Board 182: Work in Progress: Considering the Effect of Gender on a Latent Factor Model of the PSVT:R

Ms. Savanna Dautle, Rowan University

Savanna Dautle is a doctoral candidate in the Experiential Engineering Education (ExEEd) department at Rowan University, in Glassboro, NJ. She is pursing her Ph.D. in Engineering Education under the advisement of Dr. Stephanie Farrell. Her research interests include psychometrics, modeling, evaluation, and instrument development.

Dr. Stephanie Farrell, Rowan University

Dr. Stephanie Farrell is Professor and Founding Department Head of Experiential Engineering Education at Rowan University (USA). Prior to 2016 she was a faculty member in Chemical Engineering at Rowan.

WIP: Considering the effect of gender on a latent factor model of the PSVT:R

Savanna Dautle[1] & Dr. Stephanie Farrell[1]

[1]Department of Experiential Engineering Education (ExEEd), Rowan University, Glassboro, NJ

Abstract

The correlation of gender and spatial skills has been debated considerably in recent years. To add some insight to this debate, we examine the mental rotation skill of a group of first-year engineering undergraduate students at a large, public university. Using accuracy information from an online version of the Purdue Spatial Visualization Test: Rotations (PSVT:R) and self-reported gender, we performed multiple structural equation model (SEM) analyses based on a previously developed model. The aim of this work was to examine any differences that may exist between groups of test-takers, best represented by multi-group SEM; however, in spite of numerous efforts, insights into the proposed research questions could not be gained.

Introduction

In engineering education, there have been uncertainties about the effect of spatial skills on undergraduate student performance, whether it be causal or simply correlational [1], [2], [3]. Furthermore, there has been argument about whether there is a gender difference present in tests of spatial skills, with some claiming that it is a true difference in skill, whereas others posit that it is the result of the time limits on these tests [4]. The Perdue Spatial Visualization Test: Rotations is one of many spatial skills tests, designed to measure mental rotation skill.

This work aimed to give a more nuanced look at the results of the joint-population EFA in the work by Dautle and Farrell [5], in an effort to gain a better understanding of the tool used in assessing mental rotation skill at multiple US universities. The construct validity of the PSVT:R is vital to comprehending the multi-faceted relationships depicted between mental rotation skill and academic performance in undergraduate engineering.

Overarching Methods

Participant Inclusion Criteria

This work was carried out at a large, public, mid-Atlantic university. The study participants were first-year undergraduate engineering students enrolled at this university who were at least 18 years of age at the time of data collection and consented to being part of the study.

Data Collection

For this work, PSVT:R accuracy, response time, and test participant gender were collected using a computerized instrument, with self-reported gender between Fall 2015 and Fall 2023 (inclusive). This

online instrument is detailed in Dautle & Farrell [5] and Dautle [6]. This work uses the same dataset used in Dautle [6].

Data Cleaning

The data collection phase resulted in 62 variables: a test-taker ID number, gender, and 30 accuracy variables, and 30 item-response-time variables. Test-takers who did/could not legally consent to being part of the study were not included in the analyzed dataset. In addition, students taking the test in Fall 2020 were removed for inconsistent testing conditions. Furthermore, students who had taken the PSVT:R prior to time of assessment for this study were removed, as well as those who completed it too quickly (did not try to accurately respond). A more detailed explanation of this process can be found in Dautle [6]. For all analyses, $n = 1685$.

Computation

Due to sample sizes, we considered a binary gender variable: man and not-man [7]. 75% of respondents self-reported as men.

The WLSMV estimator was used for its ability to handle binary data and severely non-normal data [8, p. 666].

For this work, analyses were performed in RStudio 2023.12.0+369 "Ocean Storm" Release (33206f75bd14d07d84753f965eaa24756eda97b7, 2023-12-17) for Windows.

IRB Approval

This study was approved by Rowan University's Institutional Review Board, Pro2017001804.

Method 1

With this method, we aimed to answer the following research question:

> *What effect, if any, does gender have on an accuracy- and response-time-based latent factor model of an online version of the Perdue Spatial Visualization Test: Rotations (PSVT:R)?*

Based on the results of Study 1 of Dautle [6], where the online PSVT:R was found to have 1 latent factor and 4 initial training items, we removed accuracy and response time variables of the first 4 items from the analysis as learning items[1]. With the remaining 26 items, accuracy data and response time were fed into a 1- and 2-skill-factor SEM, with an additional, orthogonal latent factor accounting for the variance caused by the test's 20-minute time limit. In addition, the skill factors were allowed to covary. In the model, each item's accuracy and response time variable were permitted to be influenced by any/all of the 3 latent factors. (SEM was chosen because of its allowance for crossloading.)

Upon computing this model, it was determined that there was not enough specification in the structure of the model, and that thus the model was not identified. Issues with convergence further required the use of a more restrictive base model.

<u>Reason for failure: Nonconvergence/non-identification</u>

[1] *n* items at the beginning of a testing instrument where self-teaching effects may obscure latent factor effects

Method 2

With this method, we aimed to answer the same research question as in Method 1:

> *What effect, if any, does gender have on an accuracy- and response-time-based latent factor model of an online version of the Perdue Spatial Visualization Test: Rotations (PSVT:R)?*

Because a more restrictive model was needed, without any known theoretical basis, a specification search and exploratory structural equation modeling (ESEM) were employed. A specification search using ShortForm (Dec. '23) [9] for both a 1- and 2-skill-factor model was conducted, with BIC as the measure of fit.

Upon running the determined models, it was found that the models included items which did not have statistical significance at the $p > 0.05$ level. These variables were removed. The remaining variables were then assessed for their standardized loadings (desired to be greater than 0.4 [10]). One insufficiently loaded variable (std. all < 0.632) ; however, removing one item per factor at a time resulted in only three variables being predicted by each latent factor, with loadings still being insufficient, in both the 1- and 2-skill factor models. As such, a groups analysis was not conducted, as the overarching, joint-population model could not be confirmed.

Reason for failure: Insufficient path weights

Methods 3a, b, & c

With this method, we aimed to answer the following research question:

> *What effect, if any, does gender have on an accuracy-based latent factor model of an online version of the Perdue Spatial Visualization Test: Rotations (PSVT:R)?*

For this simplified SEM, no longer considering item response times, we conducted a multi-group (gender), accuracy-based model of:

a) A 22-item, previously analyzed version of PSVT:R [6] (without Items 1-4, 7,8, 17, & 18)
b) A 26-item version of the PSVT:R (without Items 1-4)
c) The full 30-item, revised PSVT:R [11]

1-factor, joint-population models for these analyses were conducted in Dautle [6], and were convergent; however, the multi-group analyses attempted here were not able to achieve convergence under any computational conditions.

Reason for failure: Nonconvergence

Conclusions

Our data from a computerized PSVT:R did not respond well to SEM modeling. Although the methods used here were chosen to theoretically give more meaningful insight than traditional psychometric methods (e.g. IRT), the data was unwilling to be represented this way and we were unable to gain insight into the posed research questions. Thus, in any future studies of this instrument, it would be recommended to use IRT or CTT. At this point, concerns regarding underlying construct validity, as

brought up in Bartlett & Camba [12], [13] are of some concern; the data requires further examination using the aforementioned alternative methods.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. IUSE/PFE:RED 1632053. Data collection prior to Fall 2021 was performed by Peter Cole.

References

[1] L. Friedman, "A Meta-Analysis of Correlations of Spatial and Mathematical Tasks," 1992, Accessed: Dec. 22, 2021. [Online]. Available: https://eric.ed.gov/?id=ED353270

[2] M. B. Casey, R. L. Nuttall, and E. Pezaris, "Mediators of gender differences in mathematics college entrance test scores: A comparison of spatial skills with internalized beliefs and anxieties," *Dev. Psychol.*, vol. 33, no. 4, pp. 669–680, 1997, doi: 10.1037/0012-1649.33.4.669.

[3] S. Sorby, E. Nevin, A. Behan, E. Mageean, and S. Sheridan, "Spatial skills as predictors of success in first-year engineering," in *2014 IEEE Frontiers in Education Conference (FIE) Proceedings*, Oct. 2014, pp. 1–7. doi: 10.1109/FIE.2014.7044005.

[4] Y. Maeda and S. Y. Yoon, "Scaling the Revised PSVT-R: Characteristics of the First-Year Engineering Students' Spatial Ability," presented at the 2011 ASEE Annual Conference & Exposition, Jun. 2011, p. 22.1273.1-22.1273.19. Accessed: Dec. 22, 2021. [Online]. Available: https://peer.asee.org/scaling-the-revised-psvt-r-characteristics-of-the-first-year-engineering-students-spatial-ability

[5] S. Dautle and S. Farrell, "Using EFA to Determine Factor Structure of a Computer-Based Version of the Purdue Spatial Visualization Test: Rotations (PSVT:R)," presented at the American Society of Engineering Education 2023 Annual Conference, Feb. 2023.

[6] S. Dautle (2024). *Mental Rotation: Psychometric analysis of the Purdue Spatial Visualization Test: Rotations and relationships between mental rotation skill and engineering undergraduate success* [Unpublished doctoral dissertation]. Rowan University.

[7] J. J. Cameron and D. A. Stinson, "Gender (mis)measurement: Guidelines for respecting gender diversity in psychological research," *Soc. Personal. Psychol. Compass*, vol. 13, no. 11, p. e12506, 2019, doi: 10.1111/spc3.12506.

[8] "Chapter16.pdf." Accessed: Jun. 14, 2022. [Online]. Available: https://www.statmodel.com/download/usersguide/Chapter16.pdf

[9] A. Raborn and W. Leite, "ShortForm: Automatic Short Form Creation." Dec. 13, 2023. Accessed: Feb. 08, 2024. [Online]. Available: https://cran.r-project.org/web/packages/ShortForm/index.html

[10] J. Meyer, "First Steps in Structural Equation Modeling: Confirmatory Factor Analysis," The Analysis Factor. Accessed: Feb. 08, 2024. [Online]. Available: https://www.theanalysisfactor.com/structural-equation-modeling-first-step-confirmatory-factor-analysis-2/

[11] S. Y. Yoon, *Psychometric Properties of the Revised Purdue Spatial Visualization Tests: Visualization of Rotations (The Revised PSVT-R)*. ProQuest LLC, 2011.

[12] K. Bartlett and J. D. Camba, "Isometric Projection as a Threat to Validity in the PSVT:R," presented at the 2022 ASEE Annual Conference & Exposition, Aug. 2022. Accessed: Feb. 04, 2023. [Online]. Available: https://peer.asee.org/isometric-projection-as-a-threat-to-validity-in-the-psvt-r

[13] K. A. Bartlett and J. D. Camba, "Is the PSVT:R Suitable for Evaluating Spatial Skill in Design? A Critique," in *Design Computing and Cognition'22*, J. S. Gero, Ed., Cham: Springer International Publishing, 2023, pp. 115–126. doi: 10.1007/978-3-031-20418-0_8.