Development, Validation, and Evidence of Measurement Invariance of a Shortened Measure of Trait Test Anxiety

Teresa M. Ober, Cheng Liu, & Ying Cheng

University of Notre Dame

(Preprint version: 12 December 2022)

Please address correspondence to: Dr. Ying Cheng, University of Notre Dame, 390 Corbett Family Hall, Notre Dame, IN 46556

CREDiT: Teresa M. Ober: Conceptualization, Methodology, Analysis, Writing - Original Draft, Funding acquisition; **Cheng Liu:** Software, Data Curation; **Ying Cheng:** Supervision, Conceptualization, Methodology, Writing - Review & Editing, Funding acquisition

Acknowledgments: This work was supported by the Spencer Foundation (Grant #202100064), as well as the University of Notre Dame through the Institute for Educational Initiatives (2020 Seed Grants Program) and the Institute for Scholarship in the Liberal Arts (Spring 2020 Large Social Sciences Research Grant) awarded to Dr. Ying Cheng, Dr. Teresa Ober, and Dr. Cheng Liu. Gratitude is also owed to members of the Learning Analytics and Measurement in Behavioral Science (LAMBS) Lab of the University of Notre Dame for their contributions to the broader discussion of the issues raised in this manuscript.

Statements and Declarations: The authors have no competing interests to declare.

Abstract

(200 / 200 words)

We develop and validate a short self-report measure of test anxiety, the Trait Test Anxiety Inventory - Short (TTAI-S) following the Kane (2013) validation framework. Data were collected from three independent samples of college students in the U.S. ($N=629$; $M_{age}=22.25$ years). Evidence was gathered to support three aspects of the validity argument (i.e., scoring, extrapolation, generalization). Good internal consistency and confirmed structure of a single factor supported scoring inferences. Scalar measurement invariance between different samples (Internet v. undergraduate students) and demographic subgroups (i.e., gender, race/ethnicity, and parental educational attainment) provided evidence for generalization inferences. Significant associations between the TTAI-S score and theoretically relevant (state test anxiety, performance expectation, and self-confidence in math) and weaker associations with less relevant constructs (enjoyment, motivation, and values in learning math) substantiated extrapolation inferences. Having established measurement invariance, we examined demographic differences and found that students historically underserved or underrepresented in STEM disciplines reported greater test anxiety than their counterparts. These findings support the validity of the TTAI-S, a concise measure that is easy to administer and easy to score. The TTAI-S may be used to further investigate trait test anxiety for a diverse population, particularly factors that may contribute to or mitigate group differences.

keywords: test anxiety, scale validation, confirmatory factor analysis, measurement invariance, trait and state anxiety

Development, Validation, and Evidence of Measurement Invariance of a Shortened Measure of Trait Test Anxiety

Introduction

Test anxiety refers to the specific feelings of anxiety one experiences in an evaluative context that impairs performance (Sarason, 1972). It has been consistently shown to have a detrimental impact on academic performance (Cassady & Johnson, 2002; von der Embse et al., 2018). Test anxiety may be particularly acute in online test administration contexts (Woldeab & Brothen, 2019), which may become more common in the aftermath of the COVID-19 pandemic (Korkmaz & Toraman, 2020) and as certain standardized assessment programs transition to a fully online format. To develop a program of research that examines test anxiety, a concise and valid measure, and which demonstrates invariance across demographic subgroups is therefore essential and timely. In the present study, we seek to fill this gap presenting validity evidence of a new measure of trait test anxiety using a sample drawn from university students with a foundational grasp of statistics.

Relevant Theories and Frameworks of Test Anxiety

Several perspectives may explain how test anxiety negatively influences performance in evaluative contexts. According to the *transactional process model*, stress induced in evaluative contexts can produce cognitions and affective states, subsequently having adverse effects on information processing and academic achievement (Speilberger & Vagg, 1995). The *control-value theory* further explains how the sequence and salience of certain cognitions can trigger emotions leading to a cascading, and often negative, effect on performance (Pekrun et al., 2007).

Test anxiety is further disambiguated into trait and state test anxiety. Trait anxiety refers to a set of global emotions and cognitions that tend to be more stable and emerge in more

general, non-context-specific evaluative contexts, while state anxiety describes a similar set of emotions and cognitions that arise in a specific evaluative context (Spielberger & Vagg, 1995).

While distinct, trait and state test anxiety are thought to correlate strongly with one another (Lotz & Sparfeldt, 2017). Students may experience performance-impairing state test anxiety if evaluated on their ability in a subject area for which the stakes are high but may otherwise have low trait test anxiety given that they are relatively untroubled in most evaluative contexts.

Correlates of Trait Test Anxiety

Other factors are likely to correlate with test anxiety. Beliefs about one's abilities or performance in subject-specific and general academic contexts (e.g., Raufelder & Ringeisen, 2016) have also been identified as correlates of test anxiety (von der Embse et al., 2018).

Students with expectations of performing well in a particular domain tend to have lower state test anxiety (von der Embse et al., 2018), though this association may be influenced by other factors (Talsma et al., 2019). Students with low expectations of performing well on an academic task (i.e., lower performance expectations), yet who highly value the perceived consequences of their performance on the task, may be more likely to experience state test anxiety (Putwain & Symes, 2011; Roick & Ringeisen, 2017). By contrast, the association between performance expectations and trait test anxiety may be even less predictable. Students may experience performance-impairing trait test anxiety if they have relatively high expectations of their performance in a particular domain yet still tend to experience anxiety in evaluative contexts.

Dimensions of Test Anxiety

The construct of test anxiety has an extensive history in educational and psychological literature. However, there is a general lack of consensus for the quantity and qualities of its dimensions. As noted by Putwain et al. (2020), early literature on test anxiety first introduced it

as a unidimensional construct (e.g., Mandler & Sarason, 1952) though later distinct affective-physiological and cognitive dimensions were identified (Liebert & Morris, 1967).

More recently, efforts have been made to synthesize multiple perspectives on test anxiety, resulting in more holistic construct frameworks (e.g., Lowe 2018, 2021). Consistent with the original definition of test anxiety as a set of emotions and cognitions that not only occur within an evaluative context but also detrimentally impact performance, a simpler test anxiety framework may be more appropriate. Putwain et al. (2020) argued for a four-factor representation of test anxiety, which encompasses two affective subdimensions (i.e., tension and physiological arousal) and two cognitive subdimensions (i.e., worry and cognitive interference). According to this framework, tension refers to nervous or anxious feelings (Sarason, 1984). Physiological arousal refers to an automatic and bodily set of sensations (Joiner et al., 1999). Worry refers to the set thoughts regarding failure and the consequences of it (Liebert & Morris, 1967; Schillinger et al., 2021; Spielberger & Vagg, 1995). Cognitive interference occurs when negative beliefs about performance intrude on one's ability to concentrate (Eysenck & Calvo, 1992). Other perspectives similarly converge on a four-factor model, yet the conceptualization of the factors may differ slightly (see Möcklinghoff et al., 2021; Mowbray et al., 2015).

While this four-dimensional framework offers clarity and simplicity, measures of test anxiety that use an even simpler unidimensional framework may be more interpretable for both researchers and practitioners. Although measures that use a single-factor model of test anxiety may lack the fine-scale precision of a more complex scale or set of measures that attempt to account for variation due to multiple dimensions of the construct, in certain contexts the validation of a single factor scale may be preferable.

Student Characteristics and Differences in Test Anxiety

Understanding how test anxiety interferes with the performance of certain students may illuminate factors that contribute to issues related to academic persistence. While test anxiety has been identified as a factor that impairs performance, many students experience stigma which prevents them from seeking help (Gerwing et al., 2015). Within the context of science, technology, engineering, and mathematics (STEM) education in the U.S., students who are considered historically underserved and underrepresented include those who identify as Black/African American, Hispanic/Latinx, American Indian/Alaskan Native, or female based on rates of participation in STEM education and employment (NCES, 2021). Such students may experience test anxiety differently than their peers (O'Brien et al., 2015), particularly considering the history of inequitable practices associated with educational assessment (Sireci & Randall, 2021). Additionally, female students (Putwain & Daly, 2014) and students from lower socioeconomic strata (Rozek et al., 2019) have also been shown to have greater test anxiety.

To study group and individual differences, valid and reliable measures must be available to researchers investigating a construct (Meade & Craig, 2012; Steedle et al., 2019). Few measures of test anxiety currently exist that meet modern standards of rigor for self-report instruments (Szafranski et al., 2012) or were not developed with the goal of demonstrating measurement invariance between groups (von der Embse et al., 2013). Considering a literature pointing to differences in test anxiety based on student characteristics, particularly gender (e.g., Lowe & Lee, 2008; Putwain & Daly, 2014), race/ethnicity (e.g., Nadler & Clark, 2011), and socioeconomic factors (e.g., Putwain, 2008; Zeidner & Safir, 1989), demonstrating measurement bias between demographic groups is important in developing a valid instrument. Past work has established measurement invariance based on gender for existing measures (e.g., Lowe, 2015;

Putwain et al., 2020) though other student demographic characteristics are rarely considered.

Research Aims

Though short-form measures of test anxiety scales exist, many are still relatively lengthy (e.g., Putwain et al., 2020), comprise multiple dimensions which make scoring more complicated (e.g., Lowe, 2021), or have not been rigorously validated with diverse populations (e.g., Taylor & Deane, 2002). Building off past efforts to develop measures of test anxiety, we first sought to revise an existing self-report measure of test anxiety and further develop it into a more concise instrument (**study 1 objective**). We sought to validate the measure while demonstrating measurement invariance (see Putnick & Borenstein, 2016) between student demographic groups and on that basis draw valid inferences for group differences (**study 2 objective**). We followed the arguments-based framework provided by Kane (2013), which regards validation as an evaluation of the coherence and completeness of scale interpretation based on evidence as well as the plausibility of inferences and assumptions. This method of scale validation has gained much attention and traction in validity research (Cook et al., 2015), and has been adopted in various assessments used in educational and clinical contexts (e.g., Whitney et al., 2019; Tavares et al., 2018). However, the application of this systematic framework in psychology has been scarce. Therefore, this paper also serves an illustrative purpose for applying the Kane (2013) framework to validate a psychological scale.

The present investigation focuses on the context of statistics education for several reasons. First, statistics and data science are growing fields of study at undergraduate level (NASEM, 2018). Second, students who pursue STEM coursework and careers are often expected to have foundational quantitative reasoning skills and statistical literacy (Weiland, 2017). Third, within undergraduate programs in STEM disciplines, there tends to be an emphasis on

assessment, particularly for summative purposes (Schneider et al., 2021). For example, among students enrolled in high school in the midwestern U.S., negative associations between test anxiety and performance on a high-stakes math assessment were stronger than those in other subject areas including science, reading, and social studies (von der Embse & Hasson, 2012).

Study 1

The purpose of study 1 was to develop a concise measure of trait test anxiety.

Methods

We report how we determined our sample size, all data exclusions, data inclusion/exclusion criteria, whether inclusion/exclusion criteria were established prior to data analysis, all measures in the study, and all analyses including all tested models. If we use inferential tests, we report exact p -values, effect sizes, and 95% confidence or credible intervals (Simmons et al., 2012).

Participants

Table 1 shows demographic information for study 1 ($N = 121$), in addition to the study 2 sample ($N=508$). Study 1 participants were recruited through a sample consisting mostly of undergraduate students enrolled in a university located in the Midwest U.S. (“undergraduate student sample”).

Table 1. *Sample demographics.*

Variable	Study 1 Sample		Study 2 Sample						Combined Total (N=629)	
	Undergraduate Student 1 (N=121)		Internet (N=301)	Undergraduate Student 2 (N=207)		Combined Study 2 (N=508)				
	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Gender										
Female	87	71.9%	165	54.8%	145	70%	310	61%	397	63.1%
Male	34	28.1%	129	42.9%	62	30%	191	37.6%	225	35.8%
Other	-	-	1		-	-	1	0.2%	1	0.2%
Prefer not to disclose	-	-	6	2%	-	-	6	1.2%	6	1%
Age (Years)										
18	22	18.2%	24	8%	41	19.8%	65	12.8%	87	13.8%
19	32	26.4%	39	13%	58	28%	97	19.1%	129	20.5%
20	31	25.6%	40	13.3%	53	25.6%	93	18.3%	124	19.7%
21	33	27.3%	30	10%	35	16.9%	65	12.8%	98	15.6%
22	3	2.5%	29	9.6%	13	6.3%	42	8.3%	45	7.2%

DEVELOPMENT VALIDATION MEASUREMENT INVARIANCE TTAIS

23	-	-	20	6.6%	-	-	21	4.1%	21	3.3%
24	-	-	19	6.3%	-	-	19	3.7%	19	3%
25 and above	-	-	100	33.2%	-	-	105	20.7%	105	16.7%
Race/Ethnicity										
American Indian/Alaska Native	0	0%	1	0.3%	0	0%	1	0.2%	1	0.2%
Asian/Asian American	19	15.7%	65	21.6%	34	16.4%	99	19.5%	118	18.8%
Black/African American	5	4.1%	24	8%	3	1.4%	27	5.3%	32	5.1%
Hispanic/Latinx	5	4.1%	18	6%	7	3.4%	25	4.9%	30	4.8%
Middle Eastern/North African	4	3.3%	0	0%	4	1.9%	4	0.8%	8	1.3%
Native Hawaiian/Other Pacific Islander	0	0%	0	0%	2	1%	2	0.4%	2	0.3%
White/European American	81	66.9%	166	55.1%	143	69.1%	309	60.8%	390	62%
Other race/ethnicity	3	2.5%	2	0.7%	7	3.4%	9	1.8%	12	1.9%
Multiple	0	0%	23	7.6%	0	0%	23	4.5%	23	3.7%
Prefer not to disclose	1	0.8%	2	0.7%	3	1.4%	5	1%	6	1%
Parental Educational Attainment										
Did not finish high school	3	2.5%	15	5%	-	-	16	3.1%	19	3%
High school diploma or G.E.D.	7	5.8%	46	15.3%	12	5.8%	58	11.4%	65	10.3%
Attended college but did not complete degree	5	4.1%	34	11.3%	4	1.9%	38	7.5%	43	6.8%
Associate's degree (A.A., A.S., etc.)	3	2.5%	23	7.6%	3	1.4%	26	5.1%	29	4.6%
Bachelor's degree (B.A., B.S., etc.)	35	28.9%	97	32.2%	48	23.2%	145	28.5%	180	28.6%
Master's degree	40	33.1%	55	18.3%	77	37.2%	132	26%	172	27.3%
Doctoral or professional degree	28	23.1%	29	9.6%	62	30%	91	17.9%	119	18.9%
Other	-	-	2	0.7%	-	-	2	0.4%	2	0.3%

Measures

Trait Test Anxiety. Participants in study 1 were administered a survey consisting of new and select items revised from an existing measure of test anxiety, the Test Anxiety Inventory (TAI; Spielberger et al., 1980). The scale consists of 20-items, with 10-items each for affective and cognitive dimensions, of which 5-items each are within the four subdimensions (affective: physiological arousal, tension; cognitive: worry, and cognitive interference; see Table 2). Ratings were provided on a 5-point Likert scale (*1=Strongly disagree, ..., 5=Strongly agree*). We revised the original scale to ensure half of the items were reverse-coded. Reverse-coding scale responses is considered one way to improve the quality of data gathered from a scale by identifying careless (Meade & Craig, 2012) or biased responses (Wetzel & Carstensen, 2015), such as acquiescent responding (Ober et al., 2021; Primi et al., 2019). There have been some critiques of including reverse-keyed items in scales measuring personal qualities such as test anxiety (e.g., Rodebaugh et al, 2007). However, assuming items clearly and unambiguously worded (e.g.,

DEVELOPMENT VALIDATION MEASUREMENT INVARIANCE TTAIS

Weijters & Baumgartner, 2012; Zhang & Savalei, 2016), evidence suggests that including such items has minimal impact on the factor structure of a scale (Baer et al., 2011) or ensuring responses are effortful (Hong et al., 2020). Table 2 provides item-level descriptives for the scale. Estimates of internal consistency (*McDonald's ω*) for this measure in its original and revised form are reported in the study 1 results section.

Table 2. *Item-level descriptive statistics on the original 20-item Trait Test Anxiety Inventory administered in Phase 1 (N=121).*

Dimensions and Subdimensions	Item wording	Mean	SD	Median	Item-rest r	
Affective Dimension: Physiological arousal + Tension						
Physiological arousal	I feel very jittery when taking an important test.	3.55	1.19	4	0.61	
	While taking examinations, I don't feel uneasy or upset. [R]	3.39	1.11	4	0.65	
	I feel very panicky when I take an important test.	3.40	1.22	4	0.71	
	I start feeling very uneasy just before getting a test paper back.	3.98	1.02	4	0.46	
	I feel my heart beating very fast during important tests.	3.38	1.21	4	0.50	
Tension	During tests, I can feel relaxed. [R]	3.36	1.20	4	0.62	
	During important tests, I am so tense that my stomach gets upset.	2.48	1.34	2	0.52	
	During examinations, I feel calm and facts or ideas come to me fluidly. [R]	3.16	1.13	3	0.67	
	As long as I have prepared, I don't feel tense before taking an important examination. [R]	3.30	1.21	4	0.56	
	Taking examinations doesn't bother me at all. [R]	3.98	1.02	4	0.62	
	Cognitive Dimension: Worry + Cognitive Interference					
Worry	I feel defeated while working on important tests.	2.40	1.23	2	0.72	
	I feel confident while taking tests. [R]	2.90	1.14	3	0.72	
	Even when I'm well prepared for a test, I feel very nervous about it.	3.83	1.01	4	0.48	
	After an exam is over, I do not worry about it. [R]	3.68	1.17	4	0.29	
	During exams, I find myself thinking about whether I'll ever get through school.	2.14	1.32	2	0.56	
Cognitive Interference	Thoughts of doing poorly on a test don't interfere with my ability to concentrate. [R]	3.59	1.17	4	0.60	
	During tests I find myself thinking about the consequences of failing.	3.16	1.36	4	0.61	
	My mind feels clear when I am working on a test. [R]	2.93	1.13	3	0.64	
	The harder I work at taking a test, the more confused I get.	2.15	1.04	2	0.39	
	Thinking about my grade in a course never interferes with my work on a test. [R]	3.84	1.09	4	0.45	
Scale Score (Mean)		-	3.23	0.73	3.25	-

Note: [R] indicates the item was reverse coded. Items in bold are also included in the 12-item revised scale

Procedure

Data collection. The study 1 undergraduate student sample was recruited in Fall 2020 as part of an experimental study examining the effects of different features of computerized assessments. As compensation for completing the study, participants either received bonus credit towards a course or monetary compensation (\$20 USD) in the form of a VISA gift card. The study had Institutional Review Board approval and all participants consented prior to

participation.

Considering that some items on the measure of trait test anxiety were reverse-coded, we anticipated participants who were thorough and honest in responding were unlikely to provide the same answer on all 12-items. Prior to analysis, the data were cleaned such that responses consisting of the same answer choice on the trait test anxiety measure were removed from the sample, a data cleaning technique using the “longstring” method to identify careless responding (Meade & Craig, 2012). No responses were removed from the sample using the method given the maximum length of consecutive responses did not exceed 9 (of 20 total possible).

Analysis. Confirmatory factor analysis (CFA) was conducted using a diagonally-weighted least-squares estimator with robust standard errors and a Satorra-Bentler scaled test statistic (Satorra & Bentler, 2010) to fit and evaluate a theoretical factor model to the data. To assess the appropriateness of the fit of the latent models, in addition to the χ^2 , multiple indices were considered (see Table 3; Hu & Bentler, 1999).

Table 3. *Thresholds for goodness-of-fit indices used to evaluate measurement models.*

Goodness-of-fit Index	Goodness-of-fit Estimate
Comparative Fit Index (CFI)	close to or greater than .95
Tucker-Lewis index (TLI)	close to or greater than .95
Root Mean Square Error of Approximation (RMSEA)	close to or less than .06
Standardized Root Mean Square Residual (SRMR)	close to or less than .08

Note: The RMSEA (Brosseau-Liard & Savalei, 2014), CFI and TLI (Brosseau-Liard et al., 2012) were based on robust estimates.

Results

First, we sought to evaluate the factor structure of the 20-item scale with the intent to revise and shorten it. The study 1 undergraduate student sample completed a 20-item test anxiety measure (*McDonald's* $\omega=.95$). A CFA consisting of two correlated factors (i.e., worry, emotionality) revealed good fit ($\chi^2_{Scaled}(df=169)=217.28, p=0.007, CFI_{Robust}=0.993, TLI_{Robust}=0.992, RMSEA_{Robust}=0.031, SRMR=.061, NCI=1.420, \hat{\gamma}=1.075$). Given the correlation between the two factors was .96, we questioned whether a single-factor model would be more

appropriate. Next, a single-factor CFA was conducted, revealing good model fit

($\chi^2_{Scaled}(df=54)=57.70, p=.340, CFI_{Robust}=.999, TLI_{Robust}=.999, RMSEA_{Robust}=.014, SRMR=.047, NCI=1.155, \hat{\gamma}=1.050$). Compared with the single-factor model, the two-factor model appeared to have improved model fit, $\Delta\chi^2(\Delta df=115)=157.32, p<.01$. However, the strong correlation between the two factors and the good fit of the one-factor CFA indicated that the scale was sufficiently unidimensional. We also calculated the effect size of the chi-square difference test and obtained $w = .1$, where w indicates the magnitude of difference in χ^2 . This indicates a small effect, suggesting the difference between the two models to be practically insubstantial though statistically significant (Newsom, 2020). Therefore, the single-factor model was chosen because it is the more parsimonious yet good-fitting model.

After inspecting factor loadings and item content, 8-items (4 each from the affective and cognitive dimensions; 2 each from the four subdimensions) were dropped due to low factor loadings or content redundancy (see Table 2). The shortened 12-item version of the scale retained good internal consistency (*McDonald's* $\omega=.95$). Fitting a single-factor model to the 12-item scale data also showed good fit ($\chi^2_{Scaled}(df=54)=57.70, p=.340, CFI_{Robust}=.999, TLI_{Robust}=.999, RMSEA_{Robust}=0.014, SRMR=.047, NCI=1.155, \hat{\gamma}=1.050$) with standardized loadings above or near .500. Hence results supported a more parsimonious, single-factor model.

Study 2

Following study 1, the purpose of study 2 was to validate the revised measure of trait test anxiety with independent samples. To validate the new scale, we followed the framework provided by Kane (2013), which describes four aspects of validity inferences (i.e., scoring, generalization, extrapolation, and implications) accompanied by arguments for evaluating validity claims against evidence (see Table 4). The last aspect, “implications”, mostly applies to

settings in which the scores of a measure are used for specific decision-making purposes, which is not applicable to our research context and is therefore not included (Whitney et al., 2019).

Table 4. *Summary of validation inferences (based on Kane, 2013).*

Type of Inference	Definition	Hypothesis	Analyses/Evidence	Criteria
Scoring	Observed performance → Observed score or set of scores.	<ul style="list-style-type: none"> Subscale scores must demonstrate evidence of coherence and independence. Internal consistency analysis reveals low error variance for (sub)scale scores. 	<ul style="list-style-type: none"> Correlations among subscale scores. (S1) McDonald's ω for scores. (S2) 	<ul style="list-style-type: none"> Significant moderate correlation between subscale scores needed to justify a multi-dimensional model. If correlations are too strong (e.g., $r > .60$), a single factor model is suggested instead. McDonald's ω must be sufficiently large to demonstrate good internal consistency (e.g., $\omega > .90$).
Generalization	Observed sample of performances → Claims about expected performance.	<ul style="list-style-type: none"> Scale items must be representative of the target content domain. The sample must be representative of the target population. Scores collected must show consistency among different samples. 	<ul style="list-style-type: none"> CFA and measurement invariance between Internet and undergraduate student samples. (G1) CFA and measurement invariance between demographic subgroups. (G2) 	<ul style="list-style-type: none"> CFA models are presumed to have good model fit if CFI > .95, TLI > .95, RMSEA < .06, SRMR < .08 (Hu & Bentler, 1999). Measurement invariance is assumed if a reduction in CFI from the less constrained to more constrained model (ΔCFI) is smaller than or equal to .01, an increase in RMSEA is not much greater than .015, an increase in SRMR is not much greater than .025 or .005 (depending on the level tested*; Chen, 2007; Jin, 2020), a reduction in McDonald's Noncentrality Index (ΔNCI) smaller or equal to .02, and a reduction in Gamma-hat ($\Delta\hat{\gamma}$) smaller or equal to .001 (Cheung & Rensvold, 2002).
Extrapolation	Observed scores → Predicted performance in some other context <i>or</i> on different tasks in different contexts.	<ul style="list-style-type: none"> Scale scores will be associated with related constructs. 	<ul style="list-style-type: none"> Association between scale scores and theoretically related constructs (i.e., state test anxiety and performance expectation). (E1) Lack of a strong association between scale scores and less theoretically related constructs (i.e., certain attitudes toward math). (E2) 	<ul style="list-style-type: none"> Significant and moderate positive correlation between trait test anxiety and state test anxiety (convergent validity evidence). Significant and moderate negative correlation between trait test anxiety and performance expectation on a statistics test. (convergent validity evidence) Non-significant or weak correlations between trait test anxiety and certain attitudes towards math (divergent validity evidence).

* SRMR is more sensitive to loading invariance than to the other two levels of invariance. When testing metric invariance, a change of $\geq .025$ or $.030$ is proposed. When testing invariance at the scalar or strict levels, a change of $\geq .005$ or $.010$ is proposed (see Chen, 2007).

Methods

Participants

In study 2, a U.S. Internet sample was recruited through Prolific¹ ($N=301$) and an additional undergraduate student sample of undergraduate students was recruited ($N=207$) as part of the same study mentioned previously. Table 1 shows the demographic information for

¹ Online participant recruitment platform (<https://prolific.co>).

DEVELOPMENT VALIDATION MEASUREMENT INVARIANCE TTAIS

both samples. To ensure the Internet sample was comparable to the undergraduate student sample, participants were screened such that only those who indicated they were (a) a current student, (b) had attained high-school degree or equivalent as their highest level of education, and (c) resided in the U.S.

Measures

Trait Test Anxiety – Short. The revised trait test anxiety inventory developed in study 1 was used in study 2. Ratings were again provided on a 5-point Likert scale (*1=Strongly disagree*, ..., *5=Strongly agree*). Table 5 provides item-level descriptives for the revised 12-item scale. Internal consistency estimates (*McDonald's ω*) for both the Internet sample and study 2 undergraduate student samples are reported in the results section that follows.

Table 5. *Item-level descriptive statistics from the study 2 sample on the revised 12-item Trait Test Anxiety Inventory - Short (TTAI-S).*

Dimensions / Subdimensions	Item Wording	Internet (N=301)				Undergraduate Student 2 (N=207)				Combined Study 2 (N=508)			
		Mean	SD	Median	Item-Rest r	Mean	SD	Median	Item-Rest r	Mean	SD	Median	Item-Rest r
Affective Dimension:													
Physiological arousal + Tension													
Physiological arousal	I feel very jittery when taking an important test.	3.64	1.22	4	0.64	3.47	1.41	4	0.57	3.57	1.30	4	0.61
	While taking exams, I don't feel uneasy or upset. [R]	3.39	1.23	4	0.72	3.19	1.41	4	0.64	3.31	1.31	4	0.69
	I feel very panicky when I take an important test.	3.50	1.30	4	0.78	3.14	1.49	4	0.66	3.35	1.39	4	0.73
Tension	During tests, I can feel relaxed. [R]	3.40	1.23	4	0.74	3.20	1.33	3	0.59	3.32	1.28	4	0.68
	During important tests, I am so tense that my stomach gets upset.	2.72	1.41	3	0.52	2.56	1.43	2	0.59	2.66	1.42	2	0.55
	During exams, I feel calm and facts or ideas come to me fluidly. [R]	3.07	1.19	3	0.74	2.98	1.27	3	0.58	3.03	1.22	3	0.67
Cognitive Dimension:													
Worry + Cognitive Interference													
Worry	I seem to defeat myself while working on important tests.	2.83	1.29	3	0.69	2.65	1.33	2	0.54	2.76	1.31	3	0.63
	I feel confident while taking tests. [R]	3.23	1.23	4	0.82	2.93	1.33	3	0.64	3.10	1.28	3	0.74
	Even when I'm well prepared for a test, I feel very nervous about it.	3.87	1.21	4	0.62	3.56	1.35	4	0.55	3.74	1.28	4	0.59
Cognitive Interference	Thoughts of doing poorly on a test don't interfere with my ability to concentrate. [R]	3.29	1.27	4	0.63	3.39	1.34	4	0.47	3.33	1.30	4	0.55
	During tests, I find myself thinking about the consequences of failing.	3.37	1.36	4	0.65	3.06	1.52	3	0.58	3.24	1.43	4	0.62

DEVELOPMENT VALIDATION MEASUREMENT INVARIANCE TTAIS

	My mind feels clear when I am working on a test. [R]	3.08	1.22	3	0.68	2.80	1.34	2	0.57	2.97	1.28	3	0.64
<i>Scale Score (Mean)</i>	-	3.28	0.94	3.28		3.08	0.91	3.17	-	3.20	0.93	3.33	-

Note: [R] indicates the item was reverse coded. Ratings provided on all items using a 5-point Likert scale (1=Strongly disagree, ..., 5=Strongly agree). Text that is underlined reflects minor word changes to the scale relative to study 1.

State Test Anxiety. Participants in the study 2 undergraduate student sample were administered a single item scale, which asked: “Please select the response that indicates how anxious you feel right now having completed the test.” Students responded using a 7-point Likert scale (1= “Not at all anxious”, ..., 7= “Most anxious I have ever felt”). Past research has found single-item measures of anxiety to have acceptable psychometric properties (Núñez et al., 2014). Table 6 provides item-level descriptives for the self-report measures used to demonstrate convergent and divergent validity.

Table 6. Descriptive statistics for the state test anxiety, performance expectation, and math attitudes scale scores.

	Undergraduate Student Sample 2 (N=207)				
	Mean	SD	Median	Min	Max
State Test Anxiety (Single-Item)	2.43	1.17	2.0	1.0	6
Test Self-efficacy (Single-Item)	12.55	3.77	13.0	2.0	20
Math Attitudes (ATMI)	3.62	1.00	3.8	1.0	5
Enjoyment	3.54	0.97	3.60	1.0	5
Motivation	3.27	1.07	3.25	1.0	5
Self-confidence	3.78	0.94	4.00	1.0	5
Values	3.90	0.84	4.00	1.2	5

Note: Ratings provided on the ATMI using a 5-point Likert scale (1=Strongly disagree, ..., 5=Strongly agree) and means for the math attitudes constructs were derived from mean scale scores after proper reverse-coding.

Test Self-efficacy. Following a 20-item test of statistics, study 2 undergraduate student participants were asked, “Out of the 20 questions you completed just now, how many did you answer correctly?” and provided responses ranging from “0 - None of them” to “20 - All of them”.

Attitudes toward Math. The short-form Attitudes Toward Mathematics Inventory (ATMI; Lim & Chapman, 2013) was administered to gather information about student’s attitudes towards math. The ATMI consists of 19 items reflecting enjoyment (5-items), motivation (4-items), self-confidence (5-items), and perceived values (5-items) associated with mathematics learning. Responses were provided using 5-point Likert scale (1 = Strongly Disagree, ..., 5 =

DEVELOPMENT VALIDATION MEASUREMENT INVARIANCE TTAIS

Strongly Agree). The scale had acceptable reliability overall (19-items, *McDonald's* $\omega=.92$), and for each subscale separately (enjoyment: *McDonald's* $\omega=.91$; motivation: *McDonald's* $\omega=.86$; self-confidence: *McDonald's* $\omega=.90$; values: *McDonald's* $\omega=.88$).

Procedure

Data collection. All participants consented prior to participation. The Internet sample was recruited via Prolific in Winter 2020. The undergraduate student sample was recruited between Spring 2021 to Spring 2022 in a similar manner to that in study 1. As compensation for completing the study, participants either received monetary compensation (Internet and undergraduate student sample) or bonus credits towards a class grade (undergraduate student sample only).

Participants in the study 2 undergraduate student sample completed the 12-item measure of trait test anxiety developed in study 1, a one-item measure to gauge their predicted scores before completing a 20-item test of statistics knowledge, and a one-item measure of state test anxiety after completing the test, and a 19-item measure of attitudes towards math. The measures for trait test anxiety and attitudes toward math were administered to participants in the study 2 undergraduate student sample in a counterbalanced fashion such that approximately half of the participants were randomly assigned to answer it before the 20-item test, while the other half completed it after. Unlike the undergraduate student sample, participants in the Internet sample were not required to have completed a college-level statistics course as they were not administered an assessment in the subject area.

Prior to analyses, data were again cleaned of responses thought to reflect carelessness in the same manner as described in study 1. No responses were removed from either the Internet or the study 2 undergraduate student sample using the longstring method to identify careless

responding given there were no consecutive responses with the same selection greater than 7 (of 12 possible).

Table 7. *Sequence of models tested to establish measurement invariance*

Model	Constraints
Configural	Same latent model structure between groups. Subgroups are tested with no additional equivalence constraints.
Metric	Same model as the “configural model,” with the addition of constraints of equivalence on factor loadings between the groups.
Scalar	Same model and constraints as the “metric model,” with the addition of constraints of equivalence on intercepts between the groups.
Strict	Same model and constraints as the “scalar model,” with the addition of constraints of equivalence on residuals between the groups.

Analysis. For both the Internet and study 2 undergraduate student sample, CFA was conducted separately to determine whether the unidimensional model fit the data well. Model fit indices were evaluated using the same criteria described in study 1. Analyses were then conducted to determine whether assumptions of measurement invariance held across the two samples (Internet v. study 2 undergraduate student). We then sought to investigate whether measurement invariance also held between different participant subgroups based on gender, underserved minority status, and parental educational attainment (a correlate of SES; see Melby, 2008). Table 7 provides a brief description of the constraints imposed in each successive measurement invariance model. Measurement invariance analyses involved a series of nested latent factor models with an increasing number of equality constraints between samples or subgroups. To compare the fit of the nested models, several indices were considered, in addition to the model fit criteria mentioned previously. We report the χ^2 difference test using a scaling to correct for non-normality (Satorra & Bentler, 2010). Given the χ^2 test is known to be influenced by factors such as the sample size (Fan et al., 1999), the number of parameters in the model, and deviation from normality (Bentler, 2007; Fan & Wang, 1998), it is often significant even when assumptions of measurement invariance hold. Thus, we considered indices of relative change between model fit more informative. We used the thresholds shown in Table 8 to evaluate

DEVELOPMENT VALIDATION MEASUREMENT INVARIANCE TTAIS

whether a more constrained measurement model maintained comparable model fit. After establishing evidence of measurement invariance, we then tested for demographic group differences in test anxiety.

DEVELOPMENT VALIDATION MEASUREMENT INVARIANCE TTAIS

Table 8. *Thresholds for change in goodness-of-fit indices used to evaluate measurement invariance when comparing more constrained measurement models.*

Goodness-of-fit Index	Δ Goodness-of-fit Estimate	Reference
Comparative Fit Index (CFI)	smaller than or equal to .01	Cheung & Rensvold (2002)
Root Mean Square Error of Approximation (RMSEA)	not much greater than .015	Chen (2007)
Standardized Root Mean Square Residual (SRMR)	not much greater than .025 when testing for metric invariance not much greater than .005 when testing for scalar or strict level invariance	Chen (2007), Jin (2020)
McDonald's Noncentrality Index (NCI)	smaller or equal to .02 (Cheung & Rensvold, 2002)	Cheung & Rensvold (2002)
Gamma-hat ($\hat{\gamma}$)	smaller or equal to .001	Cheung & Rensvold (2002)

Table 9. *Results of measurement invariance analysis showing model fit comparison between successively more constrained models to test for invariance between Internet and phase 2 undergraduate student samples (N=508).*

Model	RMSEA _{Robust}										Model Comparison									
	χ^2_{Scaled}	$p(\chi^2_{\text{Scaled}})$	df _{Scaled}	CFI _{Robust}	TLI _{Robust}	(lower 95% CI)	(upper 95% CI)	SRMR	NCI	$\hat{\gamma}$	$\Delta\chi^2$	Δdf	$p(\Delta\chi^2_{\text{Scaled}})$	ΔCFI	ΔRMSEA	ΔSRMR	ΔNCI	$\Delta\hat{\gamma}$	MI Assumed?	
Configural	213.273	<.001	108	0.994	0.992	0.040	0.032	0.048	0.045	1.018	1.006	-	-	-	-	-	-	-	-	
Metric	224.816	<.001	119	0.992	0.991	0.044	0.035	0.052	0.052	0.997	0.999	18.524	11	0.070	-0.002	0.003	0.007	-0.021	-0.007	✓
Scalar	242.499	<.001	130	0.991	0.991	0.043	0.035	0.052	0.054	0.997	0.999	17.844	11	0.085	-0.001	<.001	0.002	0.001	<.001	✓
Strict	287.798	<.001	143	0.985	0.986	0.054	0.045	0.063	0.067	0.937	0.979	30.331	13	0.004	-0.006	0.011	0.013	-0.060	-0.020	X

Note: Configural (no equality constraints), Metric (loadings constrained), Scalar (loadings and intercepts constrained), Strict (loadings, intercepts, residuals constrained).

Decision interpretation key: ✓ = Assumptions of measurement invariance at that level met. X = Assumptions of measurement invariance at that level not met.

Table 10. *Results of measurement invariance analysis showing model fit comparison between successively more constrained models to test for invariance based on student background characteristics (N=508).*

Model	χ^2_{Scaled}	$p(\chi^2_{\text{Scaled}})$	df _{Scaled}	CFI _{Robust}	TLI _{Robust}	RMSEA _{Robust}			SRMR	NCI	$\hat{\gamma}$	$\Delta\chi^2$	Δdf	$p(\Delta\chi^2_{\text{Scaled}})$	ΔCFI	Model Comparison				$\Delta\hat{\gamma}$	MI Assumed?
						(lower 95% CI)	(upper 95% CI)									ΔRMSEA	ΔSRMR	ΔNCI			
Gender (Female=1)																					
Configural	190.308	<.001	108	0.995	0.993	0.036	0.028	0.045	0.043	1.025	1.008	-	-	-	-	-	-	-	-	-	
Metric	243.916	<.001	119	0.989	0.988	0.049	0.040	0.058	0.056	0.979	0.993	29.406	11	0.002	-0.006	0.013	0.013	-0.046	-0.015	✓	
Scalar	266.975	<.001	130	0.988	0.988	0.049	0.041	0.057	0.058	0.977	0.992	23.073	11	0.017	-0.001	<.001	0.002	-0.002	-0.001	✓	
Strict	238.142	<.001	143	0.989	0.990	0.045	0.034	0.054	0.063	0.965	0.988	10.181	13	0.679	0.001	-0.004	0.004	-0.012	-0.004	X	
Race/Ethnicity (Underserved status=1)																					
Configural	170.748	<.001	108	0.996	0.995	0.030	0.021	0.038	0.039	1.041	1.014	-	-	-	-	-	-	-	-	-	
Metric	144.953	<.001	119	0.998	0.997	0.022	0.000	0.034	0.041	1.037	1.012	6.477	11	0.840	0.002	-0.008	0.003	-0.004	-0.001	✓	
Scalar	154.700	<.001	130	0.998	0.998	0.021	0.000	0.032	0.042	1.043	1.014	9.803	11	0.548	<.001	-0.001	0.001	0.006	0.002	✓	
Strict	133.352	0.011	143	1.000	1.000	<.001	<.001	0.021	0.045	1.043	1.014	4.965	13	0.976	0.002	-0.021	0.003	<.001	<.001	✓	
Parental Education (Below 4yr degree=1)																					
Configural	200.583	<.001	108	0.994	0.993	0.036	0.028	0.044	0.043	1.030	1.010	-	-	-	-	-	-	-	-	-	
Metric	185.028	<.001	119	0.995	0.994	0.034	0.024	0.043	0.048	1.021	1.007	10.511	11	0.485	<.001	-0.002	0.005	-0.009	-0.003	✓	
Scalar	199.879	<.001	130	0.994	0.994	0.034	0.024	0.042	0.049	1.024	1.008	14.780	11	0.193	<.001	-0.001	0.001	0.003	0.001	✓	
Strict	191.498	<.001	143	0.994	0.995	0.032	0.018	0.043	0.056	1.000	1.000	12.737	13	0.468	<.001	-0.002	0.007	-0.024	-0.008	X	

Note: Configural (no equality constraints), Metric (loadings constrained), Scalar (loadings and intercepts constrained), Strict (loadings, intercepts, residuals constrained).

Decision interpretation key: ✓ = Assumptions of measurement invariance at that level met. X = Assumptions of measurement invariance at that level not met.

DEVELOPMENT VALIDATION MEASUREMENT INVARIANCE TTAIS

Finally, using data from the study 2 undergraduate student sample, correlations were examined between the trait test anxiety score and related constructs (i.e., state test anxiety, performance expectation on a test of statistics knowledge, self-confidence in learning math) and constructs expected to be unrelated (i.e., enjoyment, motivation, values in learning math). Because participants were part of an experimental study, we calculated partial correlations controlling for study condition. The strength of the correlations was evaluated using the thresholds proposed by Cohen (1992), i.e., small/weak: $r < .29$, medium/moderate: $.30 < r < .50$, strong: $r \geq .50$.

Results

The results section is organized around the validation framework presented in Table 4, with evidence and inferences supporting the scoring of the scale presented first, followed by generalization, and finally, extrapolation.

Scoring Validity Evidence

We first sought to establish scoring validity evidence of the revised 12-item scale. We then fit the factor model to the two validation samples collected in study 2: an Internet sample and a undergraduate student sample. Correlations between subscale scores were again strong in both samples (Internet: $r=.84$, study 2 undergraduate student: $r=.80$; *validity evidence S1*; see Table 4), and thus we again tested a single-factor model. A single-factor CFA model was fit to the data from the Internet sample ($\chi^2_{Scaled}(df=54)=148.593$, $p<.001$, $CFI_{Robust}=.995$, $TLLI_{Robust}=.994$, $RMSEA_{Robust}=.039$, $SRMR=.041$, $NCI=1.026$, $\hat{\gamma}=1.009$) and the undergraduate student sample ($\chi^2_{Scaled}(df=54)=88.077$, $p=.037$, $CFI_{Robust}=.989$, $TLLI_{Robust}=.987$, $RMSEA_{Robust}=.042$, $SRMR=.059$, $NCI=1.005$, $\hat{\gamma}=1.002$), revealing good model fit with standardized factor loadings above .500 in both instances. There was also evidence of good internal consistency of the 12-items used to derive a single scale score in both the Internet sample (*McDonald's* $\omega=.97$) and the study 2 undergraduate student sample (*McDonald's* $\omega=.95$) (*validity evidence S2*).

Generalization Validity Evidence: Measurement Invariance

To establish generalization validity evidence, we investigated whether the 12-item revised scale was invariant between samples (Internet v. study 2 undergraduate student) and sample subgroups by conducting measurement invariance analyses.

Between Samples. We then combined data collected from the Internet sample and the study 2 undergraduate student sample ($N=508$) to examine whether the 12-item revised scale remained invariant across the two samples. Even when scalar invariance (i.e., equality constraints on loadings and intercepts) was assumed, the model showed good fit (see Table 9). The change in model fit indices also suggested scalar invariance roughly held given that across all criteria (see Table 8). Thus, the results suggested that even when equality constraints were imposed on the loadings and intercepts between the Internet and study 2 undergraduate student sample, the model fit was not compromised, and thus scalar invariance could be assumed (*validity evidence G1*).

Between Learners based on Demographic Characteristics. We next sought to determine if the revised 12-item measure was invariant based on whether the student was a member of three types of underserved groups in STEM. The sample again consisted of participants from the study 2 sample ($N=508$). Model fit and comparison indices for each successively constrained model are shown in Table 10. Based on criteria described previously for evaluating fit (see Table 8), the models appeared to fit the data well across all groups and measurement invariance levels. For both gender (female=1) and parental educational attainment (less than a four-year college degree=1), there was sufficient evidence in favor of scalar invariance (i.e., factor loadings and intercepts constrained to be equal across groups) in the single factor model for trait test anxiety. In the model comparing groups based on gender, except for $\Delta\hat{\chi}^2$, the change-in-model-fit indices suggested that even the assumption of strict invariance could be viable based on the criteria described previously. Measurement invariance analysis based on race/ethnicity (underserved status in STEM=1),

however, suggested that invariance could be at the strict invariance (i.e., factor loadings, intercepts, and residuals constrained). Thus, there was evidence of at least scalar invariance based on these demographic groups (*validity evidence G2*).

Extrapolation Validity Evidence: Associations with Related and Unrelated Constructs

Next, we investigated the association between the scale score derived from the revised 12-item measure of trait test anxiety and related constructs using data from the study 2 undergraduate student sample only ($N=207$). Table 11 shows the partial correlations between the constructs, controlling for the counterbalancing of the scale administration.

Table 11. *Partial correlations (controlling for sample condition) between trait test anxiety scale score, state test anxiety scale score, and performance expectation ($N=207$).*

	1.	2.	3.	4.	5.	6.	7.
1. Trait Test Anxiety (Scale Score)	-	<.001	<.001	<.001	.002	<.001	.016
2. State Test Anxiety (Single Item)	.310	-	.001	.215	.084	<.001	.190
3. Test Self-efficacy (Single Item)	-.295	-.231	-	<.001	<.001	<.001	.004
Math Attitudes (Scale Scores)							
4. Enjoyment	-.264	-.088	.312	-	<.001	<.001	<.001
5. Motivation	-.223	-.123	.312	.789	-	<.001	<.001
6. Self-confidence	-.535	-.346	.337	.521	.429	-	.003
7. Values	-.170	-.093	.206	.497	.547	.213	-

Note: Values in the lower-diagonal reflect correlation coefficients. Values in the upper-diagonal reflect p-values. Bolded estimates are significant with Bonferroni corrected p -value (assuming $\alpha=.05$)=.0023

We found a moderate and positive association between trait and state test anxiety ($r_{\text{partial}}=.310$) and small-to-moderate and negative association between learners' trait test anxiety and their performance expectation on the test as measured by their predicted test scores ($r_{\text{partial}}=-.295$), both of which were significant with Bonferroni correction. These findings generally provide evidence of convergent validity by showing that the average score for the trait test anxiety measure is associated with related constructs in a theoretically sound manner (*validity evidence EI*).

We examined whether there was an association between learners' trait test anxiety and their attitudes towards math, which was measured according to four dimensions (enjoyment, values, motivation, and self-confidence; see Lim & Chapman, 2013). The association between trait test anxiety and the four math attitudes assessed varied (see Table 11). Trait test anxiety was strongly and negatively associated with self-confidence in learning math ($r_{\text{partial}}=-.535$), which is consistent

DEVELOPMENT VALIDATION MEASUREMENT INVARIANCE TTAIS

considering students with lower performance expectations tend to have greater test anxiety. By contrast, trait test anxiety was only weakly correlated with enjoyment ($r_{\text{partial}}=-.264$), motivation ($r_{\text{partial}}=-.223$) in learning math. The correlation between trait test anxiety and values in learning math was not significant with corrections for multiple tests applied ($r_{\text{partial}}=-.170$, $p = .016 > .0023$). These findings generally lend support for the distinctiveness of the trait test anxiety measure by providing divergent validity evidence (*validity evidence E2*).

Demographic Group Differences

Given measurement invariance established at the scalar level or higher, we can draw valid inferences on group comparisons (Putnick & Borenstein, 2016). Hence, we tested for group differences in the trait test anxiety scale score using data from the entire study 2 sample ($N=508$). Consistent with past literature, we found significant differences across all three demographic variables, with female students ($M_{\text{female}}=3.31$ v. $M_{\text{non-female}}=3.03$; $M_{\text{diff}}=.28$ (95% CI: .11, .44); $t(507)=3.28$, $p=.001$, $d=.30$), students from underserved race/ethnicity groups ($M_{\text{UR/E}}=3.54$ v. $M_{\text{non-UR/E}}=3.16$; $M_{\text{diff}}=.38$ (95% CI: .13, .64); $t(507)=2.97$, $p=.004$, $d=.41$), and students of parents who did not have a 4-year college degree ($M_{\text{PE}<4\text{-years}}=3.60$ v. $M_{\text{PE}\geq 4\text{-years}}=3.14$; $M_{\text{diff}}=.22$ (95% CI: .03, .41); $t(507)=2.32$, $p=.02$, $d=.24$) having greater trait test anxiety than counterparts.

Discussion

Though there is an extensive history examining the effects of test anxiety in school settings in the psychological and educational research literature, relatively few concise and interpretable measures have been validated with a diverse student sample. We thus sought to update and shorten an existing measure while meeting recently innovated criteria for scale validation. We further sought to evaluate it for differences between student subgroups reflecting different data collection sources (Internet v. undergraduate student sample), as well as student demographic characteristics, including gender, race/ethnicity, and SES. The result is a concise 12-item scale that is aligned with a

DEVELOPMENT VALIDATION MEASUREMENT INVARIANCE TTAIS

theoretical framework of test anxiety and may be less susceptible to careless or biased responding.

Implications

These results have several implications for future research and practice. The findings support the validity and invariance of the Trait Test Anxiety Inventory – Short (TTAI-S), a concise measure that is easy to administer and easy to score. Furthermore, unlike existing measures of test anxiety, the current measure is balanced such that it includes an equal number of positively and negatively keyed items. This provides a simple way to identify responses that are likely to be invalid either due to careless or biased responding (Wetzel & Carstensen, 2015).

There are several possibilities for future research with this revised measure. A program of future work involving the use of this self-report measure may help in understanding individual and group differences in test anxiety (Sung et al., 2016), how such differences combined with variation in incentives for assessment moderate associations with performance (Clark et al., 2018), as well as how test anxiety may differ depending on the format or administration of exams (Martin & Lazendic, 2018). Ultimately, such knowledge could inform the theory and efficacy of interventions to mitigate test anxiety and its negative impact on performance in evaluative contexts (Putwain & Pescod, 2018; von der Embse et al., 2012, 2021). Given that we found that students from groups that have been historically underrepresented or underserved in STEM disciplines experienced significantly greater trait test anxiety, these findings have special implications for addressing a possible factor contributing to STEM participation discrepancies. Some have proposed test anxiety interventions to reduce disparities in participation in STEM fields (Harris et al., 2019; O’Brien et al., 2020).

Limitations

Despite the potential impact of this investigation and the usefulness of the scale for future research, the sample comprising U.S. undergraduate students limits the potential generalizability.

DEVELOPMENT VALIDATION MEASUREMENT INVARIANCE TTAIS

Further work would need to be conducted to investigate the validity of the measure on children, adolescents, older adults, as well as to investigate cross-cultural differences. We acknowledge that work has already been conducted to examine the validity and revise measures of test anxiety among samples from populations of different age-groups (e.g., Lowe, 2014) and from multiple countries and cultures (e.g., Lowe, 2019; Lowe et al., 2011, 2012). Concerning the instrument itself, the items were selected and revised to ensure ease of comprehension acceptable face validity. There remains the possibility that respondents may misinterpret the content of the items, or the items fail to capture certain distinct aspects of test anxiety.

Conclusions

The TTAI-S, a measure of trait test anxiety, demonstrates good psychometric properties across both phases of the study, even after reducing the scale length by almost half (20 to 12 items). We also found that the measure produced at minimum evidence of scalar measurement invariance based on indicators reflecting different data collection sources (Internet v. undergraduate student) and demographic characteristics including gender, race/ethnicity, and parental educational attainment. In addition, we found convergent validity evidence considering significant associations in the expected direction between related constructs of state test anxiety and performance expectations. These findings together support the psychometric integrity of the TTAI-S. Finally, using data collected from the revised 12-item scale, we also found significant group differences with students historically underrepresented or underserved in STEM disciplines reporting significantly greater trait test anxiety. As such, these findings not only provide a valid measure for studying test anxiety, but also highlight a critical need for interventions that aim to reduce test anxiety among certain students.

References

Baer, R. A., Samuel, D. B., & Lykins, E. L. (2011). Differential item functioning on the Five Facet

- Mindfulness Questionnaire is minimal in demographically matched meditators and nonmeditators. *Assessment*, 18(1), 3–10. <https://doi.org/10.1177/1073191110392498>
- Bentler, P. M. (2007). On tests and indices for evaluating structural models. *Personality and Individual Differences*, 42(5), 825–829. <https://doi.org/10.1016/j.paid.2006.09.024>
- Brosseau-Liard, P. E., & Savalei, V. (2014). Adjusting incremental fit indices for nonnormality. *Multivariate Behavioral Research*, 49(5), 460–470. <https://doi.org/10.1080/00273171.2014.933697>
- Brosseau-Liard, P. E., Savalei, V., & Li, L. (2012). An investigation of the sample performance of two nonnormality corrections for RMSEA. *Multivariate Behavioral Research*, 47(6), 904–930. <https://doi.org/10.1080/00273171.2012.715252>
- Cassady, J. C., & Johnson, R. E. (2002). Cognitive test anxiety and academic performance. *Contemporary Educational Psychology*, 27(2), 270–295. <https://doi.org/10.1006/ceps.2001.1094>
- Chen, F. F. (2007). Sensitivity of goodness of fit indexes to lack of measurement invariance. *Structural Equation Modeling: A Multidisciplinary Journal*, 14, 464–504. <https://doi.org/10.1080/10705510701301834>
- Cheung, G. W., & Rensvold, R. B. (2002). Evaluating goodness-of-fit indexes for testing measurement invariance. *Structural Equation Modeling*, 9(2), 233–255. https://doi.org/10.1207/S15328007SEM0902_5
- Clark, D. A., Crandall, J. R., & Robinson, D. H. (2018). Incentives and test anxiety may moderate the effect of retrieval on learning. *Learning and Individual Differences*, 63, 70–77. <https://doi.org/10.1016/j.lindif.2018.03.001>
- Cohen, J. (1992). A power primer. *Psychological Bulletin*, 112(1), 155–159. <https://doi.org/10.1037/0033-2909.112.1.155>
- Cook, D. A., Brydges, R., Ginsburg, S., & Hatala, R. (2015). A contemporary approach to validity arguments: a practical guide to Kane's framework. *Medical Education*, 49(6), 560–575. <https://doi.org/10.1111/medu.12678>

- Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition & Emotion*, 6(6), 409–434. <https://doi.org/10.1080/02699939208409696>
- Fan, X., & Wang, L. (1998). Effects of potential confounding factors on fit indices and parameter estimates for true and misspecified SEM models. *Educational and Psychological Measurement*, 58(5), 701–735. <https://doi.org/10.1177/0013164498058005001>
- Fan, X., Thompson, B., & Wang, L. (1999). Effects of sample size, estimation methods, and model specification on structural equation modeling fit indexes. *Structural Equation Modeling: A Multidisciplinary Journal*, 6(1), 56–83. <https://doi.org/10.1080/10705519909540119>
- Gerwing, T. G., Rash, J. A., Allen Gerwing, A. M., Bramble, B., & Landine, J. (2015). Perceptions and incidence of test anxiety. *The Canadian Journal for the Scholarship of Teaching and Learning*, 6(3). <https://doi.org/10.5206/cjsotl-rcacea.2015.3.3>
- Harris, R. B., Grunspan, D. Z., Pelch, M. A., Fernandes, G., Ramirez, G., & Freeman, S. (2019). Can test anxiety interventions alleviate a gender gap in an undergraduate STEM course?. *CBE—Life Sciences Education*, 18(3), ar35. <https://doi.org/10.1187/cbe.18-05-0083>
- Hong, M., Steedle, J. T., & Cheng, Y. (2020). Methods of detecting insufficient effort responding: Comparisons and practical recommendations. *Educational and Psychological Measurement*, 80(2), 312–345. <https://doi.org/10.1177/0013164419865316>
- Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, 6(1), 1–55. <https://doi.org/10.1080/10705519909540118>
- Jin, Y. (2020). A note on the cutoff values of alternative fit indices to evaluate measurement invariance for ESEM models. *International Journal of Behavioral Development*, 44(2), 166–174. <https://doi.org/10.1177/0165025419866911>
- Joiner, T. E., Steer, R. A., Beck, A. T., Schmidt, N. B., Rudd, M. D., & Catanzaro, S. J. (1999). Physiological hyperarousal: Construct validity of a central aspect of the tripartite model of depression and anxiety. *Journal of Abnormal Psychology*, 108, 290–298. <https://doi.org/10.1037/0021-843X.108.2.290>

Kane, M. T. (2013). Validating the interpretations and uses of test scores. *Journal of Educational Measurement*, 50(1), 1–73. <https://doi.org/10.1111/jedm.12000>

Korkmaz, G., & Toraman, Ç. (2020). Are we ready for the post-COVID-19 educational practice? An investigation into what educators think as to online learning. *International Journal of Technology in Education and Science*, 4(4), 293–309. <https://eric.ed.gov/?id=EJ1271308>

Liebert, R. M., & Morris, L. W. (1967). Cognitive and emotional components of test anxiety: A distinction and some initial data. *Psychological Reports*, 20(3), 975–978. <https://doi.org/10.2466/pr0.1967.20.3.975>

Lim, S. Y., & Chapman, E. (2013). Development of a short form of the attitudes toward mathematics inventory. *Educational Studies in Mathematics*, 82(1), 145–164. <https://doi.org/10.1007/s10649-012-9414-x>

Lotz, C., & Sparfeldt, J. R. (2017). Does test anxiety increase as the exam draws near?—Students' state test anxiety recorded over the course of one semester. *Personality and Individual Differences*, 104, 397–400. <https://doi.org/10.1016/j.paid.2016.08.032>

Lowe, P. A. (2014). The Test Anxiety Measure for Adolescents (TAMA) examination of the reliability and validity of the scores of a new multidimensional measure of test anxiety for middle and high school students. *Journal of Psychoeducational Assessment*, 32(5), 404–416. <https://doi.org/10.1177/0734282913520595>

Lowe, P. A. (2015). Should test anxiety be measured differently for males and females? Examination of measurement bias across gender on measures of test anxiety for middle and high school, and college students. *Journal of Psychoeducational Assessment*, 33(3), 238–246. <https://doi.org/10.1177/0734282914549428>

Lowe, P. A. (2018). An investigation into the psychometric properties of the test anxiety measure for college students. *Journal of Psychoeducational Assessment*, 36(4), 322–336. <https://doi.org/10.1177/0734282916678536>

Lowe, P. A. (2019). Cross-National Comparison between UK and US Higher Education Students in Test Anxiety. *Higher Education Studies*, 9(3), 88–97. <https://eric.ed.gov/?id=EJ1223014>

- Lowe, P. A. (2021). The test anxiety measure for college students-short form: Development and examination of its psychometric properties. *Journal of Psychoeducational Assessment*, 39(2), 139–152. <https://doi.org/10.1177/0734282920962947>
- Lowe, P. A., & Ang, R. P. (2012). Cross-cultural examination of test anxiety among US and Singapore students on the Test Anxiety Scale for Elementary Students (TAS-E). *Educational Psychology*, 32(1), 107–126. <https://doi.org/10.1080/01443410.2011.625625>
- Lowe, P. A., & Lee, S. W. (2008). Factor structure of the Test Anxiety Inventory for Children and Adolescents (TAICA) scores across gender among students in elementary and secondary school settings. *Journal of Psychoeducational Assessment*, 26(3), 231–246. <https://doi.org/10.1177/0734282907303760>
- Lowe, P. A., Ang, R. P., & Loke, S. W. (2011). Psychometric analyses of the test anxiety scale for elementary students (TAS-E) scores among Singapore primary school students. *Journal of Psychopathology and Behavioral Assessment*, 33(4), 547–558. <https://doi.org/10.1007/s10862-011-9250-9>
- Mandler, G., & Sarason, S.B. (1952). A study of anxiety and learning. *Journal of Abnormal and Social Psychology* 47, 166–173. <https://doi.org/10.1037/h0062855>
- Martin, A. J., & Lazendic, G. (2018). Computer-adaptive testing: Implications for students’ achievement, motivation, engagement, and subjective test experience. *Journal of Educational Psychology*, 110(1), 27–45. <https://doi.org/10.1037/edu0000205>
- Meade, A. W., & Craig, S. B. (2012). Identifying careless responses in survey data. *Psychological Methods*, 17(3), 437–455. <https://doi.org/10.1037/a0028085>
- Melby, J. N., Conger, R. D., Fang, S. A., Wickrama, K. A. S., & Conger, K. J. (2008). Adolescent family experiences and educational attainment during early adulthood. *Developmental Psychology*, 44(6), 1519–1536. <https://doi.org/10.1037/a0013352>
- Möcklinghoff, S., Rapoport, O., Heckel, C., Messerschmidt-Grandi, C., & Ringeisen, T. (2021). Latent profiles of test anxiety: Considering its multi-faceted structure. *International Journal of Educational Research*, 110, 101882. <https://doi.org/10.1016/j.ijer.2021.101882>

- Mowbray, T., Jacobs, K., & Boyle, C. (2015). Validity of the German Test Anxiety Inventory (TAI-G) in an Australian sample. *Australian Journal of Psychology*, 67, 121–129.
<https://doi.org/10.1111/ajpy.12058>
- Nadler, J. T., & Clark, M. H. (2011). Stereotype threat: A Meta-Analysis comparing African Americans to Hispanic Americans 1. *Journal of Applied Social Psychology*, 41(4), 872–890.
- National Academies of Sciences, Engineering, and Medicine [NASEM]. (2018). *Data science for undergraduates: Opportunities and options*. National Academies Press.
<https://www.annualreviews.org/doi/full/10.1146/annurev-statistics-060116-053930>
- National Center for Science and Engineering Statistics [NCES]. (2021, April). *Women, minorities, and persons with disabilities in science and engineering*. Directorate for Social, Behavioral and Economic Sciences, National Science Foundation. Report retrieved from
<https://nces.nsf.gov/pubs/nsf21321>
- Newsom, J. T.. (2020). Nested Models, Model Modifications, and Correlated Errors. Lecture notes from PSY 523/623: Structural Equation Modeling. Personal Collection of J. T. Newsom, Portland State University, Portland, OR. https://web.pdx.edu/~newsomj/semclass/ho_nested.pdf
- Núñez-Peña, M. I., Guilera, G., & Suárez-Pellicioni, M. (2014). The single-item math anxiety scale: An alternative way of measuring mathematical anxiety. *Journal of Psychoeducational Assessment*, 32(4), 306–317. <https://doi.org/10.1177/0734282913508528>
- O'Brien, L. T., Garcia, D. M., Blodorn, A., Adams, G., Hammer, E., & Gravelin, C. (2020). An educational intervention to improve women's academic STEM outcomes: Divergent effects on well-represented vs. underrepresented minority women. *Cultural Diversity and Ethnic Minority Psychology*, 26(2), 163. <https://doi.org/10.1037/cdp0000289>
- O'Brien, L. T., Garcia, D. M., Adams, G., Villalobos, J. G., Hammer, E., & Gilbert, P. (2015). The threat of sexism in a stem educational setting: The moderating impacts of ethnicity and legitimacy beliefs on test performance. *Social Psychology of Education*, 18, 667–684.
<https://doi.org/10.1007/s11218-015-9310-1>
- Ober, T. M., Cheng, Y., Jacobucci, R., & Whitney, B. M. (2021). Examining the factor structure of

- the Big Five Inventory-2 with an adolescent sample. *Psychological Assessment*, 33(1), 14–28. <https://doi.org/10.1037/pas0000962>
- Ober, T., & Cheng, Y. (2022, December 12). *Test Anxiety Inventory - Scale Validation*. Retrieved from <https://osf.io/ajfzx>
- Pekrun, R., Frenzel, A. C., Goetz, T., & Perry, R. P. (2007). The control-value theory of achievement emotions: An integrative approach to emotions in education. In *Emotion in education* (pp. 13–36). Academic Press.
- Primi, R., Santos, D., De Fruyt, F., & John, O. P. (2019). Comparison of classical and modern methods for measuring and correcting for acquiescence. *British Journal of Mathematical and Statistical Psychology*, 72(3), 447–465. <https://doi.org/10.1111/bmsp.12168>
- Putnick, D. L., & Bornstein, M. H. (2016). Measurement invariance conventions and reporting: The state of the art and future directions for psychological research. *Developmental Review*, 41, 71–90. <https://doi.org/10.1016/j.dr.2016.06.004>
- Putwain, D. W. (2008). Test anxiety and GCSE performance: The effect of gender and socio-economic background. *Educational Psychology in Practice*, 24(4), 319–334. <https://doi.org/10.1080/02667360802488765>
- Putwain, D. W., & Daly, A. L. (2014). Test anxiety prevalence and gender differences in a sample of English secondary school students. *Educational Studies*, 40(5), 554–570. <https://doi.org/10.1080/03055698.2014.953914>
- Putwain, D. W., & Pescod, M. (2018). Is reducing uncertain control the key to successful test anxiety intervention for secondary school students? Findings from a randomized control trial. *School Psychology Quarterly*, 33(2), 283. <https://doi.org/10.1037/spq0000228>
- Putwain, D. W., & Symes, W. (2011). Achievement goals as mediators of the relationship between competence beliefs and test anxiety. *British Journal of Educational Psychology*, 82(2), 207–224. <https://doi.org/10.1111/j.2044-8279.2011.02021.x>
- Putwain, D. W., von der Embse, N. P., Rainbird, E. C., & West, G. (2020). The development and validation of a new Multidimensional Test Anxiety Scale (MTAS). *European Journal of Psychological Assessment*, 37(3), 236–246. <https://doi.org/10.1027/1015-5759/a000604>

- Raufelder, D., & Ringeisen, T. (2016). Self-perceived competence and test anxiety. *Journal of Individual Differences*. <https://doi.org/10.1027/1614-0001/a000202>
- Rodebaugh, T. L., Woods, C. M., & Heimberg, R. G. (2007). The reverse of social anxiety is not always the opposite: The reverse-scored items of the Social Interaction Anxiety Scale do not belong. *Behavior Therapy*, 38(2), 192–206. <https://doi.org/10.1016/j.beth.2006.08.001>
- Roick, J., & Ringeisen, T. (2017). Self-efficacy, test anxiety, and academic success: A longitudinal validation. *International Journal of Educational Research*, 83, 84–93. <https://doi.org/10.1016/j.ijer.2016.12.006>
- Rozek, C. S., Ramirez, G., Fine, R. D., & Beilock, S. L. (2019). Reducing socioeconomic disparities in the STEM pipeline through student emotion regulation. *Proceedings of the National Academy of Sciences*, 116(5), 1553–1558. <https://doi.org/10.1073/pnas.1808589116>
- Sarason, I. G. (1972). Experimental approaches to test anxiety: Attention and the uses of information. In C. D. Spielberger (Ed.), *Anxiety: Current Trends in Theory and Research*, 2, 383–403.
- Sarason, I. G. (1984). Stress, anxiety and cognitive interference: Reactions to tests. *Journal of Personality and Social Psychology*, 46(4), 929–938. <https://doi.org/10.1037/0022-3514.46.4.929>
- Satorra, A., & Bentler, P. M. (2010). Ensuring positiveness of the scaled difference chi-square test statistic. *Psychometrika*, 75(2), 243–248. <https://doi.org/10.1007/s11336-009-9135-y>
- Schillinger, F. L., Mosbacher, J. A., Brunner, C., Vogel, S. E., & Grabner, R. H. (2021). Revisiting the role of worries in explaining the link between test anxiety and test performance. *Educational Psychology Review*, 33(4), 1887–1906. <https://doi.org/10.1007/s10648-021-09601-0E>
- Schneider, R., Sparfeldt, J. R., Niepel, C., Buch, S. R., & Rost, D. H. (2021). Measurement invariance of test anxiety across four school subjects. *European Journal of Psychological Assessment*. <https://doi.org/10.1027/1015-5759/a000676>
- Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2012). A 21 word solution. *Available at SSRN* 2160588. <http://dx.doi.org/10.2139/ssrn.2160588>
- Sireci, S. G., & Randall, J. (2021). Evolving notions of fairness in testing in the United States.

- In *The History of Educational Measurement* (pp. 111-135). Routledge.
- Spielberger, C. D., & Gonzalez, H. P. (1980). *Preliminary professional manual for the test anxiety inventory: (" test attitude inventory")*: TAI. consulting psychologists press.
- Spielberger, C. D., & Vagg, P. R. (1995). Test anxiety: A transactional process model. In C. D. Spielberger & P. R. Vagg (Eds.), *Test anxiety: Theory, assessment, and treatment* (pp. 3–14). Taylor & Francis.
- Steedle, J. T., Hong, M., & Cheng, Y. (2019). The effects of inattentive responding on construct validity evidence when measuring social–emotional learning competencies. *Educational Measurement: Issues and Practice*, 38(2), 101–111. <https://doi.org/10.1111/emip.12256>
- Streiner, D. L. (1994). Figuring out factors: The use and misuse of factor analysis. *The Canadian Journal of Psychiatry*, 39(3), 135–140. <https://doi.org/10.1177/070674379403900303>
- Sung, Y. T., Chao, T. Y., & Tseng, F. L. (2016). Reexamining the relationship between test anxiety and learning achievement: An individual-differences perspective. *Contemporary Educational Psychology*, 46, 241–252. <https://doi.org/10.1016/j.cedpsych.2016.07.001>
- Szafranski, D. D., Barrera, T. L., & Norton, P. J. (2012). Test anxiety inventory: 30 years later. *Anxiety, Stress & Coping*, 25(6), 667–677. <https://doi.org/10.1080/10615806.2012.663490>
- Talsma, K., Schütz, B., & Norris, K. (2019). Miscalibration of self-efficacy and academic performance: Self-efficacy ≠ self-fulfilling prophecy. *Learning and Individual Differences*, 69, 182–195. <https://doi.org/10.1016/j.lindif.2018.11.002>
- Tavares, W., Brydges, R., Myre, P., & Prpic, J. (2018). Applying Kane’s validity framework to a simulation based assessment of clinical competence. *Advances in Health Sciences Education*, 23(1), 323–338. <https://doi.org/10.1007/s10459-017-9800-3>
- Taylor, J., & Deane, F. P. (2002). Development of a short form of the Test Anxiety Inventory (TAI). *The Journal of General Psychology*, 129(2), 127–136. <https://doi.org/10.1080/00221300209603133>
- von der Embse, N., & Hasson, R. (2012). Test anxiety and high-stakes test performance between school settings: Implications for educators. *Preventing School Failure: Alternative Education*

- for *Children and Youth*, 56(3), 180–187. <https://doi.org/10.1080/1045988X.2011.633285>
- von der Embse, N. P., Kilgus, S. P., Segool, N., & Putwain, D. (2013). Identification and validation of a brief test anxiety screening tool. *International Journal of School & Educational Psychology*, 1(4), 246–258. <https://doi.org/10.1080/21683603.2013.826152>
- von der Embse, N. P., Putwain, D. W., & Francis, G. (2021). Interpretation and use of the Multidimensional Test Anxiety Scale (MTAS). *School Psychology*, 36(2), 86. <https://doi.org/10.1037/spq0000427>
- von der Embse, N., Barterian, J., & Segool, N. (2012). Test anxiety interventions for children and adolescents: A systematic review of Treatment Studies from 2000-2010. *Psychology in the Schools*, 50(1), 57–71. <https://doi.org/10.1002/pits.21660>
- von der Embse, N., Jester, D., Roy, D., & Post, J. (2018). Test anxiety effects, predictors, and correlates: A 30-year meta-analytic review. *Journal of Affective Disorders*, 227, 483–493. <https://doi.org/10.1016/j.jad.2017.11.048>
- Weijters, B., & Baumgartner, H. (2012). Misresponse to reversed and negated items in surveys: A review. *Journal of Marketing Research*, 49(5), 737–747. <https://doi.org/10.1509/jmr.11.0368>
- Weiland, T. (2017). Problematizing statistical literacy: An intersection of critical and statistical literacies. *Educational Studies in Mathematics*, 96(1), 33–47. <https://doi.org/10.1007/s10649-017-9764-5>
- Wetzel, E., & Carstensen, C. H. (2015). Multidimensional modeling of traits and response styles. *European Journal of Psychological Assessment*. <https://doi.org/10.1027/1015-5759/a000291>
- Whitney, B. M., Cheng, Y., Brodersen, A. S., & Hong, M. R. (2019). The scale of student engagement in statistics: Development and initial validation. *Journal of Psychoeducational Assessment*, 37(5), 553–565. <https://doi.org/10.1177/0734282918769983>
- Wise, S. L., & Smith, L. F. (2011). A model of examinee test-taking effort. In J. A. Bovaird, K. F. Geisinger, & C. W. Buckendahl (Eds.), *High-stakes testing in education: Science and practice in K–12 settings* (pp. 139–153). American Psychological Association. <https://doi.org/10.1037/12330-009>

Woldeab, D., & Brothen, T. (2019). 21st Century assessment: Online proctoring, test anxiety, and student performance. *International Journal of E-learning & Distance Education*, 34(1).

<http://www.ijede.ca/index.php/jde/article/view/1106>

Zeidner, M., & Safir, M. P. (1989). Sex, ethnic, and social differences in test anxiety among Israeli adolescents. *Journal of Genetic Psychology*, 150, 175–185.

<https://doi.org/10.1080/00221325.1989.9914589>

Zhang, X., & Savalei, V. (2016). Improving the factor structure of psychological scales: The Expanded format as an alternative to the Likert scale format. *Educational and Psychological Measurement*, 76(3), 357–386. <https://doi.org/10.1177/0013164415596421>

Open Science

Open Data. I confirm that there is sufficient information for an independent researcher to reproduce all the reported results, including codebook if relevant (Ober & Cheng, 2022).

Open Materials. I confirm that there is sufficient information for an independent researcher to reproduce all the reported methodology (Ober & Cheng, 2022).

Preregistration of Studies and Analysis Plans: This study was not preregistered with an analysis plan.