Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Journal of Psychiatric Research 155 (2022) 90–99

Contents lists available at ScienceDirect

Journal of Psychiatric Research

journal homepage: www.elsevier.com/locate/jpsychires

Fear learning and generalization during pandemic fear: How COVID-19-related anxiety affects classical fear conditioning with traumatic film clips

Alexander Hauck, Tanja Michael, Diana S. Ferreira de Sá *

Division of Clinical Psychology and Psychotherapy, Department of Psychology, Saarland University, Saarbrücken, Germany

ARTICLE INFO

Keywords:
COVID-19
Pandemic fear
Fear conditioning
Fear generalization

ABSTRACT

The COVID-19 pandemic greatly disrupted our daily lives. Worldwide, people were confronted with health, financial, and existential fears or trauma-like experiences. Recent studies have identified an increase in stress, anxiety, and fear symptoms in connection with the pandemic. Furthermore, fear learning processes are central mechanisms in the development and maintenance of anxiety disorders. Patients commonly show impairments not only in fear learning but also in its generalization. Thus, pandemic-related anxiety may constitute a risk factor for both enhanced fear acquisition and generalization. In a pre-registered online study with a final sample of 220 healthy university students, we investigated whether participants with higher COVID-19-related anxiety (COVID-Anxiety) show impaired fear learning and generalization. For this purpose, we used a differential fear conditioning paradigm with a traumatic film clip as the unconditioned stimulus (US) and collected US-expectancy as the main measure of interest. Participants with high COVID-Anxiety show a tendency toward poorer discrimination between the reinforced conditioned stimulus (CS+) and the unreinforced conditioned stimulus (CS−) during acquisition and significantly poorer discrimination patterns during generalization. Furthermore, participants with high COVID-Anxiety show greater general fear throughout the whole experiment. Our results show that the subjective effects of the COVID-19 pandemic on psychological well-being are associated with impairments in both fear learning and fear generalization. As expected, high COVID-Anxiety leads to poorer performance in stimulus discrimination and greater levels of fear, which might contribute to a higher risk of anxiety disorders.

German clinical trial register: DRKS00022761.

1. Introduction

With more than 460 million confirmed cases worldwide and over 6 million deaths (World Health Organization, n.d.), the COVID-19 epidemic has changed the world like no other event in recent decades has. To prevent the further spread of COVID-19, many countries have implemented severe restrictions, which not only affect countries' economies but also many areas of people's daily lives (e.g., reduced work hours, unemployment, the closure of schools and universities, restricted leisure activities, curtailed social contact, and so on).

Aside from the global and individual benefits of these restrictions, namely preventing COVID-19 infection and, thus, limiting the spread of the pandemic, they can have a negative impact on well-being and health (Brooks et al., 2020; Lades et al., 2020; Wegmann et al., 2021). In addition to the physical health risks associated with COVID-19, the prolonged pandemic and its associated restrictions are increasingly bringing more attention to mental health issues. For example, many people are reporting persistent worry and fear of illness due to the pandemic (Borade and Nagarkar, 2021; Chakraborty and Chatterjee, 2020; Šrol et al., 2021). Other stressors include being in quarantine, being overwhelmed or bored, feeling helpless, losing money, and perception of inadequate information (Brooks et al., 2020; Klaiber et al., 2021). Moreover, both younger and older people are suffering from increasing loneliness, tension, and insecurity (Ahrendt et al., 2020; Aristovnik et al., 2020; Borade and Nagarkar, 2021; Di Santo et al., 2020; Liang et al., 2020). It is also known that previous infectious

* Corresponding author. Division of Clinical Psychology and Psychotherapy, Department of Psychology, Saarland University Campus, Building A 1.3, 66123, Saarbrücken, Germany.
E-mail address: diana.ferreira@uni-saarland.de (D.S. Ferreira de Sá).

https://doi.org/10.1016/j.jpsychires.2022.07.068
Received 30 March 2022; Received in revised form 25 July 2022; Accepted 30 July 2022
Available online 10 August 2022

disease outbreaks, such as the severe acute respiratory syndrome (SARS) outbreak in 2003, the influenza A (H1N1) outbreak in 2009, or the Ebola outbreak in 2014, severely affected public mental health and, as fear-provoking events, led to symptoms of anxiety and post-traumatic stress disorder (PTSD) (Liang et al., 2020; Liao et al., 2014; Main et al., 2011; Mak et al., 2010; Maunder et al., 2003; Pfefferbaum et al., 2012; Shultz et al., 2015). In this context, since the onset of the COVID-19 pandemic, there has been a global increase in mental disorders, particularly depression and anxiety-related disorders (Fountoulakis et al., 2021; Salari et al., 2020). Recent studies have also suggested that the prevalence of stress, anxiety, and depression has increased significantly as a result of the COVID-19 pandemic (Deng et al., 2021; Sahebi et al., 2021; Salari et al., 2020; Santabárbara et al., 2021; Santomauro et al., 2021).

Fear learning processes play a crucial role in the etiology of anxiety disorders (Britton et al., 2011; Lissek et al., 2005). They are commonly studied under laboratory conditions using fear conditioning paradigms (Lonsdorf et al., 2017). Classical conditioning models show that fear can be triggered not only directly by aversive or trauma-like events but by previously harmless stimuli after being paired with aversive events, which activate the fear system (Hamm and Weike, 2005). Anxiety patients tend to show a discrimination deficit in differential fear conditioning paradigms, which manifests as a lack of safety learning (an increased fear response to safety cues), compared to controls, indicating poorer fear learning (Cooper et al., 2018; Duits et al., 2015). Similarly, Dibbets et al. (2015) found that highly anxious persons exhibit poorer discrimination between harmless and aversive stimuli in fear learning using a conditioning paradigm, making them more vulnerable to the development of anxiety disorders. Further, fear reactions can be transferred to similar neutral stimuli that were never paired with an aversive event. They can, therefore, occur not only in the presence of stimuli that were associated with the aversive situation but also in the presence of perceptually, semantically, or contextually similar stimuli (Dymond et al., 2015). This process, called fear generalization, is another characteristic of and risk factor for anxiety disorders (Britton et al., 2011; Craske et al., 2009). These inappropriately evoked fear reactions significantly contribute to the impaired quality of life of anxiety patients (Craske et al., 2009) and pose a major difficulty for successful therapy (Dymond et al., 2015). Patients with anxiety, as well as healthy but highly anxious individuals, show a stronger tendency toward fear generalization (Duits et al., 2015; Morey et al., 2015). Additionally, studies have suggested a relationship between trait anxiety and fear generalization, even before the onset of pathological anxiety (Sep et al., 2019).

Attending to this, it is our aim to investigate how the current COVID-19 pandemic, as a potential fear-provoking experience in the general population, affects the fear learning and fear generalization processes. To the best of our knowledge, such a relationship has not been investigated to date. To achieve this aim, we use a differential fear conditioning paradigm with a traumatic film clip as the unconditioned stimulus (US) and collect US-expectancy as the main measure of interest. Due to the pandemic and the constraints in place at the time of this study, including contact restrictions, we conducted the experiment online. We hypothesize that higher COVID-19-related anxiety (COVID-Anxiety) is associated with poorer fear learning and, thus, poorer discrimination performance between a safety and an aversive cue, as well as higher levels of generalization.

2. Materials and methods

2.1. Participants

We acquired our data from 297 healthy university students recruited via social media. The inclusion criteria were as follows: The individuals needed to be a current student at a German university, aged between 18 and 40 years, have no actual psychiatric disorder, have no epilepsy, and have never participated in such an experiment. To avoid fraud, participants had to provide a valid student e-mail address. Furthermore, the participant's code, generated at the end of the experiment, needed to be sent to the responsible researcher using that e-mail address.

Study procedures were approved by the local ethical review committee (Ethics Committee of the Faculty of Empirical Human Sciences and Economics at the Saarland University), follow the Declaration of Helsinki, and were registered in the German Clinical Trial Register (DRKS00022761). Complete information on the study was given at the beginning of the experiment, and they could only continue after they had confirmed that they met the inclusion criteria and once they had provided informed consent. We offered participants student credit (psychology students at Saarland University) or the opportunity to win a voucher (all participants) as an incentive for their participation.

From all acquired data, 38 participants did not complete the experiment and another 77 had to be excluded from the statistical analyses due to technical problems and lack of compliance (see supplementary Fig. S1). The final sample consisted of 220 participants (141 females) with a median age of 21 years (range 18–40). The study took place from August to December 2020, when COVID-19 preventive measures such as nocturnal lockdowns, the introduction of the mandatory use of masks in public, remote learning, and limitations on social contact (Bundesregierung, n.d.) were generally implemented across Germany.

2.2. Questionnaires

We assessed COVID-Anxiety using a modified version of the validated *DSM-5* Severity Measure For Specific Phobia Adult Scale (Beesdo-Baum et al., 2012; Craske et al., 2013) adapted for COVID-Anxiety (cf. Bendau et al., 2021; Petzold et al., 2020). The COVID-Anxiety questionnaire (COVID-Anx) consisted of 10 items assessing COVID-Anxiety symptoms, such as worries, fear, or panic. Participants were asked to indicate how often they had felt that way within the last seven days, and answers had to be given on a five-point scale ranging from *never* (0) to *constantly* (4). To screen for depression symptomatology, we applied the depression module of the Patient Health Questionnaire (PHQ-9, Spitzer, 1999), while we measured anxiety symptoms and fearfulness using the anxiety module of the PHQ (Generalized Anxiety Disorder, GAD-7, Spitzer et al., 2006) and the State–Trait Anxiety Inventory (Trait Version, STAI–T, Spielberger et al., 1983). Finally, perception of current stress was measured using the Perceived Stress Scale (PSS, Cohen et al., 1994).

2.3. Stimuli and apparatus

The conditioned stimuli (CS) consisted of two male face pictures from the Radboud Faces Database (Langner et al., 2010), matched per valence and arousal. Each picture was shown for 6s, followed by a black screen with an intertrial interval (ITI) of 4s. In a randomized manner, one of the faces was associated with an aversive US and served as the reinforced conditioned stimulus (CS+), while the other face served as the unreinforced conditioned stimulus (CS−). As a US, a 6s video clip with aversive content (explicit depiction of bodily harm) from the film *German Angst* (segment "Make a Wish", Kosakowski, 2015) was shown at the CS+ offset in the reinforced trials. The presentation order was pseudo-randomized with the restriction that no more than two consecutive presentations of the same stimulus type would occur. The generalized stimuli (GS) consisted of eight faces resulting from morphing the two CS along different gradients (i.e., 88.8% [GS1], 77.7% [GS2], 66.6% [GS3], 55.5% [GS4], 44.4% [GS5], 33.3% [GS6], 22.2% [GS7], or 11.1% [GS8] overlap with the CS+). We performed this morphing using WinMorph software (Kumar, 2000–2002, WinMorph 3.01, DebugMode: http://www.debugmode.com/winmorph/).

2.4. Subjective ratings

The US-expectancy ratings were collected during all trials in which CS and GS were presented. Two seconds after the onset of the stimuli, a visual analog scale (VAS), ranging from *very low* (0) to *very high* (100) expectancy, was shown below the stimulus for 4s, prompting participants to rate to what extent they expected the CS/GS to be followed by the aversive video. ("How much do you expect that the video will follow after this picture?") The VAS disappeared once a response was given.

Additionally, valence ratings for both CS ("How unpleasant is this picture for you?"; *not at all unpleasant* [0] to *very unpleasant* [100]) and current anxiety levels ("How anxious are you feeling right now?"; *not at all anxious* [0] to *anxious* [100]) were collected on the VAS at different points of the experiment, namely 1) before CS habituation, 2) before the acquisition phase, 3) before the generalization phase, and 4) after the generalization phase.

2.5. Procedure

The procedure of the study was modeled on similar studies of fear generalization in a laboratory context (e.g., Dunsmoor et al., 2011, 2009; Dymond et al., 2015; Haddad et al., 2013; Lissek et al., 2008). The study was conducted online using the professional web-based experiment provider LabVanced (https://www.labvanced.com/; Finger et al., 2017). After providing informed consent, participants were asked to provide their demographic data, following which they received the questionnaires. During the second phase, a differential fear conditioning procedure consisting of three phases (habituation, acquisition, and generalization) was conducted (see Fig. 1). At the start of the second phase, participants were asked to turn on the loudspeakers or use headphones so that they could hear the audio of the video that would be shown to them. They then had to test the volume and adjust it using a short test sound, which they could play repeatedly.

2.5.1. Fear acquisition

Participants were informed that faces would be presented during the experiment and that they would need to indicate to what extent they expected them to be followed by an aversive video (expectancy ratings). They were also informed that they would have only a few seconds to answer and should, therefore, answer as quickly as possible. A practice run consisting of three trials with a third neutral face serving as the CS− (no US) was completed to ensure that participants were familiar with the trial procedure and, in particular, the expectancy ratings. The practice run could be repeated if desired. A habituation phase then followed, consisting of three presentations each of the CS+ and CS−, all without the US. The instructions for acquisition indicated that one of two pictures would sometimes be followed by an aversive video. Acquisition consisted of eight CS− and eight CS+, with six of the CS+ followed by the US at the offset (75% reinforcement). A partial reinforcement rate during acquisition was used to prolong extinction and prevent ceiling effects (cf. Lonsdorf et al., 2017). For an example of the CS+ trial, see Fig. 2.

2.5.2. Fear generalization

The generalization phase started immediately after the pause for valence ratings that followed the acquisition phase, without specific instruction. During this phase, the CS+ and CS− were presented along with the eight GS. The CS+ and CS− were presented eight times each and the GS were presented four times for each of the eight GS. Half of the CS+ trials were reinforced using the US to prevent extinction learning and ensure that the focus remained on the effects of generalization (cf. Haddad et al., 2013).

2.5.3. Attention check

To ensure the quality of the data, two questions were presented at the end of the experiment. An unannounced beep was played several times, and participants were asked to indicate how often they heard the beep. This served to verify that participants watched the aversive videos with their volume on and that they were paying attention during the study. Finally, participants were asked whether they had completed the tasks conscientiously and how often they looked away during the video presentations.

2.6. Statistical analyses

All statistical analyses were conducted using IBM SPSS (version 26; IBM Corp, 2019), with the level of significance set to $\alpha = 0.05$. Sum scores were calculated to analyze the COVID-Anx. All other questionnaires were scored according to their guidelines. Non-parametric correlations (Spearman's Rho) were calculated between the COVID-Anx and the other questionnaires. For comparisons between groups, we divided participants per a median split (Median = 17) into low and high COVID-Anxiety groups. The low COVID-Anxiety group comprised 115 participants (63 women), while the high COVID-Anxiety group comprised 105 participants (78 women).

To assess US-expectancy discrimination between the CS+ and CS− during habituation and acquisition, difference scores were calculated (CS+-CS−; $Diff^{X}$, with X specifying the phase) (LaBar et al., 1995; Norrholm et al., 2006). Higher difference scores indicated better discrimination between the CS+ and CS−. The use of difference scores has advantages such as higher statistical power, the ability to account for between-subject differences in the overall response tendency, and the reflection of discrimination between stimuli, as well as what provides a better measure of learning-related effects. Additionally, it allows for better control of orientation and habituation reactions occurring at both the CS+ and the CS− (Lonsdorf et al., 2017). To test the effects of COVID-Anxiety on US-expectancy during fear acquisition, we conducted a mixed-design ANOVA with the Group (low vs. high COVID-Anxiety) as the between-group factor and the Phase (habituation vs. acquisition) as the within-participants factor.

Similarly to Lissek et al. (2008), for the analysis of US-expectancy during fear generalization, we divided the responses to the eight GS into four classes (GS_Class1–4) using the averaged response to every two GS (e.g., GS_Class1 = GS1 + GS2, see Fig. 3). The classes followed a similarity gradient, with GS_Class1 having the highest similarity to the CS+ and GS_Class4 having the highest similarity to the CS−. Averaging the stimuli into classes resulted in an equal number of trials for the CS+, CS−, and GS_Classes. To correct for answer tendencies, and to obtain a better comparison with fear acquisition, difference scores were calculated to assess discrimination between the CS+, the four classes of GS, and the CS−, respectively (CS+-CS−, GS_Class1-CS−, GS_Class2-CS−, GS_Class3-CS−, GS_Class4-CS−; $Diff^{X}$, with X specifying the CS type). Thus, five difference scores were calculated, with higher difference scores indicating better discrimination between the CS+/GS and the CS− and, therefore, less generalization. A mixed-design ANOVA was then conducted with Group (low vs. high COVID-Anxiety) as the between-group factor and CS Type ($Diff^{CS+/CS-}$ vs. $Diff^{GS\_Class1-CS-}$ vs. $Diff^{GS\_Class2-CS-}$ vs. $Diff^{GS\_Class3-CS-}$ vs. $Diff^{GS\_Class4-CS-}$) as the within-participants factor.[1]

For the analysis of subjective valence, the difference scores of valence ratings (CS+-CS−) were used as dependent variable. A mixed-design ANOVA, with Group (low vs. high COVID-Anxiety) as the between-group factor and Time (pre-habituation, pre-acquisition, post-acquisition, post-generalization) as the within-participants factor, was conducted.

CS-specific analyses (no difference scores) for US-expectancy and CS valence are reported in the supplementary data (S2) to allow for

[1] An additional regression analysis of COVID-Anxiety's effects on fear generalization, with a generalization index as the dependent variable and the COVID-Anx (non-dichotomized) as the predictor, is included in S4.

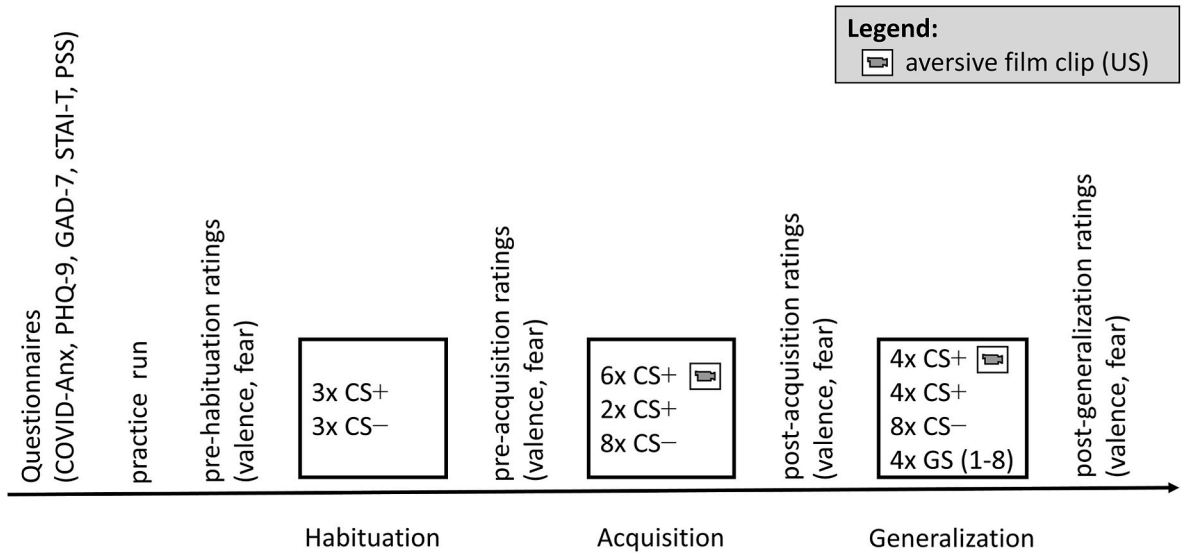

Fig. 1. Diagram of the Experimental Design. A differential fear conditioning paradigm with three different phases was used: Habituation, Acquisition and Generalization. Male faces with neutral expression were used as conditioned stimuli (CS) and a 6s aversive film clip as unconditioned stimulus (US). Each CS was presented three times during the habituation, and eight times during the acquisition and generalization. One of the CS was paired with the US in 75% of trials in acquisition and 50% of trials in the generalization (CS+). The other CS was never paired with the US (CS−). Eight morphs of CS+ and CS− on a gradient continuum were used as generalized stimuli (GS) and each was presented four times. US-expectancy ratings were measured during all CS and GS trials using a VAS appearing 2s after picture onset. Note: COVID-Anx = Questionnaire on the subjective perception of the COVID-19 epidemic (COVID-19-related anxiety [COVID-Anxiety]), PHQ-9 = Depression module of the Patient Health Questionnaire (depression), GAD-7 = Generalized Anxiety Disorder, the anxiety module of the PHQ (anxiety symptoms), PSS = Perceived Stress Scale (stress), STAI–T = The trait version of the State–Trait Anxiety Inventory (trait anxiety).

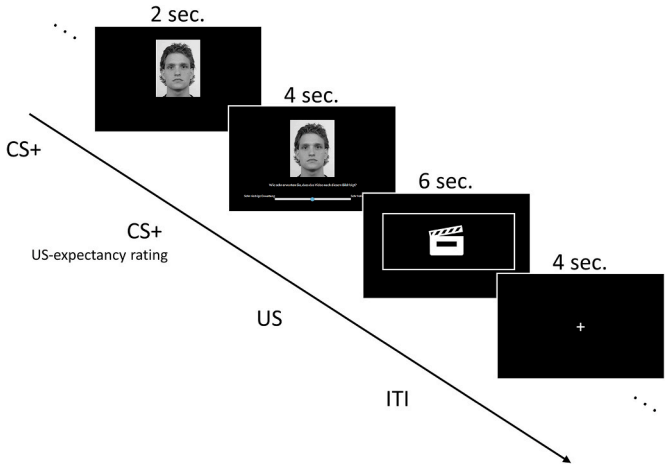

Fig. 2. Example of a Reinforced Conditioned Stimulus Trial. In every trial, CS/GS was presented for a total of 6s. A VAS for collection of US-expectancy appeared under the stimulus 2s after picture onset and remained till a response was done or otherwise, till picture offset. In the reinforced CS+ trials, the US (6s aversive film clip) appeared at picture offset. Between trials, a black screen with a fixation cross was presented during a 4s intertrial interval (ITI).

additional interpretations of threat/safety learning, as recommended by Lonsdorf et al. (2017). The results are concordant with those found for the difference scores.

For the analysis of current anxiety levels, we used the raw scores of the current anxiety ratings and mixed-design ANOVAs with the Group (low vs. high COVID-Anxiety) as the between-group factor and Time (pre-habituation, pre-acquisition, post-acquisition, post-generalization) as the within-participants factor.

Greenhouse–Geisser correction was applied whenever sphericity adjustment was required. (Adjusted *p*-values are reported with uncorrected degrees of freedom and epsilon values.) Where not specified, means and standard errors are reported.

A follow-up analysis of interaction effects with Bonferroni-adjusted pairwise comparisons was conducted. An explorative analyses of gender effects by adding gender (female, male) as an additional between-participants factor to the mixed ANOVAs was also conducted.

3. Results

3.1. Demographic variables

A chi-square test was used to compare gender distribution in the two COVID-Anxiety groups. None of the expected cell frequencies was less than 5. The results show a significantly different distribution of gender in the groups, $\chi^2\,(1) = 9.07$, $p = .003$, $\varphi = -0.20$, with fewer men in the high COVID-Anxiety group. There were no significant differences in age ($p > .050$).

3.2. Questionnaires

The descriptive statistics and correlations of the questionnaire measures are shown in Table 1. Correlations between COVID-Anx and the standardized questionnaires showed a significant relationship between COVID-Anxiety and depressive symptom severity ($r_s = .43$, $p < .001$ [PHQ-9]), anxiety severity ($r_s = 0.46$, $p < .001$ [GAD-7]), trait anxiety ($r_s = 0.39$, $p < .001$ [STAI–T]), and perceived stress ($r_s = 0.37$, $p < .001$ [PSS]), indicating the validity of the COVID-Anx questionnaire.

Concordantly, *t*-test comparisons between the two groups (low vs. high COVID-Anxiety) were significant for all questionnaires, indicating higher depressive symptom severity, anxiety severity, trait anxiety, and perceived stress in the high COVID-Anxiety group (see Table S1).

3.3. US-expectancy during habituation and fear acquisition

A main effect of Phase, $F_{1,\ 218} = 207.07$, $p < .001$, $\eta p^2 = 0.49$, and a significant interaction between Phase*Group, $F_{1,\ 218} = 7.20$, $p = .008$, $\eta p^2 = 0.03$ (Fig. 4) were found. There was no main effect of Group, $F_{1,\ 218} = 0.09$, $p = .760$, $\eta p^2 < 0.001$. As expected, US-expectancy difference

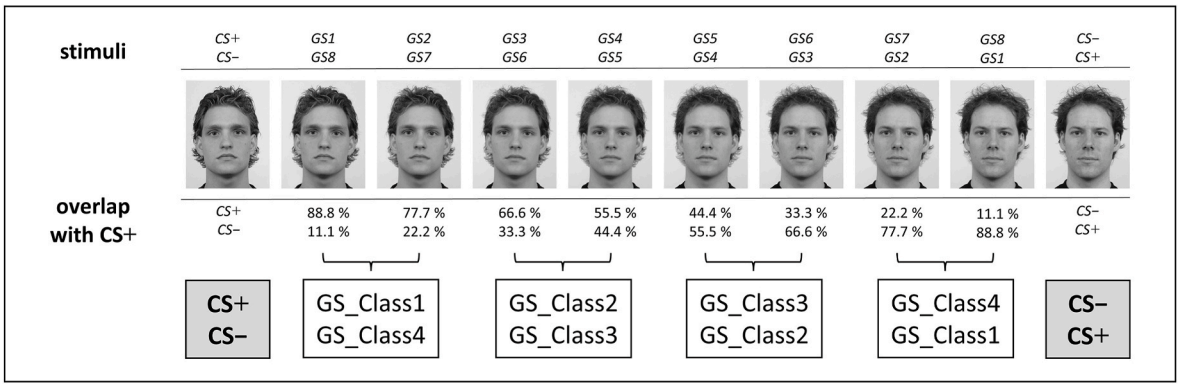

Fig. 3. Conditioned and Generalized Stimuli Used in the Paradigm. The CS were two neutral male faces taken from the Radboud Face Database (Langner et al., 2010). We randomly assigned both CS between participants to serve as the reinforced stimulus (CS+) or unreinforced stimulus (CS−). The GS consisted of the two faces morphed along a gradient from CS+ to CS− (from 88.8% to 11.1% similarity to the CS+). We divided the responses to the eight GS into four classes (GS_Class1–4), with GS_Class1 having the greatest similarity to CS+ and GS_Class4 the lowest (and, therefore, the highest similarity to the CS−).

Table 1
Correlations between the COVID-19 anxiety questionnaire and the standardized questionnaires.

Questionnaire	*M*	*SD*	COVID-Anx	PHQ-9	GAD-7	PSS
COVID-Anx (COVID-19 related anxiety)	17.20	5.78				
PHQ-9 (depression)	6.70	4.35	.43**			
GAD-7 (anxiety symptoms)	5.01	3.87	.46**	.70**		
PSS (stress)	26.73	6.15	.37**	.64**	.71**	
STAI-T (trait-anxiety)	39.55	9.74	.39**	.71**	.73**	.78**

Note: M = Mean, SD = Standard deviation, COVID-Anx = Questionnaire on the subjective perception of the COVID-19 epidemic (COVID-19-related anxiety), PHQ-9 = Depression module of the Patient Health Questionnaire (depression), GAD-7 = Generalized Anxiety Disorder, the anxiety module of the PHQ (anxiety symptoms), PSS = Perceived Stress Scale (stress), STAI–T = The trait version of the State–Trait Anxiety Inventory (trait anxiety). $^{**}p < .01$.

scores were significantly higher in the acquisition ($M_{Diff}^{Acq} = 33.80$, $SE = 1.89$) than in the habituation phase ($M_{Diff}^{Hab} = -0.80$, $SE = 1.68$), showing that CS+/CS− discrimination was generally high during acquisition but not during habituation. Pairwise comparisons showed that the Phase*Group effect was driven by a marginally significant difference between groups in fear acquisition, $F_{1,\ 218} = 3.68$, $p = .056$, $\eta p^2 = 0.01$. Furthermore, participants with high COVID-Anxiety showed lower difference scores during acquisition ($M_{Diff}^{Acq} = 30.17$, $SE = 2.74$) than participants with low COVID-Anxiety ($M_{Diff}^{Acq} = 37.44$, $SE = 2.62$), indicating worse discrimination between the CS+ and CS−. No significant differences between groups were found in the habituation phase, $F_{1,\ 218} = 2.84$, $p = .093$, $\eta p^2 = 0.01$. Explorative analysis with Gender as the additional factor did not reveal an interaction effect (Phase*Group*-Gender: $F_{1,\ 216} = 2.81$, $p = .095$).

3.4. US-expectancy during fear generalization

A main effect of CS Type, $F_{4,\ 872} = 378.94$, $p < .001$, $\varepsilon = 0.45$, $\eta p^2 = 0.64$, and a significant interaction between CS Type*Group, $F_{4,\ 872} = 4.27$, $p = .018$, $\varepsilon = 0.45$, $\eta p^2 = 0.02$ (Fig. 5) were found.

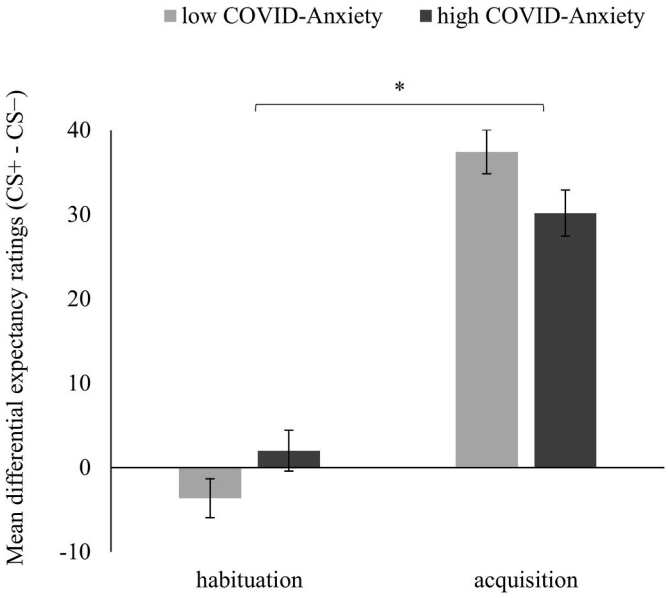

Fig. 4. The Effect of COVID-19-Related Anxiety on Habituation and Fear Acquisition. *Note*: Means and standard errors of US-expectancy difference scores. $^{*}p < .05$.

There was no main effect of Group, $F_{1,\ 218} = 3.55$, $p = .061$, $\eta p^2 = 0.02$. A decrease in differential expectancy is seen from the CS+ ($M_{Diff}^{CS+-CS-} = 52.59$, $SE = 2.38$) to GS_Class1 ($M_{Diff}^{GS\_Class1-CS-} = 47.98$, $SE = 2.29$), GS_Class2 ($M_{Diff}^{GS\_Class2-CS-} = 26.33$, $SE = 1.77$), GS_Class3 ($M_{Diff}^{GS\_Class3-CS-} = 9.62$, $SE = 1.18$), and GS_Class4 ($M_{Diff}^{GS\_Class4-CS-} = 1.13$, $SE = 0.68$), indicating the expected general generalization gradient ($ps < .001$). Pairwise comparisons showed that there were significant differences between groups for $Diff^{CS+\ -CS-}$ ($F_{1,\ 218} = 5.33$, $p = .022$, $\eta p^2 = 0.02$) and $Diff^{GS\_Class1-CS-}$ ($F_{1,\ 218} = 4.19$, $p = .042$, $\eta p^2 = 0.02$) but not for $Diff^{GS\_Class2-CS-}$ ($p = .112$), $Diff^{GS\_Class3-CS-}$ ($p = .928$), and $Diff^{GS\_Class4-CS-}$ ($p = .463$). Participants with high COVID-Anxiety showed lower difference scores for the CS+ ($M_{Diff}^{CS+-CS-} = 47.11$, $SE = 3.43$) and the most similar class of GS ($M_{Diff}^{GS\_Class1-CS-} =$

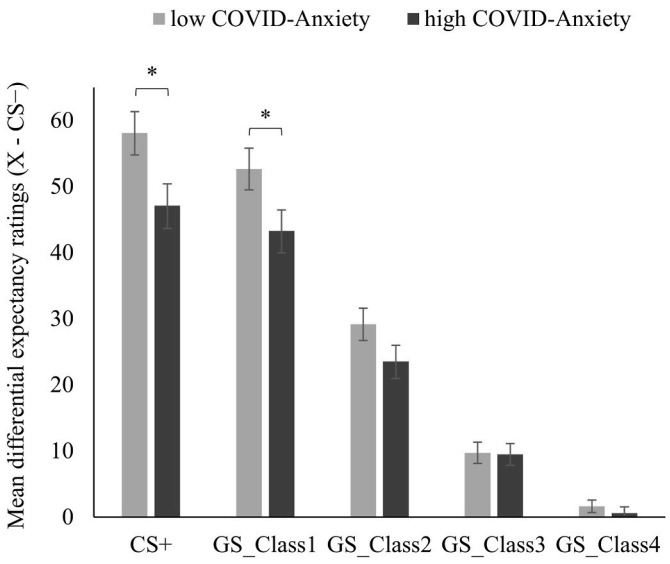

Fig. 5. The Effect of COVID-19-Related Anxiety on Fear Generalization. *Note*: Means and standard errors of US-expectancy difference scores. *$p < .05$.

43.30, $SE = 3.31$) than participants with low COVID-Anxiety ($M_{Diff}^{CS+-CS-} = 58.08$, $SE = 3.28$; $M_{Diff}^{GS\_Class1-CS-} = 52.66$, $SE = 3.16$), indicating worse discrimination between the CS+ and CS−, as well as between the highly similar GS and the CS−. Explorative analysis with Gender as the additional factor did not reveal any gender-related COVID-Anxiety effects on US-expectancy (CS Type*Group*Gender: $F_{4,\ 864} = 0.28$, $p = .727$, $\varepsilon = 0.44$).

3.5. Subjective ratings

3.5.1. CS-related valence ratings

The analysis of CS valence revealed a significant main effect of Time, $F_{3,\ 654} = 125.14$, $p < .001$, $\varepsilon = 0.65$, $\eta p^2 = 0.37$. An increase in differential valence is seen from pre-acquisition to post-acquisition and from post-acquisition to post-generalization (*ps* < .001), indicating an increase in the unpleasantness of the CS+ in relation to the CS− throughout the experiment (Fig. 6.). No other significant effects were found. Explorative analysis with Gender as the additional factor did not reveal an interaction effect (Time*Group*Gender: $F_{3,\ 648} = 0.30$, $p = .828$, $\varepsilon = 0.66$).

3.5.2. Current anxiety levels

The analysis of current anxiety levels revealed a significant main effect of Time, $F_{3,\ 654} = 9.97$, $p < .001$, $\varepsilon = 0.65$., $\eta p^2 = 0.04$, and a significant effect of Group, $F_{1,\ 218} = 19.97$, $p < .001$, $\eta p^2 = 0.08$ (Fig. 7). That is, current anxiety levels increased from pre- to post-acquisition ($p < .001$). A decrease in current anxiety levels from post-acquisition to post-generalization ($p < .001$) was observed. Participants with high COVID-Anxiety showed higher current anxiety levels than participants with low COVID-Anxiety throughout the experiment (*ps* < .011). Explorative analysis with Gender as the additional factor did not reveal an interaction effect (Time*Group*Gender: $F_{3,\ 648} = 0.55$, $p = .651$, $\varepsilon = 0.65$).

4. Discussion

This study aimed to investigate whether high anxiety associated with the COVID-19 pandemic negatively affects the fear learning and generalization processes. For this purpose, a differential fear conditioning paradigm was conducted, in which one stimulus was used as a conditioned fear cue and the other as a conditioned safety cue. We found evidence that COVID-Anxiety is associated with impaired fear learning and fear generalization, as well as increased current anxiety levels.

Notably, the study was conducted during a period of the COVID-19 pandemic in which, although some personal adjustments could already have been made, there were still high incidence numbers (Robert Koch Institut, n.d.) and stringent preventive measures (Bundesregierung, n.d.) that had a strong impact on daily life.

Fear acquisition was successful in the present study. That is, participants associated the CS+ with the aversive video and learned to discriminate it from the CS− according to its US-expectancy, which is

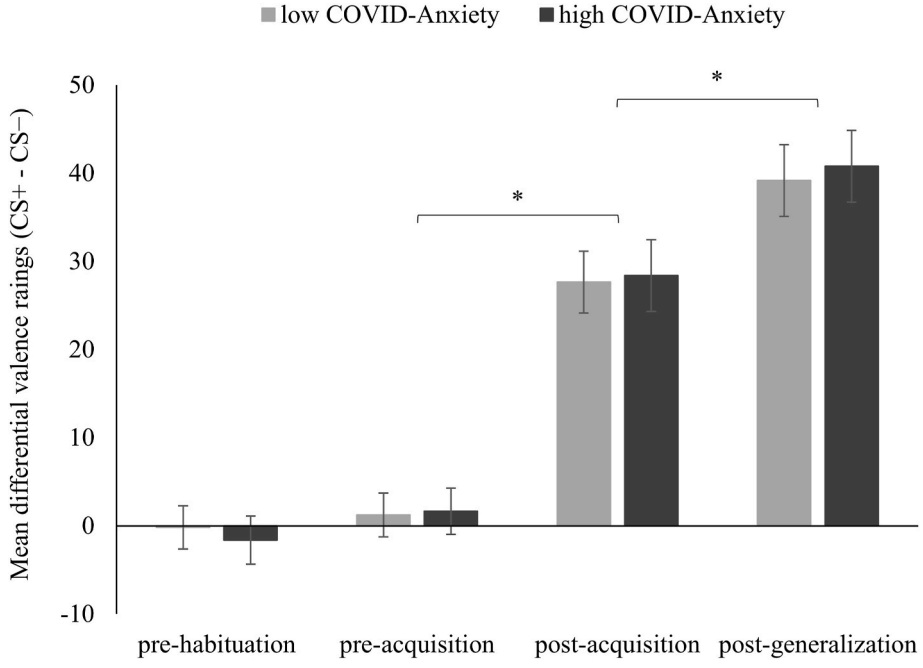

Fig. 6. The Effect of COVID-19-Related Anxiety on Valence Ratings. *Note*: Means and standard errors of valence difference scores. *$p < .05$.

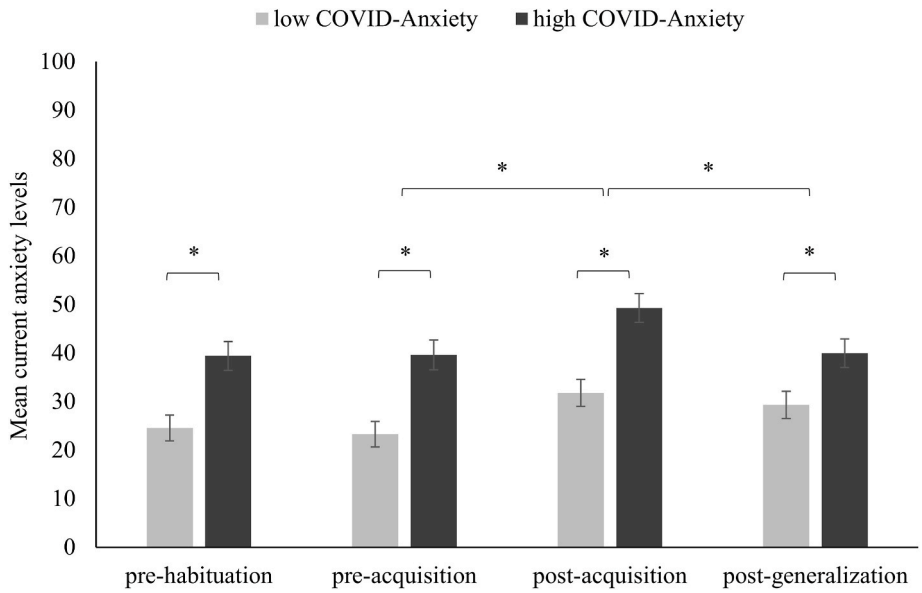

Fig. 7. The Effect of COVID-19-Related Anxiety on Current Anxiety Levels. *Note*: Means and standard errors of current anxiety ratings. *$p < .05$.

consistent with other studies of the same type (Constantinou et al., 2021; Lonsdorf et al., 2017; Mertens et al., 2021). Furthermore, a trend for differences between participants with low versus high COVID-Anxiety was evident during fear acquisition. Although both groups learned to discriminate between the stimuli from habituation to acquisition, participants with high COVID-Anxiety showed marginally significant poorer discrimination, thus indicating poorer performance in fear learning. Classical conditioning models represent a valuable tool to study the characteristic mechanisms of anxiety disorders (Blechert et al., 2007; Dibbets et al., 2015; Duits et al., 2015; Lissek et al., 2005, 2014; Mineka and Oehlberg, 2008) because they not only provide information on the development of anxiety disorders but also on the effects of anxiety on fear learning processes. High anxiety, persistent worry, or anxiety disorders can lead to impaired fear learning, as reflected in stronger fear responses to an aversive stimulus (CS+), the poorer learning of safety cues (CS−), and poorer performance in fear extinction (Blechert et al., 2007; Dibbets et al., 2015; Duits et al., 2015; Lissek et al., 2005, 2014). Impaired fear learning is, therefore, not only associated with anxiety disorders but also with its maintenance and resistance to therapy (Graham and Milad, 2011; Pittig et al., 2018). Our results indicate that participants who experience more anxiety and worry specific to the COVID-19 pandemic seem to show similar responses to those of highly anxious participants or patients with anxiety disorders in a fear conditioning paradigm, as they present with poorer fear discrimination (Duits et al., 2015).

US-expectancy difference scores during fear generalization followed a response pattern congruent with the morphing gradients. That is, the difference scores gradually decreased as the stimuli became less similar to the fear cue (CS+) and more similar to the safety cue (CS−). This general pattern of response from all participants is, therefore, in line with that of previous laboratory studies on human fear generalization that found a decrease in behavioral and psychophysiological measures—such as US-expectancy ratings, CS fear ratings, perceived risk ratings, or startle amplitude—along the similarity gradient from the CS+ to CS− (Dunning and Hajcak, 2015; Haddad et al., 2013; Lissek et al., 2008). Furthermore, participants in both groups showed decreases in US-expectancy ratings on the morph gradient from the CS+ to the CS−, suggesting that they could successfully discriminate between stimuli, regardless of COVID-Anxiety.

Fear generalization is an adaptative response that allows us to respond to novel stimuli that are similar to previously experienced threatening stimuli in an appropriate defensive manner (Dymond et al., 2015), so a degree of generalization is to be expected in all participants. Generalization can, however, turn into a maladaptive process, when new, non-threatening stimuli, i.e., with a lower resemblance to the CS+, are incorrectly perceived as harmful (Lissek et al., 2008). The impact of COVID-Anxiety on fear generalization was evident in the present study. That is, participants with high COVID-Anxiety showed significantly lower difference scores for the CS+ to CS− and GS_Class1 to CS− than participants with low COVID-Anxiety. Similar to what was observed during fear acquisition, the high COVID-Anxiety group presented with poorer discrimination between harmful and harmless stimuli (CS+ vs. CS−). Moreover, participants with high COVID-Anxiety also showed poorer discrimination between non-harmful generalization stimuli similar to the CS+ and non-harmful stimuli (GS_Class1 vs. CS−). Similarly, regression analysis with a generalization index also showed a significant effect of COVID-Anxiety (non-dichotomized) on generalization, with higher values of COVID-Anxiety significantly predicting higher generalization (S4). Overgeneralization is an important characteristic of many anxiety disorders and may not only lead to more suffering in patients but also to more difficulties in psychotherapeutic treatment (Craske et al., 2009; Dymond et al., 2015). Studies have suggested that fear can be elicited by stimuli that were never paired with the original US and that the fear of GS may be even greater than the fear of the CS (Dougher et al., 2007; Dymond et al., 2015). Additionally, the extinction of GS may be less effective and result in even greater levels of the return of fear than extinction with the CS itself (Vervliet et al., 2005). The latter, in particular, poses a major challenge for clinical practice, as exposure therapy can often only be applied to the available GS, and these first need to be identified.

Additional analysis of CS-specific US-expectancy (see S2) showed significant differences between groups during fear acquisition driven by a higher US-expectancy of the CS− in the high COVID-Anxiety group. Similarly, during the generalization phase, the high COVID-Anxiety group (vs. the low COVID-Anxiety group) also showed greater US-expectancy both of the CS− and of the GS most similar to the CS− (GS_Class3 and 4). These results suggest that the high COVID-Anxiety group seemed to have impairments in safety detection rather than in threat detection. A similar pattern can be seen in studies with patients with anxiety disorders and PTSD in which impaired safety learning has been commonly found (e.g., Duits et al., 2015; Jovanovic et al., 2009, 2005). That is, it has been suggested that impaired safety learning might be a biomarker for PTSD (Jovanovic et al., 2012). Further, difference scores for CS valence ratings increased from pre-habituation/acquisition

to post-acquisition and again to post-generalization, indicating a successful fear acquisition paradigm. We saw an increase in current anxiety levels from pre-to post-acquisition in both groups, indicating that the fear acquisition phase was mostly stressful enough and, therefore, successful. Additionally, a decrease in current anxiety levels from post-acquisition to post-generalization was found, probably due to the presence of more safety cues and a lower reinforcement rate of the CS+ (50%), allowing for a small fear extinction effect throughout generalization. Differences between the groups were also seen in current anxiety levels. That is, participants with high COVID-Anxiety showed higher anxiety ratings throughout the experiment, indicating higher psychological distress within this group.

Positive correlations between the COVID-Anx questionnaire and the standardized questionnaires testing for depression (PHQ-9), anxiety (GAD-7, STAI–T), and perceived stress (PSS) were found, showing that the items used were suitable to measure the pandemic's negative effects on psychological well-being. Additionally, significant differences between the groups in all of the used questionnaires (see Table S1) were also observed, with participants in the high COVID-Anxiety group achieving higher scores for depression, anxiety symptoms and trait, and perceived stress. These results further support studies on the impact of the current pandemic on mental health and its association with mental illnesses, such as depression or anxiety disorders (Deng et al., 2021; Sahebi et al., 2021; Salari et al., 2020; Santabárbara et al., 2021). However, notably, while the COVID-Anx questionnaire specifically addresses COVID-Anxiety, due to the cross-sectional design of the present study, we cannot rule out that the observed inter-individual differences only partially reflect differences in general anxiety. Due to a lack of longitudinal data, it remains unknown to what extent the groups differed in terms of other measures of anxiety, even before the onset of the COVID-19 pandemic.

Gender distribution was not comparable between the groups, as there were fewer men in the high COVID-Anxiety group, which is unsurprising because studies have suggested that the current pandemic affects men and women's mental health differently. That is, women appear to report more anxiety and worry and, therefore, experience greater psychological impairments (Broche-Pérez et al., 2020; Oreffice and Quintana-Domeque, 2021; Proto and Quintana-Domeque, 2021). Independent of the COVID-19 pandemic, women are also at a higher risk of developing anxiety disorders (McLean et al., 2011), a disparity that could be exacerbated by the burdens of the pandemic. Nevertheless, we did not find gender-related effects regarding fear acquisition and fear generalization. Yet, to gain a better overview of the role of gender in fear learning during COVID-19, further studies should explicitly explore gender differences.

Due to the limitations imposed by preventive COVID-19 measures, this study was conducted as an online experiment and not in a laboratory setting. Online experiments have many advantages, including easy and wide advertisement and recruitment, the 24h availability of the experiment, and greater convenience for participants. However, the disadvantages thereof include higher variability in environmental factors, such as ambient noise or technical equipment; higher susceptibility to fraud, for example, due to multiple participation or lower compliance (Anwyl-Irvine et al., 2020; Dandurand et al., 2008; Di Santo et al., 2020); and the impossibility of collecting additional physiological data. To mitigate some of these disadvantages, we employed several control measures that served as exclusion criteria and limited participation to persons with valid student e-mail addresses. Studies have shown, however, that there are differences in the psychological impact of the COVID-19 pandemic on different population and age groups (Breslau et al., 2021; Kazmi et al., 2020; Xiong et al., 2020). For example, elderly people have a higher likelihood of developing a more severe clinical course of COVID-19 (Ho et al., 2020; Rashedi et al., 2020), while societal limitations, such as those due to social isolation, can affect the elderly more significantly than younger people (Borade and Nagarkar, 2021; Di Santo et al., 2020). However, it has been found that since the pandemic started, young people have shown an increase in worries about their professional future, boredom, and frustration, as well as an increase in mental disorders (Aristovnik et al., 2020; Liang et al., 2020). Therefore, the COVID-19 pandemic is affecting all population groups, but the magnitude of and disparities in its impact have not yet been extensively studied and should be the focus of future research. Moreover, differences between subjective expectancy ratings and psychophysiological measures, such as the skin conductance response (SCR) or the startle reflex, have been reported in several fear conditioning studies (Blechert et al., 2008; Ferreira de Sá et al., 2020; Sevenster et al., 2014). These dissociations correspond to the idea of multiple memory systems being involved in fear learning (Phelps, 2004). For further studies, it would be beneficial to collect psychophysiological measures as well to obtain a broader understanding of the involved processes. However, it should also be mentioned that subjective measures, such as verbal reports or expectancy ratings, are one way to measure emotional processes reliably and directly and are the easiest to use in therapeutic settings (LeDoux and Hofmann, 2018). For example, US-expectancy ratings are widely used measures in fear conditioning research. They not only allow for inferences to be made about conscious knowledge of the CS–US contingency but are also aligned with the development of other conditioned reactions (Constantinou et al., 2021; Lonsdorf et al., 2017; Purkis and Lipp, 2001; Weidemann and Antees, 2012) and could be confirmed as a valid measure of fear responses (Boddez et al., 2013). Therefore, for a practice-oriented transfer of study results, subjective measures should always be recorded, despite their discrepancies with physiological measures. In addition, future studies should focus on COVID-Anxiety's effects on fear extinction. Additionally, to ensure that the experiment was not too long, which could compromise data quality and increase dropout rates, an extinction phase was not included in the present study. However, as mentioned above, the extinction of generalized CS–US associations poses a particular problem for the success of exposure therapies and should, therefore, also be investigated in the context of the COVID-19 pandemic.

Overall, the present results provide first evidence to show that anxiety associated with the COVID-19 pandemic might influence fear learning, and especially fear generalization, processes in a healthy sample of university students. As hypothesized, high COVID-Anxiety led to poorer discrimination performance between fear and safety cues, indicating impaired fear learning and generalization in comparison with lower COVID-Anxiety. This effect is characterized, in particular, by an impairment in safety learning, whereas the learning of threat cues did not seem to be impaired. Thus, factors that increase COVID-Anxiety may constitute a risk factor for anxiety development and other fear-related disorders, as well as contribute to greater treatment resistance. Further research should focus on other age groups and the identification of possible factors contributing to COVID-Anxiety. Prevention and impairment-reducing interventions, especially for those at a high risk (e.g., high subjective stress), should be an important public health focus in the context of the COVID-19 pandemic and similar extreme global events.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT author statement

Alexander Hauck: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data Curation, Writing – Original Draft, Writing – Review & Editing, Visualization. **Tanja Michael:** Resources, Writing – Original Draft, Supervision, Funding acquisition. **Diana S. Ferreira de Sá:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data Curation, Writing – Original Draft, Writing – Review & Editing, Supervision,

Project administration.

Declaration of competing interest

All authors declare no conflicts of interest.

Acknowledgments

We gratefully acknowledge the assistance of the students of the empirical seminar during data collection.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jpsychires.2022.07.068.

References

Ahrendt, D., Cabrita, J., Clerici, E., Hurley, J., Leončikas, T., Mascherini, M., Riso, S., Sándor, E., 2020. European Foundation for the Improvement of Living and Working Conditions. Living, working and COVID-19. Publications Office of the European Union. European Foundation for the Improvement of Living and Working Conditions, Luxembourg, p. 68. https://doi.org/10.2806/467608.

Anwyl-Irvine, A.L., Massonnié, J., Flitton, A., Kirkham, N., Evershed, J.K., 2020. Gorilla in our midst: an online behavioral experiment builder. Behav. Res. Methods 52 (1), 388–407. https://doi.org/10.3758/s13428-019-01237-x.

Aristovnik, A., Keržič, D., Ravšelj, D., Tomaževič, N., Umek, L., 2020. Impacts of the COVID-19 pandemic on life of higher education students: a global perspective. Sustainability 12 (20), 8438. https://doi.org/10.3390/su12208438.

Beesdo-Baum, K., Klotsche, J., Knappe, S., Craske, M.G., LeBeau, R.T., Hoyer, J., Strobel, A., Pieper, L., Wittchen, H.U., 2012. Psychometric properties of the dimensional anxiety scales for DSM-V in an unselected sample of German treatment seeking patients. Depress. Anxiety 29 (12), 1014–1024. https://doi.org/10.1002/da.21994.

Bendau, A., Petzold, M.B., Pyrkosch, L., Mascarell Maricic, L., Betzler, F., Rogoll, J., Große, J., Ströhle, A., Plag, J., 2021. Associations between COVID-19-related media consumption and symptoms of anxiety, depression and COVID-19-related fear in the general population in Germany. Eur. Arch. Psychiatr. Clin. Neurosci. 271 (2), 283–291. https://doi.org/10.1007/s00406-020-01171-6.

Blechert, J., Michael, T., Vriends, N., Margraf, J., Wilhelm, F.H., 2007. Fear conditioning in posttraumatic stress disorder: evidence for delayed extinction of autonomic, experiential, and behavioural responses. Behav. Res. Ther. 45 (9), 2019–2033. https://doi.org/10.1016/j.brat.2007.02.012.

Blechert, J., Michael, T., Williams, S.L., Purkis, H.M., Wilhelm, F.H., 2008. When two paradigms meet: does evaluative learning extinguish in differential fear conditioning? Learn. Motiv. 39 (1), 58–70. https://doi.org/10.1016/j.lmot.2007.03.003.

Boddez, Y., Baeyens, F., Luyten, L., Vansteenwegen, D., Hermans, D., Beckers, T., 2013. Rating data are underrated: validity of US-expectancy in human fear conditioning. J. Behav. Ther. Exp. Psychiatr. 44, 201–206. https://doi.org/10.1016/j.jbtep.2012.08.003.

Borade, N., Nagarkar, A., 2021. Daily life concerns of older adults during Covid–19 pandemic. Indian J. Gerontol. 35 (2), 151–161.

Breslau, J., Finucane, M.L., Locker, A.R., Baird, M.D., Roth, E.A., Collins, R.L., 2021. A longitudinal study of psychological distress in the United States before and during the COVID-19 pandemic. Prev. Med. 143, 106362 https://doi.org/10.1016/j.ypmed.2020.106362.

Britton, J.C., Lissek, S., Grillon, C., Norcross, M.A., Pine, D.S., 2011. Development of anxiety: the role of threat appraisal and fear learning. Depress. Anxiety 28 (1), 5–17. https://doi.org/10.1002/da.20733.

Broche-Pérez, Y., Fernández-Fleites, Z., Jiménez-Puig, E., Fernández-Castillo, E., Rodríguez-Martin, B.C., 2020. Gender and fear of COVID-19 in a Cuban population sample. Int. J. Ment. Health Addiction. https://doi.org/10.1007/s11469-020-00343-8.

Brooks, S.K., Webster, R.K., Smith, L.E., Woodland, L., Wessely, S., Greenberg, N., Rubin, G.J., 2020. The psychological impact of quarantine and how to reduce it: rapid review of the evidence. Lancet 395 (10227), 912–920. https://doi.org/10.1016/S0140-6736(20)30460-8.

Bundesregierung, n.d. Corona: Das haben Bund und Länder vereinbart | Bundesregierung. Webseite der Bundesregierung | Startseite. https://www.bundesregierung.de/breg-de/themen/coronavirus/corona-regeln-und-einschrankungen-1734724 (accessed 17 March 17).

Chakraborty, K., Chatterjee, M., 2020. Psychological impact of COVID-19 pandemic on general population in West Bengal: a cross-sectional study. Indian J. Psychiatr. 62 (3), 266. https://doi.org/10.4103/psychiatry.IndianJPsychiatry_276_20.

Cohen, S., Kamarck, T., Mrmelstein, R., 1994. Perceived stress scale. Measuring Stress: Guide Health Soc. Sci. 10 (2), 5.

Constantinou, E., Purves, K.L., McGregor, T., Lester, K.J., Barry, T.J., Treanor, M., Craske, M.G., Eley, T.C., 2021. Measuring fear: association among different measures of fear learning. J. Behav. Ther. Exp. Psychiatr. 70, 101618 https://doi.org/10.1016/j.jbtep.2020.101618.

Cooper, S.E., Grillon, C., Lissek, S., 2018. Impaired discriminative fear conditioning during later training trials differentiates generalized anxiety disorder, but not panic disorder, from healthy control participants. Compr. Psychiatr. 85, 84–93. https://doi.org/10.1016/j.comppsych.2018.07.001.

Craske, M.G., Rauch, S.L., Ursano, R., Prenoveau, J., Pine, D.S., Zinbarg, R.E., 2009. What is an anxiety disorder? Depress. Anxiety 26 (12), 1066–1085. https://doi.org/10.1002/da.20633.

Craske, M., Wittchen, U., Bogels, S., Stein, M., Andrews, G., Lebeu, R., 2013. Severity Measure for Specific Phobia—Adult. (Measurement Instrument). American Psychiatric Association.

Dandurand, F., Shultz, T.R., Onishi, K.H., 2008. Comparing online and lab methods in a problem-solving experiment. Behav. Res. Methods 40 (2), 428–434. https://doi.org/10.3758/BRM.40.2.428.

Deng, J., Zhou, F., Hou, W., Silver, Z., Wong, C.Y., Chang, O., Huang, E., Zuo, Q.K., 2021. The prevalence of depression, anxiety, and sleep disturbances in COVID-19 patients: a meta-analysis. Ann. N. Y. Acad. Sci. 1486 (1), 90–111. https://doi.org/10.1111/nyas.14506.

Di Santo, S.G., Franchini, F., Filiputti, B., Martone, A., Sannino, S., 2020. The effects of COVID-19 and quarantine measures on the lifestyles and mental health of people over 60 at increased risk of dementia. Front. Psychiatr. 11, 578628 https://doi.org/10.3389/fpsyt.2020.578628.

Dibbets, P., van den Broek, A., Evers, E.A.T., 2015. Fear conditioning and extinction in anxiety- and depression-prone persons. Memory 23 (3), 350–364. https://doi.org/10.1080/09658211.2014.886704.

Dougher, M.J., Hamilton, D.A., Fink, B.C., Harrington, J., 2007. Transformation of the discriminative and eliciting functions of generalized relational stimuli. J. Exp. Anal. Behav. 88 (2), 179–197. https://doi.org/10.1901/jeab.2007.45-05.

Duits, P., Cath, D.C., Lissek, S., Hox, J.J., Hamm, A.O., Engelhard, I.M., van den Hout, M. A., Baas, J.M.P., 2015. Updated meta-analysis of classical fear conditioning in the anxiety disorders: Review. Depress. Anxiety 32 (4), 239–253. https://doi.org/10.1002/da.22353.

Dunning, J.P., Hajcak, G., 2015. Gradients of fear potentiated startle during generalization, extinction, and extinction recall—and their relations with worry. Behav. Ther. 46 (5), 640–651. https://doi.org/10.1016/j.beth.2015.06.005.

Dunsmoor, J.E., Mitroff, S.R., LaBar, K.S., 2009. Generalization of conditioned fear along a dimension of increasing fear intensity. Learn. Mem. 16, 460–469. https://doi.org/10.1101/lm.1431609.

Dunsmoor, J.E., Prince, S.E., Murty, V.P., Kragel, P.A., LaBar, K.S., 2011. Neurobehavioral mechanisms of human fear generalization. Neuroimage 55, 1878–1888. https://doi.org/10.1016/j.neuroimage.2011.01.041.

Dymond, S., Dunsmoor, J.E., Vervliet, B., Roche, B., Hermans, D., 2015. Fear generalization in humans: systematic review and implications for anxiety disorder research. Behav. Ther. 46 (5), 561–582. https://doi.org/10.1016/j.beth.2014.10.001.

Ferreira de Sá, D.S., Römer, S., Brückner, A.H., Issler, T., Hauck, A., Michael, T., 2020. Effects of intranasal insulin as an enhancer of fear extinction: a randomized, double-blind, placebo-controlled experimental study. Neuropsychopharmacology 45 (5), 753–760. https://doi.org/10.1038/s41386-019-0593-3.

Finger, H., Goeke, C., Diekamp, D., Standvoß, K., König, P., 2017. LabVanced: a unified JavaScript framework for online studies. In: International Conference on Computational Social Science (Cologne). https://www.labvanced.com/.

Fountoulakis, K.N., Apostolidou, M.K., Atsiova, M.B., Filippidou, A.K., Florou, A.K., Gousiou, D.S., Katsara, A.R., Mantzari, S.N., Padouva-Markoulaki, M., Papatriantafyllou, E.I., Sacharidi, P.I., Tonia, A.I., Tsagalidou, E.G., Zymara, V.P., Prezerakos, P.E., Koupidis, S.A., Fountoulakis, N.K., Chrousos, G.P., 2021. Self-reported changes in anxiety, depression and suicidality during the COVID-19 lockdown in Greece. J. Affect. Disord. 279, 624–629. https://doi.org/10.1016/j.jad.2020.10.061.

Graham, B.M., Milad, M.R., 2011. The Study of fear extinction: implications for anxiety disorders. Am. J. Psychiatr. 168 (12), 1255–1265. https://doi.org/10.1176/appi.ajp.2011.11040557.

Haddad, A.D.M., Xu, M., Raeder, S., Lau, J.Y.F., 2013. Measuring the role of conditioning and stimulus generalisation in common fears and worries. Cognit. Emot. 27 (5), 914–922. https://doi.org/10.1080/02699931.2012.747428.

Hamm, A.O., Weike, A.I., 2005. The neuropsychology of fear learning and fear regulation. Int. J. Psychophysiol. 57 (1), 5–14. https://doi.org/10.1016/j.ijpsycho.2005.01.006.

Ho, F.K., Petermann-Rocha, F., Gray, S.R., Jani, B.D., Katikireddi, S.V., Niedzwiedz, C.L., Foster, H., Hastie, C.E., Mackay, D.F., Gill, J.M.R., O'Donnell, C., Welsh, P., Mair, F., Sattar, N., Celis-Morales, C.A., Pell, J.P., 2020. Is older age associated with COVID-19 mortality in the absence of other risk factors? General population cohort study of 470,034 participants. PLoS One 15 (11), e0241824. https://doi.org/10.1371/journal.pone.0241824.

IBM Corp, 2019. IBM SPSS Statistics for Windows, Version 26.0. IBM Corp, Armonk, NY.

Jovanovic, T., Kazama, A., Bachevalier, J., Davis, M., 2012. Impaired safety signal learning may be a biomarker of PTSD. Neuropharmacol. Post-Traumatic Stress Dis. 62, 695–704. https://doi.org/10.1016/j.neuropharm.2011.02.023.

Jovanovic, T., Keyes, M., Fiallos, A., Myers, K.M., Davis, M., Duncan, E.J., 2005. Fear potentiation and fear inhibition in a human fear-potentiated startle paradigm. Biol. Psychiatr. 57, 1559–1564. https://doi.org/10.1016/j.biopsych.2005.02.025.

Jovanovic, T., Norrholm, S.D., Fennell, J.E., Keyes, M., Fiallos, A.M., Myers, K.M., Davis, M., Duncan, E.J., 2009. Posttraumatic stress disorder may be associated with impaired fear inhibition: relation to symptom severity. Psychiatr. Res. 167, 151–160. https://doi.org/10.1016/j.psychres.2007.12.014.

Kazmi, S.S.H., Hasan, D.K., Talib, S., Saxena, S., 2020. COVID-19 and Lockdown: A Study on the Impact on Mental Health. Available at SSRN 3577515.

Klaiber, P., Wen, J.H., DeLongis, A., Sin, N.L., 2021. The ups and downs of daily life during COVID-19: age differences in affect, stress, and positive events. J. Gerontol.: Ser. Bibliogr. 76 (2), e30–e37. https://doi.org/10.1093/geronb/gbaa096.
Director Kosakowski, M., 2015. German Angst—Make a Wish [Film]. Kosakowski Films.
Kumar, S., 2002. WinMorph 3.01 (Version 3.01). DebugMode. http://www.debugmode.com/winmorph/.
LaBar, K., LeDoux, J., Spencer, D., Phelps, E., 1995. Impaired fear conditioning following unilateral temporal lobectomy in humans. J. Neurosci. 15 (10), 6846–6855. https://doi.org/10.1523/JNEUROSCI.15-10-06846.1995.
Lades, L.K., Laffan, K., Daly, M., Delaney, L., 2020. Daily emotional well-being during the COVID-19 pandemic. Br. J. Health Psychol. 25 (4), 902–911. https://doi.org/10.1111/bjhp.12450.
Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D.H.J., Hawk, S.T., van Knippenberg, A., 2010. Presentation and validation of the Radboud faces Database. Cognit. Emot. 24 (8), 1377–1388. https://doi.org/10.1080/02699930903485076.
LeDoux, J.E., Hofmann, S.G., 2018. The subjective experience of emotion: a fearful view. Current Opinion in Behavioral Sciences 19, 67–72. https://doi.org/10.1016/j.cobeha.2017.09.011.
Liang, L., Ren, H., Cao, R., Hu, Y., Qin, Z., Li, C., Mei, S., 2020. The effect of COVID-19 on youth mental health. Psychiatr. Q. 91 (3), 841–852. https://doi.org/10.1007/s11126-020-09744-3.
Liao, Q., Cowling, B.J., Lam, W.W., Ng, D.M., Fielding, R., 2014. Anxiety, worry and cognitive risk estimate in relation to protective behaviors during the 2009 influenza A/H1N1 pandemic in Hong Kong: ten cross-sectional surveys. BMC Infect. Dis. 14 (1), 169. https://doi.org/10.1186/1471-2334-14-169.
Lissek, S., Biggs, A.L., Rabin, S.J., Cornwell, B.R., Alvarez, R.P., Pine, D.S., Grillon, C., 2008. Generalization of conditioned fear-potentiated startle in humans: experimental validation and clinical relevance. Behav. Res. Ther. 46 (5), 678–687. https://doi.org/10.1016/j.brat.2008.02.005.
Lissek, S., Kaczkurkin, A.N., Rabin, S., Geraci, M., Pine, D.S., Grillon, C., 2014. Generalized anxiety disorder is associated with overgeneralization of classically conditioned fear. Biol. Psychiatr. 75 (11), 909–915. https://doi.org/10.1016/j.biopsych.2013.07.025.
Lissek, S., Powers, A.S., McClure, E.B., Phelps, E.A., Woldehawariat, G., Grillon, C., Pine, D.S., 2005. Classical fear conditioning in the anxiety disorders: a meta-analysis. Behav. Res. Ther. 43 (11), 1391–1424. https://doi.org/10.1016/j.brat.2004.10.007.
Lonsdorf, T.B., Menz, M.M., Andreatta, M., Fullana, M.A., Golkar, A., Haaker, J., Heitland, I., Hermann, A., Kuhn, M., Kruse, O., Meir Drexler, S., Meulders, A., Nees, F., Pittig, A., Richter, J., Römer, S., Shiban, Y., Schmitz, A., Straube, B., et al., 2017. Don't fear 'fear conditioning': methodological considerations for the design and analysis of studies on human fear acquisition, extinction, and return of fear. Neurosci. Biobehav. Rev. 77, 247–285. https://doi.org/10.1016/j.neubiorev.2017.02.026.
Main, A., Zhou, Q., Ma, Y., Luecken, L.J., Liu, X., 2011. Relations of SARS-related stressors and coping to Chinese college students' psychological adjustment during the 2003 Beijing SARS epidemic. J. Counsel. Psychol. 58 (3), 410–423. https://doi.org/10.1037/a0023632.
Mak, I.W.C., Chu, C.M., Pan, P.C., Yiu, M.G.C., Ho, S.C., Chan, V.L., 2010. Risk factors for chronic post-traumatic stress disorder (PTSD) in SARS survivors. Gen. Hosp. Psychiatr. 32 (6), 590–598. https://doi.org/10.1016/j.genhosppsych.2010.07.007.
Maunder, R., Hunter, J., Vincent, L., Bennett, J., Peladeau, N., Leszcz, M., Sadavoy, J., Verhaeghe, L.M., Steinberg, R., Mazzulli, T., 2003. The Immediate Psychological and Occupational Impact of the 2003 SARS Outbreak in a Teaching Hospital, 168/10, p. 7.
McLean, C.P., Asnaani, A., Litz, B.T., Hofmann, S.G., 2011. Gender differences in anxiety disorders: prevalence, course of illness, comorbidity and burden of illness. J. Psychiatr. Res. 45 (8), 1027–1035. https://doi.org/10.1016/j.jpsychires.2011.03.006.
Mertens, G., Boddez, Y., Krypotos, A.M., Engelhard, I.M., 2021. Human fear conditioning is moderated by stimulus contingency instructions. Biol. Psychol. 158, 107994 https://doi.org/10.1016/j.biopsycho.2020.107994.
Mineka, S., Oehlberg, K., 2008. The relevance of recent developments in classical conditioning to understanding the etiology and maintenance of anxiety disorders. Acta Psychol. 127 (3), 567–580. https://doi.org/10.1016/j.actpsy.2007.11.007.
Morey, R.A., Dunsmoor, J.E., Haswell, C.C., Brown, V.M., Vora, A., Weiner, J., Stjepanovic, D., Wagner, H.R., , VA Mid-Atlantic MIRECC Workgroup, LaBar, K.S., 2015. Fear learning circuitry is biased toward generalization of fear associations in posttraumatic stress disorder. Transl. Psychiatry 5 (12). https://doi.org/10.1038/tp.2015.196 e700–e700.
Norrholm, S.D., Jovanovic, T., Vervliet, B., Myers, K.M., Davis, M., Rothbaum, B.O., Duncan, E.J., 2006. Conditioned fear extinction and reinstatement in a human fear-potentiated startle paradigm. Learn. Mem. 13 (6), 681–685. https://doi.org/10.1101/lm.393906.
Oreffice, S., Quintana-Domeque, C., 2021. Gender inequality in COVID-19 times: evidence from UK prolific participants. J. Demograph. Econ. 87 (2), 261–287. https://doi.org/10.1017/dem.2021.2.
Petzold, M.B., Bendau, A., Plag, J., Pyrkosch, L., Maricic, L.M., Rogoll, J., Betzler, F., Große, J., Ströhle, A., 2020. Development of the COVID-19-Anxiety Questionnaire and first psychometric testing. BJPsych Open 6 (5), e91. https://doi.org/10.1192/bjo.2020.82.
Pfefferbaum, B., Schonfeld, D., Flynn, B.W., Norwood, A.E., Dodgen, D., Kaul, R.E., Donato, D., Stone, B., Brown, L.M., Reissman, D.B., Jacobs, G.A., Hobfoll, S.E., Jones, R.T., Herrmann, J., Ursano, R.J., Ruzek, J.I., 2012. The H1N1 crisis: a case study of the integration of mental and behavioral health in public health crises. Disaster Med. Public Health Prep. 6 (1), 67–71. https://doi.org/10.1001/dmp.2012.2.
Phelps, E.A., 2004. Human emotion and memory: interactions of the amygdala and hippocampal complex. Curr. Opin. Neurobiol. 14 (2), 198–202. https://doi.org/10.1016/j.conb.2004.03.015.
Pittig, A., Treanor, M., LeBeau, R., Craske, M., 2018. The role of associative fear and avoidance learning in anxiety disorders: gaps and directions for future research. Neurosci. Biobehav. Rev. 88 https://doi.org/10.1016/j.neubiorev.2018.03.015.
Proto, E., Quintana-Domeque, C., 2021. COVID-19 and mental health deterioration by ethnicity and gender in the UK. PLoS One 16 (1), e0244419. https://doi.org/10.1371/journal.pone.0244419.
Purkis, H.M., Lipp, O.V., 2001. Does affective learning exist in the absence of contingency awareness? Learn. Motiv. 32, 84–99. https://doi.org/10.1006/lmot.2000.1066.
Rashedi, J., Mahdavi Poor, B., Asgharzadeh, V., Pourostadi, M., Samadi Kafil, H., Vegari, A., Tayebi-Khosroshahi, H., Asgharzadeh, M., 2020. Risk factors for COVID-19. Inf. Med. 28 (4), 469–474.
Robert Koch Institut, n.d. *Robert Koch Institut:* COVID-19—Dashboard. https://experience.arcgis.com/experience/478220a4c454480e823b17327b2bf1d4 (accessed 17 March 2022).
Sahebi, A., Nejati-Zarnaqi, B., Moayedi, S., Yousefi, K., Torres, M., Golitaleb, M., 2021. The prevalence of anxiety and depression among healthcare workers during the COVID-19 pandemic: an umbrella review of meta-analyses. Prog. Neuro Psychopharmacol. Biol. Psychiatr. 107, 110247 https://doi.org/10.1016/j.pnpbp.2021.110247.
Salari, N., Hosseinian-Far, A., Jalali, R., Vaisi-Raygani, A., Rasoulpoor, S., Mohammadi, M., Rasoulpoor, S., Khaledi-Paveh, B., 2020. Prevalence of stress, anxiety, depression among the general population during the COVID-19 pandemic: a systematic review and meta-analysis. Glob. Health 16 (1), 57. https://doi.org/10.1186/s12992-020-00589-w.
Santabárbara, J., Lasheras, I., Lipnicki, D.M., Bueno-Notivol, J., Pérez-Moreno, M., López-Antón, R., De la Cámara, C., Lobo, A., Gracia-García, P., 2021. Prevalence of anxiety in the COVID-19 pandemic: an updated meta-analysis of community-based studies. Prog. Neuro Psychopharmacol. Biol. Psychiatr. 109, 110207 https://doi.org/10.1016/j.pnpbp.2020.110207.
Santomauro, D.F., Mantilla Herrera, A.M., Shadid, J., Zheng, P., Ashbaugh, C., Pigott, D.M., Abbafati, C., Adolph, C., Amlag, J.O., Aravkin, A.Y., Bang-Jensen, B.L., Bertolacci, G.J., Bloom, S.S., Castellano, R., Castro, E., Chakrabarti, S., Chattopadhyay, J., Cogen, R.M., Collins, J.K., et al., 2021. Global prevalence and burden of depressive and anxiety disorders in 204 countries and territories in 2020 due to the COVID-19 pandemic. Lancet 398 (10312), 1700–1712. https://doi.org/10.1016/S0140-6736(21)02143-7.
Sep, M.S.C., Steenmeijer, A., Kennis, M., 2019. The relation between anxious personality traits and fear generalization in healthy subjects: a systematic review and meta-analysis. Neurosci. Biobehav. Rev. 107, 320–328. https://doi.org/10.1016/j.neubiorev.2019.09.029.
Sevenster, D., Beckers, T., Kindt, M., 2014. Fear conditioning of SCR but not the startle reflex requires conscious discrimination of threat and safety. Front. Behav. Neurosci. 8 https://doi.org/10.3389/fnbeh.2014.00032.
Shultz, J.M., Baingana, F., Neria, Y., 2015. The 2014 Ebola outbreak and mental health: current status and recommended response. JAMA 313 (6), 567. https://doi.org/10.1001/jama.2014.17934.
Spielberger, C.D., Gorusch, R.L., Lushene, R., Vagg, P.R., Jacobs, G.A., 1983. Manual for the State–Trait Anxiety Inventory. C.A., Palo Alto.
Spitzer, R.L., 1999. Validation and utility of a self-report version of PRIME-MD: the PHQ primary care study. JAMA 282 (18), 1737. https://doi.org/10.1001/jama.282.18.1737.
Spitzer, R.L., Kroenke, K., Williams, J.B.W., Löwe, B., 2006. A brief measure for assessing generalized anxiety disorder: the GAD-7. Arch. Intern. Med. 166 (10), 1092. https://doi.org/10.1001/archinte.166.10.1092.
Šrol, J., Ballová Mikušková, E., Čavojová, V., 2021. When we are worried, what are we thinking? Anxiety, lack of control, and conspiracy beliefs amidst the COVID-19 pandemic. Appl. Cognit. Psychol. 35 (3), 720–729. https://doi.org/10.1002/acp.3798.
Vervliet, B., Vansteenwegen, D., Baeyens, F., Hermans, D., Eelen, P., 2005. Return of fear in a human differential conditioning paradigm caused by a stimulus change after extinction. Behav. Res. Ther. 43 (3), 357–371. https://doi.org/10.1016/j.brat.2004.02.005.
Weidemann, G., Antees, C., 2012. Parallel acquisition of awareness and differential delay eyeblink conditioning. Learn. Mem. 19, 201–210. https://doi.org/10.1101/lm.024851.111.
Wegmann, E., Brandtner, A., Brand, M., 2021. Perceived strain due to COVID-19-related restrictions mediates the effect of social needs and fear of missing out on the risk of a problematic use of social networks. Front. Psychiatr. 12, 623099 https://doi.org/10.3389/fpsyt.2021.623099.
World Health Organization, n.d. WHO Coronavirus (COVID-19) Dashboard. https://covid19.who.int (accessed 17 March 2022).
Xiong, J., Lipsitz, O., Nasri, F., Lui, L.M.W., Gill, H., Phan, L., Chen-Li, D., Iacobucci, M., Ho, R., Majeed, A., McIntyre, R.S., 2020. Impact of COVID-19 pandemic on mental health in the general population: a systematic review. J. Affect. Disord. 277, 55–64. https://doi.org/10.1016/j.jad.2020.08.001.