The Coronavirus Anxiety Scale: Cross-National Measurement Invariance and Convergent Validity

Abstract

Coronavirus Anxiety Scale (CAS) is a brief and widely used measure, capturing somatic symptoms of coronavirus-related anxiety. In a large-scale collaboration spanning 60 countries and 21,513 respondents, we tested measurement invariance of the scale and the convergent validity of CAS scores in relation to other measures, namely the fear of COVID-19 (FCV-19S) and life satisfaction (SWLS-3) scales. Both conventional exact invariance tests and more recent alignment procedures (including weighted least squares and Bayesian versions) were utilized, demonstrating that the single-factor model fits the data sufficiently well in almost all countries. Partial scalar invariance was supported in a reduced set of 56 countries. To test the robustness of results, given the unbalanced samples, we employed both with and without replacement resampling techniques, and found the results were more stable in the larger samples. The alignment procedure demonstrated a high degree of measurement invariance – only 9% of the parameters were non-invariant. We also ran simulations of alignment with parameters estimated in the current model which demonstrated the reliability of the means, but indicated problematic estimation of the latent variances. Positive and strong correlations between CAS and FCV-19S estimated with three different approaches were found in almost all countries. Correlations of CAS and SWLS-3 were negative, but weak, and significantly differed from zero in several countries. Overall, the study supported measurement invariance and the convergent validity of CAS but highlighted issues with variance estimation.

Keywords: Coronavirus anxiety, measurement invariance, alignment, validity, culture.

Public significance statement. We found that the widely used Coronavirus Anxiety Scale is generally suitable for cross-national research. Given that previously its comparability was

questioned, the current study provided evidence of invariance making international comparisons of Coronavirus-related anxiety possible.

The Coronavirus Anxiety Scale: Cross-National Measurement Invariance and Convergent Validity

The SARs-CoV-2 (otherwise known as coronavirus or COVID-19) pandemic has had an unprecedented impact on psychological functioning of people worldwide (Aknin et al., 2022). Notably, fear and anxiety have been common responses to the ongoing pandemic (Luo et al., 2021; Salari et al., 2020), due to its novelty, uncertainty, and unpredictability, and the scope of impact and dramatic consequences of the COVID-19 crisis. Terms "fear of COVID-19" (Ahorsu et al., 2022) and "coronaphobia" (Asmundson & Taylor, 2020) have been used to describe intense fear and discomfort experienced when a person is exposed to COVID-19 information or when they are thinking about the COVID-19 disease.

The urgency of understanding mental health aspects of the COVID-19 outbreak has led to the development of a number of questionnaires aimed at assessing fear, anxiety, and stress related to coronavirus (for a review, please see Voitsidis et al., 2021). In the present paper, we focus on a five-item Coronavirus Anxiety Scale (CAS; Lee, 2020a), one of the most popular mental health questionnaires to have emerged during the pandemic (e.g., based on the Scopus the CAS received more than 100 citations in 2020, and close to 300 during 2021). We evaluate the cross-national measurement invariance of the CAS using samples from 60 countries, and examine the convergent validity of the CAS scores in relation to fear of COVID-19 and life satisfaction scores.

The Coronavirus Anxiety Scale

The CAS is an instrument designed at the onset of the pandemic (in March 2020) to assess coronavirus related anxiety (i.e., dysfunctional anxiety in the context of the ongoing pandemic). It was developed to serve as both a screening instrument and a survey measure,

helping health practitioners and researchers alike (Lee, 2020a). The CAS consists of the following five items: 1. I felt dizzy, lightheaded, or faint, when I read or listened to news about the coronavirus; 2. I had trouble falling or staying asleep because I was thinking about the coronavirus; 3. I felt paralyzed or frozen when I thought about or was exposed to information about the coronavirus; 4. I lost interest in eating when I thought about or was exposed to information about the coronavirus; and 5. I felt nauseous or had stomach problems when I thought about or was exposed to information about the coronavirus.

Item content shows that the CAS captures exclusively physical and physiological (i.e., somatic) components of coronavirus anxiety, namely dizziness (item 1), sleep disturbances (item 2), tonic immobility (item 3), appetite changes (item 4), and nausea and abdominal distress (item 5). None of the items include cognitive (e.g., worry), behavioral (e.g., avoidance), or emotional (e.g., fear) aspects of anxiety, although items referring to these features of anxiety were included in the initial pool of 20 candidate items. The five somatic items were included in the final version of the CAS because they had the strongest factor loadings on the first component of the principal component analysis, high pattern/structure and communality coefficients, as well as low cross-loadings. As argued by the author of the scale (Lee, 2020b), two CAS items (dizziness and tonic immobility) capture physiological arousal in response to coronavirus-related fear, two items (sleep disturbances and appetite loss) capture the somatic symptoms caused by intense, persistent worry about the coronavirus and are more closely associated with anxiety, whereas the fifth item (nausea and abdominal distress) captures somatic reactions resulting from either fear (e.g., thoughts of immediate danger) or anxiety (e.g., intense worry). Therefore, the choice of five items included in the final version of the CAS appears to be justified from both psychometrical and theoretical perspective.

The original study in an adult US sample (Lee, 2020a) supported high internal consistency of the CAS, a one-factor structure, convergent validity, and measurement invariance across gender and age. However, two items (item 2: sleep disturbances, and item 4: appetite changes) operated differently across Whites and non-Whites. More specifically, these two items had stronger loadings on the latent coronavirus anxiety factor among Whites than among the non-Whites (Lee, 2020a). A subsequent psychometric examination in a new adult US sample showed that the scale has good internal consistency and convergent validity, and a one-factor structure invariant across age, gender, and race (Lee et al., 2020).

The favorable psychometric properties in the initial studies and its brevity have helped make the CAS an increasingly popular measure of coronavirus-related anxiety during the pandemic. The scale has been translated in dozens of languages and psychometrically evaluated in numerous countries, such as Bangladesh (Ahmed et al., 2022), China (Chen et al., 2021), Cuba (Broche-Pérez et al., 2022), Poland (Skalski et al., 2021), Portugal (Magano et al., 2021), South Korea (Choi et al., 2022), and Turkey (Evren et al., 2022). Furthermore, the scale has been used in several studies examining mental health and well-being during the COVID-19 pandemic around the world, including some cross-national research (e.g., Linehan et al., 2020). In the majority of studies, the results of confirmatory factor analyses have supported the one-factor model of the CAS (Broche-Pérez et al., 2022; Choi et al., 2022; Evren et al., 2022; Lee, 2020c). However, in some countries modifications have been made (e.g., correlating residuals between a pair of items) to achieve an excellent model fit (see Ahmed et al, 2022; Magano et al., 2021; Vinaccia et al., 2022). Furthermore, in several studies the upper limit of the 90% confidence interval for the RMSEA was above the acceptable cut-off (i.e., .10) (Chen et al., 2021; Skalsi et

al., 2021). Therefore, the internal structure of the CAS warrants further research, as a simple one-factor solution does not hold in all countries.

The Importance of Testing Cross-National Measurement Invariance of the CAS

Despite the widespread use of the CAS in many countries, to our knowledge, its cross-national measurement invariance has been investigated only in two studies to date (Caycho-Rodríguez et al., 2022; Lieven, 2021), both of which have some important limitations. Caycho-Rodríguez and colleagues (2022) examined the factor structure and measurement invariance of the Spanish version of the CAS across 12 Latin American countries. The authors found that the original one-factor model fitted poorly in most countries (RMSEA values were above .10 in eleven out of twelve countries), and that residuals of item 4 (appetite loss) and item 5 (nausea and abdominal distress) were strongly associated. After removing item 5, the one-factor model of the abbreviated CAS (CAS-4) provided an excellent fit to the data in most countries. The authors tested the cross-national measurement invariance of the CAS-4 and concluded that both metric and scalar invariance were met, although the large drop in RMSEA between metric and configural model (.04) suggested that the metric invariance was not supported, and that testing for partial metric invariance should have been conducted. Another important limitation of this study is that convergent validity of the CAS scores in relation to other measures was not examined. Lieven (2021) investigated the measurement invariance of the CAS across 25 countries from six continents, and contrary to Caycho-Rodríguez et al. (2022) found that the original one-factor model provided acceptable or good fit to the data in all countries, and that this model was fully invariant across countries. However, this study also has some limitations, as the majority of countries were high-income, Western countries. Furthermore, Lieven's study also did

not include convergent measures. To sum up, the cross-cultural applicability of the CAS is still largely unknown, especially in non-Western countries.

There are several issues with the CAS's item content that raise a question whether this scale is appropriate for the assessment of coronavirus anxiety in different cultural settings. The CAS was developed in a Western context, i.e., on a sample of US adults and relying on the somatic symptoms of fear and anxiety typical for people in Western cultures. For example, the content validity of the CAS items in the original study (Lee, 2020a) has been supported by the relevance of the symptoms captured by the CAS for diagnoses of mental disorders such as panic disorder, generalized anxiety disorder, post-traumatic stress disorder, and major depressive disorder as defined within DSM-5 (APA, 2013), which has been repeatedly criticized as ethnocentric and culturally insensitive approach to mental disorders (e.g., Bredström, 2019; Marecek & Lafrance, 2021). Although physical and physiological symptoms are common features of anxiety worldwide (Kirmayer, 2001), the presentation, experience, and reporting of somatic symptoms of anxiety may vary substantially across cultures (Marques et al., 2011). For example, somatic symptoms appear to have a more central role in anxiety among individuals from non-Western cultures than from Western cultures (Lewis-Fernández et al., 2010). Another potential issue with the CAS is the inclusion of common somatic symptoms of depression, such as problems with sleep and appetite problems, which may be more frequently endorsed in non-Western cultures (e.g., Ryder et al., 2008). Cross-cultural variations in physical and physiological symptoms of anxiety warrants careful research on the cross-cultural validity of the CAS as a measure of coronavirus-related anxiety.

The Present Study

The main goal of the current study was to investigate the cross-national measurement invariance of the CAS across 60 countries. Measurement invariance is necessary to ensure that a given instrument measures the construct of interest in the same way across different groups. This becomes especially important: a) when the construct of interest appears to be ubiquitous (as it is related to the pandemic) and does not discriminate between groups; and b) when the groups comprise culturally diverse populations. In this case, translation of the questionnaire and cultural differences may affect a proper understanding of the items and could then reveal biased estimates of anxiety. Although it is unable to guarantee that the instrument's adaptations are paralell , measurement invariance tests provide evidence of similarity of its functioning (Leitgöb et al., 2022). In addition, we aimed to expand from previous research by examining the convergent validity of the CAS scores in relations to alternative measure of coronavirus-related mental health (Fear of COVID-19 Scale; FCV), and in relation to the abbreviated version of the most frequently used measure of subjective well-being (Satisfaction with Life Scale; SWLS).

Method

Participants and Procedure

The data was collected as part of a larger project led by [MASKED FOR REVIEW] at the [MASKED FOR REVIEW]. The project aimed at examining the impact and experiences of COVID-19 among young people and established adults in an international perspective across major geographical regions. Due to its exploratory nature, the current XX study was not preregistered. The study was approved by [MASKED FOR REVIEW] Ethical Committee. The samples in most countries were recruited using convenience and snowball sampling methods. The sample characteristics, the CAS mean scores, and Cronbach Alphas are listed in Online Supplementary Materials (OSM), Section A. In the course of data cleaning, we removed all

observations that contained more than three missed responses on the five CAS items. It reduced the sample size down to 21,513 respondents in 60 countries.

Measures

The Coronavirus Anxiety Scale (CAS; Lee, 2020a) consists of 5 items already described. Participants are asked to rate the frequency of each symptom over the last two weeks on a 5-point scale from "*Not at all*" to "*Nearly every day*".

The Fear of COVID-19 Scale (FCV-19S; Ahorsu et al., 2022) is a 7-item questionnaire (e.g., *It makes me uncomfortable to think about coronavirus-19*). Items are rated on a 7-point scale (from "*Strongly disagree*" to "*Strongly agree*").

The abbreviated, three-item version of the Satisfaction with Life Scale (SWLS-3; Kjell & Diener, 2021) was used to assess global life satisfaction. The SWLS-3 is a brief version of the original SWLS (Diener et al., 1985), and it includes the first three items of the original scale (*In most ways my life is close to my ideal*; *The conditions of my life are excellent*; *I am satisfied with my life*). Items are rated on a 7-point scale (from "*Strongly disagree*" to "*Strongly agree*").

Data Analysis

Descriptive analysis of the CAS items demonstrated highly skewed distributions in all the groups (for the distributions, see OSM Section B). The response option "*Not at all*" was chosen disproportionally more often than all the others (range 65% to 77% across items), and the second most chosen option was "Rare, less than a day or two" (10% to 19%), while the other options were chosen only occasionally ("Several days" 6% to 10%, "More than 7 days" and "Nearly every day over the last 2 weeks" 1% to 3% in the overall sample). The distribution of responses is expected as CAS measures severe conditions in the general population, but cannot be treated as a statistically normal distribution and the responses should be treated as categorical. However,

due to low frequencies of several response options combined with the small sample sizes in many groups, the corresponding contingency tables were sparse (i.e. contained multiple zero frequencies). The sparse response patterns are highly problematic for multiple group latent variable analyses (Forero & Maydeu-Olivares, 2009). Therefore, we could not model this as an ordinal categorical (polytomous) scale. Thus, we decided to dichotomize the responses into 0 for "Not at all" and 1 for "Rarely" combined with other response options (see Liu et al., 2017; DiStefano et al., 2021). Dichotomization did not lead to a substantial loss of information because the crucial meaningful source of variance came from the difference between occurrence and non-occurrence of the five symptoms.

Measurement Invariance

In order to test measurement invariance of the CAS we employed multiple approaches, because the samples were convenient and diverse, and the study included participants from very different populations. We used both conventional exact invariance tests, as well as a more recent procedure of alignment (Asparouhov & Muthen, 2022; Leitgöb et al., 2022), including weighted least squares and Bayesian versions. The test of the exact invariance with the dichotomous indicators involves comparison of the two models: configural and scalar (Wu & Estabrook, 2016) both estimated with weighted least squares mean and variance adjusted. The goodness of fit was indicated by CFI > .90 and RMSEA <.08 (Hu & Bentler, 1999). Configural model tests for an overall similarity of factor structure, whereas scalar invariance models require equality of the factor loadings and item thresholds across groups. If the difference between the fit of the two models lies within the cutoff values of ΔCFI < .008 and ΔRMSEA < .05 (Rutkowski & Svetina, 2017; ΔCFI comes from adding two cutoffs of .004 for factor loadings and threshold constraints), then full scalar invariance is indicated. The latter would imply comparability of the

unstandardized regression coefficients as well as latent means across groups. We also applied an alignment procedure because the diverse and large group differences were unlikely to show the exact measurement invariance. Alignment is an iterative procedure that estimates a configural model without any group constraints and, similar to the factor loadings rotation in exploratory factor analysis, finds the most invariant set of parameters possible without changing the model fit to the data (Asparouhov & Muthen, 2014; 2022).

Resampling Analysis

The sample sizes of groups were very different ranging from 48 respondents in Uganda up to 1,287 in Bangladesh. This might have caused unequal influence of different groups on the overall result of the measurement invariance tests (Yoon & Lai, 2018). Therefore, another robustness check was implemented. Specifically, we employed a resampling technique described by Yoon & Lai (2018). Resampling included drawing random samples of the equal size from each group (1) and fitting multiple group factor analysis using this new sample (2). Points 1 and 2 were repeated a large number of times (we used 500 runs), and finally, the fit statistics and estimated parameters were summarized across all the runs of the resampled models. The resampling technique was applied both to the conventional tests and to the alignment. One important limitation of this technique is that the resampled N gets as small as the smallest group in the data. Since our dataset contains groups with as little sample sizes as 48, we first dropped all the groups with the sample sizes below 99 observations. It resulted in 52 groups for the resampling analysis.

The resampling was performed in two ways. First, we precisely followed the instructions given by Yoon & Lai (2018) and sampled every group with the same number of observations, where N was equal to the smallest sample in the data. Secondly, we opted to use resampling *with*

replacement, so that the group sample sizes can be larger. This enabled the models to be estimated using indefinitely large samples, we chose to use 500 and 1000 observations per group. Finally, led by the inconclusive results of the planned tests, we ran a follow-up analysis applying several alternative methods of measurement invariance testing. The details are discussed in the corresponding section.

Convergent Validity

Another task was to relate the CAS to an established Fear of COVID scale, which is closely related to anxiety. A strong, positive association between the constructs was expected in every country. In order to test for the predictive cross-national validity, we also tested a link between CAS and satisfaction with life scale, which was expected to be negative in every country. Before testing the associations of the CAS with the other scales, measures invariance on these scales was also assessed. Therefore, we tested it using the already mentioned methods of exact, approximate (alignment) invariance, as well as with a resampling technique. Finally, we computed correlations of these latent variables. The analyses were conducted using Mplus 8.8 (Muthen & Muthen, 1998-2022) as well as R (R core team, 2022), in particular, 'lavaan' (Rosseel, 2012), 'MplusAutomation' (Hallquist & Wiley, 2021), 'MIE' (Rudnev, 2022), and other packages (for the full list of the packages see the OSM). All the reproduction codes are available at the Open Science Framework directory https://osf.io/7gnz9/?view_only=7c345b583bb247ceb45194f6efb40392

Results

Exact Invariance

We tested a simple one-factor model of CAS without any correlated residuals. Before checking for measurement invariance, we tested the model in each country separately. The

results are listed in OSM Section C. The model fit the data sufficiently well in almost all the countries – the χ^2 tests *p*-values were higher than .05 in all but seven countries. Six of those had relatively large sample sizes (> 300) and good model fit in terms of CFI and RMSEA, which made a significant χ^2 less relevant. The remaining samples came from Uganda and Taiwan which showed an unacceptable fit in terms of both RMSEA and χ^2. Also, despite the model having good fit to the data, the estimated factor's variance was negative in the Czech Republic sample. These three countries were dropped from further analysis. In addition, Mozambique was dropped because the preliminary multiple group models persistently estimated a negative variance of the CAS factor in this sample. The model using the pool of 56 remaining samples revealed a very good fit to the data, CFI/TLI = .998/.996, RMSEA = .042 (90% CI = .037, .047), SRMR = .018.

Next, we turned to testing the exact measurement invariance. Table 1 lists the results of the Multigroup Confirmatory Factor Analysis (MGCFA) model fit in 56 countries. Since the indicators were dichotomized, initially two models were run: configural, with factor loadings and item thresholds estimated freely across groups, and scalar, with both sets of parameters constrained to equality across groups. Intermediary metric invariance in case of binary indicators was not viable (Wu & Estabrook, 2016). The results showed that the configural invariance model had a very good fit to the data. Scalar invariance showed acceptable CFI and SRMR statistics, RMSEA was .085 which is higher than recommended upper cutoff value of .08 (Hu & Bentler, 1999). Scanning of parameter estimates in the configural model demonstrated that thresholds of item 1 (dizziness) and item 3 (tonic immobility) showed the largest differences across groups. Therefore, we fitted a partial invariance model (Byrne et al., 1989), withdrawing the equality constraints on these two items' thresholds. The partial invariance model included relaxed constraints on the two thresholds, at the same time the corresponding "scales" were fixed at 1.

This way, the model had the same number of degrees of freedom as the scalar model, but was less constrained.[1] The resulting partial invariance model had a good fit to the data across fit indices. The differences in CFI and RMSEA between configural and partial invariance models were within the recommended range (i.e., ΔCFI = .002, ΔRMSEA = .009). Other than that, scalar invariance model estimated non-significant variances of the latent factor in approximately half of the samples, which signals a problematic solution. Therefore, we can conclude that partial invariance could be supported and the means and regression coefficients of the COVID anxiety factor can be compared across cultural groups.

Resampling of the Exact Invariance Tests

As already mentioned, we applied two resampling approaches – without replacement and with replacements. To make these resampling solutions comparable to the non-resampled models, we further excluded four countries with the smallest samples (Costa Rica, Bosnia and Herzegovina, Nigeria, and Qatar, all N < 99), therefore, the number of countries was reduced to 52. The results are listed in Table 2.

Several notable points arose from this analysis. First, the conventional invariance tests on the slightly reduced sample showed almost identical results. Second, most of the resampled solutions included a large proportion of the non-positive definite matrices (NPD) which indicates that our solution might not be reliable. The share of runs containing at least one NPD was as high as 93% when each sample's N was 99, and it decreased with a higher N per group but even with sample sizes as large as 1000 per group share of NPD was very high, reaching 56% for the best fitting partial invariance model. Third, setting the admissibility of solutions apart, every resampling supported well-fitting configural models, rejected full scalar models, and confirmed

[1] In the delta parameterization for CFA with categorical indicators, scales are additional parameters replacing residuals which are normally not identified.

partial invariance as its fit was only slightly worse than the fit of the configural models. In resampling runs with N = 500 and 1000, the partial invariance model had a marginal value of RMSEA of .083 and .084 respectively. These results imply that if we had balanced and large samples in each country partial invariance would probably not be supported. This adds some ambiguity to the results, and together with a high percentage of inadmissible solutions, it asks for further robustness tests. Therefore, we turned to an approximate invariance using the alignment procedure. It required only the configural model which did not seem to be problematic concerning oversized or insignificant estimated variances.

Measurement Invariance Alignment of the CAS

First, the alignment procedure was estimated by the mean and variance adjusted weighted least squares method (WLSMV). The model fit is the same as the configural model (see Table 1). At first, we ran a free mode alignment, identified a group with a latent mean close to zero (Malaysia), and then ran a fixed mode alignment using the identified group as a baseline. The results of the alignment procedure are listed in Table 3. Only 9% of the parameters were non-invariant, which is substantially lower than the recommended upper cutoff of 25%. The most non-invariant parameter was threshold of item 1 (*dizziness*). It was non-invariant in 21 countries. Item 3 (*tonic immobility*) threshold was non-invariant in 14 countries. This coincides with the results of the partial invariance analysis. The other thresholds had negligible numbers of non-invariant countries, whereas all the factor loadings were fully invariant across 56 groups. Overall, the alignment demonstrated a high degree of approximate measurement invariance.

Given the previously mentioned inconsistencies of the results, we also ran simulations of alignment with parameters estimated in the current model (Asparouhov & Muthén, 2014). Simulations can demonstrate whether the current model is able to correctly estimate latent means

and variances. We ran simulations for different numbers of observations per group – 100, 500, and 1000. The general approach assumes a balanced design (equal sample sizes in each group), which is not the case in our data. This might have resulted in overly optimistic estimates of the reliability of alignment. Given the unbalanced nature of our data, actual sample sizes were used in the simulation as well. There were two measures of replication. For the first one, each set of estimated means is correlated with the one found in the true means, and then these correlations are averaged across all samples. Another way to aggregate the results is to compute average estimates across all the resampled samples, and only after that correlate these average estimates to the (true) means found in the alignment at the total sample. Both approaches should arrive at correlation equal or greater than .98 to support reliability of the alignment results (ibid.). The results for different sample sizes are listed in OSM, Section D. The simulations with actual N and N = 100 suffered from a large proportion of NPD solutions. It was not the case for balanced and larger samples though. The correlations of true and estimated means were acceptable (greater than .98) in balanced sample condition with N = 500 and higher. It follows that the latent means could have been reliable if the sampling was balanced, and the samples were at least 500 per group. But for the current sampling approach, the model might have slightly misestimated the latent means of the anxiety factor. In contrast, the correlations between true and estimated variances were extremely small, the highest estimated correlation for a balanced sample and N = 1000 was only .736. This result implies that the variances of the latent variables could not be reliably estimated by the current alignment model. Yet, the other measure of reliability of variances, correlation of average estimated variance with the population values, shows higher reliability, but again reaches an acceptable level only at N = 500.

Finally, we also applied resampling to the alignment. We successfully computed 491 resampled alignments (N = 500 for each group, with replacement)[2], which resulted in 500 sets of means for each of 52 groups. A total of 66% of the solutions had an NPD issue, yet the replication rates were high. The average correlation was .991 and its SD = .002. The correlation of average estimates with the true values was .999. As mentioned above, a similar method, but for simulations rather than resampling, was suggested by Asparouhov & Muthen (2014), who also provided a cutoff of .98 as a measure of successful replication. Although there are no correlation guidelines for the resampling, the correlations seem high enough to suggest that the results of alignment might have revealed the unbiased means. The correlations between the estimated in resampling and true variances were also very high (r = .999).

Overall, however, the results were inconclusive. On one hand, both exact invariance tests and alignment suggested a high degree of (approximate) invariance. On the other hand, however, the solutions contained many NPDs, means and variances were very different across methods. In order to add more certainty, we also ran a more flexible Bayesian alignment (Asparouhov & Muthen, 2014), maximum likelihood alignment, and Bayesian approximate invariance tests (BSEM – see details in Van de Schoot et al., 2014). The details of these analyses are listed in OSM Section D. The correlations between latent means and variances estimated with six different methods are listed in Table 4.

Again, the results demonstrated differences in the parameters estimated by different methods. The means estimated by different methods, including a simple group mean score, converge. The correlation between WLSMV alignment and partial exact invariance is .96. Figure

[2] Resampling using N = 99 without replacement resulted in 91% solutions with NPD, yet the correlations of true and replicated means were relatively high; correlation of averages with the true means was .999 (and r = .994 for variances), average of correlations with true means was .972 and SD = .007.

D1 in OSM demonstrates similarity of means estimated by these two methods and their similarity to simple mean scores. The rest of correlations of means are higher than .90. The only exception are means estimated by the full scalar model which is expected as mentioned above, the model was rejected and showed estimation problems.

Unlike the means, the estimation of variances produced very different results. The largest deviation of the estimated variances is shown by the mean scores (see Figure 1). Nevertheless, correlations of the factor variances estimated by partial invariance model and different methods of alignment are around .90 which is sufficient for most practical purposes. Overall, WLS alignment seems to represent the most consensual pattern of means and variances compared to all the other methods. Having in mind all of its limitations described above, we opted to use WLS alignment results for further analysis of convergent and predictive validity.

Convergent Validity of CAS

Before examining the relations between CAS with FCV-19S and SWLS-3 scales, the latter also needed to be tested for invariance across countries. Although both scales have been shown to be invariant across various countries in other studies (e.g, Sawicki et al., 2022), it was necessary to demonstrate it with the current data to ensure that the within-country correlations were not biased (requires metric invariance) and that country-level correlations can be interpreted (requires scalar invariance). The results listed in OSM Section E demonstrate that both scales had a fair level of approximate invariance that allows comparisons of covariances and means across countries.

Methodological triangulation was used given the inconsistent results of the tests of invariance and also to test the relations between CAS and the two criterion scales. That is, we applied three different strategies. The first strategy used predicted individual factor scores and

then computed correlations. The second strategy involved merging MGCFA models with established levels of invariance into a single MGCFA model and estimating covariances between latent variables simultaneously. Finally, we made use of the possibility of conducting alignment for the entire model with factors for CAS, SWLS-3, and FCV-19S. The results are summarized in Table 5 (for details see OSM Section F). The correlations between the two factors of the FCV-19S (physiological arousal and psychological distress) and CAS were positive and significant both at the individual and at the country level in all countries except Pakistan (as well as Nepal – for psychological distress factor and USA for physiological arousal factor). The exclusion of these countries, however, barely changed the results, which supported the convergent validity of CAS. Correlations of CAS with SWLS-3 were much weaker and less stable across countries. The average correlation across different methods was between –.07 and –.15, with large standard deviations pointing to their marginal difference from zero. Indeed, the correlation was significantly different from zero only in a small fraction of countries. However, in almost all groups, this correlation was consistently negative (Table 5). Thereby, we found a weak negative association, which partially supports our expectations with regard to the link between CAS and SWLS-3.

Finally, we checked how consistent the correlations are between different methods. Consistency (correlation of Fisher-standardized correlations estimated by different methods) of within-country correlations estimated with factor scores vs. MGCFA: was .97 (psychological distress factor); .97 (physiological arousal factor); .94 (life satisfaction). Likewise, meta-correlations based on estimates from alignment factor scores and MGCFA are .93; .80; .96; and the ones based on MGCFA and the common alignment are .93, .80, .96, respectively. Mean differences between values of correlation coefficients was .10 and .08 for physiological arousal

and psychological distress factors, respectively, and .04 for life satisfaction. Overall, the correlations were moderately consistent, being the physiological arousal factor of the FCV-19S the least stable correlation.

Discussion

The present study is the largest cross-national investigation of CAS to this date, examining the factor structure, measurement invariance and convergent validity of the scale on a sample of 21,513 respondents from all five continents and 60 countries. From a methodological standpoint, this is a first study to apply both exact and approximate approaches to testing measurement invariance of the CAS, and to examine cross-national associations between the CAS and two concurrent measures of mental health and well-being. The CAS is a new measure designed to assess COVID-19 related anxiety, but its content can easily be adapted for other health crises and negative life experiences. Furthermore, the CAS's brevity and ease of administration makes it a promising tool for large surveys and cross-cultural research. Therefore, testing its measurement invariance across a large set of countries can offer valuable insights for future cross-cultural research.

Overall, the scale demonstrated the theoretically expected single-factor structure in the vast majority of countries included in this research and showed consistent strong, positive associations with fear of COVID-19 and negative (albeit less consistent) links with satisfaction with life. The one-factor model of the CAS had a poor fit to the data only in a few samples, whereas an excellent fit was observed in the vast majority of countries. This is in line with the findings by Lieven (2021) that were drawn from 10,232 respondents across 25 countries. Low RMSEA values of the single-factor model observed in most countries in the present study were not in accordance with the results of Caycho-Rodríguez et al.'s study (2022), who found large

RMSEA values in eleven out of twelve Latin American countries. Although RMSEA values can be overestimated in models with small degrees of freedom (Kenny et al., 2015), such is the case with the one-factor model of the CAS (df = 5), these discrepancies in RMSEA values in our and Caycho-Rodríguez et al.'s study (2022) suggest that single-factor model might operate differently across samples, thus warranting further research on the CAS's structure. However, it is also important to note that our results are not directly comparable to previous research due to several methodological and statistical differences. Namely, Lieven (2021) and Caycho-Rodríguez et al. (2022) used maximum likelihood (ML) and robust ML method, respectively, whereas we relied on the WLSMV. The data collection in two previous cross-cultural studies were restricted to March 2021 (Lieven, 2021) and February-March 2021 (Caycho-Rodríguez et al., 2022). On the other hand we used data that was collected from the beginning until the end of 2021. Most importantly, we dichotomized the data and treated them as binary, whereas the earlier cross-national studies relied on the original five response options in their analyses.

The results of our study showed that cross-national measurement invariance of the CAS needs to be approached with caution and that alternative methods of assessing invariance should be considered when evaluating this scale across a wide range of countries. There were several important details which we explored in depth. First, the results of various approaches to testing measurement invariance of CAS resulted in generally optimistic but unstable results. Despite good fit of the models, they often arrived at inadmissible solutions and, depending on the method, varied in the estimated levels of COVID-19-related anxiety. In order to arrive at a stable result we applied a methodological triangulation which involves application of several methods to analyze the same data (Heesen et al., 2019). The results suggested that the most stable solution was found in Bayesian alignment.

Virtually all methods pointed on the lower invariance of thresholds for items relating to *dizziness* (item 1) and *tonic immobility* (item 3). These results indicate that these two symptoms appear across samples in different degrees regardless of the overall anxiety. In other words, it might imply that culture moderates the expression of anxiety through *dizziness* (feeling dizzy, lightheaded, faint) and *tonic immobility* (feeling paralyzed, frozen) or at least regulates the self-reports of these conditions. Contrary to the other items (sleep disturbances, appetite loss, nausea/abdominal distress) capturing somatic symptoms caused primarily by intense worry about the coronavirus, dizziness and tonic immobility refer to physiological arousal in response to intense fear. Both dizziness (and other dissociative symptoms; Schalinski et al., 2015) and tonic immobility (e.g., Abrams et al., 2008) might occur in situations of perceived inescapability, threat of death, and in the context of panic attacks. Although both dizziness and tonic immobility are involuntary, automatically activated defense behaviors (Kozlowska et al., 2015), they were assessed via self-report in the present study, which might bring out some cross-cultural differences in the catastrophic interpretation of these symptoms (see Hinton & Polack, 2009) and provoke culture-specific meanings of these bodily symptoms (Hofmann & Hinton, 2014). Furthermore, the linguistic meaning of dizzy/lightheaded/faint (item 1) and paralyzed/frozen (item 3) probably varies more across languages compared to sleeping (item 2) and eating problems (item 4) which refer to basic physiological needs essential for human survival. Thus, items referring to eating and sleeping can be expected to have higher translatability and a more similar meaning across languages as they capture motivational states with a high level of universality across languages (e.g., Saucier et al., 2014). In addition, nausea/stomach problems (item 5) are closely associated with an affective state of disgust also essential for survival

(Panksepp, 2007), and thus also can be expected to have less variation across languages than terms related to dizziness and tonic immobility.

The triangulated analysis of CAS association with fear of COVID-19 and satisfaction with life did not show exactly the same strength of correlation coefficients in every studied country, but these correlations' directions were consistent with our expectations. As expected, the coronavirus anxiety (as measured by the CAS) had strong positive correlations with physiological arousal and psychological distress factors of the Fear of COVID-19 scale, and weak negative correlations with satisfaction with life. The findings support the convergent validity of the CAS scores, as it has been shown that somatic symptoms of coronavirus anxiety are more closely associated with psychological and somatic aspects of COVID-19 related fear (i.e., FCV-19S) than with a measure of people's overall evaluation of their life. Life satisfaction judgments are relatively stable and strongly influenced by objective conditions and chronically accessible information (Pavot & Diener, 2008), thus weak correlations with context-specific fears and anxiety are expected. The magnitude of correlations between CAS and two FCV-19S factors found in the present research (mostly in the range from .50 to .60) is comparable to those observed in only a few previous studies that adopted a two-factor structure of the FCV-19S (e.g., Magano et al., 2021), and suggest that the CAS and FCV-19S measure related, yet distinct constructs. The CAS focuses exclusively on somatic aspects of anxiety, whereas the FCV-19S includes items covering somatic symptoms of fear (insomnia, heart palpitations, and clammy hands), but also psychological aspects (being afraid, uncomfortable, afraid to die, and nervous/anxious), thus their relatively modest intercorrelation is as expected.

Based on our results and some previous findings on the structure of the FCV-19S (e.g., Sawicki et al., 2022) and the CAS (Lieven, 2021) across cultures, it can be concluded that the

CAS is a better alternative for cross-cultural research than FCV-19S. However, it has to be noted that the CAS is limited in its scope (no psychological, cognitive, or social dimensions of anxiety are included), so it would be preferable to complement this scale with measures that capture other aspects of anxiety beyond somatic symptoms.

Constraints on Generality

Several important limitations of the present study should be noted. First, although we covered a wide range of countries across the globe, the participants were recruited using convenience sampling and the samples in most countries included mostly young adults. This limits the generalizability of our findings as anxiety symptoms might differ substantially across age groups (e.g., Carlucci et al., 2018; Teachman & Gordon, 2009). Second, the sample sizes varied greatly across countries, which poses a challenge to testing cross-national measurement invariance. Previous studies have shown that unequal sample sizes across groups might jeopardize the results of invariance testing and lead to biased invariance findings (Yoon & Lai, 2018). Although we applied a resampling strategy (i.e., random samples of balanced groups), future studies should aim to recruit more balanced samples across cultures in terms of gender, age, and socioeconomic status. Third, the convergent validity of the CAS scores were tested only in relation to life satisfaction and fear of COVID-19. Future studies should strive to examine the relationships between the CAS and other well-established measures of anxiety (for a review of self-report anxiety scales see Wall & Lee, 2022). Finally, we did not explore potential factors that might have influenced the measurement invariance results, i.e., source of non-invariance of items 1 and 3. A recently developed procedure for disentangling different sources of item bias - the culture, comprehension, and translation bias procedure (CCT; Bader et al., 2021) - might be a useful resource for future studies aimed at understanding whether the lack of invariance on

certain CAS items results from translation bias or from systematic differences in social and cultural contexts between groups. Despite these limitations, the present study suggests that the CAS is a valid measure of somatic symptoms of health-related anxiety for purposes of cross-national research.

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Table 1.

Fit Indices of the Exact Invariance Tests of the CAS

	CFI	ΔCFI	TLI	ΔTLI	RMSEA	ΔRMSEA	SRMR	ΔSRMR
Configural	.998		.995		.047		.033	
Full Scalar	.988	.010	.984	.011	.085	.038	.048	.015
Partial Scalar	.996	.002	.983	.002	.056	.009	.043	.010

Note. In the Partial Scalar model, threshold of items item 1 (dizziness) and item 3 (tonic immobility) are free.

Table 2.

Exact Measurement Invariance Tests with the Full and Resampled Data (Number of Runs is 500; Number of Groups is 52)

	χ^2 (SD)	CFI (SD)	TLI (SD)	RMSEA (SD)	SRMR (SD)	N converged replications	NPD matrix (% of replications)
Not resampled, reduced sample of groups, N=52							
Configural	502.1	.997	.995	.049 [.042, .055]	.032	converged	No NPD
Partial	945.4	.994	.993	.057 [.053, .062]	.042	converged	No NPD
Scalar	1631.1	.987	.984	.087 [.082, .091]	.047	converged	No NPD
Δ *Configural and Scalar*	*1128.9*	*.010*	*.011*	*.038*	*.015*		
Δ *Configural and Partial*	*443.2*	*.003*	*.002*	*.006*	*.010*		
Resampling without replacement, N per group = 99							
Configural	284.9 (20.1)	.999 (.001)	.998 (.001)	.028 (.014)	.055 (.003)	485	93%
Partial	529.0 (27.7)	.996 (.001)	.995 (.001)	.053 (.006)	.070 (.003)	488	93%
Scalar	653.7 (32.7)	.992 (.001)	.990 (.002)	.077 (.005)	.070 (.003)	477	93%
Δ *Configural and Scalar*	*368.7 (12.6)*	*.007 (.000)*	*.008 (.001)*	*.049 (.009)*	*.015 (.000)*		
Δ *Configural and Partial*	*244.0 (7.6)*	*.003 (.000)*	*.003 (.000)*	*.025 (.008)*	*.015 (.000)*		
Resampling with replacement, N rep per group = 500							

	χ^2 (SD)	CFI (SD)	TLI (SD)	RMSEA (SD)	SRMR (SD)	N converged replications	NPD matrix (% of replications)
Configural	928.6 (52.3)	.995 (.000)	.990 (.001)	.072 (.003)	.044 (.002)	500	71%
Partial	1831.5 (74.7)	.990 (.001)	.987 (.001)	.083 (.002)	.057 (.002)	500	59%
Scalar	2511.2 (92.3)	.984 (.001)	.980 (.001)	.101 (.002)	.058 (.002)	500	77%
Δ *Configural and Scalar*	*1582.5 (40.0)*	*.011 (.001)*	*.010 (.000)*	*.029 (.001)*	*.014 (.000)*		
Δ *Configural and Partial*	*902.9 (22.4)*	*.005 (.001)*	*.003 (.000)*	*.011 (.001)*	*.013 (.000)*		
Resampling with replacement, N rep per group = 1000							
Configural	1633.2 (72.7)	.995 (.000)	.989 (.001)	.073 (.002)	.041 (.001)	500	42%
Partial	3316.0 (101.2)	.989 (.001)	.986 (.001)	.084 (.001)	.053 (.001)	500	56%
Scalar	4692.8 (122.8)	.983 (.001)	.979 (.001)	.102 (.001)	.055 (.001)	500	77%
Δ *Configural and Scalar*	3059.5 (50.1)	.012 (.001)	.010 (.000)	.029 (.001)	.014 (.000)		
Δ *Configural and Partial*	1682.7 (28.5)	.006 (.001)	.003 (.000)	.011 (.001)	.012 (.000)		

Note. Degrees of freedom for Configural, Partial, and Scalar models re 260, 413, and 413, respectively.

Table 3.

The Results of the Fixed-Mode WLS Alignment of CAS

Parameter	Aligned estimated parameter	R^2	N nonvariant	List of countries with non-invariant parameters
Thresholds				
Dizziness	1.08	0.76	21	Afghanistan, Armenia, Bangladesh, Bulgaria, Colombia, Cyprus, Georgia, Germany, Indonesia, Iran, Israel, Lebanon, Malaysia, Nepal, Philippines, Poland, Romania, Singapore, Syria, Ukraine, Zambia
Sleep disturbances	0.55	0.82	7	Afghanistan, Brazil, Honduras, Lebanon, Philippines, Portugal, USA
Tonic immobility	1.33	0.74	14	Bosnia and Herzegovina, Brazil, Colombia, Cuba, Ecuador, Georgia, Germany, Honduras, Poland, Romania, Serbia, Singapore, Slovenia, Turkey
Appetite changes	0.88	0.93	3	Brazil, India, Japan
Nausea and abdominal distress	0.81	0.89	4	Kosovo[a], Romania, Slovakia, Vietnam
Loadings				
Dizziness	0.87	0.59	0	
Sleep disturbances	0.90	0.29	0	
Tonic immobility	0.91	0.52	0	
Appetite changes	0.91	0.61	0	
Nausea and abdominal distress	0.93	0.42	0	

Note. [a] Kosovo declared its independence from Serbia in 2008, but there is no consensus on its status as a state. As of December 2022, out of 193 United Nations member states, 117 countries do recognize Kosovo as an independent state, whereas 76 countries, including Serbia, do not.

Table 4.

Pearson Correlations Between the Latent Means (Below the Diagonal) and variances (Above the Diagonal) Estimated by Different Methods, N = 56.

	1	2	3	4	5	6	7	8	9	10
1. Mean score	-	.22	.28*	.28*	0.33*	.34*	.37**	.22	.17	.35**
2. Configural	NA	-	.77***	.45***	.72***	.65***	.68***	.59***	.54***	.63***
3. Partial	.96***	NA	-	.58***	.94***	.92***	.92***	.82***	.80***	.78***
4. Scalar	.73***	NA	.85***	-	.55***	.49***	.51***	.51***	.53***	.55***
5. Alignment WLS	.98***	NA	.96***	.74***	-	.97***	.98***	.89***	.86***	.87***
6. Alignment MLR	.90***	NA	.93***	.81***	.91***	-	.98***	.91***	.87***	.86***
7. Alignment Bayes	.89***	NA	.92***	.82***	.89***	.93***	-	.90***	.87***	.86***
8. BSEM approximate (configural)	.91***	NA	.93***	.81***	.90***	.97***	.94***	-	.94***	.88***
9. BSEM approximate (scalar)	.94***	NA	.95***	.82***	.92***	.95***	.94***	.97***	-	.85***
10. Alignment BSEM	.93***	NA	.95***	.83***	.92***	.96***	.94***	.98***	.99***	-

Note. NA – means are not available in exact configural model because they are fixed to zero for identification purposes. WLS = Weighted Least Squares. MLR = Robust Maximum Likelihood. BSEM = Bayesian Structural Equation Modeling.

Fit indices and other details of each model are provided in the OSM, Section D.

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 5.

Summary of relations between CAS, FCV-19S and SWLS-3 (excluding Pakistan)

	Correlations between the CAS and		
	Psychological distress (FCV-19S)	Physiological arousal (FCV-19S)	Life satisfaction (SWLS-3)
Factor scores (estimated with alignment) correlations			
Average individual-level correlation (SD)	.41 (.11)	.44 (.10)	–.10 (.09)
Correlation of means	.42**	.51***	–.15
N	50	50	49
Multiple group CFA (N= 52)[a]			
Average individual-level correlation (SD)	.55 (.14)	.51 (.17)	–.13 (.10)
Common alignment (N = 48)			
Average individual-level covariance (SD)	.53 (.14)	.47 (.15)	–.13 (.11)
Correlation of means	.63***	.40**	–.07

[a] Latent means were not available for FCV and SWLS-3 scales since the established models were metric, and thus the means were fixed to 0 in all the groups. Fit indices for the Multi-group CFA are: $\chi^2 = 6868.3$, df = 4620, CFI = .973, TLI = .968, RMSEA = .035, SRMR = .055.

** $p < .01$, *** $p < .001$