

Simplifying, Identifying, and Evaluating Dimensions: Exploratory and Confirmatory Factor Analysis



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Summer School 'Applied Psychometrics in Education and Psychology'

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Course Description

Tests and self-report survey instruments generally explore multiple aspects, components, or facets of a domain. Detecting and validating those dimensions can permit diagnostic analysis or reporting of student achievement (in the case of test data) or participant psychology (in the case of self-report surveys). This course will introduce students to principles and practices behind simplifying data into its component dimensions. This assumes that data contain latent factors and that multiple indicators are used to operationalize those various dimensions. These models rely on stable simultaneous estimation of multiple parameters (incl. variance and covariance matrices of all items, error terms, and relationship structures of latent factors). Students will be taught principles for determining a defensible number of dimensions and how that exploration can be evaluated tested. It is a truism that many models of dimensions can fit data; thus, the course will introduce the importance of testing and comparing multiple plausible alternative models. Unsurprising, a small proportion of models will be inadmissible even when $N > 400$. Hence, time will be spent on identifying and troubleshooting problems such as negative error variance and covariance matrix not positive definite. Educational research studies often seek to compare participant subgroups who have completed the same test or survey. Nested multigroup invariance testing is a mechanism for determining if scores can be legitimately compared.

Key words: scale reliability; exploratory factor analysis; confirmatory factor analysis; model comparison; invariance testing.

Pre-requisite Knowledge

Students should have had exposure to the following statistical methods:

chi-square testing; confidence intervals; correlation and covariance; regression.

Learning Outcomes

- Understand the purpose and rationale for dimensionality reduction and determination
- Understand the differences in use and purpose of exploratory and confirmatory factor analysis
- Awareness of the need for and ability to test alternative models
- Ability to conduct exploratory and confirmatory factor analysis with simple correlated models
- Ability to identify and troubleshoot problems in FA

Essential Readings

- Costello, A. B., & Osborne, J. W. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment Research & Evaluation*, 10(7), <http://www.pareonline.net/pdf/v10n17.pdf>.
- Courtney, M. G. R. (2013). Determining the number of factors to retain in EFA: Using the SPSS R-Menu v2.0 to make more judicious estimations. *Practical Assessment Research & Evaluation*, 18(8), Available online: <http://pareonline.net/getvn.asp?v=18&n=18>.
- Desjardins, C. D., & Bulut, O. (2018). *Handbook of Educational Measurement and Psychometrics Using R*. Boca Raton, FL: CRC Press. (Chapter 4)
- Rosseel, Y. (2012). lavaan: An R Package for Structural Equation Modeling. *Journal of Statistical Software*, 48(2), 1-36.

Recommended Readings

- Bandalos, D. L., & Finney, S. J. (2010). Factor analysis: Exploratory and confirmatory. In G. R. Hancock & R. O. Mueller (Eds.), *The Reviewer's Guide to Quantitative Methods in the Social Sciences* (pp. 93-114). New York: Routledge.
- Brown, G. T. L., Gebriel, A., & Michaelides, M. (2019, in press). Teachers' conceptions of assessment: A global phenomenon or a global localism. *Frontiers in Education*
- Brown, G. T. L., Harris, L. R., O'Quin, C., & Lane, K. E. (2017). Using multi-group confirmatory factor analysis to evaluate cross-cultural research: identifying and understanding non-invariance. *International Journal of Research & Method in Education*, 40(1), 66-90. doi:10.1080/1743727X.2015.1070823
- Burnham, K. P., & Anderson, D. R. (2004). Multimodelinference: Understanding AIC and BIC in model selection. *Sociological Methods & Research*, 33(2), 261-304. doi:10.1177/0049124104268644
- Byrne, B. M. (2001). *Structural Equation Modeling with AMOS: Basic Concepts, Applications, and Programming*. Mahwah, NJ: LEA.
- Chen, F., Bollen, K. A., Paxton, P., Curran, P. J., & Kirby, J. B. (2001). Improper solutions in structural equation models: Causes, consequences, and strategies. *Sociological Methods & Research*, 29(4), 468-508. doi:10.1177/0049124101029004003
- Cheung, G. W., & Rensvold, R. B. (2002). Evaluating goodness-of-fit indexes for testing measurement invariance. *Structural Equation Modeling*, 9(2), 233-255. doi:10.1207/S15328007SEM0902_5
- Hoyle, R. H., & Duvall, J. L. (2004). Determining the number of factors in exploratory and confirmatory factor analysis. In D. Kaplan (Ed.), *The SAGE Handbook of Quantitative Methodology for Social Sciences* (pp. 301-315). Thousand Oaks, CA: Sage.
- Kline, P. (1994). *An easy guide to factor analysis*. London: Routledge.
- Kline, R. B. (2011). *Principles and Practice of Structural Equation Modeling* (3rd ed.). New York: Guilford Press.

Software

There are many software applications that can be used to do confirmatory factor analysis. However, not all are free or open-source.

Fee Charging: AMOS in SPSS; Mplus; LISREL; EQS, CALIS in SAS

FREE: R packages 'lavaan', 'sem', 'OPENmx'. Some of the procedures of 'lavaan' have been implemented in a graphic user interface in JAMOMI, which is also free. Instruction and practice will focus primarily on using 'lavaan' through the JAMOMI interface. Where procedures have not yet been implemented in JAMOMI, users will need to have access to RStudio a free interface to simplify use with lavaan.

JAMOMI: <https://www.jamovi.org/>

RStudio: <https://www.rstudio.com/>

lavaan: <http://lavaan.ugent.be/>

Course Outline

Day	Morning	Afternoon
1	Rationale, Purposes, Assumptions Review Basic Statistical Tools	Known 1 dimension: Scale Analysis Practice with JAMОВI
2	Exploring Multiple Dimensions Principles and Challenges in Exploratory Factor Analysis	Practice with JAMОВI
3	Evaluating Known Number of Dimensions Principles & Logic of Confirmatory Factor Analysis	Practice with JAMОВI
4	Troubleshooting Inadmissible Solutions Testing Alternative Models	Practice with JAMОВI Practice with lavaan in RStudio
5	Comparing Groups & Times Nested Multigroup Invariance Testing	Practice with lavaan in RStudio