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Just let me check: The role of individual differences in self-reported anxiety and obsessive-compulsive features on subjective, behavioural, and physiological indices during a checking task

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A B S T R A C T

Checking behaviour has been described as a form of preventative behaviour used by an individual to establish control over the environment and avoid future misfortune. However, when compulsive, checking behaviours can become disabling and distressing and have been linked to the maintenance of anxiety and obsessive-compulsive disorders. Despite this, there is limited literature across the field that has assessed the impact of dimensional measures of anxiety and obsessive-compulsive features (i.e., negative affect, uncertainty, and perfectionism) in driving checking behaviour. As such, the present study examined the impact of individual differences in self-reported anxiety and obsessive-compulsive features on subjective, behavioural, and physiological indices during a visual discrimination and checking task ($n = 87$). Higher self-reported anxiety and obsessive-compulsive features were associated with higher subjective ratings of unpleasantness and the urge to check during the task. Moreover, higher self-reported anxiety and obsessive-compulsive features related to general negative affect, uncertainty, and perfectionism were associated with greater checking frequency during the task. Lastly, stronger obsessional beliefs about perfectionism and the need for certainty were found to predict poorer accuracy, slower reaction times, and higher engagement of the corrugator supercilii during the task. In sum, these findings demonstrate how different anxiety and obsessive-compulsive features, in particular perfectionism and the need for certainty, may relate to and maintain checking behaviour in low threat contexts, which likely has implications for models of excessive and persistent checking in anxiety and obsessive-compulsive disorders.

1. Introduction

Obsessive-compulsive disorder (OCD) and anxiety disorders are categorised in separate chapters of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5, American Psychiatric Association, 2013). However, high comorbidity rates and symptom overlap may suggest shared underlying processes (Peris et al., 2017). For instance, both anxiety and OCD are characterised by safety behaviours including checking and reassurance seeking (American Psychiatric Association [APA], 2013). Checking behaviour has been described as a form of preventative behaviour used by an individual to establish control over the environment and avoid future misfortune (Rachman, 2002). However, when compulsive, checking behaviours can become disabling and distressing (Rachman, 2002). Checking is the most prevalent compulsion among individuals diagnosed with OCD, affecting as many as 80 % of patients during their lifetime (Ruscio et al., 2010). Further, cognitive-behavioural approaches to the conceptualisation and treatment of anxiety disorders have long hypothesised that reassurance seeking is a key factor in the maintenance of anxiety (Rector et al., 2011; Salkovskis and Warwick, 1986). Recent work has stated that broader reassurance seeking behaviours, for example, reassurance seeking in relation to one's partner to affirm love (Doron et al., 2012), or excessive information seeking prior to decision making (Foa et al., 2003), may also qualify as compulsive checking (Strauss et al., 2020). Such evidence supports the suggestion that OCD and anxiety disorders may share common underlying processes (Raines et al., 2014).

Rachman's (2002) cognitive theory of checking claims that compulsive checking typically occurs under high-responsibility conditions. Rachman's (2002) theory is supported by work that demonstrates that responsibility beliefs are positively associated with frequency of

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compulsive checking (e.g. Lind & Boschen, 2009). Further, under conditions of high perceived responsibility, individuals with OCD have been found to exhibit increased discomfort and urge to check (Lopatka & Rachman, 1995). Alternatively, however, it has been argued that it is in fact uncertainty that drives checking behaviour (Rotge et al., 2008; Rotge et al., 2015; Toffolo et al., 2016; Tolin et al., 2003), with even mild levels of uncertainty resulting in increased checking behaviour (Toffolo et al., 2016). According to this perspective, individuals with an increased propensity to find uncertainty aversive experience greater distress in uncertain situations, resulting in the performance of behaviours (i.e., checking) aimed at regaining certainty (Bottesi et al., 2017; Coles and Ravid, 2016).

Across the literature, several features of anxiety and OCD have been examined in relation to checking, including intolerance of uncertainty, perfectionism, and not just right experiences. Intolerance of uncertainty has been defined as "an individual's dispositional incapacity to endure the aversive response triggered by the perceived absence of salient, key, or sufficient information, and is sustained by the associated perception of uncertainty" (Carleton, 2016a, p.31). Intolerance of uncertainty is recognised as a transdiagnostic factor across anxiety, obsessive-compulsive, stress, and mood disorders (Carleton, 2016a, 2016b; Dugas et al., 2004; Holaway et al., 2006; McEvoy and Mahoney, 2012) and has been associated with checking compulsions across the literature (Bottesi et al., 2017; Calleo et al., 2010; Khawaja and McMahon, 2011; Sarawgi et al., 2013). A second transdiagnostic construct that has been associated with compulsive checking behaviour is perfectionism (Bouchard et al., 1999; Julien et al., 2006). For instance, Julien et al. (2006) found that self-reported perfectionism predicted checking behaviour and task precision. Further, researchers have highlighted that not just right experiences may also contribute to the repetitive nature of compulsive behaviour and have suggested that an individual might repeat checking behaviour until a sense of "rightness" is achieved (Coles et al., 2003).

While previous work has demonstrated evidence for strong tendencies of checking behaviour in anxiety and OCD, this research has primarily used a categorical approach (i.e., diagnostic boundaries) rather than a dimensional approach (i.e., assessing features of anxiety and OCD) (for a review see Strauss et al., 2020). As such, it is unclear how different anxiety and obsessive-compulsive features (i.e., intolerance of uncertainty, perfectionism, not just right experiences) relate to actual checking behaviour as measured in an experimental task (Jacoby et al., 2014, 2016, 2019; Sarawgi et al., 2013). Further, there is a sparsity of work across the literature that has examined anxiety and OCD-related phenomena in relation to physiological measures (Lazarov et al., 2014; Toffolo et al., 2013; Van Bennekom et al., 2021). There are several advantages of examining anxiety and OCD-related phenomena in relation to physiology. Firstly, it may provide additional information in terms of capturing anxiety and OCD-related behaviours. For instance, Toffolo et al. (2013) captured checking behaviour via eye movements. Secondly, it may reveal how anxiety and OCD-related phenomena operate and maintain core beliefs or heightened distress/relief. For example, Lazarov et al. (2014) used electromyography in the forearm to show that individuals with OCD rely less on internal states (i.e., recognising an actual muscle contractions' strength) and more on external feedback (i.e. receiving information about an actual muscle contractions' strength). Currently, there is a lack of research on whether anxiety and OCD-related core beliefs and checking behaviours maintain physiological distress/relief. Notably, as far as we are aware no research to date has addressed this question by measuring the corrugator supercilii muscle ('frowning' muscle on the face), a reliable index of physiological distress/relief (Larsen et al., 2003; Morriss, 2019; Morriss, Biagi, et al., 2021). Identifying transdiagnostic features of anxiety and OCD that maintain checking behaviours and associated distress/relief will be important for accurate targeting of transdiagnostic features in anxiety and OCD (e.g., core beliefs) that are relevant for evidence-based treatments such as exposure response prevention therapy (Barlow et al., 2017; Gillan et al., 2017; Norton and Philipp, 2008). For instance, if uncertainty is an important transdiagnostic factor that maintains cycles of compulsive checking and physiological distress/relief, then further efforts should be made to shape current evident-based therapies to target core beliefs about uncertainty.

Hence, the primary aim of the current study was to examine the impact of individual differences in self-reported anxiety and obsessive-compulsive features on subjective, behavioural, and physiological indices during a visual discrimination and checking task. We modified the experimental paradigm of a previous visual discrimination and checking task (Rotge et al., 2008), by including checking available and unavailable trials, in order increase task distress and examine the effect of checking availability on subjective and physiological indices (similar to the avoidance literature, for review see Pittig et al., 2018). During each trial of the task, participants were presented with one of three shape stimuli. The shape then disappeared, and a second shape was presented. The second shape was either identical to the first shape presented ("identical stimuli" trials) or consisted of one of four slightly rotated variations of the first shape ("different stimuli" trials). Following the presentation of the second shape, a "check cue" was presented to inform participants of whether, or not, the option to check if the first and second shape were identical or different was available. After an interval, if the option to check was not available, participants were directed to the "choice phase" where they were asked to decide whether the shapes presented during the trial were identical or different. If the option to check was available, participants were able to repeat the trial before making a choice. When available, the option to check was not limited.

Throughout the task, we recorded subjective ratings of feelings of unpleasantness and the urge to check when checking was not available, as well as checking frequency, answer accuracy, choosing to check reaction time, answer reaction time during the choice phase, and corrugator supercilii activity. We hypothesised that due to increased task difficulty for the "different stimuli" trials compared to "identical stimuli" trials, all participants, regardless of their level of self-reported anxiety and obsessive-compulsive features, would exhibit greater checking behaviour in different stimuli trials when the option to check was available. We also predicted that all participants would demonstrate reduced accuracy, but increased reaction time, when making their responses during the different stimuli trials, compared to identical stimuli trials. Given the findings of previous work that have highlighted that corrugator supercilii activity is sensitive to the valence and effort of presented stimuli (Cacioppo et al., 1985; Cacioppo et al., 1986; Larsen et al., 2003), we further hypothesised that, during the checking cue period of the trial, corrugator supercilii activity would be greater when the option to check was unavailable, compared to when the option to check was available.

Crucially, due to the findings from the previous literature that have indicated the relationship between features of anxiety and OCD (i.e. intolerance of uncertainty, perfectionism, and not just right experiences) and self-reported compulsive checking, we expected to observe significant relationships between self-reported individual differences in anxiety and obsessive-compulsive features and subjective, behavioural, and physiological dependent variables (Jacoby et al., 2014, 2016, 2019; Sarawgi et al., 2013; Toffolo et al., 2013). We predicted that higher scores of self-reported anxiety and obsessive-compulsive features would be related to higher ratings of the feelings of unpleasantness when the option to check was not available, higher ratings of the urge to check, greater checking frequency, and slower reaction times when choosing to check (Rotge et al., 2008). However, due to the limited literature in the field that has examined the impact of individual differences in self-reported anxiety and obsessive-compulsive features on behavioural and physiological measures, we did not generate a priori hypotheses related to the direction of the relationships between self-reported anxiety and obsessive-compulsive features and behavioural (i.e., task accuracy and reaction time during the choice phase) and physiological (i.e., corrugator supercilii activity) dependent variables. Further, due to the push by recent work to disentangle the role of transdiagnostic (e.g., intolerance of uncertainty) and disorder-specific dimensions related to processes underlying psychopathology (Shihata et al., 2016), we examined whether there was specificity for self-reported anxiety and obsessive-compulsive features (i.e. intolerance of uncertainty, perfectionism, and not just right experiences) in relation to subjective, behavioural, and psychological dependent variables. However, again, due to the limited literature in the field, these analyses were exploratory, and we did not generate any a priori hypotheses in relation to the specificity of any particular self-reported anxiety and obsessive-compulsive feature in predicting subjective, behavioural, and physiological responses.

2. Methods

2.1. Participants

Eighty-seven student volunteers (age: M = 20.39 years, SD = 4.13 years, range, 18–48; Sex: 76 females, 10 males, 1 unspecified) were recruited from the University of Reading to take part in this study. Participants were recruited through the University of Reading SONA panel and received course credit to remunerate them for their time. No formal power calculation was conducted. The sample size is comparable to other studies examining individual differences, behaviour, and physiological responses (Morriss et al., 2020; Toffolo et al., 2016; Wake et al., 2021).

The procedure was approved by the University of Reading Research Ethics Committee. The research adhered to relevant ethical guidelines and regulations and all participants provided informed consent.

2.2. Procedure

Upon arrival at the laboratory, participants were informed about the experimental procedure and asked to complete a consent form. They were seated in the testing booth where they completed a series of questionnaires (see "Questionnaires" below for details) on a computer. After completing the questionnaires, participants were asked to wash their hands, without using soap, before returning to the testing booth. The electromyography sensors were attached to the left corrugator supercilii and skin conductance and pulse sensors were attached to the participants' index, middle and ring finger of the left hand.[2] Participants were instructed to stay as still as possible and maintain attention to the task and respond to the ratings using the number keys on the keyboard. The Visual Discrimination and Checking Task was then presented on the computer screen while facial electromyography measurements of the left corrugator supercilii, electrodermal activity, pulse, checking responses, answer accuracy and reaction time, and subjective ratings of the "urge to check" and "unpleasant feelings" when unable to check were recorded. After the Visual Discrimination and Checking Task, participants also completed three working memory tasks to ensure that checking behaviour was not associated with individual differences in memory capacity (see supplementary material). The session took approximately 60 min in total.

2.3. Visual discrimination and checking task

The Visual Discrimination and Checking Task used in this experiment was a modified version of Rotge's Checking Task (2008) (see Fig. 1). In the current experiment, the task was designed using E-Prime 2.0 software (Psychology Software Tools Ltd., Pittsburgh, PA). Visual stimuli were presented using a screen resolution of 800 × 600 with a 60 Hz refresh rate. Participants sat approximately 60 cm from the computer screen. Visual stimuli consisted of three different geometric shapes: a circle with an x in its centre, a cross, and a three-pointed star. The task began with four practice trials (two identical, two different) using square shape stimuli. The structure of the practice trials followed the same format as outlined below, however, practice trials were not included in the analyses. All the shapes presented as visual stimuli throughout the task had a height and width of 50 mm.

All trials began with the presentation of one of the three shapes on the computer screen for 1000 ms. The shape then disappeared, and a blank black screen was presented for an interval of 3500 ms, after which a second shape was presented on the computer screen for 1000 ms. The second shape was either identical to the first shape presented (*identical stimuli trials*) or consisted of one of four slightly rotated variations of the first shape (*different stimuli trials*). The rotated shape variations between the first and second shape included: 5 degrees clockwise, 10 degrees clockwise, 5 degrees anticlockwise and 10 degrees anticlockwise (see Fig. 2). The number of trials with identical stimuli was equal to the number of trials with different stimuli. After a 2000 ms interval following the presentation of the second shape, a "check cue" was presented for 1000 ms to inform participants of whether, or not, the option to check was available. Then, a 2000 ms interval followed the checking cue. After the interval, if the option to check was not available (*checking unavailable trials*), participants were directed to the choice phase of the trial where they were asked to decide whether the stimuli presented throughout the trial were identical or different. If the option to check was available (*checking available trials*), participants were presented with the opportunity to check whether the visual stimuli presented throughout the trial were identical or different, or they could choose to proceed to the choice phase. If the participant chose to check, the trial was repeated from the presentation of the first shape, until the participant was again presented with the option to check. The opportunity to check was not restricted and participants were able repeat the trial sequence until they decided to proceed to the choice phase of the trial. There was not a time limit on providing an answer during either the check or choice phase of the trial, and the continuation of the trial depended on the participant making a response using the keyboard. Once the participant had completed the choice phase, the next trial would begin following a jittered ITI ranging between 3500 and 5000 ms. As such, the task had four within-subject conditions: identical stimuli checking available, identical stimuli checking unavailable, different stimuli checking available, different stimuli checking unavailable.

The task was comprised of a total of 48 trials, with 12 trials per condition. The trials of each condition were presented in a random order. During identical stimuli trials, the first and second shape presented during the trial were identical. However, during different stimuli trials, the second shape presented was one of four possible rotated variations of the first shape. Both clockwise and anticlockwise rotations were presented to avoid participants' expectations about the direction of the rotation. Further, rotations occurred by 5 or 10 degrees to ensure variability in the presentation of the rotation.

The presentation of the shapes used as visual stimuli was equally distributed across the four conditions with each condition featuring twelve pairs of shapes. For example, in the identical stimuli checking available and identical stimuli checking unavailable conditions there were 12 identical shape pairs presented (i.e., 4 circles, 4 crosses, and 4 stars). In the different stimuli checking available and different stimuli checking unavailable conditions there were 12 different shape pairs presented (i.e., 4 circles, 4 crosses, and 4 stars), see Fig. 2.

At three separate timepoints throughout the task (i.e., every 16 trials), participants were asked to provide subjective ratings of "To what extent do you feel the urge to go back before making your decision?", on a scale the ranged from 1 ("not at all") to 9 ("extremely"). Participants were also asked to provide ratings of "How uncomfortable do you feel when the option to go back is not available?", on a scale the ranged from 1 ("not at all") to 9 ("extremely"). Subjective ratings were always

[2] Skin conductance response and heart rate were recorded during data collection for training purposes and were not included as part of the study for analysis.

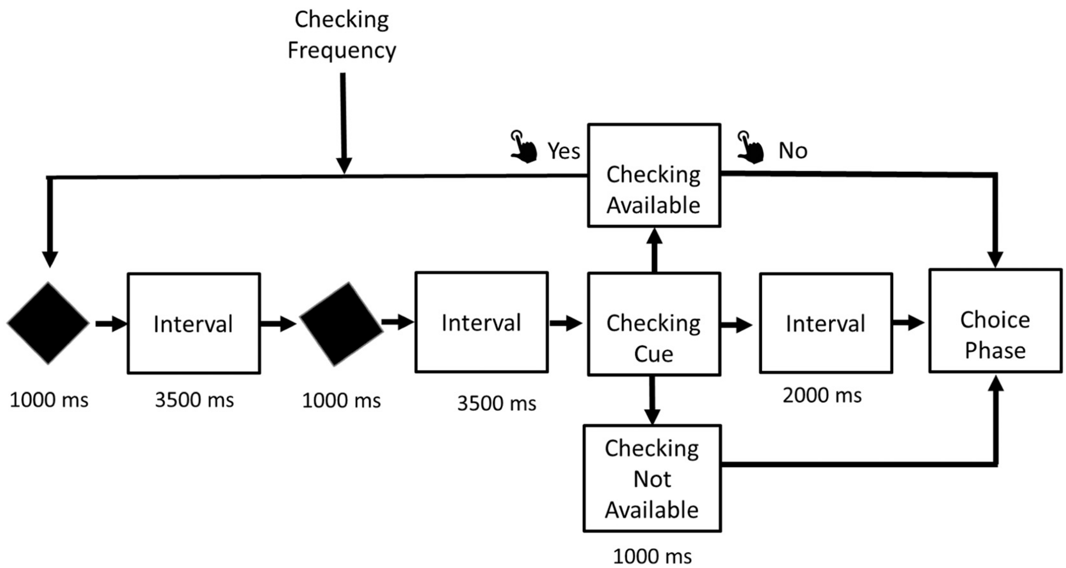

Fig. 1. Schematic representation of a trial during the visual discrimination and checking task.

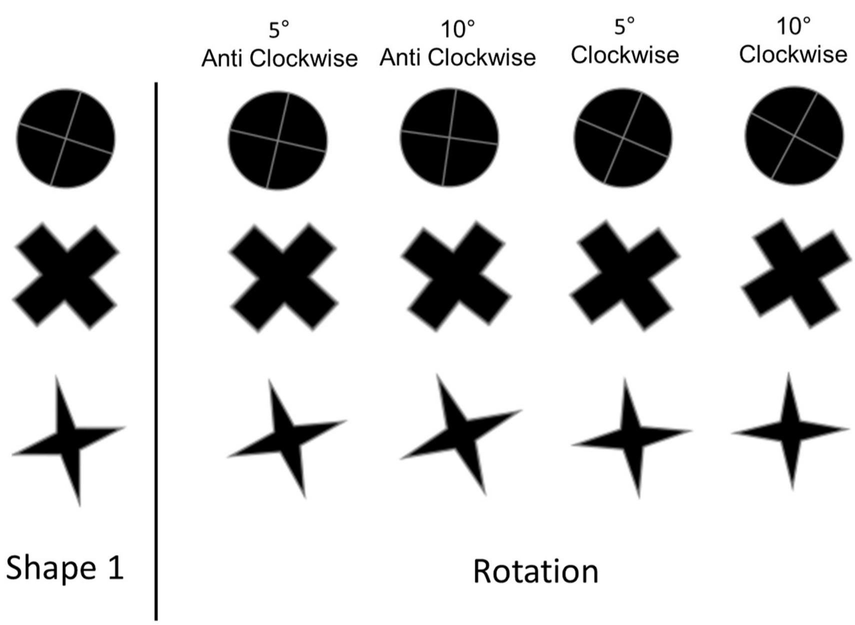

Fig. 2. Depiction of the shape stimuli used during the visual discrimination and checking task.

collected after either identical stimuli checking unavailable or different stimuli checking unavailable trials. Further, during the choice phase of the trial, the participant's accuracy in deciding whether the two shape stimuli were identical or different and their answer accuracy and reaction time when making a response was recorded.

2.4. Questionnaires

The following questionnaires were administered.

2.4.1. Intolerance of uncertainty scale

We administered the Intolerance of Uncertainty Scale (IUS) (Freeston et al., 1994), which consists of 27 items that are rated on a 5-point Likert Scale (e.g., 1 = Not at all characteristic of me, 5 = Extremely characteristic of me). Example items include, "Uncertainty makes life intolerable" and "I must get away from all uncertain situations". Cronbach's alpha for the IUS in this sample was 0.94.

2.4.2. Obsessive compulsive inventory, checking subscale

The Check Subscale of the Obsessive Compulsive Inventory (OCI-C) (Foa et al., 1998) was administered and consists of 9 items rated on a 5-point Likert Scale (e.g., 0 = Not at all, 4 = Extremely). Example items include, "I repeatedly check doors, windows, drawers etc." and "I repeatedly check anything which might cause a fire". Cronbach's alpha for the Checking Subscale of the OCI = 0.87.

2.4.3. Obsessive beliefs questionnaire, perfectionism/certainty subscale

We administered the Perfectionism/Certainty Subscale of the Obsessive Beliefs Questionnaire (P/C OBQ) (Obsessive Compulsive Cognitions Working Group, 2005), which consists of 16 items evaluating beliefs about perfectionism and certainty rated on a 7-point Likert Scale (e.g., 1 = Disagree very much, 7 = Agree very much). Item examples include "I must keep working at something until it's done exactly right" and "It is essential to me to consider all possible outcomes of a situation". Cronbach's alpha for the P/C OBQ = 0.88.

2.4.4. Not just right experiences-questionnaire-revised, severity scale

The Severity Scale of the Not Just Right Experiences-Questionnaire-Revised (NJRE-Q-R, Coles et al., 2003) was administered. The Severity Scale of the MJRE-Q-R is comprised of the last 7 items of the questionnaire rated on a 7-point Likert Scale, the phrasing of which varied depending on the question (e.g., 1 = No distress at all, 7 = Extreme distress; 1 = No urge to do something, 7 = Extreme urge to do something). Example items include, "To what extent did the not just right experience cause you distress at the time?" and "To what extent did you feel the urge to do something about this not just right experience?". Cronbach's alpha for the Severity Scale of the NJRE-Q-R = 0.82.

2.4.5. State trait anxiety inventory, trait anxiety subscale

The Trait Subscale of the State Trait Anxiety Inventory (STAI-T, Spielberger et al., 1983) was administered and includes 20 items rated on a 4-point Likert scale (e.g., 1 = Not at all, 4 = Very much so). Example items include, "I worry too much over something that really doesn't matter" and "I feel that difficulties are piling up so that I cannot overcome them". Cronbach's alpha for the STAT-T = 0.92.

2.5. Rating data scoring

Subjective ratings of the urge to check and ratings of unpleasant feelings when unable to check were reduced for each participant by calculating the average response across the three separate timepoints (i.e., every 16 trials) using the E-Data Aid tool in E-Prime (Psychology Software Tools Ltd., Pittsburgh, PA).

2.6. Checking behaviour data scoring

Checking behaviour was scored as the total frequency of checking responses per participant for each experimental condition where the option to check was available (i.e., identical stimuli checking available trials and different stimuli checking available trials). Thus, checking behaviour was represented by the total number of times the participant chose to check and repeat the trial during the conditions where the option to check was available.

2.7. Task accuracy data scoring

Accurate responses during the choice phase were scored as 1 (vs. 0) and the proportion of accurate responses was calculated per participant for each condition (identical stimuli checking available, identical stimuli checking unavailable, different stimuli checking available, different stimuli checking unavailable), i.e., total number of accurate response trials divided by the total number of trials per condition (i.e., 12).

2.8. Task reaction time

Reaction time when choosing whether to check was reduced for each participant by calculating the average response time across the 12 trials of checking available conditions (identical stimuli checking available, different stimuli checking available). Reaction time when making a response during the choice phase was reduced for each participant by calculating the average response time across the 12 trials of each condition (identical stimuli checking available, identical stimuli checking unavailable, different stimuli checking available, different stimuli checking unavailable). Reaction time was calculated using the E-Data Aid tool in E-Prime (Psychology Software Tools Ltd., Pittsburgh, PA).

2.9. Electromyography acquisition and scoring

Facial electromyography measurements of the left corrugator supercilii were obtained by using two pairs of 4 mm Ag/AgCl bipolar surface electrodes connected to the ML138 Bio Amp. The bipolar surface electrodes were approximately 15 mm apart. The reference electrode was a singular 8 mm Ag/AgCl electrode, placed upon the middle of the forehead, and connected to the ML138 Bio Amp. Before placing the electromyography sensors, the skin site was slightly abraded with isopropyl alcohol skin prep pads, to reduce skin impedance to an acceptable level (below 20 kΩ). Electromyography was sampled at 1000 Hz. A high-pass filter of 20 Hz was applied to the raw electromyography online (Solnik et al., 2008). The electromyography signal was root mean squared offline (Fridlund and Cacioppo, 1986).

Corrugator supercilii activity was extracted for the Visual Discrimination and Checking Task image viewing period and checking cue period using R software (R Core Team, 2014). During the image viewing period, (i.e., the presentation of the first shape (1000 ms), delay period between shapes (3500 ms), and second shape (1000 ms)), corrugator supercilii activity was averaged for each 1000 ms window following trial onset, resulting in seven windows of 1000 ms each. These data were baseline corrected by subtracting 2000 ms preceding each trial onset from a blank screen. For the checking cue period, (i.e., the presentation of the checking cue (1000 ms) and the delay period after (2000 ms)), corrugator supercilii activity was averaged for each 1000 ms window following checking cue onset, resulting in three windows of 1000 ms each. These data were also baseline corrected by subtracting 2000 ms preceding each checking cue from a blank screen. Following this the data were z-scored to control for interindividual differences in corrugator supercilii activity that are unrelated to the task (i.e. skin type or muscle size) (for similar analysis pipelines of the corrugator supercilii see Morriss et al., 2020; Morriss, Bradford, et al., 2021).

For the Visual Discrimination and Checking Task image viewing period, corrugator supercilii trials were averaged per trial type and second window (on a second-by-second basis) for each participant resulting in the following conditions included in analyses (identical, different). For the checking cue period, corrugator supercilii was averaged per trial type and second window (on a second-by-second basis) for each participant resulting in the following conditions included in analyses (identical stimuli checking available, identical stimuli checking unavailable, different stimuli checking available, different stimuli checking unavailable).

2.10. Analyses

Analyses were conducted using the mixed procedure in SPSS 25.0 (SPSS, Inc.; Chicago, Illinois). To examine the main effects, we conducted separate Multi Level Models (MLMs) for checking frequency, answer accuracy during the choice phase, answer reaction time during the choice phase, and corrugator supercilii activity during the Visual Discrimination and Checking Task image viewing and checking cue periods. To compare reaction time when participants chose whether to check during the checking cue of identical versus different stimuli trials, we conducted a paired samples *t*-test.

For the analysis of checking frequency data, we entered Stimulus Type (identical, different) at Level 1 and individual subjects at Level 2. To examine answer accuracy and answer reaction time during the choice phase, two separate MLMs were conducted, both entered Stimulus Type (identical, different) and Option to Check (checking available, checking unavailable) at Level 1 and individual subjects at Level 2. To examine corrugator supercilii activity during the Visual Discrimination and Checking Task image viewing period, Stimulus Type (identical/different) and Second (1, 2, 3, 4, 5, 6, 7) were entered at Level 1 and individual participants entered at Level 2. For analysis of corrugator supercilii activity during the checking cue period, Stimulus Type (identical, different), Option to Check (checking available, checking unavailable), and Second (1, 2, 3) were entered at Level 1 and individual subjects at Level 2.

Fixed effects included Stimulus Type, Option to Check, and Second. A diagonal covariance matrix for Level 1 was used in all models. A random intercept for each participant was included as random effects, where a variance components covariance structure was used. We used a maximum likelihood estimator for MLMs.

To examine the relationship between the self-reported measures of individual differences (IUS, OCI-C, P/C OBQ, NJRE-Q-R, and the STAI-T) and the dependent variables measured throughout this experiment (self-reported ratings of the urge to check and unpleasantness when unable to check, checking frequency, answer accuracy, reaction time during the choosing to check phase, answer reaction time during the choice phase, and corrugator supercilii activity), correlation analyses were performed. Analysis of the relationship between individual differences and corrugator supercilii activity were exploratory. Thus, such analyses were conducted based on the outcome of main effect analyses of corrugator supercilii activity (i.e., which period(s) of the Visual Discrimination and Checking Task to examine). If there was a significant relationship between one of the self-reported measures of individual differences (IUS, OCI-C, P/C OBQ, NJRE-Q-R, and the STAI-T) and an outcome variable, we examined the specificity of this relationship. The specificity was examined by assessing the significant difference between the significant correlation (e.g., perfectionism and checking frequency) and other correlations between individual differences measures and the same outcome variable (e.g., not just right experiences and checking frequency).

3. Results

When reporting the main effects of the task, MLM statistics that were significant, or relevant to hypotheses, for Stimulus, Check, and Second are reported in the text. All other main effects and interactions between Stimulus, Check and Second are reported in Tables 2 and 4.

3.1. *Self-reported ratings during the task*

Overall, participants did not report elevated feelings of the urge to check ($M = 3.12$, $SD = 1.56$), or unpleasantness when the option to check was not available ($M = 2.87$, $SD = 1.85$).

3.2. *Analysis of main effects*

3.2.1. *Checking frequency*

During trials where participants were given the opportunity to check, checking frequency was significantly greater in trials where different stimuli ($M = 3.54$, $SD = 3.12$) were presented, compared to trials where identical stimuli ($M = 3.02$, $SD = 2.86$) were presented, $F(1, 87) = 4.35$, $p = .04$ (see Table 1 and Fig. 3).

Table 1
Descriptive statistics (mean, standard deviation) by measure and condition.

	Identical stimuli		Different stimuli	
	Checking available	Checking unavailable	Checking available	Checking unavailable
Checking frequency	3.02 (2.86)		3.54 (3.12)	
Maximum	15		18	
Minimum	0		0	
Answer accuracy	0.86 (0.14)	0.83 (0.16)	0.56 (0.21)	0.54 (0.21)
Response reaction time to checking cue	550.43 (245.09)		541.35 (219.02)	
Answer reaction time during choice phase	901.63 (398.09)	1061.60 (484.78)	885.29 (379.07)	1104.50 (600.41)

Note: Checking frequency scored as total frequency of checking responses. Answer accuracy was scored as a proportion of actuate responses. Reaction time was measured in milliseconds.

3.2.2. *Answer accuracy*

Participants were significantly more accurate in their responses during the choice phase (i.e., when determining whether identical or different shape stimuli had been presented during the trial) when identical stimuli ($M = 0.84$, $SE = 0.02$) had been presented compared to when different stimuli ($M = 0.55$, $SE = 0.02$) had been presented during the trial, $F(1, 166.53) = 143.40$, $p < .00$ (see Table 1, Fig. 4).[3] Further, participants were significantly more accurate in their responses during the choice phase in trials where the opportunity to check was available ($M = 0.71$, $SE = 0.01$) compared to trials where opportunity to check was unavailable ($M = 0.68$, $SD = 0.01$), $F(1, 164.88) = 5.19$, $p = .02$ (see Table 1 and Fig. 4).

3.2.3. *Choosing to check reaction time*

Participants did not demonstrate a significant difference in their reaction time (ms) during trials where identical stimuli ($M = 541.35$, $SD = 219.02$) were presented compared to trials where different stimuli ($M = 550.43$, $SD = 245.09$) were presented when choosing whether to check or not, $t(86) = -0.516$, $p = .607$ (see Table 1).

3.2.4. *Answer reaction time*

Participants did not demonstrate a significant difference in their reaction time (ms) when providing a response during the choice phase in trials where identical stimuli ($M = 981.61$, $SE = 104.17$) were presented compared to trials where different stimuli ($M = 994.90$, $SE = 120.08$) were presented, $F(1, 115.97) = 0.21$, $p = .65$ (see Table 1 and Fig. 5). However, participants were significantly faster when providing a response during the choice phase in trials where the option to check was available ($M = 893.46$, $SE = 41.65$) compared to trials where the option to check was unavailable ($M = 1083.05$, $SE = 47.53$), $F(1, 88.60) = 25.14$, $p < .00$, (see Table 1 and Fig. 5).

3.2.5. *Corrugator supercilii*

During the visual discrimination viewing period, there was a significant effect of Second, where corrugator supercilii activity was smallest during second 6 ($M = -0.061$, $SE = 0.02$) and second 7 ($M = -0.186$, $SE = 0.02$) of the image viewing period (i.e., after the offset of the second visual stimulus), $F(6, 325.14) = 31.09$, $p < .001$, (see Table 3 and Fig. 6A).

During the checking cue period of the task, corrugator supercilii activity was greater when the option to check was not available ($M = 0.02$, $SE = 0.01$) compared to when the option to check was available ($M = -0.02$, $SE = 0.01$), $F(1, 969.23) = 5.97$, $p = .015$ (see Table 2 and Fig. 6B). Further, there was a significant effect of Second, and corrugator supercilii was smallest during second 2 ($M = -0.052$, $SE = 0.02$), when the checking cue was removed, $F(2, 637.30) = 33.87$, $p < .001$. There was also a marginal Check × Second interaction, $F(2, 637.30) = 2.77$, $p = .063$. Corrugator supercilii activity was significantly greater during second 2 of the checking cue period when checking was unavailable ($M = -0.052$, $SE = 0.02$) compared to when the option to check was available ($M = -0.156$, $SE = 0.02$), $p = .001$. (see Table 2).

3.3. *Analyses of individual differences*

The descriptive statistic for the questionnaire measures are presented in Table 5.

3.3.1. *Self-reported ratings during the task*

All the self-reported measures of individual differences (IUS, OCI-C,

[3] Although, the accuracy for identifying different stimuli appears to be at chance level, the accuracy for the different stimuli varied by the stimulus type presented. For instance, the cross shape was the easiest (M = 0.64, SD = 0.27), followed by the star shape (M = 0.55, SD = 0.22), and the circle shape (M = 0.44, SD = 0.23), p's < .001.

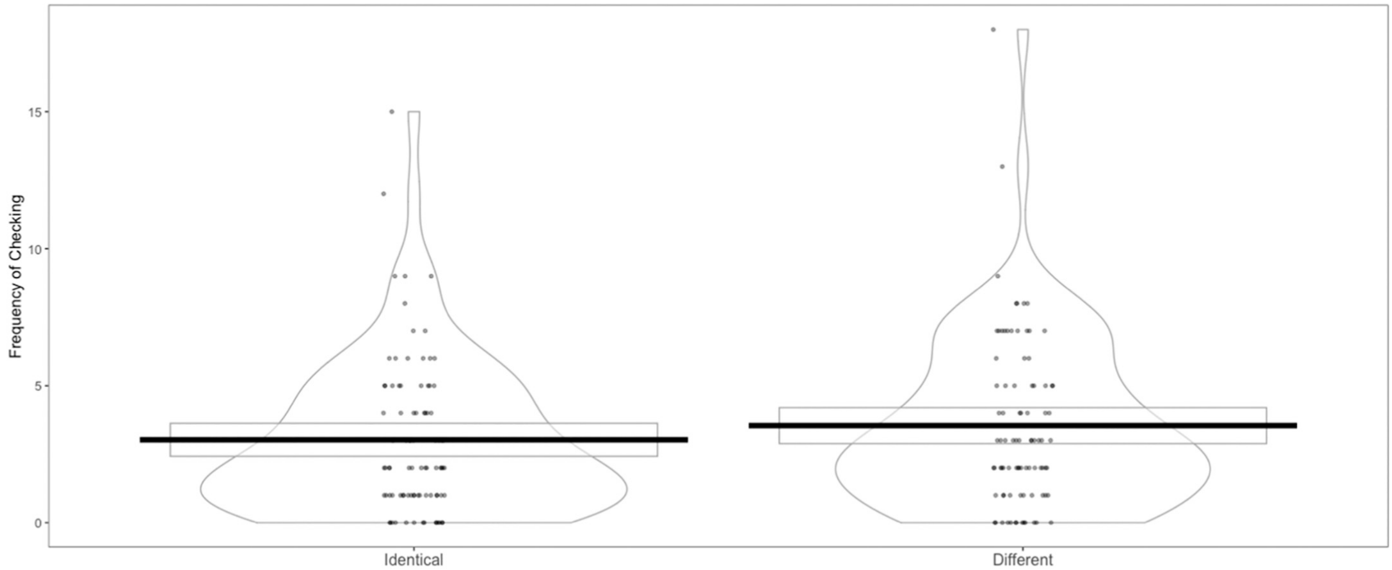

Fig. 3. Pirate plot with highest density intervals for checking frequency during identical and different stimuli trials when the option to check was available. Checking frequency was significantly greater in trials where different stimuli were presented compared to trials where identical stimuli were presented.

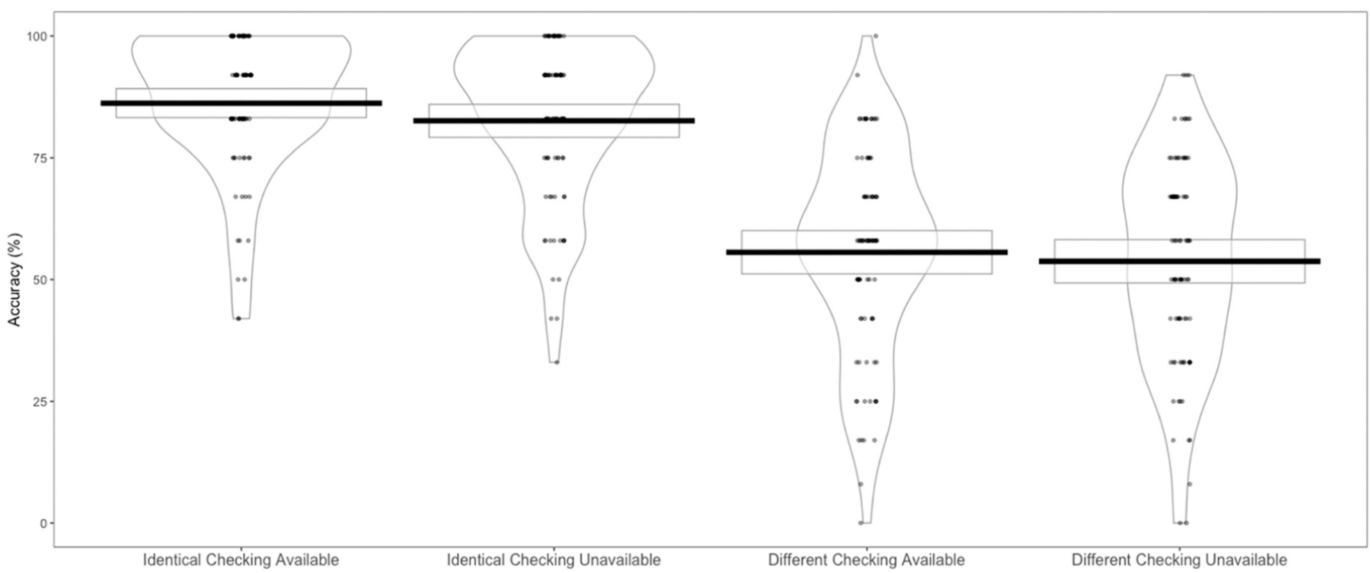

Fig. 4. Pirate plot with highest density intervals for answer accuracy (%) across conditions during the choice phase of the trials. Participants were more accurate in their responses when identical stimuli were presented during the trial, compared to when different stimuli were presented. Further, responses during the choice phase were more accurate during trials where the option to check was available compared to trials where the option to check was not available.

P/C OBQ, NJRE-Q-R, and the STAI-T) were significantly positively correlated with subjective ratings of the urge to check, p's < 0.031, and feelings of unpleasantness, p's $< .022$ (see Table 6). No specificity was found for the anxiety and obsessive-compulsive self-report measures for the subjective ratings of the urge to check, p's $> .05$, or feelings of unpleasantness, p's $> .05$.

3.3.2. Checking frequency

The IUS was significantly positively correlated with the total checking frequency (identical + different checking trials), $p = .030$, and checking frequency during trials where identical stimuli were presented, $p = .011$ (see Table 6). The P/C OBQ was significantly positively associated with checking frequency during identical stimuli checking available trials, $p = .019$, and differential checking frequency towards identical versus different stimuli trials, $p = .026$ (see Table 6). The STAI-T was significantly positively associated with total checking frequency, $p = .011$, and checking frequency in both identical, $p = .020$, and different stimuli checking available trials, $p = .020$ (see Table 6). The OCI-C and NJRE-Q-R self-report measures were not significantly associated with checking frequency during checking trials of the task, p's $>$ .077 (see Table 6). No specificity was found for the anxiety and obsessive-compulsive self-report measures for checking frequency, p's $>$ .05.

3.3.3. Answer accuracy

There was a significant negative association between P/C OBQ scores and answer accuracy during identical stimuli trials when the option to check was unavailable, $p = .016$ (see Table 6). There were no other significant correlations between the self-reported individual differences measures and answer accuracy during the choice phase across conditions, p's $> .054$. No specificity was found for the P/C OBQ over and above other anxiety and obsessive-compulsive self-report measures for

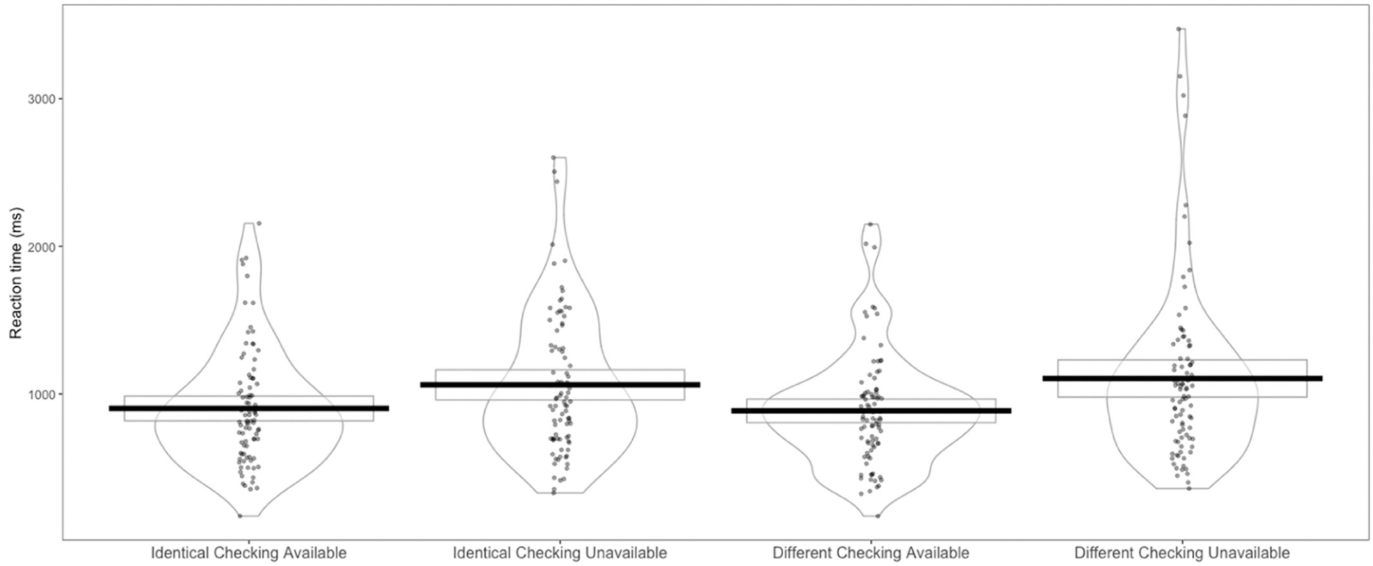

Fig. 5. Pirate plot for highest density intervals for answer reaction time (ms) during the choice phase. Reaction time to provide an answer was faster during trials where the option to check was available compared to trials where the option to check was not available.

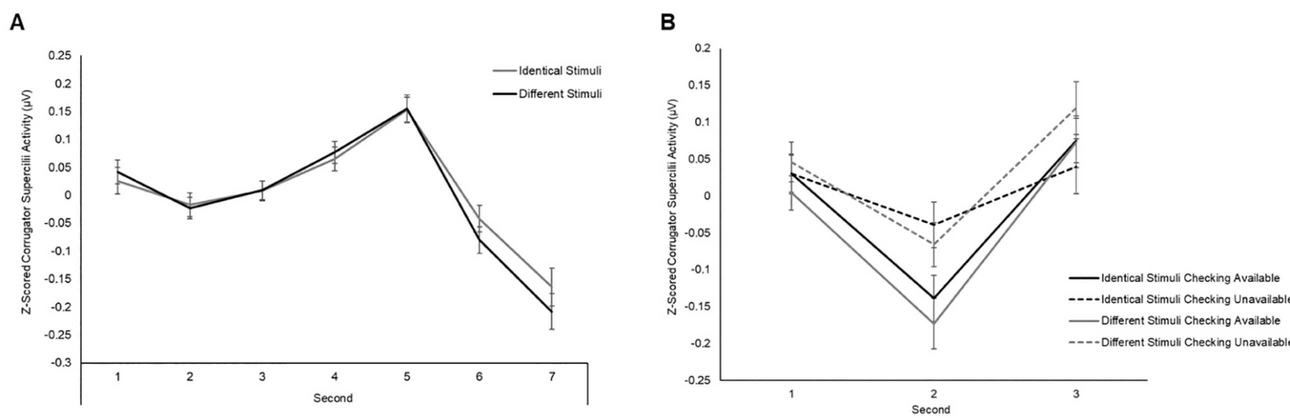

Fig. 6. Line graphs displaying mean corrugator supercilii activity for each condition during (A) the visual discrimination viewing period, and (B) the checking cue period. During the visual discrimination period, corrugator supercilii activity was smallest during identical and different stimuli trials during second 6 and second 7 (i.e., after the offset of the second visual stimulus). During the checking cue period, corrugator supercilii activity was greater when the option to check was not available compared to when the option to check was available. Further, corrugator supercilii activity was smallest during both identical and different stimuli trials during second 2, when the checking cue was removed.

Table 2
Stimulus and check main effect MLMs per outcome measure.

	Checking frequency	Answer accuracy	Response reaction time to checking cue	Answer reaction time during choice phase
Stimulus	$F(1, 87) = 124.76, p < .001$	$F(1, 166.53) = 143.40, p < .001$		$F(1, 115.97) = 0.212, p = .646$
Check		$F(1, 164.88) = 5.19, p = .024$	$t(86) = -0.516, p = .607$	$F(1, 88.60) = 25.14, p < .001$
Stimulus × check		$F(1, 164.88) = 0.558, p = .456$		$F(1, 115.97) = 1.05, p = .307$

Note. MLM statistics for Stimulus and Check are also presented in the text as they are relevant to hypotheses. MLM statistics for interactions between Stimulus × Check are presented in this table for transparency but are not presented in the text.

answer accuracy, p's $> .05$.

3.3.4. *Choosing to check reaction time*

There was a significant positive correlation between P/C OBQ scores and reaction time when choosing whether to check during trials were different stimuli were presented, $p = .039$. There were no other significant correlations between self-reported individual differences measures and reaction time when choosing to check during the check cue, $p > .072$.

There was specificity for the P/C OBQ over and above self-reported NJRE, $p = .015$, but not OCI-C, $p = .105$, or self-reported measures of anxiety (i.e., IUS and STAI-T), p's $> .441$, for reaction time when choosing to check during different stimuli trials.

3.3.5. *Answer reaction time*

There was a significant positive association between P/C OBQ scores and answer reaction time during the choice phase in different stimuli trials when the option to check was available, $p = .025$, and in different stimuli trials when the option to check was unavailable, $p < .001$ (see Table 6). There were no other significant correlations between the self-

Table 3
Descriptive statistics (mean, standard deviation) for corrugator supercilii activity during the visual discrimination image viewing period and checking cue period by stimulus type (identical, different) and condition (checking available, checking unavailable).

		Image viewing period (s)							Checking cue period (s)					
									Checking available			Checking unavailable		
		1	2	3	4	5	6	7	1	2	3	1	2	3
Z-scored corrugator supercilii activity (μV)	Identical	0.026 (0.196)	−0.017 (0.176)	0.008 (0.158)	0.065 (0.188)	0.153 (0.233)	−0.043 (0.228)	−0.164 (0.299)	0.030 (0.237)	−0.139 (0.293)	0.075 (0.278)	0.030 (0.250)	−0.039 (0.288)	0.040 (0.351)
	Different	0.042 (0.230)	−0.023 (0.200)	0.009 (0.170)	0.077 (0.198)	0.155 (0.210)	−0.080 (0.228)	−0.208 (0.314)	0.004 (0.218)	−0.173 (0.322)	0.073 (0.332)	0.046 (0.254)	−0.066 (0.281)	0.119 (0.337)

Note: Z-scored corrugator supercilii activity (μV) measured in microvolts.

Table 4
Stimulus, check and second main effect MLMs for corrugator supercilii activity during the visual discrimination image viewing period and checking cue period by stimulus type (identical, different) and condition (checking available, checking unavailable).

	Z-scored corrugator supercilii activity (μV)	
	Image viewing period	Checking cue period
Stimulus	$F(1, 1031.60) = 0.440$, $p = .507$	$F(1, 969.23) = 0.004$, $p = .951$
Check		$F(1, 969.23) = 5.97$, $p = .015$
Second	$F(1, 325.14) = 31.09$, $p < .001$	$F(1, 637.30) = 33.87$, $p < .001$
Stimulus × check		$F(1, 969.23) = 1.51$, $p = .220$
Stimulus × second	$F(1, 325.14) = 0.404$, $p = .876$	$F(1, 637.30) = 0.1.08$, $p = .340$
Check × second		$F(1, 637.30) = 2.77$, $p = .063$
Stimulus × check × second		$F(1, 637.30) = 0.324$, $p = .724$

Note. MLM statistics that are significant, or relevant to hypotheses are presented in the text. MLM statistics for interactions between Stimulus, Check, and Second are presented in this table for transparency but are not presented in the text.

Table 5
Descriptive statistics for individual differences measures (IUS, OCI-C, P/C OBQ, NJRE-Q-R and STAI-T).

	Min	Max	*M*	*SD*
IUS	27	109	61.99	18.66
OCI-C	0	30	9.18	7.16
P/C OBQ	31	100	63.14	14.93
NJRE-Q-R	0	38	20.91	8.78
STAI-T	27	71	45.8	9.93

Table 6
Correlations between self-reported individual differences measures (IUS, OCI-C, P/C OBQ, NJRE-Q-R and STAI-T).

	IUS	OCI-C	P/C OBQ	NJRE-Q-R	STAI-T
IUS		0.503**	0.674**	0.388**	0.684**
OCI-C			0.320**	0.435**	0.373**
P/C OBQ				0.311**	0.495**
NJRE-Q-R					0.266*

** Correlation significant at the 0.01 level (2-tailed).
* Correlation significant at the 0.05 level (2-tailed).

reported individual differences measures and answer reaction time during the choice phase across conditions, $p > .084$.

There was specificity for the P/C OBQ over and above other obsessive-compulsive self-report measures (OCI-C, $p = .025$; NJRE-QR, $p = .035$), but not self-reported measures of anxiety (i.e., IUS and STAI-T), *p*'s > .05, for answer reaction time during different stimuli checking available trials. No specificity was found for the P/C OBQ over and above other obsessive-compulsive and anxiety self-report measures for answer reaction time during different stimuli checking unavailable trials, *p*'s > .05.

3.3.6. *Corrugator supercilii*

As there was a main effect of checking cue (checking available versus checking unavailable) for corrugator supercilii activity during the checking cue period, we conducted correlation analyses between self-reported individual differences measures and corrugator supercilii difference scores (i.e., corrugator supercilii activity during checking available trials minus corrugator supercilii activity during checking unavailable trials during second 1, second 2, and second 3 of the checking cue window). There were no significant correlations between self-reported measures of individual differences and differential corrugator activity during the checking cue window, max $r = 0.104$, min $p = .339$.

Further, we conducted correlation analyses between corrugator supercilii difference scores during the checking cue period and self-reported individual differences measures during identical stimuli trials and different stimuli trials separately (i.e., corrugator supercilii activity during identical stimuli checking available trials during second 1, second 2, and second 3 of the checking cue window; and corrugator supercilii activity during different stimuli checking available trials during different stimuli checking unavailable trials during second 1, second 2, and second 3 of the checking cue window). Results demonstrated a significant positive correlation between P/C OBQ scores and differential corrugator supercilii activity (i.e., checking available minus checking unavailable trials) when different stimuli were presented, $p = .030$, during second 1 of the checking cue (see Table 7).

Further, there was specificity for the P/C OBQ over and above other obsessive-compulsive self-report measures (OCI-C, $p = .016$; NJRE-Q-R, $p = .039$), but not self-reported measures of anxiety (IUS and STAI-T, *p*'s > .05). There were no other significant associations between self-reported measures of individual differences and corrugator activity across conditions when the checking cue was presented, *p*'s > .106 (see Table 8).

4. Discussion

The present exploratory study examined the impact of individual differences in self-reported anxiety and obsessive-compulsive features on subjective, behavioural, and physiological indices during a visual discrimination and checking task. In line with our hypotheses, all of the self-reported anxiety and obsessive-compulsive features mapped onto at least one subjective, behavioural, and physiological indices during the visual discrimination and checking task. More specifically, all of the self-reported anxiety and obsessive-compulsive features were positively related to greater subjective ratings of unpleasantness and the urge to check during the task. In addition, individuals who reported higher general negative affect, intolerance of uncertainty, and perfectionism and the need for certainty checked more frequently during the task =. Notably, individuals with higher perfectionism and the need for certainty showed poorer accuracy, slower reaction time, and larger

Table 7
Correlations between self-reported individual differences measures (IUS, OCI-C, P/C OBQ, NJRE-Q-R and STAI-T) and task related dependent variables (subjective ratings, checking frequency, answer accuracy and answer reaction time).

	Subjective ratings		Checking frequency				Answer accuracy across conditions				Choosing to check reaction time		Answer reaction time across conditions			
	Urge to check	Unpleasantness	Total	Identical stimuli	Different stimuli	Differential checking (identical - different)	ISCA	ISCunA	DSCA	DSCunA	Identical Stimuli	Different Stimuli	ISCA	ISCunA	DSCA	DSCunA
IUS	0.355**	0.479**	0.233*	0.271*	0.163	0.115	−0.121	−0.037	0.043	0.111	0.067	0.105	0.054	0.015	0.087	0.123
OCI-C	0.370**	0.501**	0.139	0.165	0.095	0.076	−0.193	−0.097	0.030	0.019	−0.009	−0.026	−0.060	−0.079	−0.100	0.018
P/C OBQ	0.232*	0.245*	0.16	0.251*	0.052	0.238*	−0.146	−0.258*	0.004	−0.001	0.146	0.221*	0.136	0.186	0.240*	0.253*
NJRE-QR	0.322**	0.356**	0.172	0.191	0.130	0.061	−0.167	−0.090	−0.136	−0.061	−0.088	−0.151	−0.177	−0.036	−0.080	−0.019
STAI-T	0.302**	0.351**	0.270*	0.248*	0.250*	−0.026	−0.054	−0.207	0.045	0.155	0.083	0.138	0.051	0.108	0.118	0.120

Note: Condition abbreviations for answer accuracy and answer reaction time = Identical Stimuli Checking Available (ISCA), Identical Stimuli Checking Unavailable (ISCunA), Different Stimuli Checking Available (DSCA), Different Stimuli Checking Unavailable (DSCunA).

** Correlation significant at the 0.01 level (2-tailed).

* Correlation significant at the 0.05 level (2-tailed).

corrugator supercilii during parts of the task. These results provide further information as to how different anxiety and obsessive-compulsive features, in particular perfectionism and the need for certainty, may relate to and maintain checking behaviour in low threat contexts, which likely has implications for models of excessive and persistent checking in anxiety and obsessive-compulsive disorders (Rachman, 2002; Salkovskis and Warwick, 1986).

As expected, poorer task accuracy was observed for the different versus identical shape stimuli pairs, suggesting that it was more difficult to identify changes in shape stimuli. Because of this difficulty, the option to check was selected more often for the different versus identical shape stimuli pairs. No differences in corrugator supercilii activity to the different or identical shape stimuli pairs were observed during the image viewing period (i.e., when participants viewed the first shape, a delay interval, and the second shape). As predicted, greater corrugator supercilii activity was found to cues that signalled that checking was unavailable, relative to checking being available. This result may reflect greater distress or effort when not being able to check (i.e., larger corrugator supercilii activity to the checking unavailable cue), or relief when able to check (i.e., smaller corrugator supercilii activity to the checking available cue), or both. Overall, these main effects suggest that the visual discrimination and checking task was sufficiently difficult to engage checking behaviour (Rotge et al., 2008, 2015), and valence and effort-based physiological markers such as the corrugator supercilii.

Higher self-reported anxiety and obsessive-compulsive features were associated with greater subjective ratings of unpleasantness and the urge to check during the task. No specificity between self-reported anxiety and obsessive-compulsive features and subjective ratings were observed. Similar patterns of results have been observed for ratings of distress and the urge to check in prior research using checking and information gathering tasks (Jacoby et al., 2014, 2016; Sarawgi et al., 2013). However, there are some nuances. For example, one previous study demonstrated specificity of self-reported intolerance of uncertainty over broader negative affect in predicting the urge to check during a checking task embedded in a higher-level threat context (e.g., harm to self and others) (Sarawgi et al., 2013). Taken together, these results indicate that self-reported anxiety and obsessive-compulsive features broadly account for subjective ratings of unpleasantness and the urge to check during a checking task embedded in a lower-level threat context (i.e., the need to be correct or right).

Interestingly, higher self-reported general negative affect, intolerance of uncertainty, and perfectionistic and certainty-based obsessive beliefs were associated with greater checking frequency during the task. Surprisingly, self-reported obsessive-compulsive checking and not just right experiences were not associated with checking frequency during the task, although the relationships between these variables were in the expected direction. Furthermore, no specificity between self-reported anxiety and obsessive-compulsive features and checking frequency was found. From these findings, we can tentatively suggest that checking frequency within this relatively low-level threat context (i.e., the perceived need to be correct or right) is better predicted by self-reported anxiety and obsessive-compulsive features related to general negative affect, intolerance of uncertainty, and perfectionistic and certainty-based obsessive beliefs. Obsessive-compulsive checking and not just right experiences may have not been strongly related to checking frequency in this task because these self-report measures capture checking behaviour and the not just right experiences across a range of threat contexts (e.g., checking in general, related to harming self, and harming others). It is possible, however, that obsessive-compulsive checking and not just right experiences would be more predictive of checking frequency in this task within a patient sample, as the range of scores for these self-report measures would be wider and more normally distributed.

Perfectionistic and certainty-based obsessive beliefs was the only self-report measure that was associated with accuracy, reaction time, and corrugator supercilii during the visual discrimination and checking

Table 8
Correlations between self-reported individual differences measures (IUS, OCI-C, P/C OBQ, NJRE-Q-R and STAI-T) and Z-scored corrugator supercilii activity during the checking cue period.

	Differential corrugator supercilii activity (checking available – checking unavailable) (s)								
	Stimuli average			Identical stimuli			Different stimuli		
	1	2	3	1	2	3	1	2	3
IUS	−0.078	−0.052	0.037	−0.060	−0.072	0.005	0.019	−0.063	−0.023
OCI-C	−0.036	−0.009	−0.047	−0.098	−0.148	−0.089	−0.135	−0.094	−0.016
P/C OBQ	−0.126	−0.045	−0.008	−0.167	−0.175	−0.040	0.233*	0.131	0.131
NJRE-Q-R	−0.056	0.044	0.029	0.084	−0.024	−0.053	−0.082	−0.103	−0.063
STAI-T	0.104	0.048	0.070	−0.109	−0.130	−0.092	0.001	−0.081	−0.017

* Correlation significant at the 0.05 level (2-tailed).

task. More specifically, individuals with higher perfectionistic and certainty-based obsessive beliefs displayed poorer accuracy to identical shape stimuli pairs when checking was unavailable, slower reaction times when choosing to check or not after viewing different shape stimuli pairs, slower reaction times when providing an answer after viewing different shape stimuli pairs when checking was available and unavailable, and greater engagement of the corrugator supercilii to cues signalling that checking was available after viewing different shape stimuli pairs. These findings suggest that individuals with higher perfectionistic and certainty-based obsessive beliefs were more attentive and cautious, and displayed greater physiological distress or effort, during the task when faced with the difficult condition (i.e., different shape stimuli pairs), particularly when checking was available. Such findings are in line with previous studies that have observed: (1) patients with anxiety and obsessive-compulsive disorders to exhibit slower reaction times when choosing to check (Rotge et al., 2008) and when making decisions during perceptual tasks that require evidence accumulation (Banca et al., 2015; Jacoby et al., 2014; Marton et al., 2019), and (2) individuals with greater symptoms of OCD to display different physiological sensitivity during tasks with a checking component (Lazarov et al., 2015; Toffolo et al., 2013; c.f. Van Bennekom et al., 2021). While there was little evidence of specificity of the perfectionistic and certainty-based obsessive beliefs over the other self-report measures, it is striking that the perfectionistic and certainty-based obsessive beliefs mapped on to all of the dependent variables for the visual discrimination and checking task. Perfectionistic and certainty-based obsessive beliefs (i.e., 'I must be certain of my decisions') are likely to be closely linked to the threat experienced during the visual discrimination and checking task presented (e.g., the threat of not being sure/certain or correct about the answers during the task).

Taken together, the results presented here provide an exciting opportunity for further lines of research on the extent to which anxiety and obsessive-compulsive features impact subjective, behavioural, and physiological markers during checking-based tasks. In particular, future research may wish to refine and extend the task presented here by introducing blocks with varying levels of threat (e.g. the threat of receiving a mild electric shock to the self or other if an incorrect answer is given, see Jacoby et al., 2019), in order to examine the role of threat and core obsessional beliefs related to perfectionism, need for certainty, inflated responsibility, and harm in predicting checking behaviour (for meta-analysis and review see, Strauss et al., 2020). Furthermore, the task can be expanded to examine the how excessive and persistent checking can be alleviated by applying experimental interventions that emulate common therapeutic techniques for anxiety and obsessive-compulsive disorders (e.g. cognitive behavioural therapy generally or exposure response prevention specifically: (Abramowitz, 1996; Whittal et al., 2005).

The study conducted here had a few notable strengths. For instance, the study extended prior research (for review see Strauss et al., 2020) by including both checking unavailable and available conditions, several outcome measures (i.e., subjective, behavioural, and physiological) and multiple self-report measures of anxiety and obsessive-compulsive features. Only a few studies have used dimensional approaches to examine checking behaviour (e.g., correlating traits with behaviour across participants), with the majority of past research using categorical approaches to examine checking behaviour (e.g., comparing groups of participants or patients versus controls) (Jacoby et al., 2014, 2016; Rotge et al., 2008, 2015; Sarawgi et al., 2013). While the study included a relatively large student sample for this type of experimental design, the study would have benefitted from collecting further sample characteristic data (e.g., ethnicity, socioeconomic status, mental health history, psychotropic drug use), in order to assess the sample's representation and generalisability. A few limitations of the study relate to not collecting diagnostic measures of subclinical anxiety and OCD (e.g., to assess disorder-specific anxiety/OCD and comorbidity), other measures of subjective report (i.e. confidence and/or uncertainty: Radomsky et al., 2014; Stern et al., 2013), checking (e.g. eye movements: Toffolo et al., 2013), and self-reported obsessional beliefs (e.g. inflated responsibility or harm). Further, the procedure used in the current study examined checking behaviour as motivated by the perceived need to be correct or right. As such, the visual discrimination and checking task is most likely related to domains of responsibility, perfectionism and uncertainty associated with anxiety and OCD. However, there are other anxiety and OCD-related themes (e.g., disgust/contamination) that might motivate checking behaviour that cannot be assessed using the current task (De Putter et al., 2017). Further, there was no cost associated with checking behaviour in the current task. Therefore, a "better safe than sorry" coping strategy may have motivated checking behaviour in this study. While checking can become costly for individuals with OCD in terms of time, effort, and adverse social consequences (Strauss et al., 2020), future research should adapt the Visual Discrimination and Viewing task to examine checking behaviour under cost.

In conclusion, higher self-reported anxiety and obsessive-compulsive features were associated with higher subjective ratings of unpleasantness and the urge to check during the task. Moreover, higher self-reported anxiety and obsessive-compulsive features related to general negative affect, uncertainty and perfectionism were associated with greater checking frequency during the task. Lastly, stronger obsessional beliefs about perfectionism and the need for certainty were found to predict poorer accuracy, slower reaction times, and engagement of the corrugator supercilii during the task. In sum, these findings demonstrate how different anxiety and obsessive-compulsive features, in particular perfectionism and the need for certainty, may relate to and maintain checking behaviour in low threat contexts, which likely has implications for models of excessive and persistent checking in anxiety and obsessive-compulsive disorders. These results support the notion that targeting the transdiagnostic features that maintain checking behaviour in anxiety and OCD is relevant for evidence-based treatments. For example, further efforts should be made to structure current evidence-based therapies to target core beliefs about perfectionism and the need for certainty that maintain cycles of compulsive checking and physiological distress associated with checking behaviours.

Preregistration and data statement

This study was not preregistered. All data and analyses have been made publicly available on the Open Science Framework and can be accessed at https://osf.io/ujcm3/.

Declaration of competing interest

The authors state no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijpsycho.2022.06.011.

References

Abramowitz, J.S., 1996. Variants of exposure and response prevention in the treatment of obsessive-compulsive disorder: a meta-analysis. Behav. Ther. 27 (4), 583–600.
American Psychiatric Association, 2013. DSM-5 Task Force, (5th ed.). American Psychiatric Publishing, Inc. https://doi.org/10.1176/appi.books.9780890425596.
Banca, P., Vestergaard, M.D., Rankov, V., Baek, K., Mitchell, S., Lapa, T., Voon, V., 2015. Evidence accumulation in obsessive-compulsive disorder: the role of uncertainty and monetary reward on perceptual decision-making thresholds. Neuropsychopharmacology 40 (5), 1192–1202.
Barlow, D.H., Farchione, T.J., Bullis, J.R., Gallagher, M.W., Murray-Latin, H., Sauer-Zavala, S., Cassiello-Robbins, C., 2017. The unified protocol for transdiagnostic treatment of emotional disorders compared with diagnosis-specific protocols for anxiety disorders: a randomized clinical trial. JAMA Psychiatry 74 (9), 875–884.
Bottesi, G., Ghisi, M., Sica, C., Freeston, M.H., 2017. Intolerance of uncertainty, not just right experiences, and compulsive checking: test of a moderated mediation model on a non-clinical sample. Compr. Psychiatry 73, 111–119.
Bouchard, C., Rhéaume, J., Ladouceur, R., 1999. Responsibility and perfectionism in OCD: an experimental study. Behav. Res. Ther. 37 (3), 239–248.
Cacioppo, J.T., Petty, R.E., Morris, K.J., 1985. Semantic, evaluative, and self-referent processing: memory, cognitive effort, and somatovisceral activity. Psychophysiology 22 (4), 371–384.
Cacioppo, J.T., Petty, R.E., Losch, M.E., Kim, H.S., 1986. Electromyographic activity over facial muscle regions can differentiate the valence and intensity of affective reactions. J. Pers. Soc. Psychol. 50 (2), 260–268.
Calleo, J., Hart, J., Björgvinsson, T., Stanley, M., 2010. Obsessions and worry beliefs in an inpatient OCD population. J. Anxiety Disord. 24, 903–908.
Carleton, R.N., 2016a. Fear of the unknown: one fear to rule them all? J. Anxiety Disord. 41, 5–21.
Carleton, R.N., 2016b. Into the unknown: a review and synthesis of contemporary models involving uncertainty. J. Anxiety Disord. 39, 30–43.
Coles, M.E., Ravid, A., 2016. Clinical presentation of not-just right experiences (NJREs) in individuals with OCD: characteristics and response to treatment. Behav. Res. Ther. 87, 182–187.
Coles, M.E., Frost, R.O., Heimberg, R.G., Rhéaume, J., 2003. "Not just right experiences": perfectionism, obsessive–compulsive features and general psychopathology. Behav. Res. Ther. 41 (6), 681–700.
De Putter, L.M., Van Yper, L., Koster, E.H., 2017. Obsessions and compulsions in the lab: a meta-analysis of procedures to induce symptoms of obsessive-compulsive disorder. Clin. Psychol. Rev. 52, 137–147.
Doron, G., Derby, D., Szepsenwol, O., Talmor, D., 2012. Flaws and all: exploring partner-focused obsessive-compulsive symptoms. J. Obsessive Compulsive Relat. Disord. 1, 234–243.
Dugas, M.J., Buhr, K., Ladouceur, R., 2004. The role of intolerance of uncertainty in etiology and maintenance of generalised anxiety disorder. In: Heimberg, R.G., Turk, C.L., Mennin, D.S. (Eds.), Generalised Anxiety Disorder: Advances in Research and Practice. Guilford Press, New York, NY, pp. 143–163.
Foa, E.B., Kozak, M.J., Salkovskis, P.M., Coles, M.E., Amir, N., 1998. The validation of a new obsessive-compulsive disorder scale: the obsessive-compulsive inventory. Psychol. Assess. 10 (3), 206–214.
Foa, E.B., Mathews, A., Abramowitz, J.S., Amir, N., Przeworski, A., Riggs, D.S., Filip, J. C., Alley, A., 2003. Do patients with obsessive-compulsive disorder have deficits in decision-making? Cogn. Ther. Res. 27 (4), 431–445.
Freeston, M.H., Rhéaume, J., Letarte, H., Dugas, M.J., Ladouceur, R., 1994. Why do people worry? Personal. Individ. Differ. 17 (6), 791–802.
Fridlund, A.J., Cacioppo, J.T., 1986. Guidelines for human electromyographic research. Psychophysiology 23 (5), 567–589.
Gillan, C.M., Fineberg, N.A., Robbins, T.W., 2017. A trans-diagnostic perspective on obsessive-compulsive disorder. Psychol. Med. 47 (9), 1528–1548.
Holaway, R.M., Heimberg, R.G., Coles, M.E., 2006. A comparison of intolerance of uncertainty in analogue obsessive-compulsive disorder and generalized anxiety disorder. J. Anxiety Disord. 20 (2), 158–174.
Jacoby, R.J., Abramowitz, J.S., Buck, B.E., Fabricant, L.E., 2014. How is the beads task related to intolerance of uncertainty in anxiety disorders? J. Anxiety Disord. 28 (6), 495–503.
Jacoby, R.J., Abramowitz, J.S., Reuman, L., Blakey, S.M., 2016. Enhancing the ecological validity of the beads task as a behavioral measure of intolerance of uncertainty. J. Anxiety Disord. 41, 43–49.
Jacoby, R.J., Reuman, L., Blakey, S.M., Hartsock, J., Abramowitz, J.S., 2019. "What if I make a mistake?": examining uncertainty-related distress when decisions may harm oneself vs. others. J. Obsessive-Compulsive Relat. Disord. 20, 50–58.
Julien, D., O'Connor, K.P., Aardema, F., Todorov, C., 2006. The specificity of belief domains in obsessive–compulsive symptom subtypes. Personal. Individ. Differ. 41 (7), 1205–1216.
Khawaja, N.G., McMahon, J., 2011. The relationship of meta-worry and intolerance of uncertainty with pathological worry, anxiety, and depression. Behav. Chang. 28 (4), 165–180.
Larsen, J.T., Norris, C.J., Cacioppo, J.T., 2003. Effects of positive and negative affect on electromyographic activity over zygomaticus major and corrugator supercilii. Psychophysiology 40 (5), 776–785.
Lazarov, A., Liberman, N., Hermesh, H., Dar, R., 2014. Seeking proxies for internal states in obsessive–compulsive disorder. J. Abnorm. Psychol. 123 (4), 695.
Lazarov, A., Cohen, T., Liberman, N., Dar, R., 2015. Can doubt attenuate access to internal states? Implications for obsessive-compulsive disorder. J. Behav. Ther. Exp. Psychiatry 49, 150–156.
Lind, C., Boschen, M.J., 2009. Intolerance of uncertainty mediates the relationship between responsibility beliefs and compulsive checking. J. Anxiety Disord. 23 (8), 1047–1052.
Lopatka, C., Rachman, S., 1995. Perceived responsibility and compulsive checking: an experimental analysis. Behav. Res. Ther. 33 (6), 673–684.
Marton, T., Samuels, J., Nestadt, P., Krasnow, J., Wang, Y., Shuler, M., Nestadt, G., 2019. Validating a dimension of doubt in decision-making: a proposed endophenotype for obsessive-compulsive disorder. PloS One 14 (6), e0218182.
McEvoy, P.M., Mahoney, A.E., 2012. To be sure, to be sure: intolerance of uncertainty mediates symptoms of various anxiety disorders and depression. Behav. Ther. 43 (3), 533–545.
Morriss, J., 2019. What do I do now? Intolerance of uncertainty is associated with discrete patterns of anticipatory physiological responding to different contexts. Psychophysiology 56 (9), e13396.
Morriss, J., Biagi, N., Dodd, H., 2020. Your guess is as good as mine: a registered report assessing physiological markers of fear and anxiety to the unknown in individuals with varying levels of intolerance of uncertainty. Int. J. Psychophysiol. 156, 93–104.
Morriss, J., Bradford, D.E., Wake, S., Biagi, N., Tanovic, E., Kaye, J.T., Joormann, J., 2021. Intolerance of uncertainty and physiological responses during instructed uncertain threat: a multi-lab investigation. Biol. Psychol. 108223.
Morriss, J., Biagi, N., Lonsdorf, T.B., Andreatta, M., 2021. The role of intolerance of uncertainty in the acquisition and extinction of reward. Eur. J. Neurosci. 53 (9), 3063–3071.
Norton, P.J., Philipp, L.M., 2008. Transdiagnostic approaches to the treatment of anxiety disorders: a quantitative review. Psychother. Theory Res. Pract. Train. 45 (2), 214–226.
Obsessive Compulsive Cognitions Working Group, 2005. Psychometric validation of the obsessive belief questionnaire and interpretation of intrusions inventory—part 2: factor analyses and testing of a brief version. Behav. Res. Ther. 43 (11), 1527–1542.
Peris, T.S., Rozenman, M., Bergman, R.L., Chang, S., O'Neill, J., Piacentini, J., 2017. Developmental and clinical predictors of comorbidity for youth with obsessive compulsive disorder. J. Psychiatr. Res. 93, 72–78.
Pittig, A., Treanor, M., LeBeau, R.T., Craske, M.G., 2018. The role of associative fear and avoidance learning in anxiety disorders: gaps and directions for future research. Neurosci. Biobehav. Rev. 88, 117–140.
Rachman, S., 2002. A cognitive theory of compulsive checking. Behav. Res. Ther. 40 (6), 625–639.
Radomsky, A.S., Dugas, M.J., Alcolado, G.M., Lavoie, S.L., 2014. When more is less: doubt, repetition, memory, metamemory, and compulsive checking in OCD. Behav. Res. Ther. 59, 30–39.
R Core Team, 2014. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.
Raines, A.M., Oglesby, M.E., Capron, D.W., Schmidt, N.B., 2014. Obsessive compulsive disorder and anxiety sensitivity: identification of specific relations among symptom dimensions. J. Obsessive-Compulsive Relat. Disord. 3 (2), 71–76.
Rector, N.A., Kamkar, K., Cassin, S.E., Ayearst, L.E., Laposa, J.M., 2011. Assessing excessive reassurance seeking in the anxiety disorders. J. Anxiety Disord. 25 (7), 911–917.
Rotge, J.Y., Clair, A.H., Jaafari, N., Hantouche, E.G., Pelissolo, A., Goillandeau, M., Aouizerate, B., 2008. A challenging task for assessment of checking behaviors in obsessive–compulsive disorder. Acta Psychiatr. Scand. 117 (6), 465–473.
Rotge, J.Y., Langbour, N., Dilharreguy, B., Bordessoulles, M., Guehl, D., Bioulac, B., Burbaud, P., 2015. Contextual and behavioral influences on uncertainty in obsessive-compulsive disorder. Cortex 62, 1–10.

Ruscio, A.M., Stein, D.J., Chiu, W.T., Kessler, R.C., 2010. The epidemiology of obsessive-compulsive disorder in the National Comorbidity Survey Replication. Mol. Psychiatry 15 (1), 53–63.
Salkovskis, P.M., Warwick, H.M., 1986. Morbid preoccupations, health anxiety and reassurance: a cognitive-behavioural approach to hypochondriasis. Behav. Res. Ther. 24 (5), 597–602.
Sarawgi, S., Oglesby, M.E., Cougle, J.R., 2013. Intolerance of uncertainty and obsessive-compulsive symptom expression. J. Behav. Ther. Exp. Psychiatry 44 (4), 456–462.
Shihata, S., McEvoy, P.M., Mullan, B.A., Carleton, R.N., 2016. Intolerance of uncertainty in emotional disorders: what uncertainties remain? J. Anxiety Disord. 41, 115–124.
Solnik, S., DeVita, P., Rider, P., Long, B., Hortobágyi, T., 2008. Teager-kaiser operator improves the accuracy of EMG onset detection independent of signal-to-noise ratio. Acta Bioeng. Biomech. 10 (2), 65.
Spielberger, C.D., Gorsuch, R.L., Lushene, R., Vagg, P.R., Jacobs, G.A., 1983. Manual for the State-Trait Anxiety Inventory. Consulting Psychologists Press, Palo Alto, CA.
Stern, E.R., Welsh, R.C., Gonzalez, R., Fitzgerald, K.D., Abelson, J.L., Taylor, S.F., 2013. Subjective uncertainty and limbic hyperactivation in obsessive-compulsive disorder. Hum. Brain Mapp. 34 (8), 1956–1970.
Strauss, A.Y., Fradkin, I., McNally, R.J., Linkovski, O., Anholt, G.E., Huppert, J.D., 2020. Why check? A meta-analysis of checking in obsessive-compulsive disorder: threat vs. distrust of senses. Clin. Psychol. Rev. 75, 101807.
Toffolo, M.B., van den Hout, M.A., Hooge, I.T., Engelhard, I.M., Cath, D.C., 2013. Mild uncertainty promotes checking behavior in subclinical obsessive-compulsive disorder. Clin. Psychol. Sci. 1 (2), 103–109.
Toffolo, M.B., Van Den Hout, M.A., Engelhard, I.M., Hooge, I.T., Cath, D.C., 2016. Patients with obsessive-compulsive disorder check excessively in response to mild uncertainty. Behav. Ther. 47 (4), 550–559.
Tolin, D.F., Abramowitz, J.S., Brigidi, B.D., Foa, E.B., 2003. Intolerance of uncertainty in obsessive-compulsive disorder. J. Anxiety Disord. 17 (2), 233–242.
Van Bennekom, M.J., De Koning, P.P., Gevonden, M.J., Kasanmoentalib, M.S., Denys, D., 2021. A virtual reality game to assess OCD symptoms. Front. Psych. 11, 1640.
Wake, S., van Reekum, C.M., Dodd, H., 2021. The effect of social anxiety on the acquisition and extinction of low-cost avoidance. Behav. Res. Ther. 146, 103967.
Whittal, M.L., Thordarson, D.S., McLean, P.D., 2005. Treatment of obsessive–compulsive disorder: cognitive behavior therapy vs. Exposure and response prevention. Behav. Res. Ther. 43 (12), 1559–1576.