Measuring Statistics Attitudes and Anxieties

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ECOTS 2020
Virtual Conference
2020-05-19

Data Collection Plan (Spring 2020)

Phase 1: Technology Pilot

- Sample: students enrolled in *Introduction to Statistics II* (no compensation)
- Scales and items:
  - *Task Effort Cost* (Flake et al., 2015)
  - *Emotional Cost* (Flake et al., 2015)
  - In-development *Cost* scale (S-SOMAS Project, see supplementary material)
  - Additional assorted items

Phase 2: Full Pilot

- Sample: students enrolled in *Introduction to Statistics I* (with compensation)
- Scales and items:
  - Four scales from Flake et al. (2015)
  - Statistics Anxiety Rating Scale (Cruise et al., 1985)
  - In-development *Cost* scale (S-SOMAS project)
  - Additional assorted items and scales

Data Collection Plan (Spring 2020)

Phase 1: Technology Pilot

- Sample: students enrolled in *Introduction to Statistics II* (no compensation)
- Scales and items:
  - *Task Effort Cost* (Flake et al., 2015)
  - *Emotional Cost* (Flake et al., 2015)
  - In-development *Cost* scale (S-SOMAS Project, see supplementary material)
  - Additional assorted items

Phase 2: Full Pilot

- Sampl[illegible] students enroll[illegible] in *Introd[illegible]n to Statis[illegible]* (with co[illegible]nsatio[illegible]
- Scales and [illegible]
  - Four scales [illegible]ake et al. (2015)
  - Statistic[illegible]ng Scale (Cruis[illegible]., 198[illegible]
  - In-d[illegible]opment *Cost* [illegible] (S-SO[illegible]s project)
  - Additional assorted items and scales

All new ethics clearance applications suspended until May due to COVID-19.

Background

- **Attitudes** are commonly measured by the *Survey of Attitudes Toward Statistics* (SATS-36) instrument (Schau, 2003)
- **Anxieties** are commonly measured by the *Statistics Anxiety Rating Scale* (STARS) instrument (Cruise et al., 1985)

- A few studies have used both instruments:
  - Reports of Encouraging Excellence in Statistics (EncStat), an intervention to address statistics anxiety (e.g. Watson et al., 2002, 2004; Watson, Kromrey, Ferron, et al., 2003; Watson, Kromrey, & Hess, 2003; Watson, Kromrey, Lang, et al., 2003; Watson, Lang, et al., 2003)
  - Studies with Italian psychology students (e.g. Chiesi & Primi, 2010; Galli et al., 2008)
  - Study with US graduate students in education statistics courses (e.g. Devaney, 2010)
- Few studies report information on the relationship between students' attitudes and anxieties as measured by these instruments

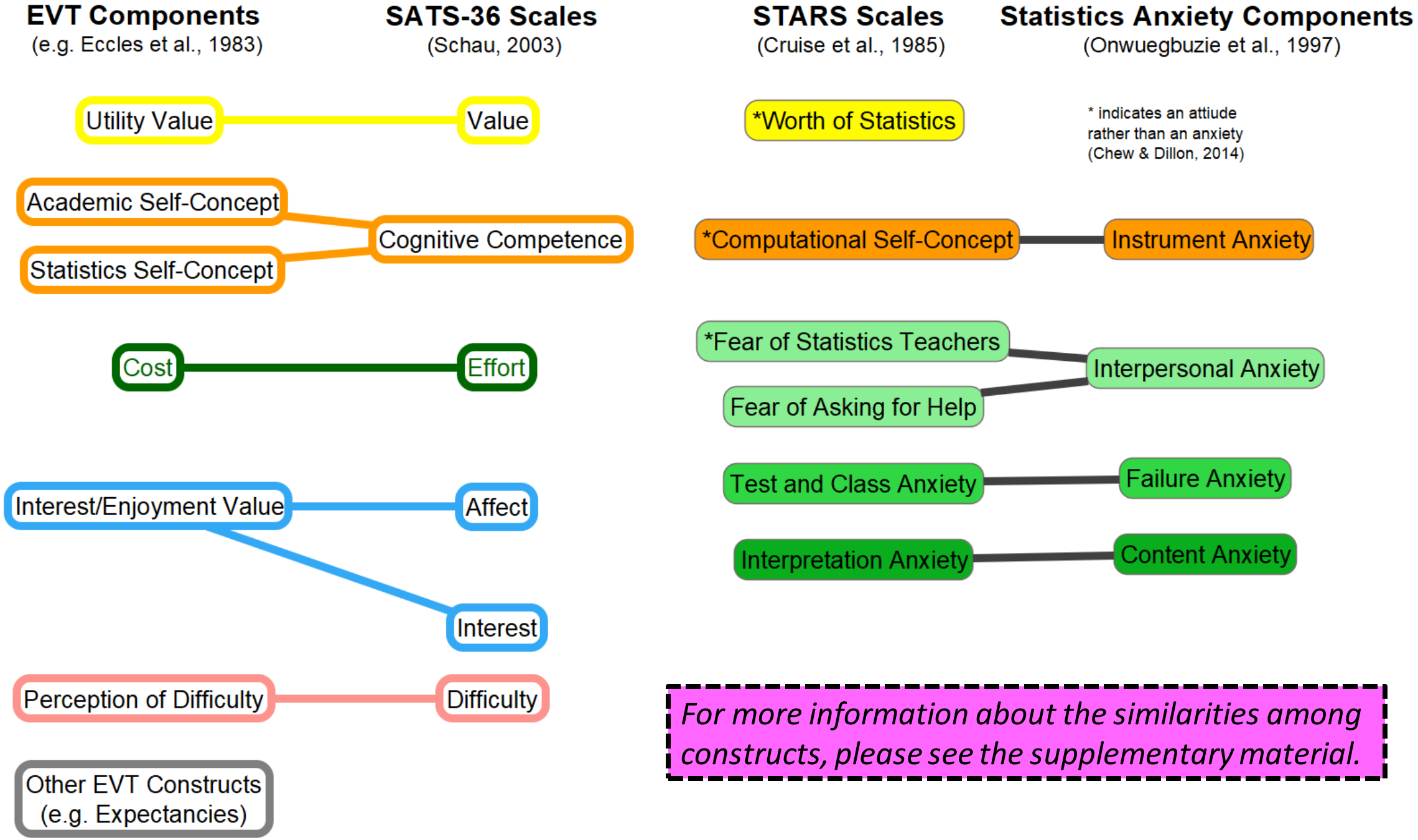
Evolving Understanding of Constructs

- SATS-36 is aligned with a theoretical framework, *Expectancy-Value Theory* (EVT) (e.g. Eccles, 1983, 2014)
- Because the the SATS-36 was aligned to EVT was a posteriori (Ramirez et al., 2012; Schau et al., 1995), there are concerns about the extent to which the alignment is appropriate (Whitaker, Unfried, & Bond, 2019b).

- Decades of research on statistics anxiety exists, much using STARS
- "Research on statistics anxiety has been hampered by the lack of distinction between statistics anxiety and related variables, such as mathematics anxiety and attitudes toward statistics" (Chew & Dillon, 2014, p. 197)

Research Questions

1. How is *Statistics Anxiety* related to *Expectancy-Value Theory* (theoretical framework for SATS-36)?
2. What are students attitudes and anxieties (as measured by the scales used in this pilot study)?
   - Task Effort Cost (Flake et al., 2015)
   - Emotional Cost (Flake et al., 2015)
   - In-development Cost scale (S-SOMAS Project)
3. Were students' perceptions of the cost of learning statistics affected by COVID-19 disruptions?


EVT Components
(e.g. Eccles et al., 1983)
SATS-36 Scales
(Schau, 2003)
STARS Scales
(Cruise et al., 1985)
Statistics Anxiety Components
(Onwuegbuzie et al., 1997)
Utility Value
Value
*Worth of Statistics
* indicates an attiude rather than an anxiety (Chew & Dillon, 2014)
Academic Self-Concept
Statistics Self-Concept
Cognitive Competence
*Computational Self-Concept
Instrument Anxiety
Cost
Effort
*Fear of Statistics Teachers
Fear of Asking for Help
Interpersonal Anxiety
Interest/Enjoyment Value
Affect
Interest
Test and Class Anxiety
Failure Anxiety
Interpretation Anxiety
Content Anxiety
Perception of Difficulty
Difficulty
Other EVT Constructs
(e.g. Expectancies)
For more information about the similarities among constructs, please see the supplementary material.

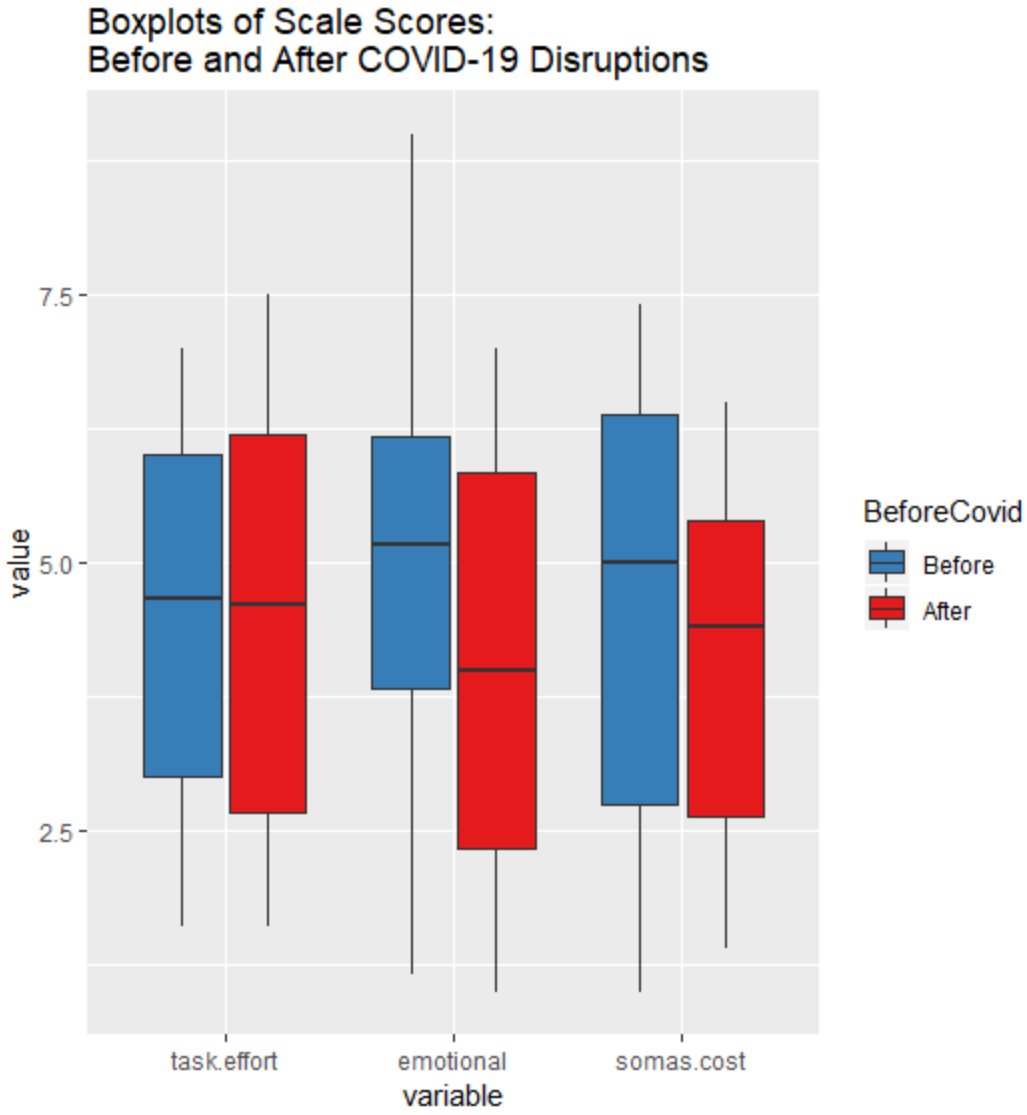
Participants

- Anonymous survey distributed to students enrolled in *Introduction to Statistics II* aged 19 or older
- On Campus and Online courses
  - On Campus courses transitioned to Online courses due to COVID-19 during the study

- Sample size: 42 responses (of 316 students enrolled)
- 19 Likert-type items (9-point scale, higher values indicate more cost)
  - Subset of larger survey

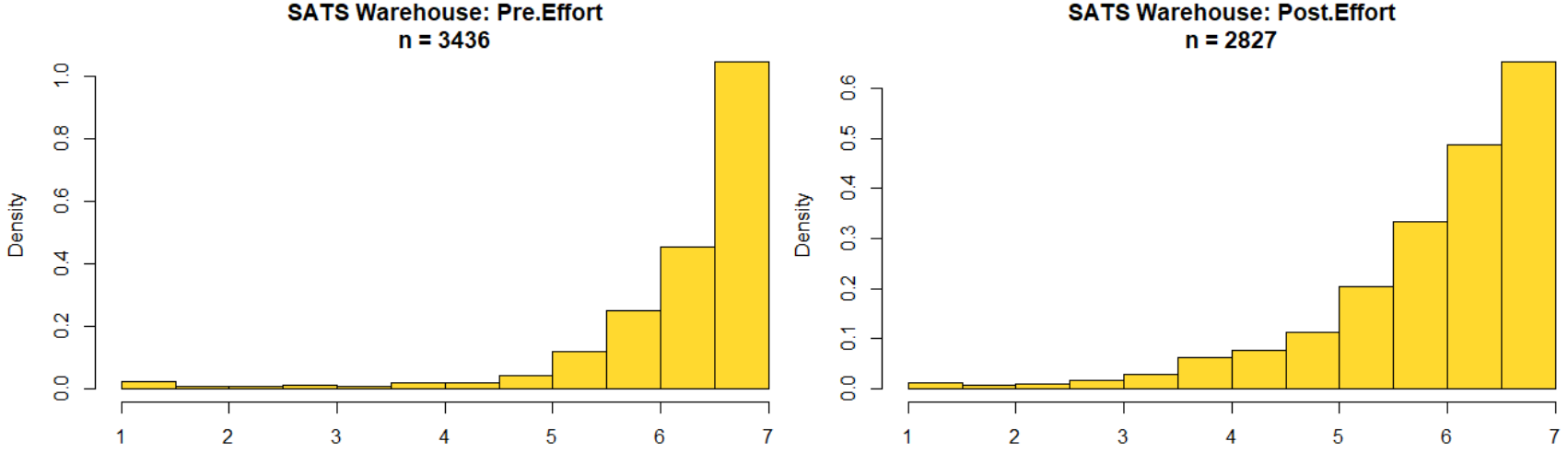
Boxplots: COVID Impact?

- Due to anonymous nature of the survey, exact time data not collected
- Based on incremental downloads of the data, we can form two *approximate* groups:
  - Before: students who responded prior to COVID disruptions (n=21)
  - After: students who responded after COVID disruptions (n=21)

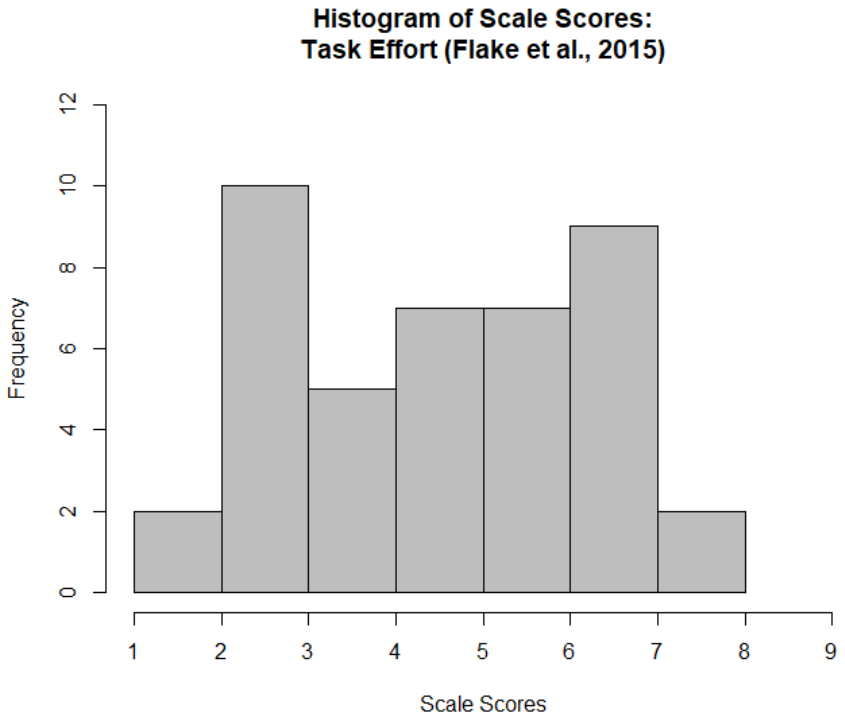


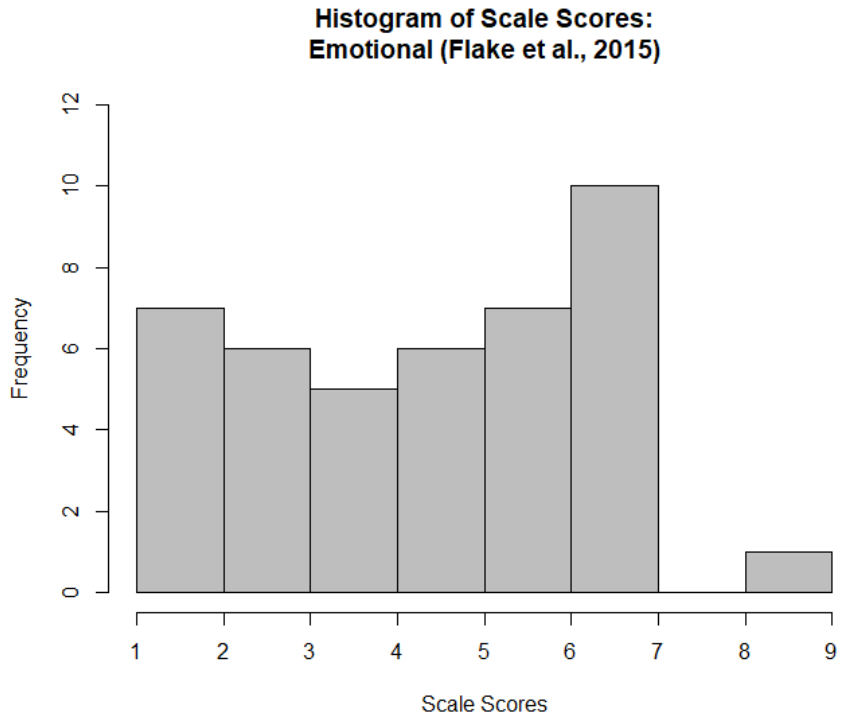
*Boxplots for each of the scale scores look similar. If anything, students might have perceived **less** emotional cost **after** the COVID disruptions. A combined group is used for subsequent analyses (n=42).*

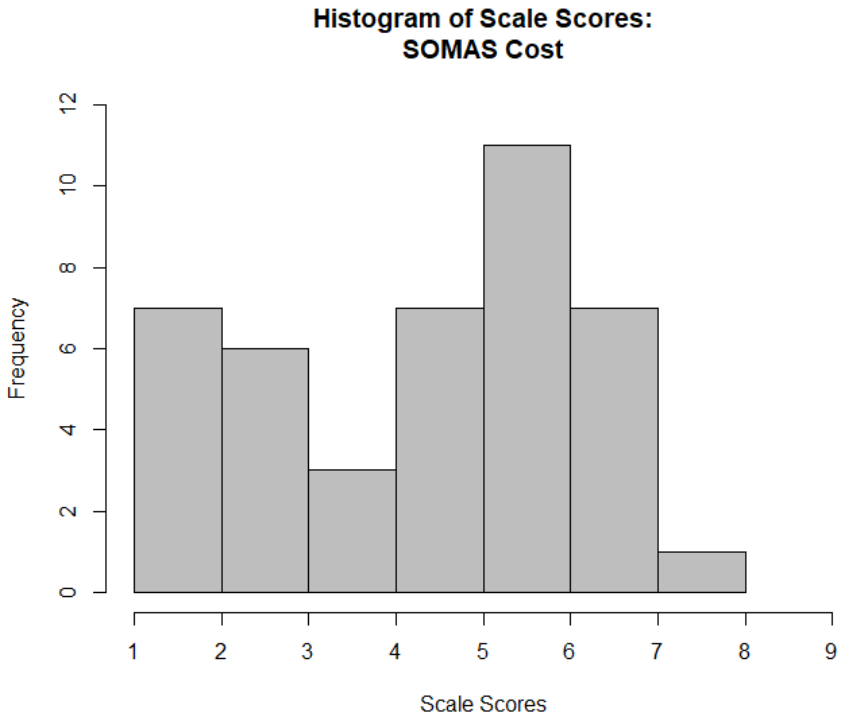
Histograms of Scale Scores



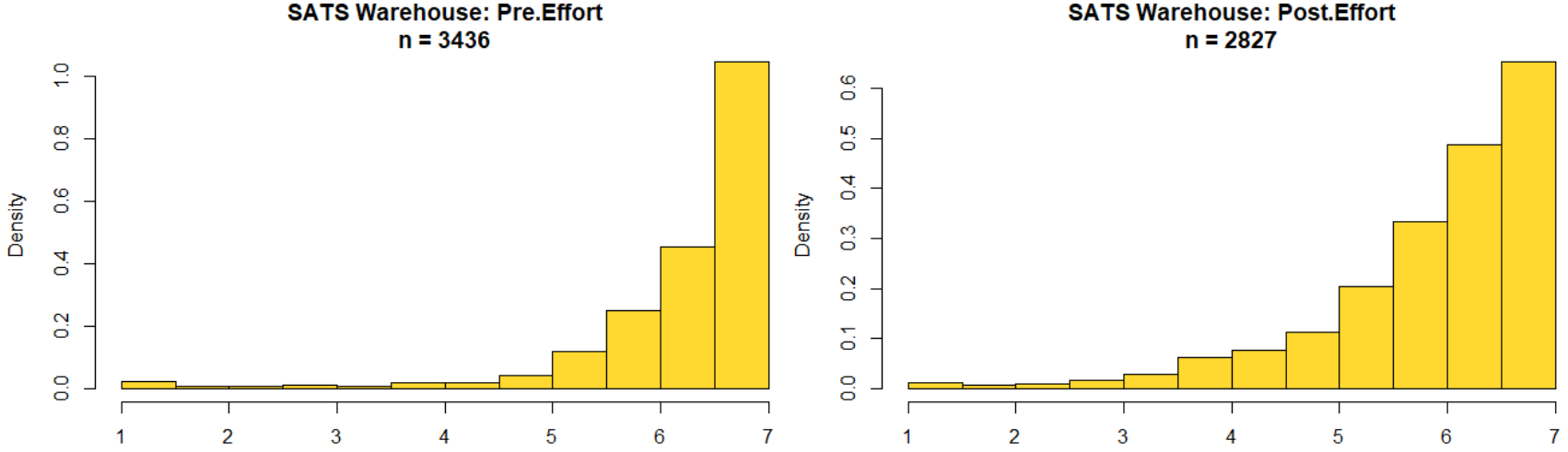
(Whitaker, Unfried, & Bond, 2019b)



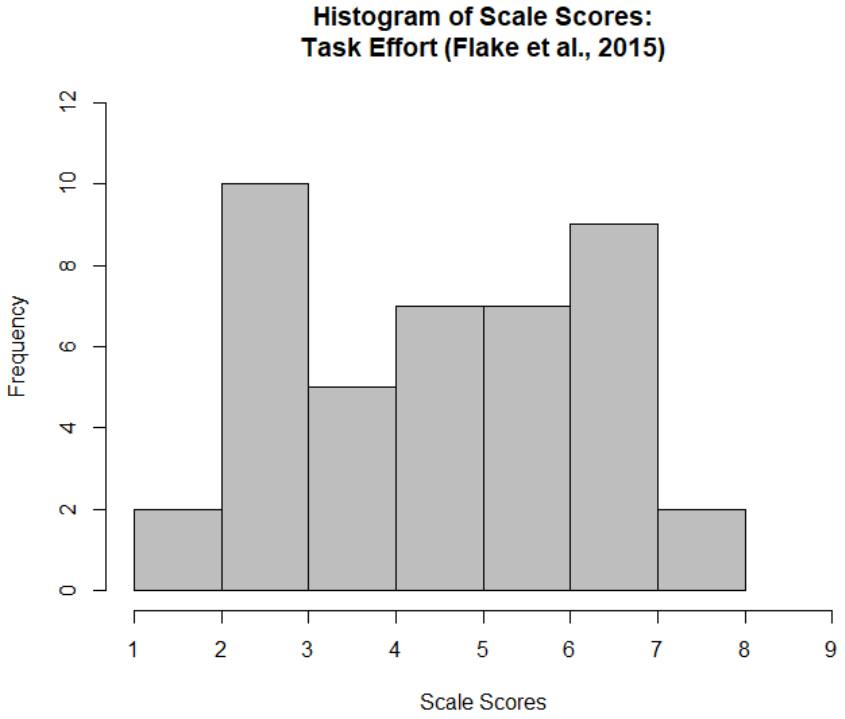


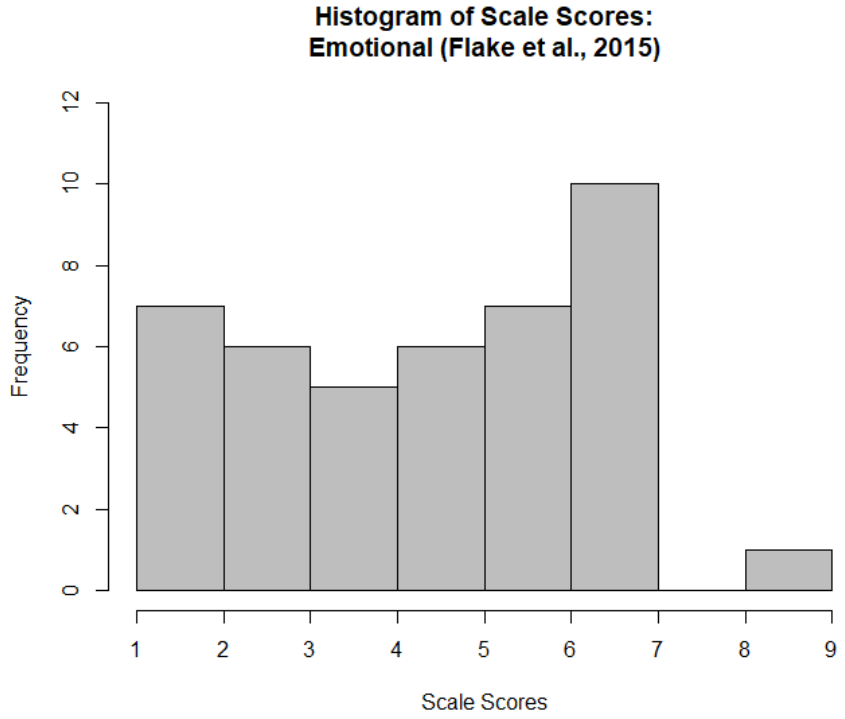


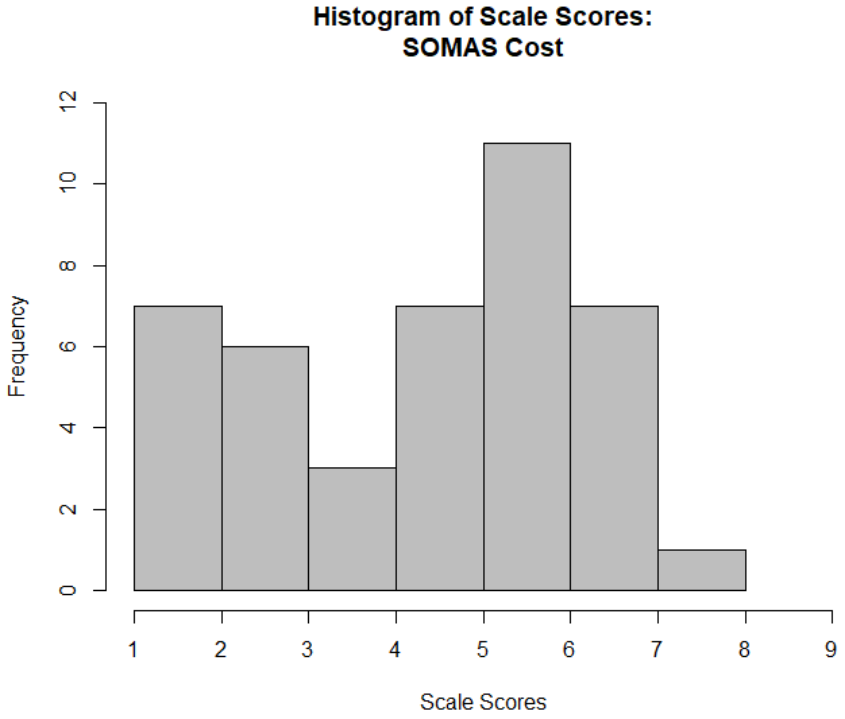
Histograms of Scale Scores



While all scales nominally assess some aspect of the EVT cost construct, ceiling effects do not seem to appear in the three scales used in this study.



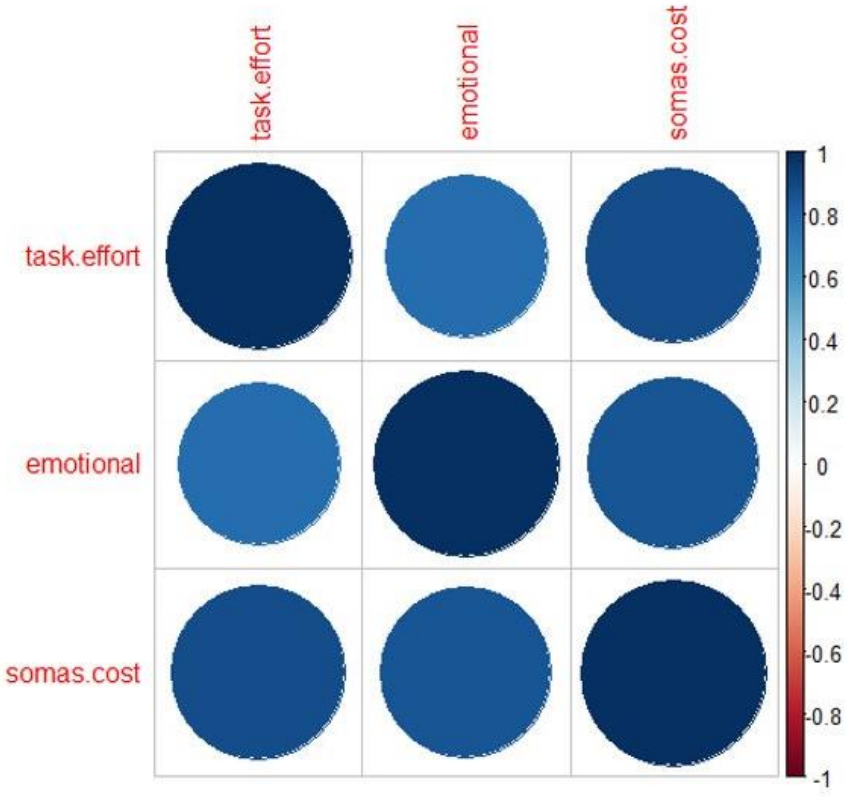




Correlation Plots

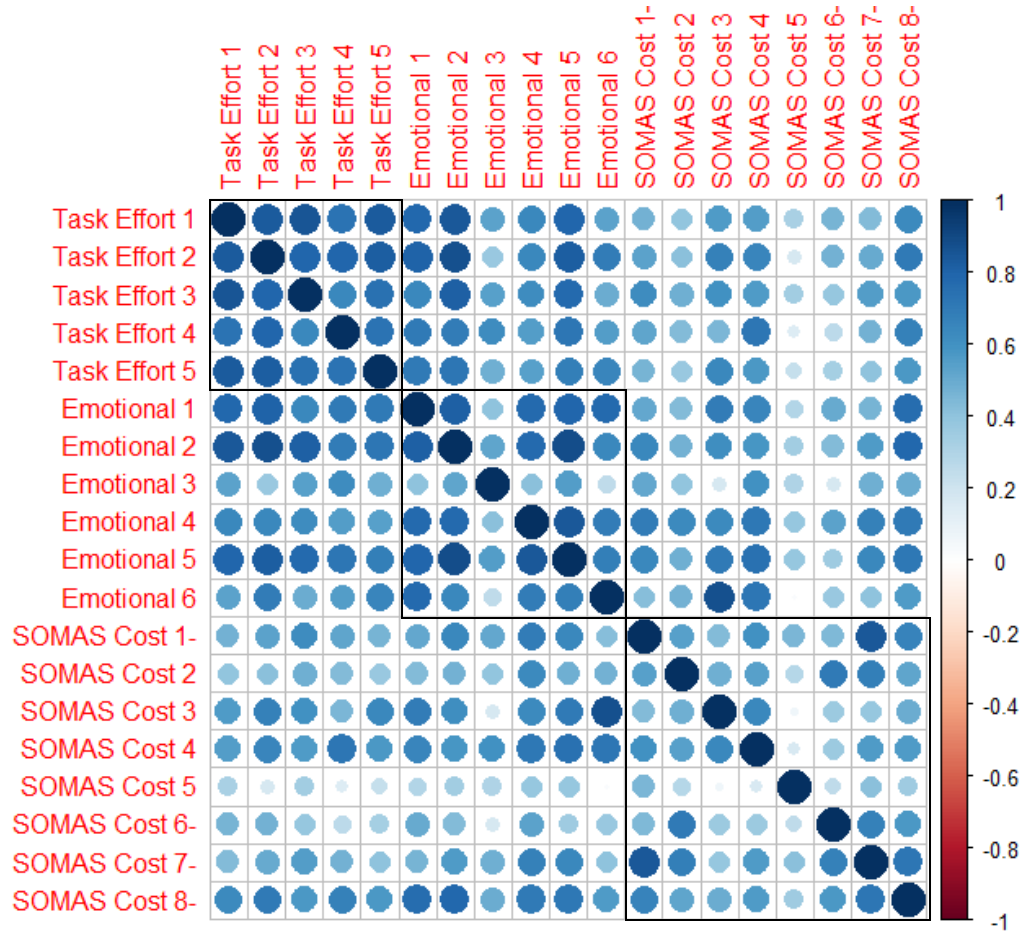
Moderate to strong positive correlations exist among the scales and most individual items, as would be expected.

Correlation Among Scales



Spearman rank-order correlation coefficient

Correlation Among Items



Conclusion

- The SATS and STARS instruments may be measuring some of the same constructs, but more research is needed
- Positive correlations among different scales measuring Cost in the EVT framework
- Cost scales used in this study do not exhibit ceiling effects (unlike SATS Effort scale)
- On average, students did not perceive statistics as having high or low cost.
- Students scores before and after COVID-19 disruptions seem similar.

Future Steps

- More data collection
  - More participants
  - More scales – especially STARS
- Use of non-Likert type items (e.g. grid items)
  - On-going work (Whitaker, 2020)
- Development of new student attitudes instrument
  - On-going work: S-SOMAS project (e.g. Unfried et al., 2018; Whitaker et al., 2019a, 2018)

Questions?

Live Q&A on Tuesday,
May 19th at 10:15-11:15 AM
and 5:00-6:00 PM Eastern

Thank you!

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Annotated supplementary material follows.

Measuring Statistics Attitudes and Anxieties

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Task Effort Cost (Flake et al., 2015)	Emotional Cost (Flake et al., 2015)	SOMAS Cost (SOMAS Project)
1. This class demands too much of my time.	1. I worry too much about this class.	1. Learning statistics is a good use of my time.
2. I have to put too much energy into this class.	2. This class is too exhausting.	2. I have more important things to do than spending time learning statistics.
3. This class takes up too much time.	3. This class is emotionally draining.	3. I avoid working on statistics because it makes me feel bad
4. This class is too much work.	4. This class is too frustrating.	4. Taking statistics will limit my future prospects (for example, lower my GPA).
5. This class requires too much effort	5. This class is too stressful.	5. I prioritize other tasks over statistics
	6. This class makes me feel too anxious	6. Acquiring statistical skills is worth the effort.
		7. Learning statistics is worth spending money on.
		8. If I had to take another course, I would choose a statistics course.

These items were displayed to respondents in a random order with 10 items on one page and 9 items on another.

Summary Statistics

Data were analyzed using R 3.6.3 (R Core Team, 2020) with the following packages:

- corrplot (Wei & Simko, 2017)
- ggplot2 (Wickham, 2009)
- psych (Revelle, 2018)

	Task Effort	Emotional	SOMAS Cost
Task Effort	1	0.765	0.882
Emotional	0.765	1	0.851
SOMAS Cost	0.882	0.851	1

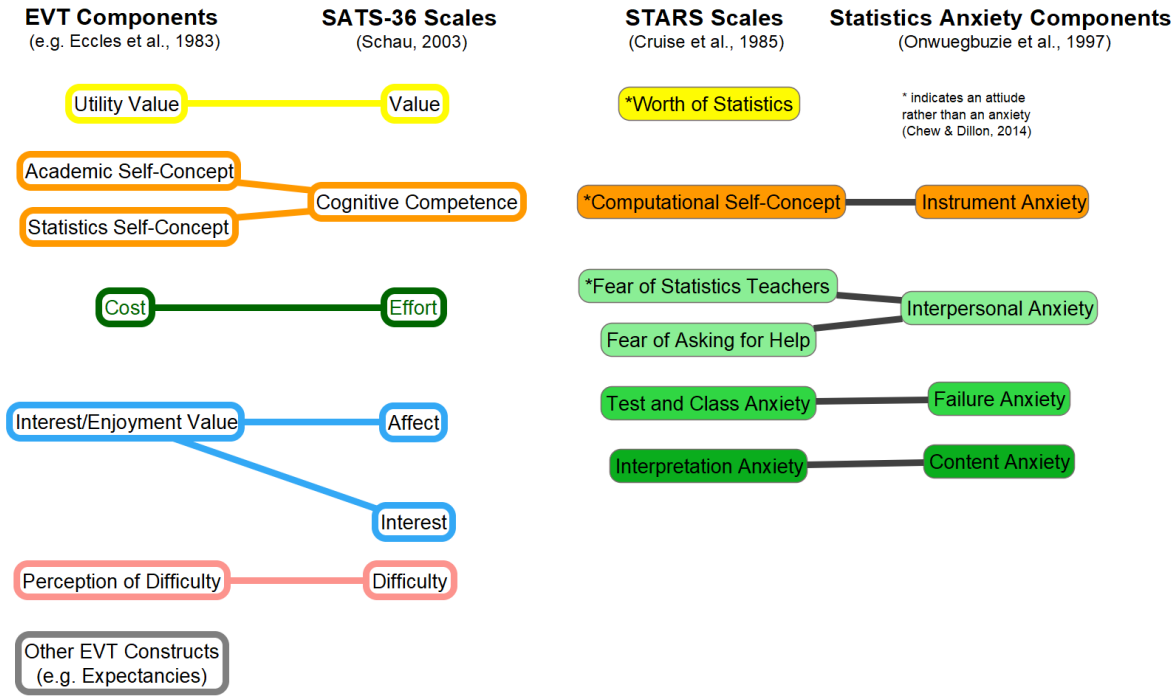
Spearman rank-order correlation coefficient

Vars	n	Mean	St. Dev	Min.	Q1	Median	Q3	Max.
Task Effort (Flake et al., 2015)	42	4.62	1.75	1.60	3.00	4.63	6.15	7.50
Emotional (Flake et al., 2015)	42	4.44	2.03	1.00	2.63	4.67	6.13	9.00
SOMAS Cost	42	4.33	1.85	1.00	2.63	4.64	5.86	7.40

*On all three of these scales, higher responses (closer to 9) and scale scores indicate **more cost** to the student (ostensibly a "negative attitude"), while lower responses (closer to 1) and scale scores indicate **less cost** to the student (ostensibly a "positive attitude").*

SATS and STARS Constructs

- The next few slides quote definitions of constructs measured by the SATS instrument (top) and STARS instrument (bottom).
- Highlighting is used to indicate similarities, with colour used matching the construct mapping.



SATS and STARS Constructs

- **Attitudes:** **Manners of acting, feeling, or thinking that show one's disposition or opinion**. Attitudes change more slowly than emotions, but they change more quickly than beliefs. Attitudes, like emotions, may involve positive or negative feelings, and they are felt with less intensity than emotions. **Attitudes are more cognitive than emotion but less cognitive than beliefs**. (Philipp, 2007, p. 259)

> *Attitudes and anxieties are conceptually distinct, but the way instruments have operationalized these ideas may have resulted in a lack of distinction.*

- **Statistics Anxiety:** **a negative state of emotional arousal** experienced by individuals as a result of encountering statistics in any form and at any level; **this emotional state is preceded by negative attitudes toward statistics** and is related to but distinct from mathematics anxiety (Chew and Dillon, 2014, p. 199)

SATS and STARS Constructs

- **Value:** students' attitudes about the usefulness, relevance, and worth of statistics in personal and professional life (Schau, 2005, p. 2)

Both definitions emphasize the usefulness and relevance of statistics.

- **Worth of Statistics:** This factor has to do with the student's perception of the relevance of statistics. A person scoring high on this factor sees no purpose in taking a statistics course and no possible future personal or professional application. Another aspect is that the students find statistics pointless because it does not fit their personality. It can also indicate a negative attitude toward statistics. (Cruise et al., 1985, p. 93)

SATS and STARS Constructs

- **Cognitive Competence:** students' attitudes about their intellectual knowledge and skills when applied to statistics (Schau, 2005, p. 1)

Both definitions indicate students' perceptions of their abilities to engage with statistics.

- **Computation Self-Concept:** This factor involves anxiety experienced when doing mathematical problems, as well as the student's perception of his/her ability to understand and calculate statistics. It doesn't reflect so much the student's ability to do mathematics, but rather measures the student's attitude toward mathematics. A person soring high on this factor might not mind statistics per se, but experiences anxiety because it involves mathematical calculations, and he/she feels inadequate to comprehend statistics. (Cruise et al., 1985, p. 93)

SATS and STARS Constructs

- **Effort:** amount of work the student expends to learn statistics (Schau, 2005, p. 3)

  *There does **not** seem to be alignment between the SATS Effort construct and these STARS constructs, despite all being illustrated as measuring EVT Cost earlier…*

- **Interpretation Anxiety:** This factor is concerned with the anxiety experienced when a student is faced with making a decision from or interpreting statistical data.
- **Test and Class Anxiety:** This factor deals with the anxiety involved when taking a statistics class or test.
- **Fear of Asking for Help:** This factor measures the anxiety experienced when asking for help. (Cruise et al., 1985, p. 93)

SATS and STARS Constructs

- **Cost:** any factors that operate to inhibit or deter the performance of a sequence of behavior (Thibaut & Kelley, 1959, p. 12)

… but examining the original conception of Cost in EVT (which draws on Social Exchange Theory) reveals a connection. Anxiety could operate to inhibit performance, and Effort needed might also inhibit performance.

- **Interpretation Anxiety:** This factor is concerned with the anxiety experienced when a student is faced with making a decision from or interpreting statistical data.
- **Fear of Asking for Help:** This factor measures the anxiety experienced when asking for help.
- **Test and Class Anxiety:** This factor deals with the anxiety involved when taking a statistics class or test. (Cruise et al., 1985, p. 93)

SATS and STARS Constructs

- **Cost:** any factors that operate to inhibit or deter the performance of a sequence of behavior (Thibaut & Kelley, 1959, p. 12)

While fearing a statistics teacher could inhibit performance, this STARS construct is seems to be less about anxiety related to statistics as a subject and more about how one views an instructor, which is not unique to statistics.

- **Fear of Statistics Teachers:** This factor is concerned with the student's perception of the statistics teacher. A person scoring high on this factor perceives the statistics teacher as lacking the ability to relate to the student as a human being. He questions the humanness of the teacher and regards him as someone who the student must fear. (Cruise et al., 1985, p. 94)

SATS and STARS Constructs

- **Affect:** students' feelings concerning statistics
- **Interest:** students' level of individual interest in statistics
- **Difficulty:** students' attitudes about the difficulty of statistics as a subject (Schau, 2005, pp. 1-2)

*These SATS constructs do **not** seem to have corresponding STARS constructs.*

SOMAS Project

- SOMAS: Surveys of Motivational Attitudes toward Statistics

- Larger project to develop a family of instruments to measure students' attitudes toward statistics (S-SOMAS), instructors' attitudes toward statistics (I-SOMAS), and characteristics of the learning environment (E-SOMAS)
- S-SOMAS is in an early pilot phase now
- S-SOMAS and I-SOMAS will be aligned with EVT framework (e.g. Eccles, 1983, 2014) a priori

Selected SOMAS Papers and Presentations

Student Instrument (S-SOMAS)

- Unfried, A., Kerby, A., & Coffin, S. (2018). Developing a Student Survey of Motivational Attitudes Toward Statistics. *2018 JSM Proceedings*. Presented at the Joint Statistical Meetings 2018, Vancouver, Canada.
- Whitaker, D., Unfried, A., & Batakci, L. (2018). A Framework and Survey for Measuring Students' Motivational Attitudes Toward Statistics. In M. A. Sorto, A. White, & L. Guyot (Eds.), *Looking back, looking forward. Proceedings of the Tenth International Conference on Teaching Statistics (ICOTS10, July, 2018), Kyoto, Japan*. Retrieved from http://iase-web.org/icots/10/proceedings/pdfs/ICOTS10_C200.pdf
- Whitaker, D., Unfried, A., & Bond, M. (2019). Design and Validation Arguments for the Student Survey Of Motivational Attitudes toward Statistics (S-SOMAS) Instrument. In J. D. Bostic, E. E. Krupa, & J. C. Shih (Eds.), *Assessment in Mathematics Education Contexts: Theoretical Frameworks and New Directions* (1st ed., pp. 120–146). New York, NY: Routledge.

Instructor Instrument (I-SOMAS)

- Batakci, L., Bolon, W., & Bond, M. E. (2018). A Framework and Survey for Measuring Instructors' Motivational Attitudes Toward Statistics. In M. A. Sorto, A. White, & L. Guyot (Eds.), *Looking back, looking forward. Proceedings of the Tenth International Conference on Teaching Statistics (ICOTS10, July, 2018), Kyoto, Japan*. Retrieved from http://iase-web.org/icots/10/proceedings/pdfs/ICOTS10_4J3.pdf

Environment Instrument (E-SOMAS)

- Bond, M., Batakci, L., Bolon, W., & Whitaker, D. (2019, May). *Environment Matters: Institution and Course Characteristics and Pedagogy*. Poster presented at the United States Conference On Teaching Statistics (USCOTS) 2019, State College, PA.

SOMAS Team

The *Surveys of Motivational Attitudes toward Statistics* (SOMAS) team:

- Leyla Batakci *Elizabethtown College*
- Wendi Bolon *Monmouth College*
- Marjorie Bond *Monmouth College*
- April Kerby *Winona State University*
- Michael Posner *Villanova University*
- Alana Unfried *California State University, Monterey Bay*
- Douglas Whitaker *Mount Saint Vincent University*

Also: numerous undergraduate and graduate student assistants; Research On Statistics Attitudes (ROSA) Working Group, USCOTS 2015 and 2017 Workshop participants

USCOTS 2019 poster that was referenced in this poster (Whitaker, Unfried, & Bond, 2019b)

Full citation for future reference:

Whitaker, D., Unfried, A., & Bond, M. (2019, May). *Challenges to Using and Interpreting the SATS-36 Instrument: Do you like statistics? Do your students like statistics? How do you know?* [Poster]. United States Conference on Teaching Statistics (USCOTS), State College, PA

Challenges to Using and Interpreting the SATS-36 Instrument:

Do you like statistics? Do your students like statistics? How do you *know*?

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About the SATS Instrument

- Widely-used to measure attitudes toward statistics
- 28-item (Schau, 1992) *Affect*, *Cognitive Competence*, *Value*, and *Difficulty*
- 36-item (Schau, 2003) the above, with *Interest* and *Effort*
- Primarily used with undergraduate, introductory statistics students
- Translated into many languages

Data & Analysis

- Graphs and analysis are based on student data in the SATS data warehouse, collected from 2007-2010
- Students in introductory statistics courses
- Approximately 2300 students across 120 courses
- Missing values excluded from these analyses
- STEM results graph is from internal data collection using adapted instruments for which validity evidence is largely unavailable

Other Challenges

- Neutral option included, coupled with non-standard instructions:
  - "If you have no opinion, choose Neither disagree nor agree."
- Difficulty may depend on type of student/course
  - Example: Engineering students at BYU tend to have higher difficulty scores than for general populations at UNM.
- Negatively worded items use "not" – may be overlooked by students
- Claimed congruence with Expectancy Value Theory (EVT; e.g. Eccles, 1983, 2014)
  - Potential misalignment between SATS constructs and EVT constructs (e.g. Cost)
- Rigid pre/post structure makes longitudinal research (e.g. Kerby & Wroughton, 2017; Millar & White, 2014) difficult at best
- Not appropriate for use with other populations of interest (e.g. Teachers)

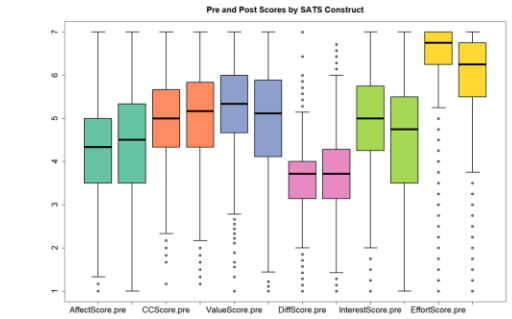


Figure 1. Boxplots showing the Pre (left) and Post (right) scores of students for each SATS construct.

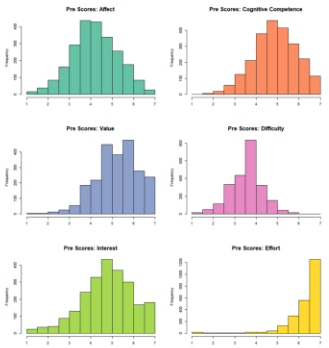


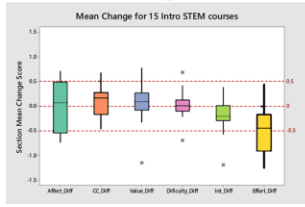
Figure 2. Histograms for student Pre scores for each SATS construct.

Component	Mean Difference	Cohen's d	Interpretation
Affect	0.01	0.01	Small
Cognitive Competence	0.00	0.00	Small
Value	-0.37	-0.39	Medium
Difficulty	-0.06	-0.08	Small
Interest	-0.82	-0.68	Large
Effort	-0.56	-0.65	Large

Table 1. Mean difference (Post-Pre), effect size, and interpretation for each SATS construct.

Figure 3. Mean change scores for 15 sections of introductory STEM courses. These data are from instruments internally adapted for STEM fields. Validity evidence is largely unavailable

STEM Results Using Section Means



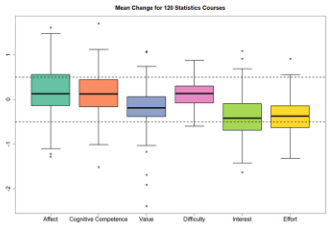


Figure 4. Mean change scores for 120 sections of introductory statistics courses. This figure is modeled on Schau and Emmioğlu's (2012) Figure 3 and exhibits the same pattern.

Changes from Pre to Post

- Changes often absent from Pre to Post (especially *Affect*, *Cognitive Competence*, and *Value*)
  - Does this reflect a true lack of change in the underlying constructs?
  - Or does this reflect an inability for the instrument to detect such changes?
  - Initial development article (Schau et al., 1995) includes only Pre survey
- More variability in Post scores than Pre scores
- Adapted version of SATS to STEM demonstrates similar patterns among scores (see Figures 3 and 4)
- See Figure 1 and Table 1

Interest and *Effort* Scales

- Only four items per construct while the original SATS-28 attitude constructs had no less than 6 items: Affect (6 items), Cognitive Competence (6 items), Value (9 items), and Difficulty (7 items).
  - "More discrete" than the other constructs: possible values for the construct end in .00, .25, .50, .75
  - No negatively-worded items while SATS-28 constructs did include negatively-worded items
- All the Interest items have the word "interest" in them.
  - Example item: *I am interested in learning statistics.* (Schau, 2003, p. 3)
- All the Effort items have the word "plan" in them.
  - Example item: *I plan to complete all my statistics assignments.* (Schau, 2003, p. 3)
- Students who reviewed the Effort items in focus groups (SofIA, STEM Attitudes, 2014 and 2015) indicated that one would tend to strongly agree to all of the items.
- Effort scale tends to exhibit a ceiling effect (especially on Pre), that is the distribution is not symmetric, bounded by 7 (Strongly Agree), and skewed towards 1 (Strongly Disagree) (see Figure 2)
- Students tend to overestimate their effort at the beginning of the semester.

Ways to Address these Challenges

- Understand limitations of SATS when using it or reading reports that use it
- Document validity evidence for your intended uses and question uses that are not supported
- Revisions to SATS? Lots of challenges to address.
- Development of a new instrument? Ongoing project: Surveys of Motivational Attitudes toward Statistics: SOMAS (e.g. Batakci, Bolon, & Bond, 2018; Unfried, Kerby, & Coffin, 2018; Whitaker, Unfried, & Batakci, 2018; Whitaker, Unfried, & Bond, 2019)

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