductance electrodes were attached to the distal phalanges of the index and middle fingers on the participant's left hand. The participant was instructed to rest their left hand upon a polystyrene block to allow their fingers to float over the edge, hence minimizing disruption to electrode positioning throughout the experiment. The participant was instructed to assume a comfortable position, to attempt to keep their left hand as still as possible, and to avoid crossing or bouncing their legs during the experimental procedure to reduce movement-based artefacts in the data (Boucsein, 2012). Before commencing, the experimenter checked the quality of the skin conductance data by instructing the participant to take a deep breath; if

a skin conductance response (SCR) was observed the experiment commenced. If an SCR was not observed, the electrodes were readjusted to ensure valid recording of data.

Subsequently, the main conditioning task commenced. The conditioning task was presented on a computer screen whilst skin conductance and behavioural data were collected simultaneously. On day one, participants were instructed to maintain attention to the experimental stimuli i.e., squares and sounds, to respond to the behavioural rating scales, and were reminded to remain still throughout. On day two, participants received a similar set of instructions. Day one and two of testing took approximately 1 h and 30 min, respectively.

2.8. Analysis plan

Sets of multi-level models (MLMs) were conducted using the mixed procedure in SPSS (IBM inc., Armonk, NY; v28.1.1.0). Raw data and SPSS outputs can be accessed via the open science framework at: https://osf.io/y95an/?view_only=8114381c9cff478c962b59285bab7e36. Two separate MLMs (Model 1 and Model 2) were carried out per dependent variable (anxiety, stimulus expectancy, and SCR magnitude), per conditioning phase (acquisition, extinction, and retention), resulting in a total of 18 MLMs. For anxiety ratings, expectancy ratings, and SCR magnitudes during the acquisition phase Stimulus type (CS+, CS-) was entered at level 1, and individual participants at level 2. For anxiety ratings, expectancy ratings, and SCR magnitudes during extinction and retention both Stimulus type (CS+, CS-) and Time (Early: first 8CS+/CS-, Late: last 8CS+/CS-) were entered into the model at level 1, and individual participants at level 2.

Each of the above MLMs were run twice in accordance with either Model 1 or Model 2. Within Model 1, IUS-12 and STAI-T were entered into the model as covariates. Within Model 2, IUS-12, GAD-7, PDSS-SR, PHQ-9, OCI-R, and SIPS were entered into the model as covariates. The MLMs were run using mean-centred questionnaire scores. Fixed effects included Stimulus type and Time, and random effects included Participant. The maximum likelihood method was utilised within each MLM. Pairwise comparisons were used to follow-up both two-way and three-way interactions using the 'COMPARE' function within SPSS syntax which were adjusted using the least significant differences (LSD) method. Model 1 MLMs were interpreted first, if a significant IUS-12 main effect was present this demonstrated a specific association between IU and the dependent variable whilst controlling for trait anxiety, in this case Model 2 was interpreted and reported to assess the specificity of IU over disorder-specific measures. The aforementioned sequential analytical structure was employed to coalesce with the primary aim of this paper i.e., to determine whether specific associations between IU and extinction learning (differential responding) that were present whilst controlling for TA continue to hold whilst controlling for anxiety- and depression-related symptoms. Given the hierarchical relationship between neuroticism i.e., trait anxiety and IU (Carleton, 2016a, 2016b; Hong & Cheung, 2015; McEvoy & Mahoney, 2012; Paulus et al., 2015) it stands to reason that IU-specific effects must first demonstrate specificity over TA before being investigated in relation to other variables. If a significant Stimulus x IUS-12, Time x IUS-12, or Stimulus x Time × IUS-12 interaction was observed within both Model 1 and Model 2, estimated marginal means of the CS+ and CS- were calculated at 1 standard deviation above and below the mean IUS-12 score and then plotted in bar charts to ascertain the direction of the IU effect.

Lastly, three sets of bivariate, parametric correlational analyses were carried out as exploratory analyses. This included correlating both trait and disorder-specific measure scores with conditioned stimulus difference scores (CS+ - CS-), individual CS+ and CS- scores, and overall arousal scores (mean of CS+ and CS- scores) per dependent variable (anxiety ratings, stimulus expectancy ratings, and SCR magnitudes), per conditioning phase (acquisition, extinction, and retention). Although the results of said analyses are not outlined here as they are beyond the remit of this paper, please see supplement B for a summary "mini paper" of these analyses.

3. Results

3.1. Questionnaires

Descriptive statistics, and the internal consistency, associated with each questionnaire are presented in Table 1. The IUS-12 and STAI-T data were relatively normally distributed, whereas the symptom questionnaire data displayed a slight, but not extensive, positive skew (see supplement A for violin plots).

3.2. Manipulation check

As expected, the sound stimulus was rated as both aversive (M = 2.34, SD = 1.30, where 1 = very negative and 9 = very positive) and arousing (M = 6.80, SD = 2, where 1 = calm and 9 = excited) therefore was appropriately used as an unconditioned stimulus.

3.3. Threat conditioning data

The following results are structured by conditioning phase i.e., acquisition, extinction, and retention and by dependent variable i.e., anxiety ratings, stimulus expectancy ratings, and SCR magnitudes (see Fig. 2 for a visualisation of these results). The first set of MLMs (Model 1) tested for Stimulus (CS+ vs CS-), Time (early vs late extinction and extinction retention), IUS-12 (IU), and STAI-T (TA) main effects, as well as two-way and three-way interactions between these variables. The first paragraph of each section outlines the Stimulus, Time, and Stimulus x Time effects pertaining to hypotheses 1-3. The second paragraph of each section outlines the IU-related main effects and interactions whilst controlling for TA as pertaining to hypothesis 4 (see Table 2). TA-related effects are not outlined within the text but are detailed in Table 2. Similarly, the second paragraph of each section outlines the significant IU-related effects that maintained their significance in the second set of MLMs (Model 2) i.e., whilst controlling for all disorder-specific measures. Said results pertain to hypothesis 5 and are denoted by bold text within Table 2. The disorder-specific questionnaire effects are not outlined within either the text or table as they were not related to our hypotheses (all remaining MLM effects are available at https://osf.io/y95an/?view_only=8114381c9cff478c962b59285bab7e36). Lastly, IU-related follow up tests are then presented to ascertain the direction of

Table 1
Means, Standard Deviations, and Ranges Associated with each Questionnaire.

Measure	M	SD	α	Observed Score Range	Possible Range
IUS-12	29.43	8.52	0.89	12-54	12-60
STAI-T	11.07	2.89	0.75	5-20	5-20
GAD-7	6.67	4.17	0.82	0-19	0-21
PDSS-SR	3.17	3.33	0.84	0-15	0-28
PHQ-9	6.84	5.33	0.86	0-23	0-27
OCI-R	13.69	9.12	0.86	0-45	0-72
SIPS	15.79	11.83	0.93	0-52	0-56

Note. 'α' represents Cronbach's alpha coefficient.

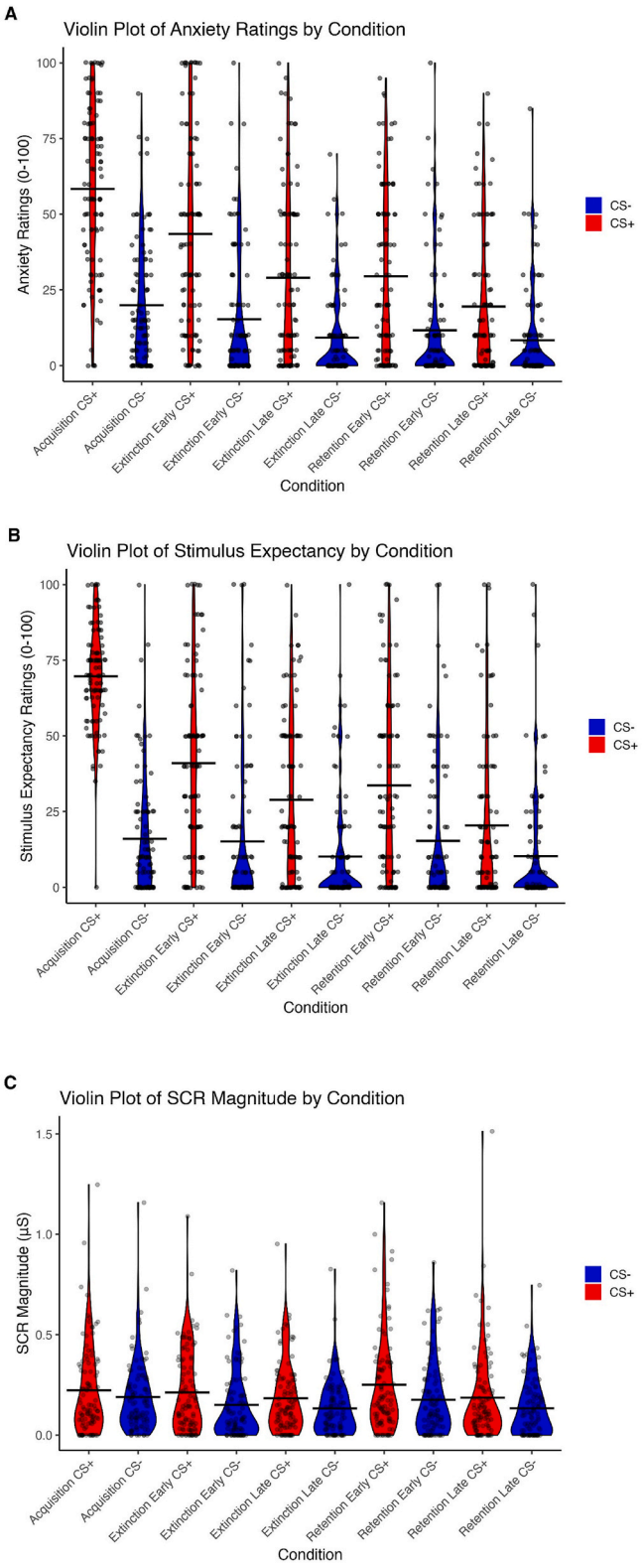

Fig. 2. A set of three violin plots outlining the main effects of stimulus and time per conditioning phase, per dependent variable. Each circle represents the participant mean associated with each stimulus type (CS+ or CS-), per time block (early or late), per conditioning phase (acquisition, extinction, or retention). The solid black line represents the sample mean associated with each stimulus type, per time block, per conditioning phase. See supplement C for trial-by-trial line plots of the SCR data across all three phases.

all significant IU-related interactions.

3.3.1. *Threat acquisition*

Anxiety Ratings. As expected, anxiety ratings were significantly higher in response to the CS+, as opposed to the CS-, within the acquisition phase (Stimulus: $F(1,98) = 204.18$, $p = <0.001$, *95% CI* = [32.99, 43.63]).

Further, IUS-12 did not significantly predict anxiety ratings (IUS-12: $F(1, 98) = 3.01$, $p = .086$, *95% CI* = [−0.25, 0.97]), nor did IUS-12 interact with Stimulus type whilst predicting anxiety ratings (Stimulus x IUS-12: $F(1, 98) = 0.51$, $p = .477$, *95% CI* = [−0.51, 1.09]), within the acquisition phase.

Stimulus Expectancy Ratings. As expected, stimulus expectancy ratings were higher in response to the CS+, as opposed to the CS-, within the acquisition phase (Stimulus: $F(1, 193.83) = 444.32$, $p = <0.001$, *95% CI* = [48.77, 58.83]).

Mirroring anxiety ratings within the acquisition phase, IUS-12 did not significantly predict stimulus expectancy ratings (IUS-12: $F(1, 193.83) = 0.544$, $p = .462$, *95% CI* = [−0.90, 0.23]), nor did IUS-12 interact with Stimulus type whilst predicting stimulus expectancy ratings (Stimulus x IUS-12: F(1, 193.83) = 1.02, p = .315, *95% CI* = [−0.37, 1.15]), within the acquisition phase.

SCR Magnitudes[1]. As expected, SCR magnitudes were significantly higher in response to the CS+, as opposed to the CS-, within the acquisition phase (Stimulus: $F(1, 99) = 4.89$, $p = .029$, *95% CI* = [0.003, 0.06]).

Consistent with prior measures, IUS-12 did not significantly predict SCR magnitudes (IUS-12: $F(1, 99) = 0.63$, $p = .431$, *95% CI* = [−0.01, 0.01]), nor did it interact with Stimulus type whilst predicting SCR magnitudes (Stimulus x IUS-12: $F(1,99) = 1.00$, $p = .321$, *95% CI* = [−0.002, 0.01]), within the acquisition phase.

[1] Z transformed SCR magnitudes achieved similar results to the square-root transformed SCR magnitudes, hence these results are not outlined for brevity.

3.3.2. *Threat extinction*

Anxiety Ratings. Interestingly, participants continued to report higher anxiety ratings in response to the CS+, vs the CS-, across the entire extinction phase (Stimulus: $F(1, 199.36) = 146.41$, $p = <0.001$, *95% CI* = [15.02, 24.47]). As expected, anxiety ratings were significantly higher within early vs late extinction (Time: $F(1, 199.36) = 26.70$, $p =< 0.001$, *95% CI* = [3.07, 8.93]). Additionally, the analysis revealed a significant Stimulus x Time interaction (Stimulus x Time: $F(1, 199.36) = 4.58$, $p = .034$, *95% CI* = [0.67, 16.30]). Yet, follow-up pairwise comparisons revealed that anxiety ratings were significantly higher in response to the CS+, vs the CS-, during both early and late extinction (Early: $p = <0.001$); Late: $p = <0.001$). Further, anxiety ratings were significantly higher in early vs late extinction for both the CS+ and the CS- (CS+: $p = <0.001$; CS-: $p = <0.001$).

Interestingly, IUS-12 scores predicted anxiety ratings, such that higher IU was associated with greater anxiety ratings, throughout the extinction phase (IUS-12: $F(1, 154.19) = 10.92$, $p = .001$, *95% CI* = [0.03, 0.93]); this effect retained its significance whilst controlling for all disorder-specific measures (IUS-12 Model 2: $F(1, 153.61) = 9.13$, $p = .003$, *95% CI* = [−0.01, 0.89]). Interestingly, all IU-related interactions were not significant within the extinction phase (Stimulus x IUS-12: $F(1, 199.36) = 3.51$, $p = .062$, *95% CI* = [−0.14, 1.29]; Time x IUS-12: $F(1, 199.36) = 0.23$, $p = .633$, *95% CI* = [−0.29, 0.60]; Stimulus x Time x IUS-12: $F(1, 199.36) = 0.01$, $p = .964$, *95% CI* = [−1.21, 1.15]).

Stimulus Expectancy Ratings. Interestingly, participants continued to report higher stimulus expectancy ratings in response to the CS+, vs the CS-, across the extinction phase (Stimulus: $F(1, 200.82) = 157.80$, $p = <0.001$, *95% CI* = [14.57, 23.04]). As expected, stimulus expectancy ratings were higher during early vs late extinction (Time: $F(1, 200.82) = 22.82$, $p = <0.001$, *95% CI* = [1.94, 7.96]). Similarly, a significant Stimulus × Time interaction was revealed (Stimulus x Time: $F(1,$

Table 2
Table showing IUS-12 and STAI-T main effects and interactions within MLM analyses per experimental phase, per dependent variable.

Effect	ACQ			EXT			RET		
	Anx	Exp	SCR	Anx	Exp	SCR	Anx	Exp	SCR
IUS-12	$F(1, 98) = 3.01$, $p = .086$, [-0.25, 0.97]	$F(1, 193.83) = 0.54$, $p = .462$, [-0.90, 0.23]	$F(1, 99) = 0.63$, $p = .431$, [-0.01, 0.002]	**$F(1, 154.19) = 10.92$, $p = .001$**, [0.03, 0.93]	$F(1, 121.17) = 3.55$, $p = .062$, [-0.35, 0.78]	$F(1, 96.83) = 0.48$, $p = .490$, [-0.004, 0.01]	**$F(1, 118.34) = 5.02$, $p = .027$**, [-0.27, 0.69]	$F(1, 107.55) = 0.12$, $p = .732$, [-0.87, 0.36]	$F(1, 87.20) = 0.38$, $p = .541$, [-0.01, 0.004]
STAIT	$F(1, 98) = 1.12$, $p = .294$, [-1.44, 2.19]	$F(1, 193.83) = 6.45$, $p = .012$, [0.89, 4.27]	$F(1, 99) = 0.03$, $p = .864$, [-0.01, 0.02]	$F(1, 154.19) = 0.88$, $p = .351$, [-1.45, 1.22]	$F(1, 121.17) = 0.06$, $p = .801$, [-0.48, 2.86]	$F(1, 96.83) = 0.09$, $p = .759$, [-0.02, 0.01]	$F(1, 118.34) = 0.10$, $p = .748$, [-1.13, 1.69]	$F(1, 107.55) = 2.08$, $p = .153$, [0.11, 3.72]	$F(1, 87.20) = 0.02$, $p = .890$, [-0.01, 0.02]
Stim x IUS-12	$F(1, 98) = 0.51$, $p = .477$, [-0.51, 1.09]	$F(1, 193.83) = 1.02$, $p = .315$, [-0.37, 1.15]	$F(1, 99) = 1.00$, $p = .321$, [-0.002, 0.01]	$F(1, 199.36) = 3.51$, $p = .062$, [-0.14, 1.29]	**$F(1, 200.82) = 3.96$, $p = .048$**, [-0.23, 1.05]	$F(1, 262.37) = 0.10$, $p = .755$, [-0.01, 0.003]	**$F(1, 214.01) = 6.88$, $p = .009$**, [0.01, 1.17]	$F(1, 225.84) = 2.55$, $p = .111$, [-0.16, 1.10]	$F(1, 255.93) = 0.06$, $p = .813$, [-0.004, 0.01]
Stim x STAIT	$F(1, 98) = 0.80$, $p = .373$, [-1.31, 3.46]	$F(1, 193.83) = 3.91$, $p = .049$, [-4.51, −0.01]	$F(1, 99) = 3.11$, $p = .081$, [-0.03, 0.001]	$F(1, 199.36) = 2.48$, $p = .117$, [-3.27, 0.96]	$F(1, 200.82) = 6.47$, $p = .012$, [-3.88, −0.09]	$F(1, 262.37) = 0.32$, $p = .570$, [-0.01, 0.02]	$F(1, 214.01) = 3.56$, $p = .061$, [-2.81, 0.62]	$F(1, 225.84) = 2.97$, $p = .086$, [-3.03, 0.69]	$F(1, 255.93) = 1.10$, $p = .295$, [-0.02, 0.01]
Time x IUS-12	-	-	-	$F(1, 199.36) = 0.23$, $p = .633$, [-0.29, 0.60]	$F(1, 200.82) = 1.17$, $p = .281$, [-0.29, 0.62]	$F(1, 262.37) = 2.28$, $p = .132$, [-0.01, 0.001]	$F(1, 214.01) = 0.07$, $p = .794$, [-0.42, 0.48]	$F(1, 225.84) = 0.38$, $p = .539$, [-0.64, 0.44]	$F(1, 255.93) = 0.001$, $p = .972$, [-0.004, 0.01]
Time x STAIT	-	-	-	$F(1, 199.36) = 0.001$, $p = .977$, [-1.09, 1.53]	$F(1, 200.82) = 0.004$, $p = .947$, [-1.26, 1.44]	$F(1, 262.37) = 0.10$, $p = .748$, [-0.01, 0.02]	$F(1, 214.01) = 0.01$, $p = .908$, [-1.02, 1.64]	$F(1, 225.84) = 0.03$, $p = .856$, [-1.59, 1.59]	$F(1, 255.93) = 0.32$, $p = .573$, [-0.02, 0.01]
Stim x Time x IUS-12	-	-	-	$F(1, 199.36) = 0.002$, $p = .964$, [-1.21, 1.15]	$F(1, 200.82) = 0.21$, $p = .647$, [-0.81, 1.30]	$F(1, 262.37) = 0.28$, $p = .595$, [-0.01, 0.01]	$F(1, 214.01) = 0.02$, $p = .883$, [-0.87, 1.01]	$F(1, 225.84) = 0.05$, $p = .821$, [-1.13, 0.90]	$F(1, 255.93) = 0.26$, $p = .611$, [-0.01, 0.01]
Stim x Time x STAIT	-	-	-	$F(1, 199.36) = 0.08$, $p = .784$, [-3.99, 3.01]	$F(1, 200.82) = 0.002$, $p = .963$, [-3.22, 3.07]	$F(1, 262.37) = 0.08$, $p = .772$, [-0.02, 0.02]	$F(1, 214.01) = 0.11$, $p = .744$, [-3.22, 2.31]	$F(1, 225.84) = 0.03$, $p = .858$, [-3.26, 2.72]	$F(1, 255.93) = 0.35$, $p = .556$, [-0.02, 0.03]

Note. ACQ, EXT, and RET refer to the experimental phases acquisition, extinction, and extinction retention respectively. Additionally, Anx, Exp, and SCR refer to anxiety ratings, stimulus expectancy ratings, and SCR magnitudes respectively, Further, Stim and Time refer to CS+ vs CS- effects and early vs late extinction/retention effects respectively. Bolded **IU effects** indicate retained significance within the subsequent set of MLMs i.e., whilst controlling for all symptom measures Numbers within square brackets represent 95% confidence intervals.

200.82) = 3.99, $p = .047$, *95% CI* = [0.09, 14.12]). Yet, follow-up pairwise comparisons revealed that stimulus expectancy ratings were higher in response to the CS+, vs the CS-, in both early and late extinction (Early: $p = <0.001$; Late: $p = <0.001$), and higher in early vs late extinction for both the CS+ and CS- (CS+: $p = <0.001$; CS-: $p = .001$).

Interestingly, IUS-12 scores did not predict stimulus expectancy ratings within extinction (IUS-12: $F(1, 121.17) = 3.55$, $p = .062$, *95% CI* = [−0.35, 0.78]), however there was a significant interaction between IUS-12 and Stimulus type (Stimulus x IUS-12: $F(1, 200.82) = 3.99$, $p = .048$, *95% CI* = [−0.23, 1.05]); this effect also retained its significance whilst controlling for disorder-specific measures (Stimulus x IUS-12 model 2: $F(1, 199.22) = 4.07$, $p = .045$, *95% CI* = [−0.24, 1.03]). Please see the 'Stimulus x IUS-12 Follow-Up Analyses' subsection for the direction of all significant Model 1 and 2 Stimulus x IUS-12 interactions. The remaining IU interactions were not significant (Time x IUS-12: $F(1, 200.82) = 1.17$, $p = .281$, *95% CI* = [−0.29, 0.62]; Stimulus x Time x IUS-12: $F(1, 200.82) = 0.21$, $p = .647$, *95% CI* = [−0.81, 1.30]).

SCR Magnitudes[2]**.** Interestingly, participants continued to exhibit higher SCR magnitudes in response to the CS+, vs the CS-, across the extinction phase (Stimulus: $F(1, 262.37) = 26.24$, $p = <0.001$, *95% CI* = [0.02, 0.08]). As expected, SCR magnitudes were higher for early vs late extinction (Time: $F(1, 262.37) = 4.62$, $p = .032$, *95% CI* = [−0.01, 0.05]). The Stimulus × Time interaction was not significant in relation to SCR magnitudes within extinction (Stimulus x Time: $F(1, 262.37) = 0.27$, $p = .603$, *95% CI* = [−0.03, 0.06]).

Interestingly, all IU-SCR magnitude main effects and interactions were not significant within the extinction phase (IUS-12: $F(1, 96.83) = 0.48$, $p = .490$, *95% CI* = [−0.004, 0.01]; Stimulus x IUS-12: $F(1, 262.37) = 0.10$, $p = .755$, *95% CI* = [−0.01, 0.003]; Time x IUS-12: $F(1, 262.37) = 2.28$, $p = .132$, *95% CI* = [−0.01, 0.001]; Stimulus x Time x IUS-12: $F(1, 262.37) = 0.28$, $p = .595$, *95% CI* = [−0.01, 0.01]).

[2] Z transformed SCR magnitudes achieved similar results to the square-root transformed SCR magnitudes, hence these results are not outlined for brevity.

3.3.3. Threat extinction retention

Anxiety Ratings. Unexpectedly, participants continued to report higher anxiety ratings in response to the CS+, vs the CS-, within the retention phase (Stimulus: $F(1, 214.01) = 83.34$, $p = <0.001$, *95% CI* = [7.18, 14.90]). In line with expectations, anxiety ratings were higher in early vs late retention (Time: $F(1, 214.01) = 17.73$, $p = <0.001$, *95% CI* = [0.29, 6.28]). Mirroring the earlier extinction phase, there was a significant Stimulus × Time interaction in predicting anxiety ratings in retention (Stimulus x Time: $F(1, 214.01) = 4.54$, $p = <0.034$, *95% CI* = [0.50, 12.94]). Follow-up, pairwise comparisons revealed that anxiety ratings were higher for CS+, vs the CS-, trials within both early and late retention (Early: $p = <0.001$; Late: $p = <0.001$). Further, anxiety ratings were significantly higher in early vs late retention for both the CS+ and CS- (CS+: $p = <0.001$; CS-: $p = .030$).

In line with the prior extinction phase, IUS-12 scores predicted anxiety ratings, such that higher IU was associated with greater anxiety ratings, throughout the extinction retention phase (IUS-12: $F(1, 118.03) = 5.02$, $p = .027$, *95% CI* = [−0.27, 0.69]) and this effect retained significance when controlling for disorder-specific measures (IUS-12 Model 2: $F(1, 115.73) = 5.09$, $p = .026$, *95% CI* = [−0.21, 0.80]). Interestingly, a significant interaction emerged between IUS-12 and Stimulus type (Stimulus x IUS-12: $F(1, 214.01) = 6.88$, $p = .009$, *95% CI*

= [0.01, 1.17]); this effect also retained its significance whilst controlling for disorder-specific measures (Stimulus x IUS-12 Model 2: $F(1, 216.95) = 8.41$, $p = .004$, *95% CI* = [−0.06, 1.16]). The remaining IU-related interactions were not significant (Time x IUS-12: $F(1, 214.01) = 0.07$, $p = .794$, *95% CI* = [−0.42, 0.48]; Stimulus x Time x IUS-12: $F(1, 214.01) = 0.02$, $p = .883$, *95% CI* = [−0.87, 1.01]).

Stimulus Expectancy Ratings. Unexpectedly, participants continued to report higher stimulus expectancy ratings in response to

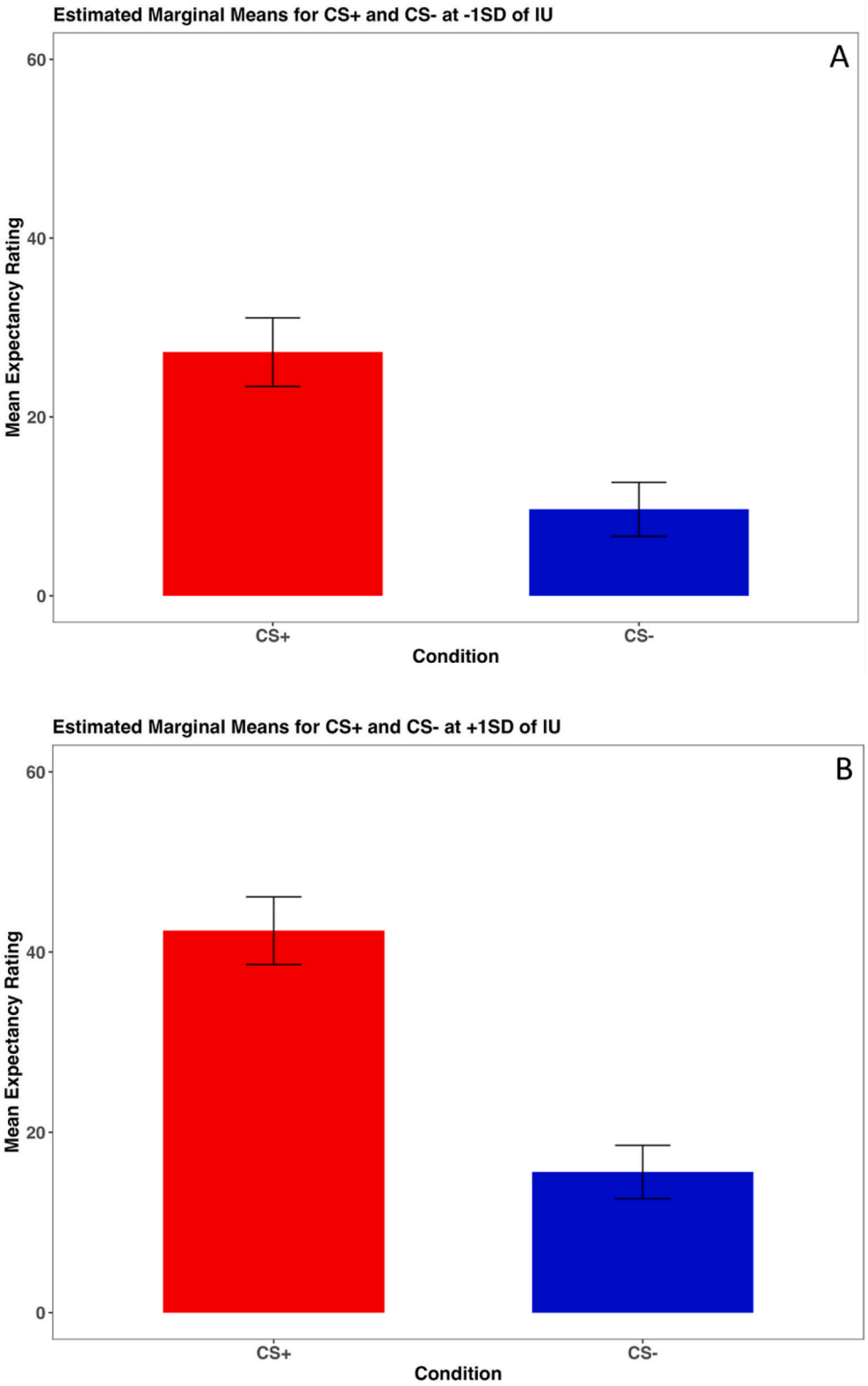

Fig. 3. A set of bar charts demonstrating estimated mean stimulus expectancy ratings for the CS+ and CS- at either 1 standard deviation above or below the mean IUS-12 score during extinction.
Note. *Error bars represent standard error estimated at either + or − 1 standard deviation of mean IUS-12.*

the CS+, as opposed to the CS-, throughout the retention phase (Stimulus: $F(1, 225.84) = 69.59$, $p = <0.001$, *95% CI* = [5.91, 14.28]). In line with expectations, higher stimulus expectancy ratings were reported in early vs late retention (Time: $F(1, 225.84) = 29.04$, $p = <0.001$, *95% CI* = [1.49, 8.63]). Mirroring the earlier extinction phase, there was a significant stimulus x time interaction in predicting stimulus expectancy ratings (Stimulus x Time: $F(1, 225.84) = 5.88$, $p = .016$, *95% CI* = [1.55, 15.00]). Yet, follow-up, pairwise comparisons revealed that stimulus expectancy ratings were higher for the CS+, as opposed to the CS-, within both early and late extinction retention (Early: $p = <0.001$; Late:

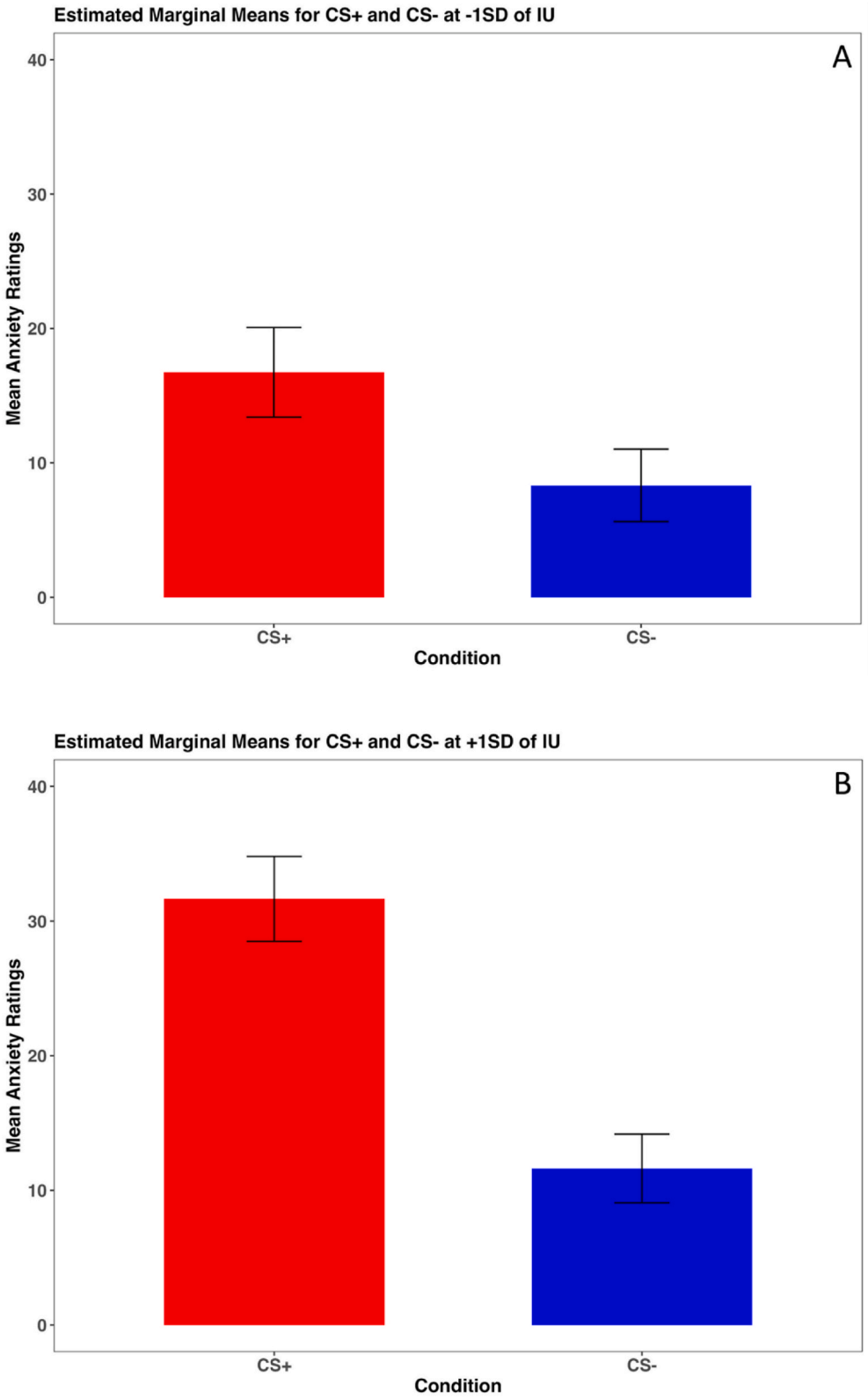

Fig. 4. A set of bar charts demonstrating estimated mean anxiety ratings for the CS+ and CS- at either 1 standard deviation above or below the mean IUS-12 score during retention. Error bars represent standard error estimated at either + or – 1 standard deviation of mean IUS-12.

$p = <0.001$). Further, stimulus expectancy ratings were higher in early vs late extinction retention for both the CS+ and CS- (CS+: $p = <0.001$; CS-: $p = .006$).

In line with the prior extinction phase, IUS-12 scores did not predict stimulus expectancy ratings within the extinction retention phase (IUS-12: $F(1, 107.55) = 0.12$, $p = .732$, *95% CI* = [−0.87, 0.36]). Interestingly, all IU-related interactions were not significant within the retention phase (Stimulus x IUS-12: $F(1, 225.84) = 2.55$, $p = .111$, *95% CI* = [−0.16, 1.10]; Time x IUS-12: $F(1, 225.84) = 0.38$, $p = .539$, *95% CI* = [−0.64, 0.44]; Stimulus x Time x IUS-12: $F(1, 225.84) = 0.05$, $p = .821$, *95% CI* = [−1.13, 0.90]).

SCR Magnitudes[3]. Unexpectedly, participants continued to exhibit larger SCR magnitudes in response to the CS+, vs the CS-, within the extinction retention phase (Stimulus: $F(1, 255.93) = 28.49$, $p = <0.001$, *95% CI* = [0.02, 0.09]). Yet, in line with expectations, higher SCR magnitudes were exhibited within early, vs late, extinction retention (Time: $F(1, 255.93) = 19.38$, $p = <0.001$, *95% CI* = [0.01, 0.07]). Mirroring the prior extinction phase, the Stimulus × Time interaction was not significant within the retention phase (Stimulus x Time: $F(1, 255.93) = 0.79$, $p = .376$, *95% CI* = [−0.03, 0.07]).

Interestingly, yet in line with the prior extinction phase, all IU-SCR magnitude main effects and interactions were not significant within the extinction retention phase (IUS-12: $F(1, 87.20) = 0.38$, $p = .541$, *95% CI* = [−0.01, 0.004]; Stimulus x IUS-12: $F(1, 255.93) = 0.06$, $p = .813$, *95% CI* = [−0.004, 0.01]; Stimulus x Time x IUS-12: $F(1, 255.93) = 0.26$, $p = .611$, *95% CI* = [−0.01, 0.01]).

[3]Z transformed SCR magnitudes achieved similar results to the square-root transformed SCR magnitudes, hence these results are not outlined for brevity.

3.4. Stimulus x IUS-12 Follow-Up Analyses

Bar charts (Figs. 3 and 4) demonstrate the direction of the Stimulus × IUS-12 interactions that emerged within the MLM analyses (see Supplement F for IUS-12 x CS+/CS- difference score correlation plots). Fig. 3 shows larger differences between stimulus expectancy ratings associated with the CS+ and CS- when the IUS-12 score is estimated at 1 standard deviation above the mean (chart B) vs 1 standard deviation below the mean (chart A). This shows that IUS-12 is significantly associated with heightened stimulus expectancy ratings to the CS+, but not the CS-, within extinction.

Fig. 4 shows larger differences between anxiety ratings associated with the CS+ and CS- when the IUS-12 score is estimated at 1 standard deviation above the mean (chart B) vs 1 standard deviation below the mean (chart A). This shows that IUS-12 is significantly associated with heightened anxiety ratings to the CS+, but not the CS-, within extinction retention.

4. Discussion

The current study utilised a two-day threat conditioning paradigm to examine whether IU was specifically associated with individual differences in threat extinction learning and retention whilst controlling for either trait anxiety or anxiety- and depression-related symptoms. On balance, this study failed to replicate the well-established association between high IU and dampened threat extinction learning (Morriss, Wake et al., 2021, Morriss, Zuj, & Mertens, 2021). More specifically, IU was not associated with differential responding in relation to anxiety ratings or SCR magnitudes during threat extinction whilst controlling for trait anxiety. However, high IU was specifically associated with heightened stimulus expectancy ratings to the CS+, vs the CS-, within extinction whilst controlling for both trait anxiety and anxiety- and depression-related symptoms separately. Further, IU was not associated with differential responding to stimulus expectancy ratings or SCR magnitudes during extinction retention whilst controlling for trait anxiety. Yet, high IU was specifically associated with heightened anxiety ratings in response to the CS+, vs the CS-, within extinction retention whilst controlling for both trait anxiety and anxiety- and depression-related symptoms separately. Interestingly, IU was not associated with threat acquisition learning within this study hence adding to the literature demonstrating such null associations (Morriss, Zuj, & Mertens, 2021). Namely, IU was not associated with differential responding in relation to anxiety ratings, stimulus expectancy ratings, or SCR magnitudes during threat acquisition whilst controlling for trait anxiety. Hence, based on the results of this study, it would appear that IU is not associated with threat acquisition learning. Similarly, IU is not consistently, or specifically, associated with poorer extinction learning and retention, although this effect appears to vary on the basis of extinction index and extinction phase.

Within acquisition successful threat conditioning was achieved, with participants demonstrating heightened responding to the CS+, vs the CS-, for anxiety ratings, expectancy ratings, and SCR magnitudes. Yet, heightened conditioned responding to the CS+, vs the CS-, continued throughout the extinction phase for all three measures, suggesting a lack of extinction within the sample. However, Stimulus × Time interactions observed in the extinction phase revealed larger stimulus difference scores (CS+ - CS-) within the earlier half, as opposed to the latter half, of extinction for both anxiety and stimulus expectancy ratings therefore demonstrating a trend towards extinction for these measures. This trend was not observed for SCR magnitudes, however. Mirroring the extinction phase, continued heightened responding to the CS+, vs the CS-, was observed throughout the retention phase for all three measures further demonstrating a lack of extinction, statistically. In line with predictions, a slight increase in stimulus expectancy ratings and SCR magnitudes to the CS+ in early retention vs late extinction was demonstrated, although this did not occur in relation anxiety ratings. Similarly, Stimulus × Time interactions revealed larger stimulus difference scores within the earlier half, vs the latter half, of retention for both anxiety and stimulus expectancy ratings, again demonstrating a trend towards extinction retention for these measures. Mirroring the extinction phase, this trend was not observed for SCR magnitudes within retention. In summary, the sample did not fully extinguish their aversion to the CS+ within this study hence failing to demonstrate a typical threat extinction pattern, particularly in relation to SCR magnitudes where extinction trends were non-existent statistically, and weak visually.

Furthermore, the muted extinction effect on SCR magnitude was an unexpected finding considering that many human threat conditioning studies have achieved extinction of SCR magnitudes using similar experimental designs (Dunsmoor, Campese, et al., 2015; Lucas et al., 2018). One possible explanation of this discrepancy relates to the effect of sample age on extinction learning, particularly with regards to indices that capture arousal such as SCR. For instance, it is well-established within conditioning research that adolescent humans and rodents exhibit muted or reduced extinction effects in comparison to same-species adults (Pattwell et al., 2012). This is likely due to a relative neurobiological immaturity in higher-order cortical structures, such as the ventromedial prefrontal cortex, producing a reduction in top-down regulation of fear-related subcortical structures, such as the amygdala, during extinction (Morriss, Christakou, & Van Reekum, 2019). Given that human neurobiological maturation occurs post-20 years of age (Semple et al., 2013) and that the current sample had a mean age of 23.13, it is likely that a large proportion of our participants were displaying continued conditioning during the extinction phase due to developmental effects. Indeed, previous conditioning research has failed to achieve extinction when experimenting on younger samples (Morriss, Christakou, & Van Reekum, 2019). In fact, conditioning studies often require twice the number of extinction trials when experimenting on adolescent rats in order to achieve extinction (Kim et al., 2011). Therefore, it is plausible that the current study failed to demonstrate extinction in SCR magnitudes due to the sample age. Further, with a higher number of extinction trials the expected extinction effect is likely to have been observed.

The current study outlines an absence of specific associations between IU and heightened responding to the CS+, vs the CS-, during both extinction and retention (poorer extinction learning) which is contrary to the wider literature. For instance, high IU has been specifically associated with poorer extinction learning by multiple studies utilizing multiple indices of extinction e.g., skin conductance, corrugator supercilii activity, pupil dilation, amygdala activity, and greater late positive potential whilst controlling for trait anxiety and worry (Morriss, Zuj, & Mertens, 2021). This association has been particularly reliably demonstrated in relation to SCR (Morriss, Wake et al., 2021). Hence, it is interesting that the current study failed to replicate this association with SCR. Although less is known about extinction retention, previous research has outlined that high IU is associated with heightened skin conductance responding to the CS+, vs the CS- (Morriss, Zuj, & Mertens, 2021), with an emphasis on the initial retention trials (Dunsmoor, Campese, et al., 2015; Wake et al., 2024). Again, such results were not replicated here. One could argue that the current results suggest a null relationship between IU and threat extinction learning, particularly in relation to skin conductance. However, given the ubiquity and robustness of the IU-extinction learning association elsewhere in the literature, this is unlikely to be the case (Morriss, Wake et al., 2021, Morriss, Zuj, & Mertens, 2021). Instead, this lack of detection may have been caused by the significantly weakened extinction effect observed within the sample. Given that the sample continued to demonstrate conditioned responding to the CS+ throughout the conditioning task it is likely that this resulted in reduced variance in sample-wide stimulus-difference scores (CS+ - CS-) which may have thwarted our ability to detect an effect. Indeed, previous research has failed to detect IU-extinction learning associations within samples that did not achieve extinction. For example, Morriss et al. (2024) found a similar lack of IU-extinction learning associations within a clinical sample of individuals with heightened IU scores that did not demonstrate extinction and attributed this result to the limited variance in IU and stimulus-difference scores. Hence, it is likely that the IU-extinction learning association would have been detected in the current study if extinction were achieved. Indeed, it is well-known that limited measure variance is associated with a lack of power and an inflation of type 2 error risk (Simkovic & Trauble, 2019).

Further, this study outlined an absence of specific associations between IU and threat acquisition learning. This result, therefore, adds to the body of literature demonstrating a null relationship between IU and threat acquisition learning (Morriss, Zuj, & Mertens, 2021). On reflection, this result may lend further credence to the notion that IU is only relevant to threat acquisition learning when carried out using protocols that increase the level of uncertainty (Morriss, Zuj, & Mertens, 2021). For instance, of the few studies that have demonstrated altered threat acquisition learning in relation to high IU, most have been characterised by atypical conditioning procedures, such as using two CS+'s and a 37.5% reinforcement rate (Kanen et al., 2021) or unpredictable startle probes when measuring fear-potentiated startle (Chin et al., 2016; Sjouwerman et al., 2020). Arguably, these conditions increase the difficulty in determining the exact CS-US contingency during threat acquisition. Therefore, producing a heightened sense of uncertainty and, by extension, a potential IU-related effect upon threat acquisition learning (Morriss, Zuj, & Mertens, 2021). As the current study used a relatively straightforward and unambiguous conditioning procedure i.e., two easily distinguished CS stimuli coupled with a 50% reinforcement rate, this may have produced an environment that is relatively low in uncertainty. Hence, making it unlikely that IU would interact with acquisition learning to a significant extent as is the case in the majority of studies (Morriss, Zuj, & Mertens, 2021). In any case, further research is required to elucidate the conditions that moderate the relationship between IU and threat acquisition learning.

This study had some noteworthy limitations. As mentioned, the sample did not achieve extinction from a statistical standpoint. Relatedly, the study sample was largely homogenous in terms of age and student-status. Future replications may wish to increase the variance in sample age or increase the number of extinction trials to mitigate these limitations. Further, recent findings question the validity of the STAI-T as a measure of trait anxiety, instead suggesting that it measures individual differences in negative affectivity (Knowles & Olatunji, 2020). Given the research demonstrating that IU retains its association with both symptoms and extinction learning whilst controlling for negative affect/neuroticism this does not weaken the appropriateness of its use within the current study (McEvoy & Mahoney, 2011, 2012; Morriss, Wake et al., 2021). Yet, readers should consider this nuance when referring to our results. Additionally, questionnaires were presented to participants in a fixed order therefore order effects may have occurred. Similarly, each questionnaire differs with regards to their assessment window length i.e., the PDSS-SR asks participants to identify symptoms over the last week whereas the OCI-R measures symptoms over the last month, whereas the SIPS does not specify an assessment window. Hence, it is possible that those with longer assessment windows could be more likely to detect trait-level neurotic tendencies than those with shorter timeframes hence making inter-diagnostic comparisons more complicated. Moreover, the power analysis method used in this study was non-optimal as correlational analyses do not account for random effects. As the employed MLMs included random effects it is possible that this study was underpowered; potentially explaining the unexpected null results. Future studies may wish to employ an alternative power analysis method that accounts for any random effects present in the analyses. Lastly, the current sample was not a clinical sample, hence caution must be made when interpreting the associations between conditioning processes and disorder-specific symptoms as high symptom scores as measured via questionnaires are not equivalent, qualitatively speaking, to a diagnosed psychiatric disorder. Nonetheless, the current study is the first of its kind to investigate the association between IU and threat extinction whilst controlling for trait and disorder-specific measures. The associated findings should be of use to future researchers aiming to investigate threat conditioning processes in relation to IU.

In sum, the current experiment showed an absence of specific associations between IU and poorer threat extinction learning as indexed by differential SCR magnitudes in both the extinction and extinction-retention phase whilst controlling for trait anxiety, failing to replicate previous findings. Specific IU associations with extinction learning, as indexed by differential responding, in relation to stimulus expectancy and anxiety ratings were mixed; IU was associated with differential stimulus expectancy and anxiety ratings within extinction and retention, respectively (whilst controlling for both trait anxiety and disorder-specific measures). Yet, IU was not specifically associated with these measures elsewhere within the conditioning procedure. In terms of general conditioning effects, successful threat conditioning to the CS+, vs the CS-, was observed during acquisition, however extinction of said conditioned responses was not achieved, statistically speaking, within either extinction or retention. However, an extinction trend was observed with regards to anxiety and stimulus expectancy ratings with stimulus-difference scores being significantly higher in early, vs late extinction and retention. The authors speculate whether this lack of extinction was partially responsible for the failure to replicate previous IU-extinction learning associations given the presumed lack of variance in stimulus-difference scores. Researchers may wish to consider the factors highlighted in this paper that may have affected our ability to replicate prior findings e.g., sample age, number of extinction trials, power analysis method and other limitations discussed when investigating IU and extinction learning in future studies. Overall, this study represents a valuable attempt to investigate the specificity of IU associations with threat conditioning processes whilst controlling for anxiety- and depression-related symptoms providing suggestions for future research in this area.

CRediT authorship contribution statement

Kane Steggles: Writing – original draft, Visualization, Formal

analysis. **Nico Biagi:** Visualization, Formal analysis, Data curation. **Matthew Garner:** Writing – review & editing, Supervision. **Jayne Morriss:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Data curation, Conceptualization.

Declaration of competing interest

The authors have no conflicts of interest to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2026.105039.

Data availability

The data are on OSF and the link is included in the paper

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