Relationship between Interoceptive Sensibility, Age, and COVID-19 Anxiety During the First National Lockdown in the United Kingdom

Jennifer Elliott and Gaby Pfeifer*

Leeds School of Social Sciences, Leeds Beckett University, Leeds, United Kingdom

* Correspondence should be addressed to Dr Gaby Pfeifer, g.pfeifer@leedsbeckett.ac.uk

Orchid ID: 0000 0002 8734 1255

Leeds Beckett University

City Campus

Leeds School of Social Sciences

Calverley Building, Room 815

Leeds LS1 3HE

Tel: +44 (0) 113 81 29918

Abstract

Objectives: Interoception refers to the multidimensional representation of the internal states of the body, including sensation, appraisal, integration, and regulation. COVID-19 targets internal respiratory, temperature and gastrointestinal systems, thus posing a threat to humans that causes anxiety. Here, we examined the relationship between interoceptive sensibility and COVID-19 anxiety during the first UK national lockdown, when uncertainties surrounding the virus were at their peak. **Methods:** Between April and July 2020, *N*=232 individuals across four age-categories completed questionnaires measuring interoceptive sensibility (BPQ-SF and MAIA-2), an adapted State-Trait-Anxiety Inventory (STAI) to assess COVID-19 anxiety, and a Perceived Quality of Life (QoL) questionnaire. **Results:** Higher scores on the BPQ-SF were related to higher levels of COVID-19 anxiety, while the MAIA-2 subscales Not Worrying, Attention Regulation, and Trusting of bodily signals were related to lower levels of COVID-19 anxiety. Age was related to lower levels of COVID-19 anxiety yet showed no significant (Bonferroni-corrected) relationship with interoceptive dimensions. Trait anxiety, Not Worrying, perceived quality of work, and COVID-19-related media consumption emerged as significant predictors of COVID-19 anxiety. **Conclusion:** Findings suggest that interoceptive dimensions differentially relate to COVID-19 anxiety irrespective of age, with implications for managing health anxiety and adaptive behaviour during a pandemic across the lifespan.

Keywords

Interoception, Aging, COVID-19, Anxiety, Mental Health, Pandemic

Introduction

Interoception is concerned with the ability to detect changes to internal bodily signals (Craig 2002), such as breathing, temperature, heart rate and gastrointestinal functions, all of which are likely to be affected by Corona virus disease (COVID-19). Symptoms of COVID-19 infection such as a high temperature, persistent cough, shortness of breath and fatigue are well documented (NHS, 2020, July 31; NHS, 2021, September 10), with some patients also reporting gastro-intestinal problems (Han et al, 2020). Since COVID-19 emerged rapidly as a new virus in the first quarter of 2020, uncertainty surrounding virus contraction, anticipation of symptoms, disease progression and outcome meant that the detection of apparent symptoms could be perceived by many as an existential threat, leading to a heightened state of anxiety (Office for National Statistics (ONS), 2020a). Individuals with higher COVID-19 anxiety are significantly more likely to experience somatic symptoms (Shevlin et al., 2020), suggesting a link between the perception of bodily sensations and one's emotional response.

The term "interoceptive sensibility" is commonly used to describe subjective (questionnaire-based) accounts concerning the perception and appraisal of internal bodily signals (Garfinkel et al., 2015). By contrast, "interoceptive accuracy" refers to an objective perception of bodily signals, typically focused on cardiac perception and measured using the heartbeat counting (Schandry, 1981) and/or the heartbeat discrimination task (Katkin et al., 1983). A third dimension described by Garfinkel et al., (2015) is "interoceptive awareness", defined as the metacognitive awareness of interoceptive accuracy. This dimension incorporates confidence ratings of one's own perceived performance on cardiac perception tasks and measures the relationship between objective (actual) interoceptive and metacognitive (perceived) ability. The present study used two questionnaires (MAIA-2; Mehling et al., 2018; BPQ-SF; Porges, 1993) to measure interoceptive sensibility. Using questionnaires facilitated data collection of a UK-wide and age-stratified sample during an unprecedented time of a national lockdown that

prevented face-to-face participant testing. Two questionnaires were included due the respective unidimensional versus multidimensional nature of the BPQ and MAIA-2, which have previously yielded divergent yet complementary findings (Murphy et al., 2018; Nusser et al., 2020; Pearson & Pfeifer, 2020). By relating interoceptive sensibility to COVID-19 anxiety, we aimed to extend existing cognitive explanations of anxiety and demonstrate a potential link to bodily sensitivity.

A critical factor for examining COVID-19 anxiety was that of age. COVID-19 is particularly dangerous for older adults who are at higher risk of severe disease (NHS, 2020, August 1), and mortality (ONS, 2020b), than young adults. Counterintuitively, findings have reported lower levels of COVID-19 anxiety among older adults, suggesting that older populations are susceptible to health concerns during the pandemic (Kwong et al., 2020; Vahia et al., 2020; García-Portilla et al., 2020). It is unclear which factors contribute to the age-related reduction in anxiety. Most explanations focus on cognitive, social, socio-economic and environmental changes that might have been more harshly experienced by the younger cohort, especially at the early stages of the COVID-19 outbreak when novelty and uncertainty around the virus were at the peak (Kwong et al., 2020; Vahia et al., 2020; García-Portilla et al., 2020). However, aging has previously been associated with better emotion regulation, evidenced by older adults rating sadness-inducing images as less negative compared to younger adults (Mikkelsen et al., 2018). Moreover, a longitudinal study showed a progressive increase in emotional stability and well-being in a representative sample of older adults that was asked to rate the perception of day-to-day emotional experiences at different time-points between 1993 and 2005 (Carstensen et al., 2011). Here, we examine the biopsychological effects of age-related changes in interoception on emotional reactivity. Existing evidence regarding age-related changes in interoception is sparse and mixed: Three studies reported an age-related decrease in interoceptive accuracy (Khalsa et al., 2009; Murphy et al., 2018; Nusser et al., 2020), while

one study found no significant age differences in interoceptive accuracy (Mikkelsen et al., 2019). Age was also associated with poorer interoceptive sensibility when measured using the BPQ-SF (Murphy et al., 2018), while no relationship was found between age and three subscales of the MAIA (Noticing, Attention Regulation, and Body Listening; Nusser et al., 2020). In the present study we suggest that age-related changes in interoceptive sensibility might contribute to attenuated emotional responses in older individuals and manifest as lower COVID-19 anxiety. This is consistent with Mikkelsen et al., (2019), where young but not older adults showed a relationship between interoceptive accuracy and emotional responses to affective images, implying a potential disconnect between bodily sensitivity and emotional reactivity with age. Historically, the ability to detect bodily sensations forms the basis of our emotions, and the detection and appraisal of these sensations is an important part of our emotional experience (James, 1884). An existing body of evidence supports the direct link between interoception and anxiety disorders. In clinical populations, the heightened perception of bodily sensations has been related to health anxiety (Krautwurst et al., 2016). Moreover, panic disorder patients displayed enhanced cardiac awareness during heartbeat perception tasks (Ehlers, 1993). Positive relationships between interoceptive accuracy (Pollatos et al., 2009a; 2009b), and between interoceptive sensibility (Ewing et al., 2017; Murphy et al., 2020) and anxiety further indicate that interoception may have some influence on the underlying cause of anxiety.

The purpose of the present study was to investigate the factors predicting emotional reactivity in the form of anxiety, specifically in relation to COVID-19 during the first national lockdown in the UK. One factor that has received particular attention in the context of the pandemic is perceived quality of life (QoL). Existing research has examined the impact of COVID-19 on people's QoL, showing detrimental effects of the pandemic on social interactions, work and financial stability, and mental health (Lardone et al., 2020; Satici et al., 2020). However, the

opposite relationship also shows that perceived QoL can impact on stress management and coping with the pandemic (Park et al., 2020), suggesting that perceived QoL might contribute to COVID-19-related anxiety. Quality of life factors have included an individual's perceived social situation, financial well-being and exposure to COVID-19-related media (Park et al., 2020). Others have focused on environmental conditions, demonstrating, e.g., that the frequency of garden usage was related to improved physical and mental health during lockdown in older adults (Corley et al., 2021). Here, we included a perceived QoL questionnaire to further strengthen our model with factors contributing to COVID-19 anxiety alongside interoception, age, and trait anxiety. Compiling previous factors of perceived QoL (Park et al., 2020; Corley et al., 2021), we asked participants to rate the perceived quality of their work, environmental and social living conditions, physical health, financial situation, and the number of hours spent consuming COVID-19-related media.

Our study prompted a cross-sectional sample of young, middle-aged, and older participants to think of the COVID-19 pandemic when completing the State anxiety scale of the State-Trait-Anxiety Inventory (STAI; Spielberger, 1983), providing a measure of anxiety specifically related to COVID-19. Trait anxiety was measured using the Trait anxiety scale of the STAI. We hypothesised that higher Trait anxiety scores would be related to higher levels of COVID-19 anxiety. The Body Perception Questionnaire-Short Form (BPQ-SF; Porges, 1993) and the Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2; Mehling et al., 2018) were used to examine the uni- and multidimensional nature of interoceptive sensibility, respectively. The BPQ-SF is considered a unidimensional measure of interoceptive sensibility (Mehling et al., 2009; 2018), focusing primarily on the sensation of internal bodily states (e.g. "*During most situations, I am aware of how fast I am breathing*"). We hypothesised that, in the context of the pandemic where the subjective sensibility to bodily states might be distressing, higher scores on the BPQ-SF would be related to higher levels of COVID-19

anxiety. Concerning the MAIA-2 it was hypothesised that high scores for the subscales Noticing, Attention Regulation, Emotional Awareness and Body Listening would be related to high levels of COVID-19 anxiety, whilst high scores for the subscales Not Worrying, Not Distracting, Self-Regulation and Body Trusting would be related to lower levels of COVID-19 anxiety. This is because the latter subscales focus on the appraisal of bodily signals, with higher scores representing a positive evaluation of interoceptive states (Mehling et al, 2018) that is coupled with reduced emotional reactivity to stressful events. With most of the evidence pointing to an age-related decline in interoceptive accuracy (Khalsa et al., 2009; Murphy et al., 2018; Nusser et al., 2020) and sensibility (BPQ; Murphy et al., 2018), we hypothesised a negative relationship between age and interoceptive dimensions that are concerned with the more primary sensitivity to internal bodily signals, including the BPQ-SF and the MAIA-2 subscales Noticing, Attention Regulation, Emotional Awareness and Body Listening. Based on previous research showing an age-related reduction in emotional reactivity (Carstensen et al., 2011; Mikkelsen et al., 2018), it was hypothesised that higher age categories would be related to lower levels of COVID-19 anxiety. Finally, participants filled in a Perceived Quality of Life (QoL) questionnaire to examine the relationship with COVID-10 anxiety. We hypothesised that high scores on the perceived QoL measures work, environmental and social living, physical health and financial well-being would be related to lower levels of COVID-19 anxiety, while the number of hours consuming COVID-19-related media would be related to greater COVID-19 anxiety.

Method

Participants

A cross-sectional sample of UK residents (N=360) completed the questionnaires, distributed through the online survey platform, Qualtrics, (Qualtrics, Provo, UT;

http://www.qualtrics.com). Participants were recruited online through social media posts on Facebook, Twitter, Instagram, LinkedIn, and word of mouth. Exclusion criteria eliminated individuals with a known diagnosis of an Anxiety Disorder, based on self-disclosure by participants. The final sample consisted of *N*=232 participants (*N*=165, female) and included only completed responses. Demographic characteristics Age, Gender, Ethnicity and Education are shown in Table 1. Ethical approval was obtained from the Institutional Research Ethics Committee and complied with The British Psychological Society's (2018) Code of Ethics and Conduct. Participants completed an informed consent form before filling in the questionnaire.

-Table 1 here-

Measures and Procedure

Data collection took place via an online questionnaire powered by Qualtrics between April and July 2020. Participants gave demographic information regarding their age-category, gender, ethnicity and level of education before completing the following measures:

Body Perception Questionnaire-Short Form (BPQ-SF)

The Body Perception Questionnaire-Short Form (BPQ-SF; Porges 1993) was used to assess individual differences in interoceptive sensibility and consisted of 26 questions derived from the larger 45-item Body Awareness subscale of the BPQ. Participants indicated their level of awareness for bodily sensations by responding to statements such as "during most situations I am aware of an urge to clear my throat". A 5-point scale was used to measure responses ranging from 1 = "never" to 5 = "always".

Multi- dimensional Assessment of Interoceptive Awareness Version 2 (MAIA-2)

Multiple dimensions of interoception were assessed using the Multi- dimensional Assessment of Interoceptive Awareness Version 2 **(**MAIA-2; Mehling et al, 2018). This assessment

consisted of 37 items, divided into 8 different subscales that constituted 5 dimensions of interoceptive awareness (see Supplementary Table 1). Participants responded to each item of the scale by indicating how much the statement applied to their general life using a 6-point scale ranging from 0 = "never" to 5 = "always".

State Trait Anxiety Inventory (STAI)

Participants completed the State-Trait-Anxiety Inventory (STAI; Spielberger 1983). The STAI contained the Trait and State anxiety scales, both consisting of 20 items. The Trait anxiety scale contained statements to assess individual differences in proneness to anxiety, such as "I feel nervous and restless". A 4-point scale was used to measure responses ranging from 1 = "almost never" to 4 = "almost always". The State anxiety scale contained statements to assess the participants' emotional state in relation to their present state, such as "I feel strained". A 4-point scale was used to measure responses ranging from 1 = "not at all" to 4 = "very much so". While completing the State anxiety scale participants were prompted to specifically consider COVID-19, as follows: "Read each statement and then pick the appropriate number to indicate how you feel right now, that is, at this moment, ***as you think about the COVID 19 pandemic***".

Perceived Quality of Life (QoL)

To assess the effects of quality of life on COVID-19 anxiety, we devised a short, perceived quality of life (QoL) questionnaire (see Supplementary Table 2), asking participants to respond to descriptors and rate the perceived quality of their current work and financial situation, health status, and environmental and social living situation on a 5-point scale (1=poor quality; 5=high quality). Participants further indicated, using a 5-point scale, how many hours per day they spent consuming media related to the COVID-19 pandemic (1 = 0 hours; 2 = 0-1 hours; 3 = 1-2 hours; 4 = 2-3 hours; 5 = 3+ hours).

Statistical Analysis

Statistical analysis was carried out using SPSS v.26 (IBM Inc., Armonk, NY, USA). Reliability measures were computed on our sample for the BPQ-SF, MAIA-2 and STAI using Cronbach's alpha. A Kolmogorov-Smirnov test was performed on the variables Age, STAI, BPQ-SF, MAIA-2, and QoL perception scores, indicating a violation of the assumption of normality (p>.05) for 88.88% of the variables. Non-parametric Spearman's correlations (r_s) were performed to establish the relationship between the total scores of the STAI, the mean scores of the BPQ-SF and MAIA-2 subscales, QoL perception scores, and Age. Relationships with age were established using categorical scores, derived from the age stratifications on the questionnaire (Table 1). This resulted in 4 age categories coded as 1 (18-24 years), 2 (25-34 years), 3 (35-54 years), and 4 (55-76 years). Correlational analyses were Bonferroni-corrected and computed as one-tailed tests, consistent with the directional hypotheses. To examine the variables predicting COVID-19 State anxiety, a multiple regression analysis was carried out with COVID-19 State anxiety as the dependent variable. Trait anxiety, Age, BPQ-SF, the 8 MAIA-2 subscales and 6 QoL perception scores were included as predictors using the forced entry method. Assumptions of linearity, homoscedasticity, and independence of residuals were met for each variable. There was no evidence of influential outliers apparent (Cook's Distance < 1; Standardised Residuals < ± 3), and no indication of multicollinearity: the largest VIF factor was substantially below 10 (2.237 for MAIA-2 Self-Regulation), and the average VIF factor across the 17 variables was not substantially above 1 (1.39), indicating no cause for concern (Field, 2009). A significance level of p<0.05 was applied throughout the analyses, except for the Bonferroni-corrected Spearman Rho correlations where the significance threshold was set at $p\leq0.003$.

Results

Reliability measures

Adequate internal consistency was obtained for all questionnaire subscales, ranging from Cronbach's alpha 0.667 – 0.952. The BPQ-SF yielded a Cronbach's alpha of 0.951. Cronbach's alphas for the MAIA-2 ranged from 0.667 to 0.911 (0.782 for "Noticing"; 0.862 for "Not-distracting"; 0.667 for "Not-worrying"; 0.860 for "Attention regulation"; 0.841 for "Emotional awareness"; 0.809 for "Self-regulation"; 0.883 for "Body listening"; 0.911 for "Trusting"). Cronbach's alphas for the STAI were 0.952 for COVID-19 State anxiety and 0.947 for Trait anxiety.

Correlations

Table 2 presents the relationships between measures of Trait anxiety, interoception, QoL perception, Age, and COVID-19 State anxiety.

Trait anxiety: We found a significant positive relationship between Trait anxiety and COVID-19 State anxiety ($r_s = 0.702$, $p < 0.001$, $N = 232$).

Interoception: There was a significant positive relationship between scores of the BPQ-SF and COVID-19 State Anxiety ($r_s = 0.281$, $p < 0.001$, $N = 232$). We found no significant relationship (using the Bonferroni-threshold of $p \leq 0.003$), between COVID-19 State anxiety and scores of the MAIA-2 subscales "Noticing" ($r_s = 0.156$, $p = .009$, $N = 232$), "Emotion Awareness" ($r_s = 0.192$, $p = .025$, $N = 232$), and "Body Listening" ($r_s = 0.111$, $p = .045$, $N = 232$). Contrary to our prediction, COVID-19 State anxiety showed a significant negative relationship with scores of the MAIA-2's "Attention Regulation" subscale ($r_s = -0.179$, $p = 0.003$, $N = 232$). Consistent with our prediction, we found two significant (Bonferroni-corrected) negative relationships between MAIA-2 subscales focussing on the appraisal of bodily signals and COVID-19 State anxiety. Specifically, these relationships were found for "Not Worrying" ($r_s = -0.519$, $p < .001$, $N = 232$), and "Trusting" of body sensations ($r_s = -0.359$, $p < .001$, $N = 232$), while the relationships between COVID-19 State anxiety and the subscales "Not Distracting" (r_s

= −0.008, p = .449, N = 232) and "Self-Regulation" (r_s = −0.088, p = .092, N = 232) remained non-significant.

QoL Perception: Several significant negative relationships were found between COVID-19 State anxiety and scores on perceived quality of work (r_s= -0.318, p < .001, N = 232), environmental living (r_s= -0.232, p = .001, N = 232), social living (r_s= -0.215, p = .001, N = 232), physical health (r_s= -0.193, p = .002, N = 232), and financial well-being (r_s= -0.247, p < .001, N = 232). The number of hours spent consuming COVID-19-related media showed a significant positive relationship with COVID-19 State anxiety (r_s= 0.186, p = .002, N = 232).

Age: We found a weak negative relationship between age and the BPQ-SF that was non-significant at the Bonferroni-threshold of $p \leq 0.003$, (r_s= -0.119, p = .035, N = 232). None of the (Bonferroni-corrected) relationships between age and the MAIA-2 subscales were significant (Table 2), suggesting that age-categories were unrelated to interoceptive sensibility. Two significant positive relationships emerged between age-categories and the QoL perception scores work quality (r_s= 0.249, p < .001, N = 232) and environmental living (r_s= 0.240, p < .001, N = 232), suggesting an increase in perceived work quality and environmental living with age. Consistent with our prediction, age correlated significantly negatively with COVID-19 State anxiety (r_s= -0.334, p < .001, N = 232). However, age also showed a significant negative relationship with Trait anxiety (r_s= -0.344, p < .001, N = 232), suggesting that Trait anxiety might have been the driving factor in the negative relationship between age and COVID-19 State anxiety. To examine this further, a separate, non-parametric partial correlation analysis was computed between age and COVID-19 State anxiety while controlling for Trait anxiety. The result yielded a significant negative relationship between age and COVID-19 State anxiety (r_s= -0.139, p = .018, N = 232), demonstrating an age-related decline in COVID-19 anxiety even after controlling for Trait anxiety.

-Table 2 here-

Multiple Regression

Trait anxiety, Age, interoceptive sensibility (BPQ-SF and subscales of the MAIA-2), and QoL perception as predictors of COVID-19 State anxiety.

The multiple regression model was significant and explained 66.2% of the variance in COVID-19 State anxiety ($F(17,214)=24.61$, $p<0.001$, $R^2 = 0.662$). Table 3 shows the beta coefficients *B*, including standard errors of *B*, standardised betas β, and significance values for each predictor. Four of the 17 predictors contributed significantly to COVID-19 State anxiety: Trait anxiety was the best predictor ($\beta = 0.456$, $p<0.001$). This was followed by the MAIA-2 subscale Not Worrying ($\beta = -0.226$, $p<0.001$) and the Work quality perception score ($\beta = -0.136$, $p=0.003$), both emerging as significant negative predictors of COVID-19 State anxiety, while the number of hours consuming COVID-19-related media ($\beta = 0.143$, $p=0.001$) contributed significantly positively to COVID-19 State anxiety.

-Table 3 here-

Discussion

The present study examined the factors relating to COVID-19 anxiety, including interoceptive sensibility, age, trait anxiety, and perceived quality of life (QoL). Previous evidence suggested that older individuals experience lower levels of emotional distress concerning COVID-19 compared to younger cohorts (Kwong et al., 2020; Vahia et al., 2020; García-Portilla et al., 2020) despite an increased risk of severe illness (NHS, 2020, August 1), and mortality (ONS, 2020b) from COVID-19 infections, particularly at the early stages of the pandemic before vaccinations were offered. The reduced age-related COVID-19 anxiety has largely been explained by cognitive, social, socio-economic, and environmental factors. The central aim of the current research was to examine whether biopsychological factors such as interoception

might further explain reduced COVID-19 anxiety in a general population sample as well as in older individuals. We found that higher scores on the BPQ-SF awareness subscale were related to higher levels of COVID-19 anxiety in our population sample. This is consistent with previous reports of a positive relationship between the BPQ and anxiety, including trait anxiety (Ewing et al., 2017; Mehling et al., 2012; Murphy et al., 2020; Pollatos et al., 2009a; 2009b) and trait neuroticism (Pearson & Pfeifer, 2020). One explanation for this finding is that the one-dimensional nature of the BPQ has been likened to a proxy measure for anxiety symptoms (Mehling et al., 2009; 2018), focusing on the sensibility of internal bodily states including breathing, temperature, heart rate and gastrointestinal functions. With COVID-19 specifically targeting these internal bodily states (Han et al., 2020; NHS, 2020, July 31; NHS, 2021, September 10), our finding suggests that individuals scoring high for bodily sensitivity might have been more preoccupied with somatic sensations and experienced greater state anxiety around COVID-19. By contrast, scores on the MAIA-2 subscales Attention Regulation, Not Worrying, and Body Trusting correlated significantly negatively with COVID-19 anxiety. This supports the notion that higher-order interoceptive dimensions such as the ability to attend to, appraise, and trust one's bodily sensations facilitate the coping with stressors (Mehling et al., 2009) including COVID-19. Specifically, Not Worrying emerged as a strong predictor for reducing COVID-19 anxiety. This suggests that reduced worry about changing or discomforting physical sensations originating from inside the body might alleviate thoughts around worst-case health scenarios that are characteristic of health anxiety (Krautwurst et al., 2016).

Age was unrelated to any of the interoceptive measures, including the BPQ-SF and the MAIA-2. Yet, consistent with previous research, we replicated the significant negative relationship between age and COVID-19 anxiety (Kwong et al., 2020; Vahia et al., 2020; García-Portilla et al., 2020), even after controlling for trait anxiety. Together, these results suggest that, while

age was associated with reduced anxiety around COVID-19, there was no evidence of age-related changes in interoception that could explain the reduced anxiety. However, several caveats need to be considered with this finding. Firstly, a limitation of the present study was the use of categorical measures of age, which might have masked any significant relationships with interoceptive dimensions measured using the BPQ-SF and MAIA-2. It should also be noted that our study used a cross-sectional design, raising potential concerns that any significant age-effects found (e.g. for COVID-19 state anxiety, trait anxiety and QoL) may reflect cohort effects. Secondly, the non-significant relationships between age and interoception were based on a stringent Bonferroni-threshold to correct for multiple comparisons with QoL and trait anxiety. When considering interoceptive sensibility and age independent of these measures, the BPQ-SF as well as the MAIA-2 subscale Body listening showed weak negative correlations with age at $p < 0.05$, suggesting a weak age-related decline in two interoceptive subscales. An age-related interoceptive decline has previously been reported, specifically within the dimension measuring the sensitivity to bodily sensations using either the BPQ-SF (Murphy et al., 2018) or heartbeat perception tasks (Khalsa et al., 2009; Murphy et al., 2018). The age-related decline in bodily sensitivity has been explained by neurophysiological changes in older adults, such as nerve atrophy in the central (Marner et al., 2003) and peripheral nervous system (Dorfman & Bosley, 1979; Verdu et al., 2000) affecting nerve conduction speed, as well as pervasive cardiovascular changes (Ferrari et al., 2003) that might impair the quality of perceived internal bodily sensations in older individuals (Pollatos et al., 2007). However, existing evidence for an age-related decline in the sensitivity to bodily sensations is still sparse and equivocal, e.g. one study found no age-difference in interoceptive accuracy (Mikkelsen et al., 2019). Similarly, regarding interoceptive sensibility, only one published study to date has examined age-related interoceptive changes using the MAIA (Nusser et al., 2020), and no significant age effect was found. However, Nusser et al.'s findings

were based on a composite score of three MAIA subscales (Noticing, Attention Regulation, and Body Listening), thus making it difficult to detect and disclose potential age-related changes in the three dimensions separately. Given the sparsity and the methodological differences in existing studies, further research is warranted to identify the specific age-related changes across multiple dimensions of interoception to determine their relationship with anxiety. Clinical research might also benefit from investigating anxiety treatment (i.e. psychotherapy, mind body therapies, pharmacological interventions) alongside measuring multidimensional interoceptive abilities. This might give clues about the effectiveness of interoceptive abilities as a potential alternative intervention in managing anxiety.

Consistent with our prediction, trait anxiety showed a strong positive correlation and emerged as the best predictor for COVID-19 anxiety in our population sample. A feasible explanation for this finding is that individuals scoring high for anxiety tend to appraise life events as more stressful and display reduced tolerance to uncertainty – a characteristic feature of pandemics. As demonstrated during the H1N1 swine flu pandemic, anxiety was highest in individuals who indicated low tolerance to uncertainty, and who rated the pandemic as more threatening (Taha et al., 2014). Second, dispositional anxiety was shown to be strongly related with health anxiety during the COVID-19 pandemic, as measured using the General Anxiety Disorder Scale in self-disclosed participants (Landi et al., 2020). The specific anxiety around health illustrates the tendency of trait anxious individuals to ruminate and worry about projected, undesirable health outcomes in the context of a pandemic and might explain the strong relationship between trait- and COVID-19 state anxiety in our study.

Perceived quality of life factors (QoL) were all significantly related with COVID-19 anxiety in our population sample, including perceived work quality, environmental and social living conditions, physical health, financial well-being, and the number of hours consuming COVID-19-related media. Specifically, higher work quality emerged as a significant predictor for *lower*

COVID-19 anxiety, while increased media consumption was a significant predictor for *increased* COVID-19 anxiety. Consistent with previous research, this suggests that people's perceived QoL can significantly influence stress management and coping with major uncertainties surrounding the pandemic (Park et al., 2020). The moderate negative relationship between work quality and COVID-19 anxiety might also reflect the timing of our investigation at the early stages of the pandemic when work situations have changed dramatically for many individuals. If these changes were perceived as positive (Weitzer et al., 2020), such as working from home, eliminating commute, reducing exposure to the virus, they might have played a major role in reducing anxiety around COVID-19. By contrast, if work quality was perceived as negative (furlough or job loss, home working associated with reduced productivity, additional caring responsibilities, lack of interaction with colleagues), they were likely to increase anxiety around COVID-19. Perhaps unsurprisingly, the increased number of hours consuming COVID-19-related media was associated with enhanced COVID-19 anxiety in our study. Media portrayal of pandemics and other catastrophic events have been shown to result in increased anxiety and stress responses (Garfin et al., 2020). Repeated media exposure continuously revives health-concerning images around COVID-19 and may exacerbate the perceived threat even among those at relatively low risk for contracting the virus such as healthy young adults. This was supported by our finding that age was unrelated to media consumption, ruling out the possibility that consuming COVID-19 media was confined to 'at risk' groups such as older individuals. The QoL factors work, and environmental living showed a positive relationship with age, suggesting that work and physical living conditions were rated more favourably with higher age. Speculatively, higher work quality scores might be related to the more stable and upward career patterns typically achieved by middle-age (Schellenberg et al., 2016), and to retirement in the older age categories who consequently perceived their work-situation as pleasant. Similarly, perceived QoL regarding environmental living was framed

around descriptors such as small community living and having direct access to outdoor spaces in our study. Usage of outdoor space has been shown to improve physical and mental health during lockdown in older adults (Corley et al., 2021) and may well have contributed to the overall reduced COVID-19 anxiety observed with age in our sample.

In summary, we demonstrated a link between interoceptive sensibility and COVID-19 anxiety in a representative population sample. Interoceptive sensibility was unrelated to age and thus unsuitable as an explanatory factor for the reduced COVID-19 anxiety in older individuals. Trait anxiety, perceived quality of life and media consumption around COVID-19 were all significantly associated with COVID-19 anxiety across age-groups. Concerning interoceptive abilities in our population sample, individuals with heightened bodily sensibility (measured using the BPQ-SF) experienced greater levels of COVID-19 anxiety, while individuals with greater attention regulation, trusting and reduced worry about bodily sensations (measured using the MAIA-2) experienced lower levels of COVID-19 anxiety. Individual differences in interoceptive processing may reflect behavioural decisions around reducing the risk of contracting COVID-19 (e.g. wearing a face covering, social distancing, etc.) and therefore raise important questions about best-practice guidance for individuals in protecting their physical and mental health during a pandemic. For example, individuals with high interoceptive accuracy showed greater emotional reactivity and demonstrated improved situational decision making (Dunn et al., 2010; see also Kandasamy et al., 2016). Impaired interoceptive abilities could therefore put individuals at higher risk of blunted emotional experiences that might affect responsible decision making to protect themselves and others against the virus. Future work should build on examining higher-order interoceptive dimensions including the appraisal, integration and regulation of bodily sensations (Chen et al., 2021; Mehling et al., 2012) to better characterise their relationship with emotional experiences and predict behaviour towards major threats such as a pandemic. Moreover,

systematic investigation into the age-related changes across multiple interoceptive dimensions is required to establish a link with emotional responses in older individuals and understand age-related adaptive behaviour towards major threats such as COVID-19.

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Table 1. Sociodemographic frequencies and percentages.

Measure	Type	N (%)
Age (categories)	18-24	42 (18.1)
	25-34	108 (46.6)
	35-54	51 (22.0)
	55-76	31 (13.4)
Gender	Male	67 (28.9)
	Female	165 (71.1)
Ethnicity	White	206 (88.8)
	Mixed/Multiple Ethnic Groups	11 (4.7)
	Asian/Asian British	11 (4.7)
	Black/African/Caribbean/ Black British	2 (0.9)
	Other Ethnic Group	1 (0.4)
	Prefer not to say	1 (0.4)
Education	A level or equivalent	42 (21.1)
	Higher education degree	177 (78.5)
	Prefer not to say	1 (0.4)

Table 2. Correlation matrix showing relationships between measures of Trait anxiety, interoceptive sensibility (BPQ-SF and subscales of the MAIA-2), QoL perception, Age, and COVID-19 State anxiety.

	COVID-19 State anxiety	**Age**
Trait anxiety	0.702**	-0.344**
	< 0.001	*< 0.001*
BPQ-SF		
Body Awareness	0.281*	-0.119
	< 0.001	0.035
MAIA-2 subscales		
Noticing	0.156	-0.047
	0.009	0.237
Not Distracting	-0.008	-0.022
	0.449	0.368
Not Worrying	-0.519**	0.077
	< 0.001	0.120
Attention Regulation	-0.179*	0.003
	0.003	0.483
Emotion Awareness	0.192	-0.036
	0.025	0.293
Self-Regulation	-0.088	-0.069
	0.092	0.148

Body Listening	0.111	-0.119
	0.045	0.036
Body Trusting	-0.359**	0.035
	< 0.001	0.297
Quality of Life (QoL) Perception Scores		
Work Quality	-0.318**	0.249**
	< 0.001	*< 0.001*
Environmental Living	-0.232**	0.240**
	0.001	*< 0.001*
Social Living	-0.215**	0.048
	0.001	0.232
Health Quality	-0.193*	0.108
	0.002	0.051
Financial Quality	-0.247**	0.161
	< 0.001	0.007
Hours consuming COVID-19-related media	0.186*	0.088
	0.002	0.091
Age	-0.334**	1
	< 0.001	

Note: In each cell, the upper number corresponds to the Spearman Rho correlation coefficient r_s and the bottom number denotes the *p*-value (*Bonferroni*-corrected significant values are shown in italics; *$p \leq 0.003$, one-tailed; **$p \leq 0.001$, one-tailed). Scale correlations with Age are also presented.

Table 3. Regression model showing Trait anxiety, Age, MAIA-2 subscales and QoL perception variables as predictors of COVID-19 State anxiety.

	Variable	*B*	*SE B*	*β*	*p*
	Trait anxiety	0.482	0.063	0.456	*< 0.001**
	Age	-1.273	0.660	-0.089	0.055
BPQ-SF					
	Body Awareness	0.747	0.758	0.047	0.325
MAIA-2 subscales					
	Noticing	0.635	0.615	0.052	0.303
	Not Distracting	-0.060	0.580	-0.004	0.918
	Not Worrying	-3.491	0.734	-0.226	*< 0.001**
	Attention Regulation	0.142	0.782	0.010	0.856
	Emotion Awareness	0.680	0.719	0.053	0.346
	Self-Regulation	-1.109	0.768	-0.086	0.150
	Body Listening	0.734	0.603	0.070	0.225
	Body Trusting	-0.934	0.594	-0.093	0.099
QoL Perception Scores					
	Work Quality	-1.432	0.476	-0.136	*0.003**
	Environmental Living	-0.704	0.609	-0.052	0.249
	Social Living	-0.568	0.616	-0.043	0.358
	Health Quality	0.449	0.696	0.029	0.519
	Financial Quality	-0.940	0.946	-0.044	0.322
	Hours consuming COVID-19-related media	1.855	0.543	0.143	*0.001**

Significant results are shown in italics; *$p < 0.05$, 2-tailed.

Supplementary Table 1. Five dimensions and corresponding subscales of interoceptive awareness measured by the MAIA-2.

MAIA-2 Dimensions	Subscales
1. **Awareness of body sensations**	**'Noticing'** (4 items) The frequency of noticing bodily sensations, including statements such as "I notice when I am uncomfortable in my body".
2. **Emotional reaction and attentional response to sensations**	**'Not Distracting'** (6 items) The suppression or distraction from body sensations via statements such as "I ignore physical tension or discomfort until they become more severe". **'Not Worrying'** (5 items) Examining worry about unusual bodily sensations, by responding to statements such as "when I feel physical pain, I become upset".
3. **Capacity to regulate attention**	**'Attention Regulation'** (7 items) Levels of adaptive behaviours towards bodily sensations, using statements such as "I can pay attention to breath without being distracted by things happening around me".
4. **Awareness of mind body integration**	**'Emotional Awareness'** (5 items) The ability to recognise the connection between bodily sensations and emotions, e.g. "I notice how my body changes when I am angry". **'Self-regulation'** (4 items) The ability to regulate emotions, e.g. "When I feel overwhelmed, I can find a calm place inside" **'Body Listening'** (3 items) Levels of intuitive listening to bodily sensations via statements such as "I listen for information from my body about my emotional state".
5. **Trusting Body sensations**	**'Trusting'** (3 items), Trustworthiness of bodily sensations. Statements include "I feel my body is a safe place".

Supplementary Table 2. Five Quality of Life (QoL) perception dimensions.

QoL Dimensions	Descriptors and perception ratings
1. Work Quality	Descriptors: • I work from home • I go to my workplace. State number of hours at the work place per week: • Key worker. State profession: • Retired • Other: Perceived quality: • Please rate the perceived quality of your current work situation on a scale from 1 – 5, (1 = extremely low; 5 = extremely high). *In your rating, you may want to think about factors such as perceived convenience, productivity, risk and / or enjoyment of your current work situation.*
2. Environmental Living	Descriptors: • I have direct access to outdoor space (e.g. balcony or garden) • I live in a community with ▪ < 30.000 inhabitants ▪ 30.000 – 90.000 inhabitants ▪ 90.000 – 300.000 inhabitants ▪ 300.000 – 1 Mio inhabitants ▪ 1 Mio inhabitants Perceived quality: • Please rate the perceived quality of your current environmental living situation on a scale from 1 – 5, (1 = extremely low; 5 = extremely high).
3. Social Living	Descriptors: • I live alone • I live with one other person • I live with several others • I have additional caring responsibilities as a result of the COVID-19 crisis • Self-isolating • Other: Perceived quality: Please rate the perceived quality of your current social living situation on a scale from 1 – 5, (1 = extremely low; 5 = extremely high).

4. Health Quality	Descriptors: • I enjoy good health • I am considered high risk • I am showing symptoms (fever, dry cough) • I have been tested positive for COVID-19 • I have been tested negative for COVID-19 • Please provide the following details: • Height (cm): • Weight (kg): Perceived quality: Please rate the perceived quality of your current physical health on a scale from 1 – 5, (1 = extremely low; 5 = extremely high).
5. Financial Quality	Descriptors: Please think about your *current* financial situation (i.e. this may or may not have changed as a result of the COVID-19 crisis) Annual income: < 10k 10k – 20k 20k – 30k 30k – 40k 40k – 50k 50k – 100k > 100k Perceived quality: Under how much financial pressure do you perceive yourself in the current situation: 1 = absolute destitute (severe debt and no income) 2 =financial crisis (severe debt and not enough income to cover daily living) 3 = at risk of going into debt 4 = coping (under some financial pressure but manageable) 5 = no financial problems