



# Psychometric validity and reliability of the 10- and 2-item Connor–Davidson resilience scales among a national sample of Americans responding to the Covid-19 pandemic: an item response theory analysis

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## Abstract

**Purpose** Psychometric validity/reliability of 10-item and 2-item abbreviations of the Connor–Davidson Resilience Scale (CD-RISC-10; CD-RISC-2) was investigated via item response theory and classic approaches.

**Methods** We sampled 5023 adult American participants in a June/July 2020 survey on the COVID-19 pandemic’s psychological effects. Our questionnaire incorporated the CD-RISC-10 with other validated measures. CD-RISC-10 items were ranked on item-to-scale correlations, loadings on a one-factor confirmatory factor analysis model, and item slope/threshold parameters plus information curves from a unidimensional graded response model. Concurrent validity of the highest ranked item pair was evaluated vis-à-vis the CD-RISC-10 and CD-RISC-2. Internal consistency, based on average variance extracted (AVE) and multiple reliability coefficients, was also compared. Convergent/divergent validity was tested by correlating anxiety, depression, fear of COVID-19, anxiety sensitivity, coping, and personality measures with both scales and the highest ranked item pair. Binary agreement/classification indexes assessed inter-rater reliability.

**Results** Items 2 and 9 from CD-RISC-10 ranked the highest. Reliability coefficients were  $> 0.93$ ,  $> 0.72$ , and  $> 0.82$  for the CD-RISC-10, CD-RISC-2, vs summation of items 2 and 9. AVEs were 0.66, 0.67, and 0.77. CD-RISC abbreviations and the summation of items 2 and 9 correlated negatively with anxiety ( $> -0.43$ ), depression ( $> -0.42$ ), and fear of COVID-19 ( $> -0.34$ ); positively with emotional stability ( $> 0.53$ ) and conscientiousness ( $> 0.40$ ). Compared to the CD-RISC-2, summative scores of items 2 and 9 more efficiently classified/discriminated high resilience on the CD-RISC-10.

**Conclusion** We confirmed construct validity/reliability of copyrighted CD-RISC abbreviations. The CD-RISC-10’s items 2 and 9 were psychometrically more salient than the CD-RISC-2.

**Keywords** COVID-19 pandemic · CD-RISC-10 · CD-RISC-2 · Resilience · Item response theory · Graded response model

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## Plain English summary

Two abbreviated Connor-Davidson Resilience Scales (CD-RISC-10; CD-RISC-2) have been validated for measuring resilience, namely the ability to adapt to, bounce back from, and even thrive after adversity. Experts disagree on which of many published resilience measures is the best one. Most studies show that the CD-RISC-10 captures resilience as a single, overall ability. Some recent studies, applying newer methods, find the CD-RISC-10 to represent more than one facet of resilience. Thus, further research, using modern approaches, is needed. We re-evaluated CD-RISC-10 and CD-RISC-2 scales via item response theory. We studied the extent to which the CD-RISC-10 captures “overall” resilience versus multiple domains, and whether the CD-RISC-2 contains the strongest pair out of all CD-RISC-10 items. Our intention was to contribute towards improved resilience measures. We sampled 5023 adult Americans facing the COVID-19 pandemic. Our findings confirmed that the CD-RISC-10 accurately measures “overall” resilience. Study participants rated another item pair (CD-RISC-10 items 2 and 9) as superior to the CD-RISC-2 in capturing resilience towards the surging pandemic. The scales inefficiently captured high resilience. This calls for new measures that more efficiently capture high-end resilience plus the varying flavors of resilience utilized in adapting to different adversities.

## Introduction

There is growing interest in *resilience*, broadly defined an individual’s capacity to adapt, bounce back and potentially even thrive after experiencing adversity [1–4]. Research frequently shows that resilience directly or indirectly influences individual and social well-being indicators [5, 6], hence the increased focus on this construct. Resilience is a vital component in the optimal functioning of healthcare professionals [7, 8], corporate leaders [9], military personnel [10], first responders [11], educationists [12], and the general community at large [13]. This is especially the case following stressful events such as the global 2019 coronavirus disease (COVID-19) pandemic caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-Cov-2) [14–17].

Metrics of resilience in the literature include the Connor–Davidson Resilience Scale (CD-RISC), Resilience Scale for Adults, Brief Resilience Scale, and Five-by-Five Resilience Scale [18–21]. There is no “gold standard” measure of individual resilience [19]. Lack of consensus on the most suitable resilience measure limits deeper research into factors influencing depletion, gain/regain, conservation, and/or growth/cultivation of resilience. Of the existing measures, the CD-RISC ranks among the most validated [18–20]. It

was developed as a multi-factorial scale comprising five dimensions: (i) personal competence, high standards and tenacity; (ii) trust in one’s intuition, tolerance of negative affect and strengthening effects of stress; (iii) positive acceptance of change and secure relationships; (iv) control; and (v) spirituality [22]. Subsequent studies failed to replicate this five-factor structure [23–27], and its conceptual validity was weakened by items representing qualities that foster resilience but are not part of the core construct [28]. The 25-item scale (CD-RISC-25) was also initially validated [22] via outmoded methods (e.g., Kaiser–Guttman factor retention criterion, orthogonal rotation) [29]. The 10-item abbreviation (CD-RISC-10), developed by deleting items with tenuous conceptual validity and weak item-to-scale correlations [23], is mostly shown as uni- rather than multi-factorial [23, 25, 30–34]. However, some studies find a two-factor model superior to the single-factor model [35–37], suggesting further investigation of the scale is warranted. Moreover, validations of the CD-RISC-10 rarely exploit advantages of item response theory (IRT) [38–41] over classical test theory (CTT).<sup>1</sup> Two Rasch analyses of the CD-RISC-25 yielded 21- and 22- item revisions with good data fit but with ceiling effects that indicated poor capture of high resilience [42, 43]. Ehrich et al. (2017)’s Rasch partial credit model study of the CD-RISC-10 among Australian university students ( $N = 288$ ), found evidence of multiple factors and misfitting items not detected by CTT, leading authors to propose a shorter, 8-item abbreviation [44]. In contrast, Rasch analyses by Pulido-Martos et al. (2020) on a sample of Spanish citizens ( $N = 1011$ ) confirmed CD-RISC-10’s unifactorial structure [45]. Nevertheless, Heritage et al. (2021)’s Rasch rating scale model study among Canadian/Australian nursing students ( $N = 708$ ) did not support a unifactorial model, leading authors to propose a 7-item abbreviation [46]. Despite extant literature suggesting the graded response model (GRM) [47, 48] is a superior approach for Likert scales [49, 50], most IRT analyses of the CD-RISC-10 apply Rasch models. Heritage et al. (2021) advocated for using the GRM in future studies [46]. Lim et al. (2019)’s GRM study among older adults awaiting knee replacement surgery for osteoarthritis ( $N = 700$ ) supported the CD-RISC-10’s unifactorial structure but their report provided scanty details [51].

The present study primarily aimed to investigate the validity/reliability of unidimensional 10- [23], and 2-item abbreviations [52] of the Connor–Davidson Resilience scale (CD-RISC-10, and CD-RISC-2) [32, 33] using a GRM-based analysis to augment CTT findings. Secondly, we examined whether the copyrighted CD-RISC 2

<sup>1</sup> For detailed reviews of the advantages of IRT, refer to Hambleton et al. [38], de Ayala [40], and Millsap [41].

comprises the most valid and reliable pair out of the ten CD-RISC-10 items. Thirdly, if any pair of items ranked higher than the CD-RISC-2's contents, we aimed to test their concurrent validity and inter-rater reliability versus the traditional two-item scale. The purpose of this item validity, reliability, and calibration study of CD-RISC abbreviations was to contribute evidence towards eventual consensus regarding quantitative measurement of resilience. We intentionally did not focus on modifying the copyrighted scales. We hypothesized that the study would confirm the CD-RISC-10's unifactorial model and prove the CD-RISC-2's contents as the item duo with the strongest concurrent validity and inter-rater reliability. We further hypothesized that the CD-RISC-10 and CD-RISC-2 would exhibit robust convergent and divergent validity plus measurement invariance.

## Methods

### Study design

This was an in-depth psychometric validation and recalibration study nested within a prospective, observational study of a nationwide cohort of Americans responding to the COVID-19 pandemic. The parent project was approved by the Institutional Review Board (IRB) at Baylor Scott and White Research Institute (protocol # 020-035). The IRB determined that, owing to the anonymous/de-identified nature of the survey, the study presented only minimal risk to participants and qualified for a waiver of the written informed consent requirement. Prospective participants first read a cover letter describing the study, the privacy/confidentiality of survey responses, and the free option not to respond if one did not consent to participating in the study. Informed consent was indicated by opting to answer the survey and to submit one's responses.

### Participants and recruitment procedure

Participants were English-speaking adult Americans (aged  $\geq 18$  years) who responded to an online survey-questionnaire distributed via the Qualtrics™ platform (Qualtrics, Inc.; Seattle, WA) across all states of the country from June 22 to July 5, 2020 [53]. The questionnaire assessed participants' psychological responses to the first surge of the COVID-19 pandemic. A total of 5023 participants were sampled. The Qualtrics platform eliminated invalid/incoherent responses. Questionnaires with incomplete responses ( $\approx 2.03\%$ ) were excluded from analysis.

### Study measures

**Reference scale** The CD-RISC-10 was our referent based on its superior validity/reliability among published CD-RISC versions [31, 45, 54]. It includes items 1, 4, 6, 7, 8, 11, 14, 16, 17, and 19 from the CD-RISC-25 [23]. Most studies find the CD-RISC-10 to have a unifactorial model [23, 25, 30–34] different from the 5-factor structure in the initial CD-RISC-25 validation [22]. Respondents rate, on a 5-point Likert spectrum from 0 (“not true at all”) to 4 (“true nearly all the time”), how frequently they achieve each of ten abilities (e.g., “able to adapt when changes occur”). Summating all items yields scale scores, with higher totals (minimum = 0, maximum = 40) implying greater resilience. We evaluated continuous CD-RISC-10 scores and binary dummy variables of “high” resilience. The “high resilience” threshold was one standard deviation above the sample's mean CD-RISC-10 score rounded to the nearest whole number (i.e., scores  $\geq 36$ ).

**Index scale** The CD-RISC-2 [52] was our index scale. It incorporates two items (“able to adapt when changes occur” and “tend to bounce back after... hardships”) [52], which are items 1 and 5 of the CD-RISC-10 [23]. Their inclusion in CD-RISC-2 was based on a subjective judgment that they best represent “adaptability” and “bouncing back”, the two concepts deemed most essential to defining resilience [52]. For the purposes of this study, we ranked CD-RISC-10 items on (a) item-to-scale correlations, (b) item difficulty indices, and (c) item information functions from a unidimensional GRM [47, 48]. Concurrent validity and inter-rater reliability of a summated score of the two highest ranking items was tested against the CD-RISC-10 and CD-RISC-2.

**Convergent and divergent validity** Polychoric correlations of abbreviated CD-RISC scales with subscales of the Brief COPE Inventory [55], and the Ten-Item Personality Inventory (TIPI)'s five subscales [56] were used to test convergent validity. Correlations of abbreviated CD-RISC scales with the seven-item Generalized Anxiety Disorder (GAD-7) scale [57], eight-item patient health questionnaire (PHQ-8) scale [58], seven-item Fear of COVID-19 (FCV-19) scale [59], and the Anxiety Sensitivity Index-3 (ASI-3) subscales [60], were used to demonstrate discriminant validity. Previous studies found resilience to be positively correlated with adaptive coping styles [61] and conscientious/extraverted personality [61] but negatively correlated with anxiety [31–33], depression [31–33, 62], anxiety sensitivity [63], and COVID-19 fear [64, 65].

**Internal consistency reliability** was assessed using ordinal coefficients alpha ( $\alpha$ ) and theta ( $\theta$ ) [66, 67], Cronbach's coefficient alpha ( $\alpha$ ) [68], McDonald's omega ( $\omega$ ) coefficient [69, 70], the Spearman-Brown formula [71, 72], and average variance extracted (AVE) [73]. AVEs  $\geq 0.50$  indicated adequate

convergence between items. Reliability coefficients  $\geq 0.70$  indicated high internal consistency [74].

*Sample characteristics and other contextual variables* The questionnaire included these demographics: gender, age, race/ethnicity, marital status, education level, occupation/profession, income, and years of experience in occupation/profession. Geographic variables were: residential zip code, metropolitan status of neighborhood, state of residence, and census region. Clinical information included prior medical/mental health history, comorbidities, and personal/family experience(s) of the COVID-19 pandemic (e.g., whether a participant had tested positive for the SARS-Cov-2 virus, knew someone with COVID-19, or had cared for patients with COVID-19).

### Statistical analysis strategy

The study dataset was randomly and equitably split 50:50 into derivation and validation subsamples ( $N = 2512$  and  $2511$ , respectively) to enable a split-sample internal validation strategy [75]. Demographics, geographic locales, personality traits, physical/mental health histories, and COVID-19 experiences were compared between derivation and validation subsamples. Lack of significant differences ( $p > 0.05$ ) in inter-subsample distributions of these variables was taken to confirm successful random partitioning. Bartlett's test of sphericity [76] and the Kaiser–Meyer–Olkin (KMO) test [77] assessed adequacy of the data as a source of factor-analytic correlation matrices.

We tested the assumption that the CD-RISC-10 measures only one dominant latent ability (i.e., *unidimensionality*) via inter-item correlations, parallel analysis [78], Velicer's minimum average partial (MAP) test [79], and confirmatory factor analysis (CFA) [74, 80]. The comparative fit index (CFI), Tucker–Lewis index (TLI) [81], and standardized root mean square of approximation (SRMR) [82] assessed CFA models' global fit to the data. Per Shi et al. (2020) [83], the SRMR was preferred over the root mean square error of approximation (RMSEA). Meeting a combined cutoff threshold of  $CFI \geq 0.95$ ,  $TLI \geq 0.95$ ,  $SRMR \leq 0.08$  [80], and standardized factor loadings  $> |0.400|$  [74] suggested that a scale's constituent items were “good” indicators of the latent trait. CFAs were based on polychoric correlations [84]. Robust maximum likelihood (MLR), means- and variance-adjusted weighted least square (WLSMV), and means- and variance-adjusted unweighted least squares (ULSMV) estimators were compared [85] to find the method yielding the best data fit. CD-RISC-10 items were ranked on CFA factor loadings, item-to-scale correlations, and item reliabilities.

A GRM was fitted to the CD-RISC-10 to derive item discriminant/difficulty indices plus Eigenvalues and to plot response option characteristic curves (OCCs) plus information function curves for scales/items. The GRM was the

preferred IRT model due to the polytomous, ordered categorical nature of the scale/items. For each scale item, 1 slope (discrimination,  $\alpha$ ) and 4 threshold ( $b$ ) parameters were estimated. Steeper  $\alpha$  parameters indicate which items more efficiently discriminate between respondents' resilience levels.  $\alpha$  values from 0.65–1.34 indicate “moderate”, 1.35–1.75 “high”, and  $> 1.76$  “very high” discrimination [86]. Item  $b$  parameters assessed the point on the resilience continuum at which a respondent was most likely to select each response option. Higher  $b$  values indicate more “difficult” options. Item response OCCs and item information function (IIF) plots visually illustrate how much psychometric information each item/scale captures. The generalized S- $\sum^2$  index assessed item goodness-of-fit in the GRM [87]. Significance for the S- $\sum^2$  index was set at  $p < 0.0001$  as scales were short [88]. Standardized local-dependence (LD)  $\sum^2$  statistics for item pairs test the assumption that each item contributes uniquely to the latent trait (resilience) measured (i.e., *local item independence*) [89]. LD statistics  $< |5|$  are small/inconsequential,  $|5|$  to  $|10|$  moderate/questionable, and  $> |10|$  large (i.e., indicating excessive residual covariance between  $\geq 2$  items not captured by the GRM). The assumption that probability of selecting higher response options rises with greater resilience (i.e., *monotonicity*) was tested via Mokken's  $H$  scalability coefficient [90] for each item/scale. Item scalability ( $H_i$ ) coefficients  $\geq 0.3$  and scale-level scalability ( $H_s$ ) coefficients  $\geq 0.5$  confirm monotonicity [91].

Mixed-effects logistic regressions of high resilience per the CD-RISC-10 scale (scores  $\geq 36$ ) on continuous 2-item scale scores were fitted to yield receiver operating characteristic (ROC) curves. ROC plots visually depicted the optimal cut-off thresholds on index scales that provide the best sensitivity in discriminating high CD-RISC-10 scores while maintaining high specificity. We employed these thresholds to delineate “high” resilience on index scales. Interrater reliability was assessed via percent agreement, kappa coefficients, Gwet's  $AC_1$  coefficient, Krippendorff's alpha, Brennan-Prediger coefficient [92], accuracy, sensitivity, specificity, positive predictive value, negative predictive value, plus areas under the ROC and precision-recall curves (PRCs) [93]. Measurement invariance of the CD-RISC-10 scale across subgroups of the sample was assessed via global fit indices of multi-group CFAs [94]. Statistical analyses were conducted using SAS® version 9.4 (SAS Inc, Cary, NC), R® version 3.6.0 (R Development Core Team, Vienna, Austria), and Mplus® version 8.6 (Muthén & Muthén, Los Angeles, CA).

**Table 1** Characteristics of the Study Sample

Respondent attribute	verall Study Sample (N= 5023)	Derivation Subsample (n= 2512)	Validation Subsample (n= 2511)	Significance (p)
<i>Gender, n (%)</i>				
Female	2,960 (58.9)	1,482 (59.0)	1,478 (58.9)	0.9730 <sup>a</sup>
Male	2,042 (40.7)	1,020 (40.6)	1,022 (40.7)	
Undisclosed	21 (0.4)	10 (0.4)	11 (0.4)	
<i>Age in years</i>				
median (Q <sub>1</sub> , Q <sub>3</sub> )	52 (38, 61)	52 (38, 61)	51 (38, 62)	0.5057 <sup>b</sup>
<i>Marital status, n (%)</i>				
Married/partnered	2806 (55.86)	1433 (57.05)	1373 (54.68)	0.5387 <sup>a</sup>
Single	1547 (30.80)	745 (29.66)	802 (31.94)	
Divorced/separated	630 (12.54)	318 (12.66)	312 (12.43)	
Undisclosed	40 (0.80)	16 (0.64)	24 (0.96)	
<i>Race/ethnicity, n (%)</i>				
White/Non-Hispanic	3,724 (74.14)	1,882 (74.92)	1842 (73.36)	0.4782 <sup>a</sup>
Black	392 (7.80)	184 (7.32)	208 (8.28)	
Hispanic	376 (7.49)	180 (7.17)	196 (7.81)	
Asian	359 (7.15)	185 (7.36)	174 (6.93)	
Other	172 (3.42)	81 (3.22)	91 (3.62)	
<i>Education level, n (%)</i>				
≤ 8th Grade	6 (0.12)	2 (0.08)	4 (0.16)	0.9147 <sup>a</sup>
9th – 11th Grade	34 (0.68)	16 (0.64)	18 (0.72)	
High school/GED®	615 (12.24)	318 (12.66)	297 (11.83)	
Vocational/technical	249 (4.96)	113 (4.50)	136 (5.42)	
Associate degree	1152 (22.93)	561 (22.33)	591 (23.54)	
Bachelor's degree	1648 (32.81)	849 (33.80)	799 (31.82)	
Advanced degree	1299 (25.86)	644 (25.64)	655 (26.09)	
Other	14 (0.28)	8 (0.32)	6 (0.24)	
Undisclosed	6 (0.12)	1 (0.04)	5 (0.20)	
<i>Income level, n (%)</i>				
< 30,000 \$	792 (15.77)	406 (16.16)	386 (15.37)	0.1194 <sup>a</sup>
30,000 to < 60,000 \$	1,166 (23.21)	554 (22.05)	612 (24.37)	
60,000 to < 100,000 \$	1,259 (25.06)	657 (26.15)	602 (23.97)	
≥ 100,000 \$	1,580 (31.46)	785 (31.25)	795 (31.66)	
Undisclosed	226 (4.50)	110 (4.38)	116 (4.62)	
<i>Occupation type, n (%)</i>				
Healthcare practitioner	1,419 (28.25)	699 (27.83)	720 (28.67)	0.3670 <sup>a</sup>
Essential worker	501 (9.97)	265 (10.55)	236 (9.40)	
General public	3,103 (61.78)	1,548 (61.62)	1,555 (61.93)	
<i>RUCA category, n (%)</i>				
Large metropolitan area	4457 (88.89)	2221 (88.59)	2236 (89.19)	0.8178 <sup>a</sup>
Suburban area	337 (6.72)	167 (6.66)	170 (6.78)	
Small town/rural area	220 (4.39)	119 (4.75)	101 (4.03)	
<i>Census region, n (%)</i>				
South	1,787 (35.58)	875 (34.83)	912 (36.32)	0.9219 <sup>a</sup>
North East	1,143 (22.76)	576 (22.93)	567 (22.58)	
West	1,070 (21.30)	556 (22.13)	514 (20.47)	
Midwest	993 (19.77)	489 (19.47)	504 (20.07)	
Puerto Rico & Islands	21 (0.42)	11 (0.44)	10 (0.40)	
Undisclosed	9 (0.18)	5 (0.20)	4 (0.16)	
<i>TIPI, median (Q<sub>1</sub>, Q<sub>3</sub>)</i>				

**Table 1** (continued)

Respondent attribute	verall Study Sample (N= 5023)	Derivation Subsample (n= 2512)	Validation Subsample (n= 2511)	Significance (p)
Agreeableness	5.5 (4.5, 6.5)	5.5 (4.5, 6.5)	5.5 (4.5, 6.5)	0.2529 <sup>b</sup>
Conscientiousness	6 (5, 7)	6 (5, 7)	6 (5, 7)	0.4069 <sup>b</sup>
Extraversion	4 (2.5, 5)	4 (2.5, 5)	4 (2.5, 5)	0.4087 <sup>b</sup>
Neuroticism	5 (4, 6.5)	5 (4, 6.5)	5 (4, 6.5)	0.4917 <sup>b</sup>
Openness	4.5 (4, 5.5)	4.5 (4, 5.5)	4.5 (4, 5.5)	0.5851 <sup>b</sup>
<i>H/o mental illness, n (%)</i>				
Depression	502 (9.99)	236 (9.39)	266 (10.59)	0.9646 <sup>a</sup>
Bipolar Disorder/Mania	113 (2.25)	61 (2.43)	52 (2.07)	0.9857 <sup>a</sup>
Generalized anxiety	428 (8.52)	198 (7.88)	230 (9.16)	0.9531 <sup>a</sup>
PTSD	158 (3.15)	77 (3.07)	81 (3.23)	0.9980 <sup>a</sup>
OCD	72 (1.43)	31 (1.23)	41 (1.63)	0.9724 <sup>a</sup>
Psychotic Disorder	29 (0.58)	20 (0.80)	9 (0.36)	0.9199 <sup>a</sup>
Any phobia	59 (1.17)	22 (0.88)	37 (1.47)	0.9285 <sup>a</sup>
Other	72 (1.45)	19 (0.76)	31 (1.23)	0.8973 <sup>a</sup>
<i>H/o medical illness, n (%)</i>				
Asthma/emphysema/COPD	308 (6.13)	148 (5.89)	160 (6.37)	0.9906 <sup>a</sup>
Diabetes Mellitus	315 (6.27)	149 (5.93)	166 (6.61)	0.9817 <sup>a</sup>
CVD/hypertension/CHF	685 (13.64)	334 (13.30)	351 (13.98)	0.9916 <sup>a</sup>
Chronic kidney disease	36 (0.70)	18 (0.72)	18 (0.72)	0.9998 <sup>a</sup>
Liver disease	35 (0.70)	16 (0.64)	19 (0.76)	0.9949 <sup>a</sup>
Cancer(s)	127 (2.53)	64 (2.55)	63 (2.51)	0.9998 <sup>a</sup>
<i>Exposure to COVID, n (%)</i>				
Tested Positive for COVID	67 (1.33)	37 (1.47)	30 (1.19)	0.6156 <sup>a</sup>
Cared for COVID Patients	619 (12.32)	305 (12.14)	314 (12.50)	0.6587 <sup>a</sup>
Knew Person with COVID	2,009 (40.00)	1,023 (40.72)	986 (39.27)	0.0867 <sup>a</sup>

CHF chronic heart failure, COPD chronic obstructive pulmonary disorder, COVID2019 Coronavirus Infectious Disease, CVD cardiovascular disease, GED® general educational development tests, H/o history of, OCD obsessive compulsive disorder, PTSD posttraumatic stress disorder, Q<sub>1</sub> first quartile; Q<sub>3</sub> third quartile, RUCAR rural–urban commuting areas, TIPITen-Item Personality Inventory

Key: <sup>a</sup>denotes a p-value for Chi-square test; <sup>b</sup>denotes a p-value for Kruskal–Wallis or Wilcoxon test

## Results

### Participants sampled

A total of 5023 out of 6461 initial respondents (77.74%) provided complete responses for the baseline survey [53]. As shown in Table 1, there were no significant differences in the distribution of sociodemographic, geographic, personality, and clinical attributes or COVID-related experiences between the overall sample and the two analysis sub-samples. Participants were predominantly (59%) female, white (74%), married or partnered (56%), educated up to college or beyond (59%), urbanized (89%), members of the general public (62%) (i.e., neither healthcare practitioners nor essential workers),

and earning \$60,000 or more annually (57%). The median ( $\pm$  interquartile range) age was 52 (38, 61) years. Just over 1% of respondents had personally tested positive for SARS-Cov-2. Almost one of eight (12% of) participants had cared for patients with COVID-19, and 40% knew someone who had been infected with the disease.

### Sample adequacy and number of extractable resilience factors

Bartlett's test of sphericity on CD-RISC-10 items within the derivation subsample was significant (Chi-square = 15.785;  $p < 0.0001$ ), indicating support for a single underlying latent factor. The KMO value for the CD-RISC-10 scale was 0.950, and values for all items (from 0.925 for item 2 to 0.963 for item 8) exceeded the

**Table 2** Score dispersion and inter-item correlations of the abbreviated Connor–Davidson resilience scale in the derivation subsample

CD-RISC-10 <sup>®</sup> Scale Item	Item Score Dispersion		Inter-item Polychoric Correlation, $\rho$ (SE)							Cronbach's alpha if the item is deleted				
	Mean ( $\pm$ SD)	Skewness Kurtosis	1	2	3	4	5	6	7		8	9	10	
1 “able to adapt when changes occur”	2.974 (.983)	-0.887 0.545	1.000											0.925
2 “can deal with whatever comes”	2.975 (.944)	-0.758 0.318	0.823 (.009)	1.000										0.922
3 “try to see humorous side of things”	2.665 (1.071)	-0.488 -0.358	0.545 (.017)	0.601 (.016)	1.000									0.931
4 “...stress can make me stronger”	2.652 (1.014)	-0.433 -0.252	0.605 (.016)	0.641 (.015)	0.615 (.015)	1.000								0.926
5 “tend to bounce back after... hardships”	3.022 (.979)	-0.932 0.590	0.659 (.014)	0.723 (.013)	0.567 (.016)	0.676 (.014)	1.000							0.924
6 “can achieve... goals, even if... obstacles”	2.986 (.953)	-0.813 0.397	0.650 (.015)	0.690 (.014)	0.530 (.017)	0.639 (.015)	0.717 (.013)	1.000						0.923
7 “Under pressure, I stay focused...”	2.807 (.988)	-0.650 0.093	0.672 (.014)	0.719 (.012)	0.517 (.017)	0.611 (.015)	0.660 (.014)	0.719 (.012)	1.000					0.923
8 “not easily discouraged by failure”	2.570 (1.102)	-0.456 -0.432	0.568 (.016)	0.624 (.015)	0.505 (.017)	0.570 (.016)	0.616 (.015)	0.650 (.014)	0.687 (.013)	1.000				0.927
9 “strong... when dealing with challenges”	2.978 (1.022)	-0.857 0.236	0.661 (.014)	0.721 (.013)	0.544 (.017)	0.627 (.015)	0.716 (.013)	0.754 (.011)	0.736 (.012)	0.696 (.013)	1.000			0.922
10 “able to handle unpleasant or painful feelings”	2.835 (1.032)	-0.734 0.121	0.642 (.015)	0.695 (.013)	0.525 (.017)	0.605 (.015)	0.686 (.013)	0.674 (.014)	0.680 (.013)	0.656 (.014)	0.772 (.011)	1.000		0.924

**Table 2** (continued)

CD-RISC-10 <sup>®</sup> Scale Item	Item Score Dispersion			Inter-item Polychoric Correlation, $\rho$ (SE)										Cronbach's alpha if the item is deleted
	Mean ( $\pm$ SD)	Skewness	Kurtosis	1	2	3	4	5	6	7	8	9	10	
Scale	Mean ( $\pm$ SD)	Percent Floor	Percent Ceiling	Item-to-Scale Polychoric Correlation, $\rho$ (SE)										Polychoric correlation, $\rho$ (SE), with CDRISC-10
CDRISC-10	28.463 (7.926)	0.70	6.60	0.831 (.008)	0.881 (.006)	0.737 (.010)	0.809 (.008)	0.853 (.007)	0.851 (.007)	0.852 (.007)	0.810 (.008)	0.878 (.006)	0.843 (.007)	1.000
CDRISC-2	5.996 (1.745)	1.30	24.70	0.943 (.004)	-	-	-	0.935 (.004)	-	-	-	-	-	0.908 (.004)
Summation of Items 2 and 9	5.953 (1.785)	1.20	25.00	-	0.949 (.003)	-	-	-	-	-	-	0.959 (.003)	-	0.936 (.003)

Key: CD-RISC-10 = Ten-item abbreviation of the Connor–Davidson resilience scale; SD = standard deviation; SE = standard error; © As the CD-RISC-10 is a proprietary scale protected by copyright, the brief phrases here do not reveal the entire framing of items

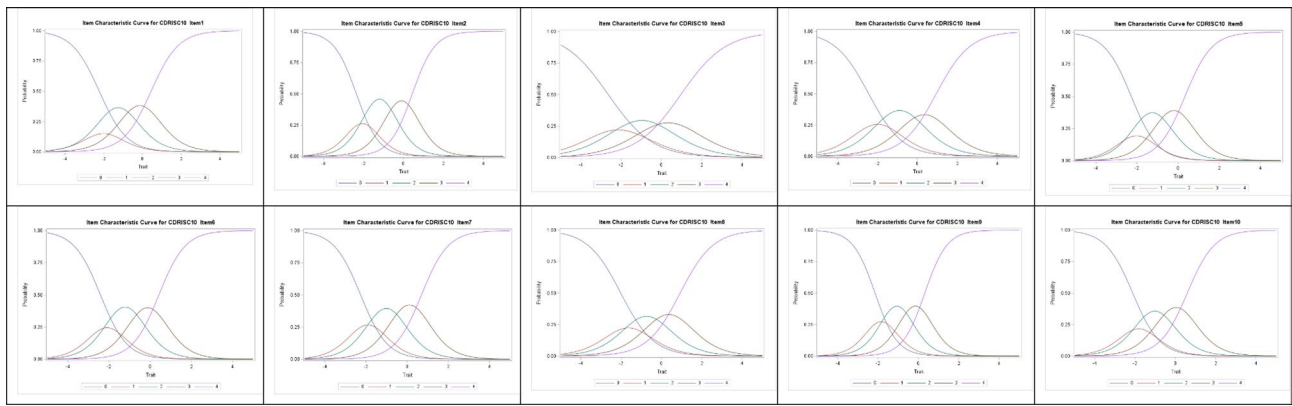
0.800 threshold of sampling adequacy for factor analysis. In Velicer’s MAP test on derivation data, the Eigenvalue of a first component (14.712) accounted for almost 100% of total variance. Parallel analysis also supported the CD-RISC-10 items being summarized with a single domain (i.e., *unidimensionality*).

**Item score distribution and item-level reliability**

Table 2 illustrates the CD-RISC-10-item score distributions and correlations within the derivation subsample. Mean ( $\pm$  standard deviation) item scores ranged from a low of 2.57 (1.10) on item 8 to a high of 3.02 (0.98) on item 5. Appendix B in the supplement lists the frequencies with which respondents endorsed various response options on the CD-RISC-10 items. As tests for normality (e.g., Kolmogorov-Smirnoff D test, Anderson–Darling test, and Shapiro–Wilk W test) were all significant ( $p < 0.05$ ), we reject the null hypothesis of normal distribution of item scores within the study sample. Inter-item polychoric correlations ranged from a low of 0.51 (SE 0.20) between items 3 and 8 to a high of 0.82 (SE 0.01) between items 1 (“able to adapt”) and 2 (“can deal with whatever comes”). Item 3 (“try to see humorous side”) was least correlated with other items. The two CD-RISC-10 items with the highest item-to-scale polychoric correlations were items 2 ( $\rho = 0.88$ , SE = 0.01) and 9 ( $\rho = 0.88$ , SE = 0.01). Among CD-RISC-10 items, deletion of items 2 (“can deal with whatever comes”) and 9 (“think of myself as strong person”) causes the largest decrease(s) in the scale’s Cronbach’s alpha coefficient. Despite similar floor (1.20 vs 1.30%) and ceiling effects (25.0 vs 24.7%), a summated score of items 2 and 9 is more correlated ( $\rho = 0.936$ , SE = 0.003) than the CD-RISC-2 ( $\rho = 0.908$ , SE = 0.004) with the CD-RISC-10 scale.

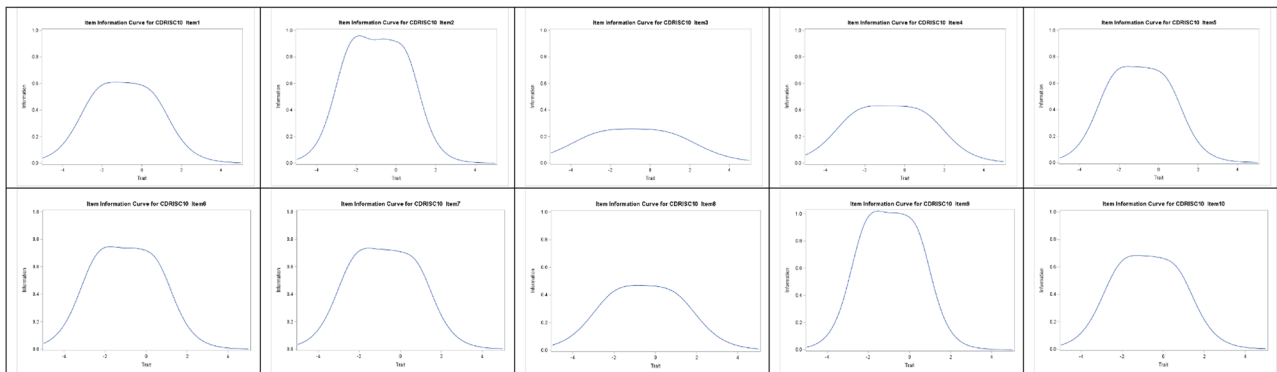
CFAs of the CD-RISC-10 based on the ULSMV estimator provided the best fit to the derivation data (SRMR = 0.024; CFI = 0.976; TLI = 0.969). The good fit of a one-factor ten-item CFA model supports *unidimensionality*. Standardized loadings ( $\lambda_{\text{standardized}}$ ) for all items exceeded 0.700 ( $p < 0.001$ ). Items 2 and 9 had the highest and second highest factor loadings ( $\lambda_{\text{standardized}} = 0.866$  and 0.865) plus proportions of variance in item scores ( $R^2 = 0.750$  and 0.748) accounted for by the single factor. Appendix C reports findings from multi-group CFAs of the CD-RISC-10 within the derivation subsample. The ULSMV-estimated CFA model showed good overall fit to the data (SRMR  $\leq 0.800$ , CFI  $\geq 0.950$ ; TLI  $\geq 0.950$ ) among the subpopulations tested. Indices of global fit to the derivation data were weakest among rural/small town respondents (CFI = 0.949; TLI = 0.934) and strongest for micro-urban areas (CFI = 0.986; TLI = 0.983).



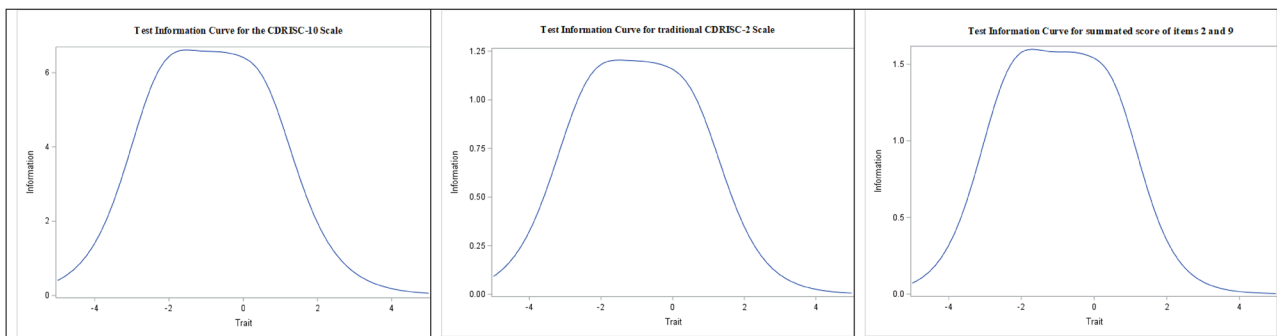


**Fig. 1** Response option characteristic curves for the ten items of the abbreviated Connor–Davidson Resilience Scale

**A**



**B**



**Fig. 2** **A** Item information curves for the ten items of the abbreviated Connor–Davidson Resilience Scale. **B** Test information curves for ten-item and two-item abbreviations of the Connor–Davidson Resilience Scale

**Calibration with the unidimensional graded response model**

Examination of item response OCCs (cf. Fig. 1) confirms that CD-RISC-10 items validly capture respondents’ resilience. Item 3 had the flattest OCCs (lowest endorsements) for response options 1, 2, and 3. Respondents endorsed a

wide spread of responses (from 0 to 4) on the other 9 items. As resilience (x axis) rises, probability (y axis) of endorsing higher options (3 or 4) increases but that of selecting lower options (0 or 1) decreases, supporting *monotonicity*. Parameter estimates from the unidimensional GRM of CD-RISC-10 in the derivation subsample are listed in Table 3. *Monotonicity* was confirmed by item scalability coefficients ranging

**Table 3** Unidimensional Graded Response Model of the Ten-Item Abbreviated Connor–Davidson Resilience Scale in the Derivation Subsample – Item Scalability, Slope (Discrimination), and Response Category Threshold (Difficulty) Parameters

CD-RISC-10 <sup>®</sup> Scale Item	Monotonicity $H_i$ (SE)	Slope <sup>f</sup> $\alpha$ (SE)	Response Category Thresholds <sup>f</sup>				Item Goodness of Fit	
			$b_1$ (SE)	$b_2$ (SE)	$b_3$ (SE)	$b_4$ (SE)	S- $\Sigma^2$ Index	p
1 “able to adapt when changes occur”	0.604 (0.014)	2.587 (.047)	– 2.360 (.071)	– 1.819 (.055)	– 0.687 (.034)	0.431 (.033)	105.997	0.004
2 “can deal with whatever comes”	0.662 (0.011)	3.208 (.061)	– 2.458 (.075)	– 1.770 (.051)	– 0.621 (.031)	0.448 (.030)	110.430	<0.001
3 “try to see humorous side of things”	0.529 (0.015)	1.630 (.032)	– 2.679 (.097)	– 1.604 (.063)	– 0.285 (.038)	0.927 (.048)	120.611	0.014
4 “...stress can make me stronger”	0.605 (0.013)	2.132 (.039)	– 2.501 (.081)	– 1.522 (.053)	– 0.226 (.033)	0.923 (.041)	80.227	0.112
5 “tend to bounce back after... hardships”	0.634 (0.012)	2.796 (.051)	– 2.365 (.072)	– 1.773 (.054)	– 0.717 (.033)	0.341 (.031)	86.718	0.053
6 “can achieve... goals, even if...obstacles”	0.635 (0.012)	2.856 (.052)	– 2.456 (.079)	– 1.769 (.054)	– 0.650 (.032)	0.425 (.031)	81.090	0.062
7 “Under pressure, I stay focused...”	0.639 (0.012)	2.836 (.050)	– 2.316 (.071)	– 1.537 (.048)	– 0.449 (.031)	0.696 (.034)	102.67	0.003
8 “not easily discouraged by failure”	0.593 (0.014)	2.310 (.040)	– 2.062 (.066)	– 1.245 (.045)	– 0.196 (.032)	0.883 (.041)	135.391	<0.001
9 “strong... when dealing with challenges”	0.657 (0.012)	3.387 (.062)	– 2.194 (.066)	– 1.524 (.045)	– 0.589 (.030)	0.326 (.029)	73.082	0.138
10 “able to handle unpleasant or painful feelings”	0.624 (0.013)	2.792 (.048)	– 2.176 (.067)	– 1.513 (.048)	– 0.497 (.031)	0.572 (.033)	99.400	0.005

Key  $\alpha$  is the item slope (discrimination) parameter;  $b_1$  to  $b_4$  are item response category threshold (difficulty, location) parameters;

$H_i$  is the scalability index of monotonicity; SE=standard error;  $f$  indicates that  $p < 0.0001$  for all the slope ( $\alpha$ ) and threshold ( $b$ ) parameters, S- $\Sigma^2$  is the generalized item-level goodness-of-fit index (calculated on 2460 observations with complete data);  $p$  is significance level for the S- $\Sigma^2$  index

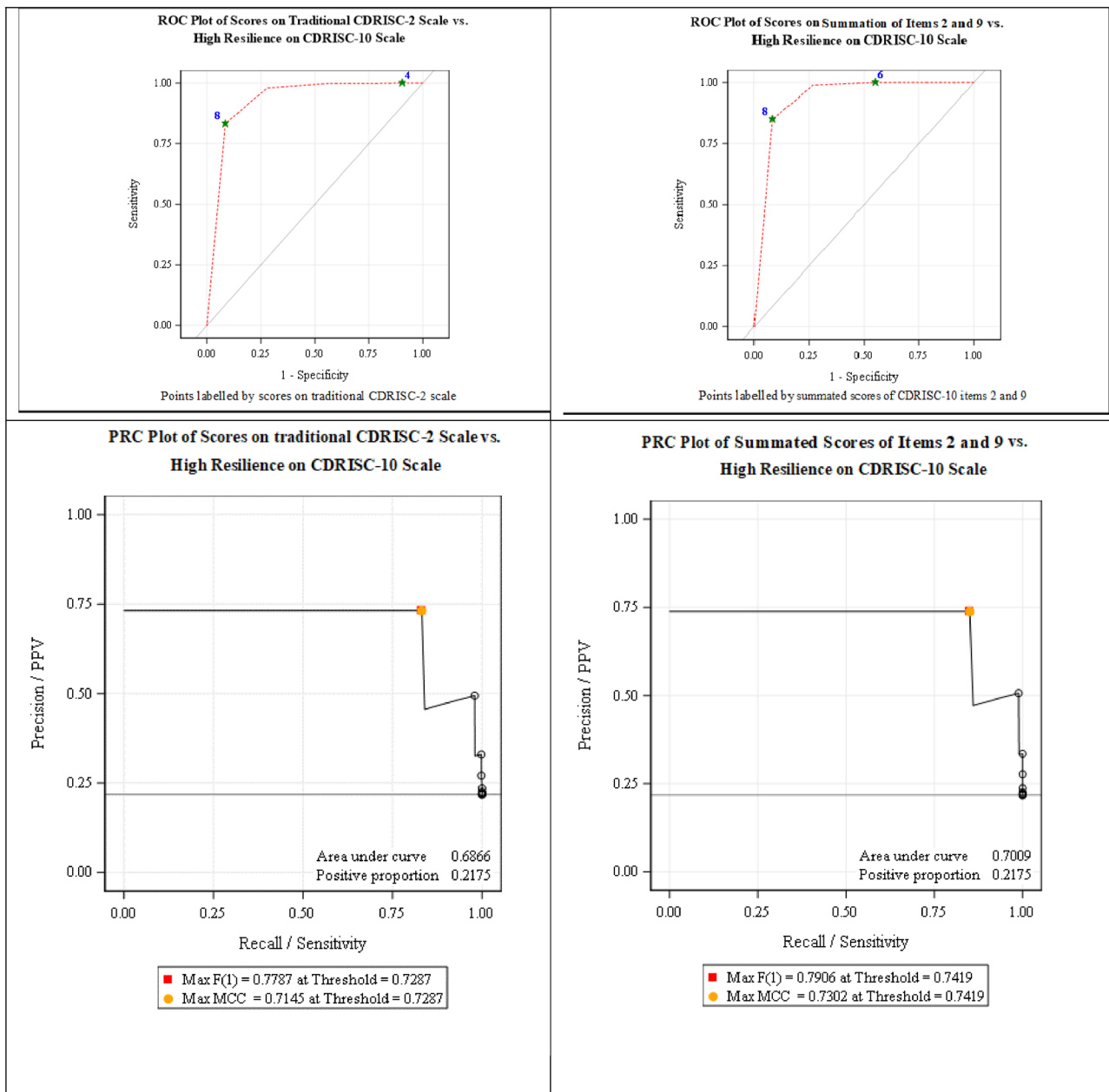
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from  $H_i = 0.529$  for item 3 to  $H_i = 0.662$  for item 2, and a Mokken scalability ( $H_s$ ) coefficient (95% CI) of 0.617 (0.597 – 0.638) for the entire CD-RISC-10. Item 3 had a “high” slope ( $\alpha = 1.35$ – $1.75$ ). The other 9 items had “very high” slopes ( $\alpha \geq 1.70$ ). Item 9 had the steepest slope ( $\alpha = 3.387$ ) followed by item 2 ( $\alpha = 3.208$ ). Thus, these were the two most efficient items at discriminating between respondents’ self-rated resilience on the CD-RISC-10. Response category thresholds ranged from – 2.679 for  $B_1$  on item 3 to 0.927 for  $B_4$  on item 3. *Local independence* is supported by absence of extremely high slope parameters ( $> 4$ ), and by the very small/inconsequential standardized LD  $\Sigma^2$  statistics for all item pairs (from |0.074| for items 2 and 7 to |0.217| for items 1 and 2). The S- $\Sigma^2$  index showed good overall fit ( $p \geq 0.001$ ) for most CD-RISC-10 items, with only items 8 and 2 showing weak fit ( $p < 0.001$ ). Figure 2A shows the information function curves for the CD-RISC-10 items. The plots reveal that items 2 and 9 captured the highest amount of psychometric information on resilience across the entire breadth of its variability. In contrast, item 3 displayed the flattest information curve. Figure 2B compares test information curves for the CD-RISC-10 scale, the CD-RISC-2 scale, and

a summated score of items 2 and 9. A summation of items 2 and 9 captures more psychometric information than the CD-RISC-2, despite the latter’s good performance.

### Concurrent validity and reliability of the CD-RISC-2 versus a summation of items 2 and 9

Figure 3 shows the ROC and PRC plots of how well high resilience on the CD-RISC-10 scale (score  $\geq 36$ ) is predicted by continuous scores on the conventional CD-RISC-2 scale versus the summated score of items 2 and 9. For both item pairs, a combined score of 8 represents the optimum threshold corresponding with high resilience ( $\geq 36$ ) on the CD-RISC-10. Despite the good predictive validity of the CD-RISC-2, summation of items 2 and 9 slightly but consistently outperforms it in discriminating high CD-RISC-10 scores (area under the ROC = 0.940 vs 0.928,  $p < 0.001$ ; area under the PRC = 0.701 vs 0.687,  $p = 0.050$ ; respectively). Table 4 lists internal consistency reliability indices for the CD-RISC-10, the CD-RISC-2 and summation of items 2 and 9 from CD-RISC-10. AVE was  $> 0.500$  and other reliability coefficients were  $> 0.700$  for all three item



**Fig. 3** Receiver operating characteristic and Precision-recall curve plots of CD-RISC-2 scale’s ability to discriminate high CD-RISC-10 scale scores in the derivation subsample

combinations, supporting internal consistency. The summation of items 2 and 9 has higher internal consistency than the CD-RISC– 2. Negative correlations >0.300 with anxiety, depression, anxiety sensitivity, COVID fear, and 2 avoidant (behavioral disengagement, self-blame) coping orientations (cf. Table 5) support discriminant validity for

the CD-RISC-10, CD-RISC-2, and summation of items 2 and 9. Positive correlations >0.300 with ‘emotionally stable’, ‘conscientious’, and ‘open to experience’ personalities plus >0.250 with 1 approach (acceptance) coping orientation (cf. Table 5) support convergent validity. Kruskal–Wallis nonparametric analyses of variance found

**Table 4** Internal Consistency Reliability Indices of the Abbreviated Connor–Davidson Resilience Scales in the Validation Subsample

Index of Scale Reliability	CDRISC-10 Scale	CDRISC-2 Scale	Summated Score of Items 2 and 9
Ordinal alpha ( $\alpha$ ) coefficient	0.950	0.794	0.856
Ordinal theta ( $\theta$ ) coefficient	0.951	0.794	0.856
Cronbach's alpha ( $\alpha$ ) coefficient (standardized)	0.934	0.726	0.804
Cronbach's alpha ( $\alpha$ ) coefficient (raw)	0.933	0.726	0.801
Spearman-Brown coefficient	0.945	0.726	0.804
McDonald's omega ( $\omega$ ) coefficient of composite reliability	0.950	0.791	0.855
Average variance extracted (AVE)	0.657	0.665	0.767

**Table 5** Convergent and Discriminant Validity of the Abbreviated Connor–Davidson Resilience Scales in the Validation Subsample

Type of Criterion Validity	Construct	Measurement Scale or Subscale	CD-RISC-10	CD-RISC-2	Summation of	
			Scale	Scale	Items 2 and 9	
			$\rho$ (SE)	$\rho$ (SE)	$\rho$ (SE)	
Divergent validity	Anxiety	GAD-7 Scale	– 0.450 (.018)	– 0.437 (.018)	– 0.435 (.019)	
	Depression	PHQ-8 Scale	– 0.460 (.017)	– 0.424 (.018)	– 0.448 (.018)	
	Anxiety Sensitivity	ASI-3 physical concerns	– 0.354 (.019)	– 0.332 (.019)	– 0.349 (.019)	
		ASI-3 cognitive concerns	– 0.400 (.019)	– 0.374 (.019)	– 0.404 (.019)	
		ASI-3 social concerns	– 0.259 (.019)	– 0.247 (.020)	– 0.259 (.020)	
COVID Fear	FCV-19 Scale	– 0.357 (.026)	– 0.342 (.027)	– 0.371 (.027)		
Convergent validity	Personality Traits	TIPI – agreeableness	0.308 (.019)	0.275 (.019)	0.302 (.020)	
		TIPI – conscientiousness	0.453 (.017)	0.404 (.018)	0.480 (.017)	
		TIPI – emotional stability	0.588 (.014)	0.539 (.015)	0.578 (.015)	
		TIPI – extraversion	0.302 (.019)	0.275 (.019)	0.295 (.020)	
		TIPI – openness to experience	0.330 (.018)	0.306 (.019)	0.313 (.019)	
	Coping Orientation	Brief COPE – acceptance	0.254 (.020)	0.278 (.021)	0.258 (.021)	
		Brief COPE – positive reframing	0.223 (.020)	0.185 (.021)	0.190 (.021)	
		Brief COPE – active coping	0.213 (.020)	0.174 (.020)	0.189 (.020)	
		Brief COPE – religion	0.122 (.022)	0.076 (.023)	0.103 (.023)	
		Brief COPE – planning/strategizing	0.088 (.021)	0.072 (.022)	0.077 (.022)	
		Brief COPE – use of humor	0.077 (.022)	0.044 (.023)	0.026 (.023)	
		Brief COPE – emotional support	0.042 (.022)	0.018 (.022)	0.041 (.022)	
		Divergent validity	Brief COPE – behavioral disengagement	– 0.378 (.022)	– 0.399 (.022)	– 0.402 (.022)
			Brief COPE – self-blame	– 0.384 (.021)	– 0.372 (.021)	– 0.396 (.021)
Brief COPE – substance abuse	– 0.246 (.025)		– 0.268 (.025)	– 0.271 (.025)		
Brief COPE – denial of reality	– 0.222 (.024)		– 0.250 (.024)	– 0.255 (.024)		
Brief COPE – venting	– 0.121 (.021)		– 0.109 (.022)	– 0.141 (.022)		
	Brief COPE – self distraction	– 0.046 (.021)	– 0.039 (.022)	– 0.047 (.022)		
	Brief COPE – instrumental support	– 0.043 (.022)	– 0.079 (.023)	– 0.076 (.023)		

**KEY** ASI-3=Anxiety Sensitivity Index-3; Brief COPE=Coping Orientation to Problems Experienced Inventory; CD-RISC-10=Ten-item abbreviation of the Connor–Davidson Resilience Scale; CD-RISC-2=Two-item abbreviation of the Connor–Davidson Resilience Scale; FCV-19=Seven-item Fear of COVID-19 Scale; GAD-7=Seven-item Generalized Anxiety Disorder Scale; PHQ-8=Eight-item Patient Health Questionnaire;  $\rho$ =polychoric correlation coefficient; SE=standard error of correlation coefficient; TIPI=Ten-item Personality Inventory;

that COVID-related experiences (testing positive for SARS-Cov-2, caring for COVID-19 patients, or knowing someone with COVID) had no significant association ( $p > 0.05$ ) with scores on the CD-RISC-10, CD-RISC-2, or summation of

items 2 and 9. Table 6 compares inter-rater reliability for CD-RISC-10, CD-RISC-2, and summated score of items 2 and 9 in discriminating high resilience in the validation subsample. Agreement coefficients and binary/prediction

**Table 6** Inter-rater Reliability of the Abbreviated Connor–Davidson Resilience Scales in the Validation Subsample

	CD-RISC-2 Scale vs CD-RISC-10 Scale	Summation of Items 2 and 9 vs CD-RISC-10 Scale	CD-RISC-2 Scale vs Summation of Items 2 and 9
<i>Coefficients of agreement</i>			
Percent agreement	88.875	90.805	86.172
Cohen's kappa statistic ( $\kappa_c$ )	0.692	0.750	0.638
Conger's kappa statistic	0.692	0.746	0.617
Fleiss' kappa statistic ( $\kappa_f$ )	0.692	0.749	0.639
Gwet's AC <sub>1</sub> coefficient	0.826	0.855	0.776
Brennan-Prediger coefficient ( $\kappa_3$ )	0.778	0.816	0.723
Krippendorff's alpha ( $\alpha$ ) coefficient	0.692	0.750	0.638
<i>Discrimination and classification indices</i>			
Accuracy	0.889	0.908	–
Misclassification (Error) rate	0.111	0.092	–
Sensitivity/Recall (True positive probability)	0.819	0.890	–
Specificity (True negative probability)	0.908	0.913	–
Positive predictive value/Precision	0.717	0.743	–
Negative predictive value	0.947	0.967	–
False negative probability	0.181	0.110	–
False positive probability (1 – Specificity)	0.092	0.087	–
Area under the ROC curve	0.934	0.952	–
Area under the PRC curve	0.624	0.688	–
Matthews correlation coefficient ( $\phi$ )	0.695	0.755	–
F1-score	0.765	0.810	–

Key: CDRISC-10 = Ten-item abbreviation of the Connor–Davidson Resilience Scale; CDRISC-2 = Two-item abbreviation of the Connor–Davidson Resilience Scale; ROC = receiver operating characteristic; PRC = precision recall characteristic

indexes with the CD-RISC-10 were consistently higher for the summation of items 2 and 9 versus the CD-RISC-2.

## Discussion

An in-depth investigation of the validity and reliability of abbreviated CD-RISC scales was conducted using both CTT- and IRT-based methods among a nationwide sample of Americans responding to the COVID-19 pandemic. This psychometric validation study aimed to augment previous research by adducing evidence based on modern measurement theory to contribute towards eventual consensus on effective ways of tracking personal resilience. In correspondence with past studies, our findings confirm the construct validity, reliability, internal consistency, unidimensionality, and monotonicity of the CD-RISC-10 scale. However, study data did not support our hypothesis that, among CD-RISC-10 items, CD-RISC-2 items would be the most valid/reliable item duo. A summation of CD-RISC-10 items 2 and 9 slightly but significantly outperforms the CD-RISC-2 on concurrent validity and inter-rater reliability indices.

The mean ( $\pm$  SD) CD-RISC-10 score of 28.46 (7.93) in our sample is comparable to that in the initial validation study [23], lower than reported for U.S. community samples in previous years [95, 96] but identical to findings in populations responding to the COVID-19 pandemic [97] or similar crises [98]. Compared to validations in U.S. [23, 52, 95] and other settings [31–33], we observed higher internal consistency for the CD-RISC-10 and CD-RISC-2 (cf. Table 4). In concurrence with prior studies [31–33], the CD-RISC-10 had greater internal consistency in our sample than the CD-RISC-2. This could be partially due to how the CD-RISC-2 scale was originated more on subjective than empirical criteria [52].

In convergent/divergent validity analyses, both the CD-RISC-2 and summation of items 2 and 9 correlated with measures of depression, anxiety, COVID-19 fear, and coping styles to the same degree and in the same direction as the CD-RISC-10 (cf. Table 5). Thus, two-item and ten-item CD-RISC abbreviations show identical convergent/divergent validity. Compared to previous reports [32, 33, 62, 64], larger correlations of CD-RISC-2 and CD-RISC-10 scales with depression, anxiety, and fear of COVID-19 measures were observed in the present study. Prior studies used Pearson and Spearman, instead of polychoric, correlation

coefficients in convergent/divergent validity analyses [32, 33, 64], despite the ordinal nature of Likert scales such as the CD-RISC-10/-2, PHQ-8/-9, GAD-7, and FCV-19. Unlike polychoric correlations, Pearson/Spearman correlations under-estimate associations between ordinal scales [84]. Higher correlations with anxiety and depression were reported in a study using the Hospital Anxiety and Depression Scale (HADS) [31] instead of the PHQ-9 [32, 33, 62] and GAD-7 [32, 33] employed in aforementioned studies. Of the five personality traits, emotional stability was most correlated with abbreviated CD-RISC scales, followed by conscientiousness, findings that concur with Zager Kojcan et al. [99].

The present study supports the psychometric quality and utility of the CD-RISC-10 and CD-RISC-2 scales. We also found evidence, based on CTT and IRT methods, that a summation of items 2 and 9 of the CD-RISC-10 slightly but consistently outperforms the CD-RISC-2 on multiple validity/reliability indices. Summated scores of items 2 and 9 correlated better than the CD-RISC-2 with the CD-RISC-10, and manifested superior agreement and inter-rater reliability. Some previous studies also found items 2 and 9 to have the highest factor loadings among CD-RISC-10 items [25, 37]. However, we know of no prior study that conducted GRM-based item diagnostics to test the CD-RISC-2's concurrent validity and reliability against alternative item pairings from the CD-RISC-10. This study is not intended to modify the CD-RISC-2, a copyright-protected proprietary scale. Rather, the study yields evidence that, contrary to the CD-RISC-2's emphasis on *adaptability* and *bouncing back*, Americans facing a surging COVID-19 pandemic rated their *ability to cope with adversity* and *mental strength* as more salient pillars of resilience. Thus, the salience of different flavors of resilience rises or falls based on variation in adaptation demands arising from the evolution of adverse stimuli across time and context [3]. Future studies should utilize IRT-based item-level diagnostics of old and new resilience measures to test varying salience of different flavors of resilience among persons responding to one adversity versus another. High ceiling effects reported in past studies such as Heritage et al. [46], now corroborated by our findings, call for fresh, innovative measures incorporating items that conceptually reflect and psychometrically capture the sentiments of highly resilient persons more efficiently than CD-RISC scales do.

Limitations of the present study are worth noting. The cross-sectional sample precluded test–retest reliability assessment. The U.S. English context limits generalizability/transferability to non-U.S. geographic/cultural contexts without further evidence. Multi-group CFAs revealed scalar variance [94] by the metropolitan status of respondents' residential areas. The survey did not include another single-factor resilience measure (e.g., the Brief Resilience Scale [100]) against which to test the relative performance of CD-RISC

scales. The self-administered, self-report, subjective scales were not validated against external observer ratings (e.g., situational judgment tests [20, 101]), nor objective metrics (e.g., genetic markers [102], stress hormones [103]). We also did not assess the extent of *acquiescence response* bias. The large, nationwide sample; diverse range of validity/reliability inferential tests reported compared to the few indices in past studies; and the split-sample internal validation strategy to minimize overfitting were notable strengths. The study's timing, in the midst of a surging COVID-19 pandemic, was a further strength. Past resilience research has predominantly focused on responses to violent events [13], natural disasters [104], or wartime combat [26]. The COVID-19 surge allowed us to expand the evidence base by investigating resilience within the context of a pervasive, escalating stressor.

## Conclusion

In an extensive psychometric validation study that employed both classic and modern approaches, we adduced sufficient evidence to confirm our hypothesis that the CD-RISC-10 and CD-RISC-2 exhibit good construct validity, internal consistency, and inter-rater reliability, in addition to unidimensionality, monotonicity, and local independence. However, the data failed to support our hypothesis that the CD-RISC-2's constituent items represented the most empirically robust pairing out of the ten CD-RISC-10 items. Summative scores of items 2 and 9 (instead of items 1 and 5) from the CD-RISC-10 slightly but consistently outperformed the CD-RISC-2 on all empirical indices of validity and reliability. This study adds new psychometric evidence from a rigorous GRM-based evaluation of the abbreviated CD-RISC scales.

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**Author contributions** Study concept and design – ACW, BMB, MMB, DCM, AMW. Acquisition of data – AMW, MMB. Analysis and interpretation of data – ACW, JRP, MCM, RDB, DCM. Drafting of manuscript – ACW, BMB, JRP, DCM. Critical revision of the manuscript for intellectual content – All authors. Final approval of version to be published – All authors. Accountable for all aspects of the work – ACW.

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**Data availability** Data from this study are strictly protected by privacy and confidentiality agreements specified in the study protocol that was approved by the institutional review board.

**Code availability** Samples of the kind of software syntax that was utilized in the quantitative analyses can be requested from the

corresponding author. All requests will be subject to vetting by the institutional review board prior to dissemination.

## Declarations

**Conflict of interest** The authors have no conflicting interests to declare.

**Ethical approval** The Institutional Review Board (IRB) at Baylor Scott and White Research Institute approved the parent project under protocol # 020-035.

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