**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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Abstract

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 APA, 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 & 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.

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 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 & 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 (IU) 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). IU 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 & Mahoney, 2012) and has been associated with checking compulsions across the literature (Bottesi et al., 2017; Calleo, Hart, Björgvinsson, & Stanley, 2010; Khawaja & McMahon, 2011; Sarawgi et al., 2013). A second transdiagnostic construct that has been associated with compulsive checking behaviour is perfectionism (Bouchard, Rheume, & Ladouceur, 1999; Julien, O’Connor, Aardema, & Todorov, 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, Frost, Heimberg, & Rhéaume, 2003).

Whilst 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. IU, 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 (Rotge et al., 2015; Toffolo et al., 2013), such as corrugator supercilii activity, which may be advantageous over self-reported measures in capturing arousal and negative affect (e.g. distress). Identifying transdiagnostic features of anxiety and OCD that maintain distress associated with increased checking behaviours will be important for accurate targeting of transdiagnostic features in anxiety and OCD that are relevant for evidence-based treatments such as exposure response prevention therapy (Gillan, Fineberg, & Robbins, 2017; Barlow et al., 2017; Norton & Phillip, 2008).

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 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, Petty, Losch, & Kim, 1986; Cacioppo, Petty & Morris, 1985; Larsen, Norris, & Cacioppo, 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. IU, 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. IU) 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. IU, 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 (Toffolo et al., 2016; Morriss, Biagi, & Dodd, 2020; 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 hand¹. 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 whilst 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. The session took approximately 60 minutes 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 Figure 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 x 600 with a 60 Hertz 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. 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

¹ 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.

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 Figure 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 – 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 Figure 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 that 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 that ranged from 1 ("not at all") to 9 ("extremely"). Subjective ratings were always 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 Working Memory Tasks

After the Visual Discrimination and Checking Task, participants were asked to complete three working memory tasks. The tasks were presented in a random order and consisted of Operation span (OSPAN), Reading span (RSPAN) and Symmetry span (SSPAN). For full details of these tasks, please see Oswald, McAbee, Redick, and Hambrick (2015).

2.5 Questionnaires

The following questionnaires were administered.

2.5.1 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 .94.

2.5.2 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 = .87.

2.5.3 Obsessive Beliefs Questionnaire, Perfectionism/Certainty Subscale

We administered the Perfectionism/Certainty Subscale of the Obsessive Beliefs Questionnaire (P/C OBQ) (OCCWG, 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 = .88.

2.5.4 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 = .82.

2.5.5 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 = .92.

2.6 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).

2.5 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 k Ω). 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 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).

2.9 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).

To make sure that checking frequency was not related to working memory capacity, correlations between checking frequency and working memory scores were conducted.

3. Results

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 were presented, compared to trials where identical stimuli were presented, $F(1, 87) = 4.35$, $p = .04$ (see Table 1 and Figure 3).

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 had been presented compared to when different stimuli had been presented during the trial, $F(1, 166.53) = 143.40$, $p < .00$ (see Table 1, Figure 4). Further, participants were significantly more accurate in their responses during the choice phase in trials where the opportunity to check was available compared to trials where opportunity to check was unavailable, $F(1, 164.88) = 5.19$, $p = .02$ (see Table 1 and Figure

4). However, there was not a significant stimulus (identical vs different) x check (check available vs check unavailable) interaction for answer accuracy during the choice phase, $F(1, 164.88) = .56, p = .46$.

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 were presented compared to trials where different stimuli were presented when choosing whether to check or not, $t(86) = -.516, p = .607$ (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 were presented compared to trials where different stimuli were presented, $F(1, 115.97) = .21, p = .65$ (see Table 1 and Figure 5). However, participants were significantly faster when providing a response during the choice phase in trials where the option to check was available compared to trials where the option to check was unavailable, $F(1, 88.60) = 25.14, p < .00$, (see Table 1 and Figure 5). There was not a significant stimulus (identical vs different) x check (check available vs check unavailable) interaction for reaction time when providing an answer during the choice phase, $F(1, 115.97) = 1.05, p = .31$.

3.2.5 Corrugator Supercilii

There was not a significant effect of stimulus (i.e., identical versus different) or a stimulus x second interaction for corrugator supercilii activity during the visual discrimination viewing period, Stimulus: $F(1, 1031.60) = 0.44, p = .51$; Stimulus x Second: $F(6, 325.14) = 0.40, p = .88$. There was a significant effect of Second, where corrugator supercilii activity was smallest during second 6 and second 7 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 2 and Figure 6A).

During the checking cue period of the task, corrugator supercilii activity was greater when the option to check was not available compared to when the option to check was available, $F(1, 969.23) = 5.97, p = .015$ (see Table 2 and Figure 6B). Further, there was a significant effect of Second, and corrugator supercilii was smallest during second 2, when the checking cue was removed, $F(2, 637.30) = 33.87, p < .001$. There was also a marginal Check x 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 compared to when the option to check was available, $p = .001$. There was not a significant difference in corrugator supercilii activity between trials where the option to check was available and trials where the option to check was unavailable during second 1, $p = .402$, and second 3, $p = .872$, of the checking cue period (see Table 2). No other significant main effects or interactions were observed for corrugator supercilii activity during the checking cue period of the task [stimulus: $F(1, 969.23) = .004, p = .951$; stimulus x check: $F(1, 969.23) = 1.51, p = .220$; stimulus x second $F(1, 637.30) = 1.08, p = .340$; stimulus x check x second $F(1, 637.30) = .324, p = .724$].

3.3 Analyses of Individual Differences

3.3.1 Self-reported ratings during the task

All the self-reported measures of individual differences (IUS, OCI-C, P/C OBQ, NJRE-Q-R, and the STAI-T) were significantly positively correlated with subjective ratings of the urge to check, p 's $< .031$, and feelings of unpleasantness, p 's $< .022$ (see Table 4). 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 $> .05$.

3.3.1 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 4). 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 4). 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 4). 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 4). No specificity was found for the anxiety and obsessive-compulsive self-report measures for checking frequency, $p's > .05$.

3.3.2 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 4). 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 answer accuracy, $p's > .05$.

3.3.3 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 where 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.

3.3.4 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 4). There were no other significant correlations between the self-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 $> .05$.

3.3.5 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 $r = .104$, 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 5).

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 $> .106$.

3.4 Relationship between Checking Frequency and Working Memory Capacity

There were no significant correlations between checking frequency (i.e., total checking frequency, checking frequency in identical stimuli trials, checking frequency in different stimuli trials, and differential (identical-different) checking frequency) and working memory capacity scores (OSPAN scores, RSPAN scores, SSPAN scores), max $r = .130$, min $p = .230$.

4. Discussion

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. All of the self-reported anxiety and obsessive-compulsive features mapped on to subjective ratings of unpleasantness and the urge to check during the task (i.e., IUS, NJRE-Q-R, OCI-C, P/C OBQ, and STAI-T). In addition, some of the self-reported anxiety and obsessive-compulsive features were associated with checking frequency during the task (i.e., IUS, P/C OBQ, STAI-T; but not OCI-C or NJRE-Q-R). Notably, perfectionism and the need for certainty (i.e., P/C OBQ) was the only self-report measure that was associated with accuracy, reaction time, and corrugator supercilii during 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 & Warick, 1986).

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). Notably, greater corrugator supercilii activity was found to cues that signalled that checking was unavailable, relative to checking being available. This result may reflect greater negative affect 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 the IUS 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 IUS, STAI-T, and P/C OBQ were associated with greater checking frequency during the task. Surprisingly, OCI-C and NJRE-Q-R, were not associated with checking frequency during the task, although the relationships between these variables was 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 (i.e., STAI-T), uncertainty (i.e., IUS), and perfectionism (i.e., P/C OBQ). OCI-C and NJRE-Q-R 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 OCI-C and NJRE-Q-R 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.

The P/C OBQ capturing perfectionism was the only self-report measure that was associated with accuracy, reaction time, and corrugator supercilii during the visual discrimination and checking task. More specifically, higher P/C OBQ predicted 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 P/C OBQ were more attentive and cautious 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 patients with anxiety and obsessive-compulsive disorder to exhibit slower reaction times when choosing to check (Rotge et al., 2008) and making decisions during perceptual tasks that require evidence accumulation (Banca et al., 2014; Jacoby et al., 2014; Marton et al., 2019). While there was little evidence of specificity of the P/C OBQ over the other self-report measures, it is striking that the P/C OBQ maps on to all of the dependent variables for the visual discrimination and checking task. The P/C OBQ scale represents perfectionistic and certainty-based obsessive beliefs (i.e., 'I must be certain of my decisions'), and these types of beliefs 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 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 versus exposure response prevention: (Abramowitz, 1996; Whittal, Thordarson & McLean, 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, 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 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).

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.

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Conflict of Interest Statement

The authors state no conflict of interest.

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/>

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Figure Captions

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

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

Figure 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.

Figure 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.

Figure 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.

Figure 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 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)	
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 accurate responses. Reaction time was measured in milliseconds.

Table 2

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 (μ V)	Identical	.026	-.017	.008	.065	.153	-.043	-.164	.030	-.139	.075	.030	-.039	.040
		(.196)	(.176)	(.158)	(.188)	(.233)	(.228)	(.299)	(.237)	(.293)	(.278)	(.250)	(.288)	(.351)
	Different	.042	-.023	.009	.077	.155	-.080	-.208	.004	-.173	.073	.046	-.066	.119
		(.230)	(.200)	(.170)	(.198)	(.210)	(.228)	(.314)	(.218)	(.322)	(.332)	(.254)	(.281)	(.337)

Note: Z-scored corrugator supercilii activity (μ V) measured in microvolts

Table 3

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		.503**	.674**	.388**	.684**
OCI-C			.320**	.435**	.373**
P/C OBQ				.311**	.495**
NJRE-Q-R					.266*

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

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

Table 4

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	.355**	.479**	.233*	.271*	.163	.115	-.121	-.037	.043	.111	.067	.105	.054	.015	.087	.123
OCI-C	.370**	.501**	.139	.165	.095	.076	-.193	-.097	.030	.019	-.009	-.026	-.060	-.079	-.100	.018
P/C OBQ	.232*	.245*	.16	.251*	.052	.238*	-.146	-.258*	.004	-.001	.146	.221*	.136	.186	.240*	.253*
NJRE-QR	.322**	.356**	.172	.191	.130	.061	-.167	-.090	-.136	-.061	-.088	-.151	-.177	-.036	-.080	-.019
STAI-T	.302**	.351**	.270*	.248*	.250*	-.026	-.054	-.207	.045	.155	.083	.138	.051	.108	.118	.120

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

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

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)

Table 5

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	-.078	-.052	.037	-.060	-.072	.005	.019	-.063	-.023
OCI-C	-.036	-.009	-.047	-.098	-.148	-.089	-.135	-.094	-.016
P/C OBQ	-.126	-.045	-.008	-.167	-.175	-.040	.233*	.131	.131
NJRE-Q-R	-.056	.044	.029	.084	-.024	-.053	-.082	-.103	-.063
STAI-T	.104	.048	.070	-.109	-.130	-.092	.001	-.081	-.017

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

A **B**