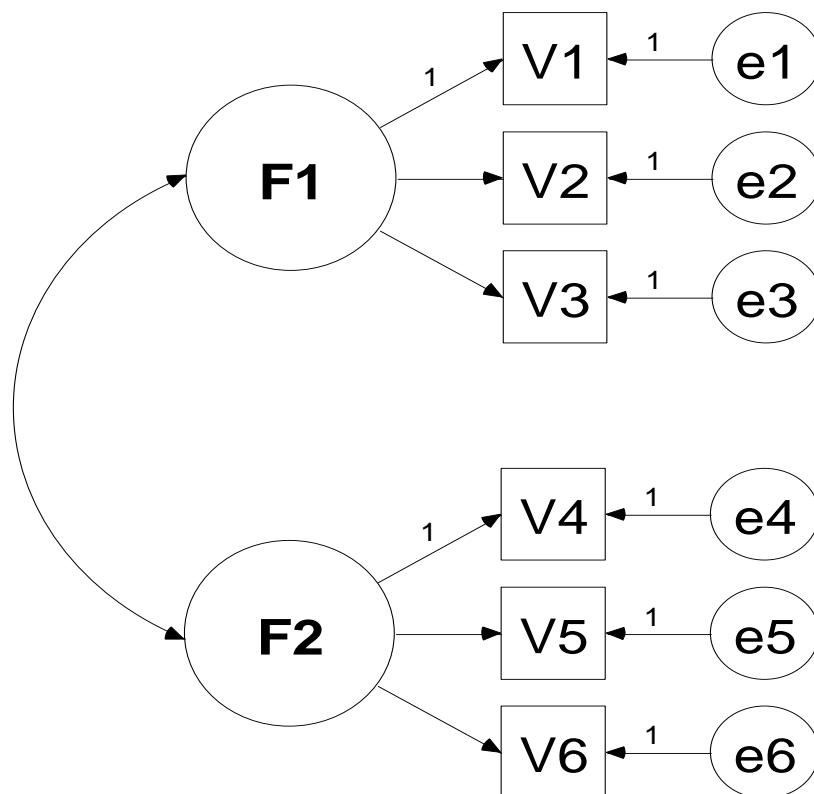


Structural Equation Modelling

975C8



Tutor: Rod Bond, Pevensey 1 1C13, r.bond@sussex.ac.uk

Module Outline

Structural equation modelling (SEM) is a general method of data analysis that brings together path analysis and factor analysis. In path analysis, the aim is to specify and test models of causal relationships among variables, and to estimate direct and indirect effects. SEM extends traditional path analysis by estimating the full model simultaneously and by providing overall measures of model fit. In factor analysis, the goal is to identify unobserved, latent variables that account for the relationships between observed variables. Traditionally, this has been data driven - that is, the factors emerge from the analysis - and is known as exploratory factor analysis. In SEM, the emphasis is on confirmatory factor analysis where you propose a factor model and test to see whether it fits the data. Finally, SEM allows you to combine path analysis and confirmatory factor analysis by testing models of causal relationships among hypothesised factors. The module will provide a thorough introduction to SEM, and will also deal with some important, related issues. These include mediation analysis, moderation, and methods for handling missing data. The emphasis will be on analysing continuous variables with approximately normal distributions, but we will also cover how to handle non-normal data. Most of the analyses will be carried out using the **lavaan** package in R and a further aim of the module is to enable you to use this program and to introduce you to the R statistical environment

Prerequisites

We do not assume any prior knowledge of SEM but we do assume familiarity with correlation and regression, including multiple regression.

Learning Outcomes

By the end of the course, you should be able:

- to run path models, confirmatory factor analysis, structural equations with latent variables, and multi-sample analyses using appropriate SEM software
- to evaluate reports of such analyses and, in particular, understand reports of model fit, specification and re-specification
- be familiar with exploratory factor analysis and with techniques for handling missing data

Preparatory Reading

Kline, R.B. (2016). *Principles and practice of structural equation modelling*. (4th. Ed.) New York: Guilford Press. Part 1: Concepts and Tools. Chapters 1-5.

SEM texts

Kline, R.B. (2016). *Principles and practice of structural equation modelling*. (4th. Ed.). New York: Guilford Press.

Brown, T.A. (2015). *Confirmatory factor analysis for applied research*. (2nd. Ed.). New York: Guilford Press. (This book complements Kline very well – worth considering.)

Hoyle, R. H. (Ed.) (2012). *The handbook of structural equation modelling*. New York: Guilford Press.

Beaujean, A.A. (2014). *Latent variable modeling using R: A step-by-step guide*. New York: Routledge.

Holmes Finch, W. & French, B.F. (2015). *Latent variable modeling with R*. New York: Routledge.

Introductions to R

Field, A., Miles, J., & Field, Z. (2012). *Discovering statistics using R*. London: Sage.

Online free resources:

Venables, W.N., & Smith, D.M. & the R Core Team. An introduction to R
<http://cran.r-project.org/doc/manuals/R-intro.html>

Verzani, J. simple R – Using R for introductory statistics. (cran.r-project.org/doc/contrib/Verzani-SimpleR.pdf)

Clark, M. Introduction to R.

http://www3.nd.edu/~mclark19/learn/Introduction_to_R.pdf

Web resources

There is a huge amount of resources available on the web. I list below a few resources I find useful but this is just the tip of the iceberg. Look also on

YouTube for videos on R and specifically on **lavaan**.

For lavaan:

The lavaan project website: lavaan.ugent.be/

Lavaan at CRAN: <https://cran.r-project.org/web/packages/lavaan/lavaan.pdf>

For R in general, I find these sites really useful:

Quick-R: <http://www.statmethods.net/>

Cookbook for R: <http://www.cookbook-r.com/>

Forums:

<http://stackoverflow.com/questions/tagged/r>

www.r-bloggers.com

www.r-statistics.com/

Note that both core texts have associated web support including data and syntax files to run examples in the book: e.g. Kline (2016)

www.guilford.com/kline

Week 1: Regression and introduction to R and lavaan

Key topics

- Independent and dependent variables
- Drawing path diagrams
- Model parameters
- Specifying linear regression models

Reading:

Kline (2016). Part 1. Chapters 1 – 5

Problem

Nezu and Rodin (1985) collected data from 205 undergraduates on 4 measures:

- Depressive symptoms using the Beck Depression Inventory (BDI)
- Problem-Solving Inventory (PSI) – a 32-item self-report measure that assesses personal problem-solving behaviour and attitudes (high score = ineffective)
- Problem Checklist (PCL) – rate the frequency of problems currently experiencing in 15 areas of life. (High = greater frequency)
- Life stress using the Life Experiences Survey (LES) – indicate incidents and stressful impact of various important life change events over the last 6 months.

Simulated data are in nezu.csv

Week 2: Path Analysis

Key topics

Path Analysis

- Path diagrams
 - Use of Nezu & Ronan model
- Model parameters and systems of equations
- Recursive and nonrecursive models

Kline (2016). Chapter 6.

Problem

Using the Nezu and Rodin (1985) data to estimate a path model predicting depression.

Simulated data are in nezu.csv

Week 3: Estimating Path Models

Key topics

- Deriving correlations from path diagrams

- Direct and indirect effects
- Identification: Just-identified, under- and over-identified models
- Model covariance matrix and residual covariance matrix
- Residuals and goodness of fit
- Maximum likelihood estimation
- Chi-square test

Reading

Kline (2016) Chapters 7 & 8

Example

Remarriage and well-being (Greene, 1990)

Data are in remarry.csv

An example in Klem (1995, pp. 70-72) is data collected by Greene (1990) on the relationship between remarriage of older widowers and their feelings of well-being. The path diagram is attached.

The correlation matrix reported in Table 2, p.72 is in file remarry.csv

Reproduce the path analysis reported in Figure 2, p. 71.

Improve the model.

What are the total, direct and indirect effects on well-being?

Week 4. Evaluating model fit and re-specification

Reading

Kline (2016) Chapters 11 & 12

Key topics

- Hierarchical models
- Fit indices: RMSEA, CFI, TLI, SRMR, AIC, BIC
- Inspection of residuals
- Modification indices

Week 5: Confirmatory Factor Analysis

Key topics

- Identifying scale: reference indicators or fixing factor variance
- Identification of latent variables: 3-indicator and 2-indicator rules
- Item Parcelling

Reading

Kline (2016) Chapter 9.

Examples

1. Structure of ability tests (Holzinger & Swineford, 1939).

Data are in holz.csv and also in the lavaan package

Nine tests administered to 145 seventh- and eighth-grade children. Expected to reflect three common factors: visual perception, verbal ability and speed. V1 – V3 measure VISUAL; V4 – V6 measure VERBAL; V7 – V9 measure SPEED.

Estimate the model and examine how the fit can be improved.

2. Maslach Burnout Inventory (Byrne, 1994) Data are in

maslach.csv

The MBI is a 22-item inventory where responses are on 7-point Likert scales ranging from 0 (feeling has never been experienced) to 6 (feeling experienced daily). Items reflect 3-subscales; Emotional Exhaustion (Items 1,2,3,6,8,13,14,16,20), Performance Difficulty (Items 5,10,11,15,22) and Personal Accomplishment (Items 4,7,9,12,17,18,19,21). Data are from 372 male elementary school teachers. Fit a model representing the three correlated factors and look to improve model fit. This is Application 2 reported in Chapter 4 of Byrne (2001)

Week 6: Review of assignment and re-cap

Key topics

- Specification search in AMOS
- Nonrecursive models
- Equivalent models

Hershberger, S.L. (2006). The problem of equivalent structural models. In G.R. Hancock & R.O. Mueller (Eds.), *Structural equation modelling: A second course*. Greenwich, CT: Information Age Publishing

Other published examples of path analysis:

Tesser, A., & Paulhus, D.L. (1976). Toward a causal model of love. *Journal of Personality and Social Psychology*, 34, 1095-1105.

Taasoobshirazi, G., & Carr, M. (2009). A structural equation model of expertise in college physics. *Journal of Educational Psychology*, 101, 630-643.

Li, M. & Yang, Y. (2009). Determinants of problem solving, social support seeking, and avoidance: A path analytic model. *International Journal of Stress Management*, 16, 155-176.

Keith, T.Z. (1982). Time spent on homework and high school grades: A large-sample path analysis. *Journal of Educational Psychology*, 74, 248-253.

Aldwin, C.M., Levenson, M.R., Spiro, A., & Bosse, R. (1989). Does emotionality predict stress? Findings from the normative aging study. *Journal of Personality and Social Psychology*, 56, 618-624.

Leiner, A.S., Compton, M.T., Houry, D., & Kaslow, N.J. (2008). Intimate partner violence, psychological distress, and suicidality: A path model

- using data from African American women seeking care in an urban emergency department. *Journal of Family Violence*, 23, 473-481.
- Bachman, J.G., & O'Malley, P.M. (1977). Self-esteem in young men: A longitudinal analysis of the impact of educational and occupational attainment. *Journal of Personality and Social Psychology*, 35, 365-380.
- Faye, D., & Sharper, D. (2008). Academic motivation in University: The role of basic psychological needs and identity formation. *Canadian Journal of Behavioural Science*, 40, 189-199.

Week 7: Structural equations with latent variables

Key topics

- Measurement model and structural model
- Errors and disturbances
- Sample size and power

Reading

Kline (2016) Chapter 14

Examples

1. Perceived coping as a mediator between attachment and psychological distress

Wei, Heppner and Mallinkrodt (2003) sampled 515 undergraduates and examined the relationship between indicators of attachment anxiety, attachment avoidance, perceived coping and psychological distress. The correlation matrix in Table 2, p. 442 is in wei.csv.

Evaluate the measurement model and the path model in Figure 2, p. 443.

Note that correlations are only given for the combined score for attachment anxiety and attachment avoidance and so these must be treated as observed scores. We are not able to estimate the latent variables from the indicators. You could try different values for the reliability of these variables to see how it affects results.

2. Adolescent girls' weight control behaviours

Mackey, E.R., & La Greca, A.M. (2008). Does this make me look fat? Peer crowd and peer contributions to adolescent girls' weight control behaviours. *Journal of Youth and Adolescence*, 37, 1097-1110.

Data are in mackey.csv

3. Teacher burnout (Byrne, 1994) – secind1.csv

Byrne examined determinants of burnout among a sample of 716 secondary school teachers. The diagram depicting the hypothesized model is below and the data are in secind1.csv. Evaluate the model

Week 8: Mediation: Indirect effects

Key topics

- Baron & Kenny's causal steps
- Sobel tests for indirect effect
- Bootstrapping

Reading

Kline (2011) Ch 12

Hayes, A.F. (2013). *Introduction to mediation, moderation, and conditional process analysis*. New York: Guilford Press.

Kenny, D.A., Kashy, D.A., & Bolger, N. (1998). Data analysis in social psychology. In D. Gilbert & S. Fiske, G. Lindzey (Eds.), *The handbook of social psychology* (4th Ed, Vol. 1, pp. 233-265). Boston: McGraw-Hill.

MacKinnon, D.P. (2008) *Introduction to statistical mediation analysis*. New York: Erlbaum. Especially Chapters 1-4.

Preacher, K. J. (2015). Advances in mediation analysis: A survey and synthesis of new developments. *Annual Review of Psychology*, 66, 825-852.

Muthén, B., & Asparouhov, T. (2015) Causal effects in mediation modeling: an introduction with applications to latent variables. *Structural Equation Modeling: A Multidisciplinary Journal*, 22:1, 12-23, DOI: 10.1080/10705511.2014.935843.

Valeri, L., & VanderWeele, T.J. (2013). mediation analysis allowing for exposure–mediator interactions and causal interpretation: theoretical assumptions and implementation with SAS and SPSS macros. *Psychological Methods*, 18, 137-150.

See also Kristopher Preacher's website at www.quantpsy.org for useful material on interaction effects and Andrew Hayes's website, <http://www.afhayes.com/introduction-to-mediation-moderation-and-conditional-process-analysis.html>

See the R Package **mediation**:

Tingley, D. , Yamamoto, T., Hirose, K., Keele, L., & Imai , K. (2014). mediation: R package for causal mediation analysis. *Journal of Statistical Software*, 59, 1-40.

Week: 9. Moderation: Interaction effects and multi-sample analysis

Key topics:

- Specifying and interpreting interaction terms
- Simple effects
- Set-up for multi-sample analysis
- Equality constraints
- Measurement invariance

Reading:

Kline (2016). Chapters 16 & 17.

Hayes, A.F. (2013). *Introduction to mediation, moderation, and conditional process analysis*. New York: Guilford Press.

Aiken, L.S., & West, S.G. (1991). *Multiple regression: Testing and interpreting interactions*. Thousand Oaks, CA: Sage.

Examples

1. Determinants of delinquency among White and African male adolescents (Lynam et al, 1993).

Data are in lynamafmr.csv and lynamwhi.csv

Social class, Motivation and Verbal Ability are exogenous variables hypothesized to predict achievement and delinquency. Delinquency is also expected to be predicted by Achievement. Samples are 214 African American male adolescents and 181 White US male adolescents. Test the model and evaluate whether the determinants of delinquency differ between the two groups.

2. Equality of factor structure between males and females.

Data are in grntmal.csv and grntfem.csv. The Holzinger and Swineford (1939) data for the six tests designed to measure visual and verbal ability are given separately for males and females.

Evaluate whether the factor structure is the same in the two samples.

3. Rejection-identification model among younger and older adults Gartska,

Schmitt, Branscombe, and Hummert (2004) examine the impact of perceived age discrimination on age group identification and psychological well-being among young adults (aged 17-20 years) and older adults (aged 64-91 years). The correlations reported in Table 3, p.330, are given in gartskay.csv and gartskao.csv for the young and older samples respectively. Evaluate the results reported in the paper.

4. Determinants of burnout among elementary and secondary school teachers. (Byrne, 1994)

Data are in secind1.csv and secind2.csv respectively.

Examine whether the model of determinants of burnout among secondary school teachers examined in Example C.4 above also holds among a sample of 714 elementary school teachers.

Week 10. Mean structures and measurement invariance

Key topics:

- Means and intercepts
- Covariance and mean structures
- Configural, weak, strong and strict factorial invariance
- Partial measurement invariance

Kline (2016). Chapter 15.

Millsapp, R. (2011). *Statistical approaches to measurement invariance*. New York: Taylor & Francis

Week 11. Missing data

Key topics:

- Types of missing data mechanisms: Missing completely at random (MCAR), missing at random (MAR), not missing at random (NMAR)
- Pairwise and listwise deletion
- Full information maximum likelihood
- Multiple Imputation

Reading:

Enders, C.K. (2010). *Applied missing data analysis*. New York: Guilford Press.

Schafer, J.L., & Graham, J.W. (2002). Missing data: Our view of the state of the art. *Psychological Methods*, 7, 147-177.

Enders, C.K. (2001). A primer on maximum likelihood algorithms for use with missing data. *Structural Equation Modeling*, 8, 128-141.

Enders, C.K. (2006). Analyzing structural equation models with missing data. In G.R. Hancock & R.O. Mueller (Eds.), *Structural equation modelling: A second course* (pp. 313-342). Greenwich, CT: Information Age Publishing.

See also www.missingdata.org – a site funded by ESRC Research Methods programme.

Example

The data file for females from the Grant school collected by Hozinger & Swineford (1938) where 30% of the observations are deleted at random are in grantx.csv

Week 12: In-class test.

Module assessment Information

Please access Sussex Direct for the assessment and submission deadlines for this module: <https://direct.sussex.ac.uk>

Information on the following can be found at the link below:

- Submitting your work
- Missing a deadline
- Late penalties
- Exceptional circumstances
- Exams
- Help with managing your studies and competing your work
- Assessment Criteria

<http://www.sussex.ac.uk/psychology/internal/students/examinationsandassessment>

E-submission

From 2016/17, Masters and MRes students taking PG year modules will usually be asked to submit assessments electronically where assessments are text-based, for example, an essay. Your Sussex Direct - Assessment Deadlines & Exam Timetable will give all assessment details, including whether the assessment is to be submitted via e-submission through Sussex Direct or via a different method. Feedback for all e-submission assessments will also be provided electronically.

Please refer to the frequently asked questions available on the following webpage for further information:

<http://www.sussex.ac.uk/tel/submission/students/esubmission>

<http://www.sussex.ac.uk/tel/submission/students/faqs>

www.sussex.ac.uk/adqe/standards/examsandassessment/esubmission