

Structural Equation Modeling

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Dr. Rex B. Kline¹
Department of Psychology
Concordia University, Montréal, Québec, Canada



Content, Objectives, and Course Web Page

This two-week course introduces the principles, assumptions, strengths, limitations, and applications of the family of techniques known as structural equation modeling (SEM). Basic SEM techniques, including path analysis, confirmatory factor analysis (CFA), and analysis of full “LISREL” (structural regression) models, will be covered. Familiarity with basic multivariate statistical techniques, including multiple regression and exploratory factor analysis, is assumed, but higher levels of quantitative knowledge are not required.

The presentation of topics will be conceptually rather than mathematically oriented, and many examples of the application of SEM to different kinds of actual research problems are considered. There is a strong emphasis on avoiding common mistakes in SEM. Computer tools are described, and participants will gain hands-on practice with LISREL, a widely used computer application. Even if participants eventually use a different SEM computer tool in their own work, principles learned from working with LISREL generalize to related applications.

There is a web page for this course at

<http://psychology.concordia.ca/fac/kline/sem/istql.html>

Participants can freely download in PDF format this course outline, slides for all lectures, computer output for selected examples, and articles listed next from the reading list. This page will be available June 1, 2013.

Course Readings and Computer Tool

Main source (optional)

Kline, R. B. (2010). *Principles and practice of structural equation modeling* (3rd ed.). New York: Guilford Press.

Articles (available on course web page)

Hoyt, W. T., Leierer, S., & Millington, M. J. (2006). Analysis and interpretation of findings using multiple regression techniques. *Rehabilitation Counseling Bulletin*, 49, 223–233. doi: 10.1177/00343552060490040401

Lei, P.-W., & Wu, Q. (2007). Introduction to structural equation modeling: Issues and practical considerations. *Educational Measurement: Issues and Practice*, 26(3), 33–43. doi: 10.1111/j.1745-3992.2007.00099

MacCallum, R. C., & Austin, J. T. (2000). Applications of structural equation modeling in psychological research. *Annual Review of Psychology*, 51, 201–226. doi:10.1146/annurev.psych.51.1.201

McCoach, D. B., Black, A. C., & O'Connell, A. A. (2007). Errors of inference in structural equation modeling. *Psychology in the Schools*, 44, 461–470. doi: 10.1002/pits.20238

¹rex.kline@concordia.ca; <http://tinyurl.com/rexkline>

Narayanan, A. (2012). A review of eight software packages for structural equation modeling. *American Statistician*, 66, 129–138. doi:10.1080/00031305.2012.708641

Sava, F. A. (2002). Causes and effects of teacher conflict-inducing attitudes towards pupils: A path analysis model. *Teaching and Teacher Education*, 18, 1007–1021. doi:10.1016/S0742-051X(02)00056-2

Shah, R., & Goldstein, S. M. (2006). Use of structural equation modeling in operations management research: Looking back and forward. *Journal of Operations Management*, 24, 148–169.
<http://dx.doi.org/10.1016/j.jom.2005.05.001>

Computer Tool

The computer practice component of the course involves the Student Version of LISREL 9 for Windows by Scientific Software International. It can be freely downloaded from

<http://www.ssicentral.com/lisrel/student.html>

It is recommended that participants install LISREL on their own laptop computers.

Topics and Reading Schedule

Week 1

July 1 Course overview, smart modeling, fundamental SEM concepts

July 2 Background statistical concepts, multiple regression basics

Hoyt et al. (2006)

July 3 Data preparation, computer tools

Narayanan (2012)

July 4 Specification, path models

Lei & Wu (2007)

July 5 Model testing

Sava (2002)
Computer practice 1

Week 2

July 8 Model testing, continued; exploratory factor analysis (EFA) & confirmatory factor analysis (CFA)

McCoach et al. (2007)
Computer practice 2

July 9 CFA testing

MacCallum & Austin (2000)

July 10 CFA testing, continued; structural regression (SR) models

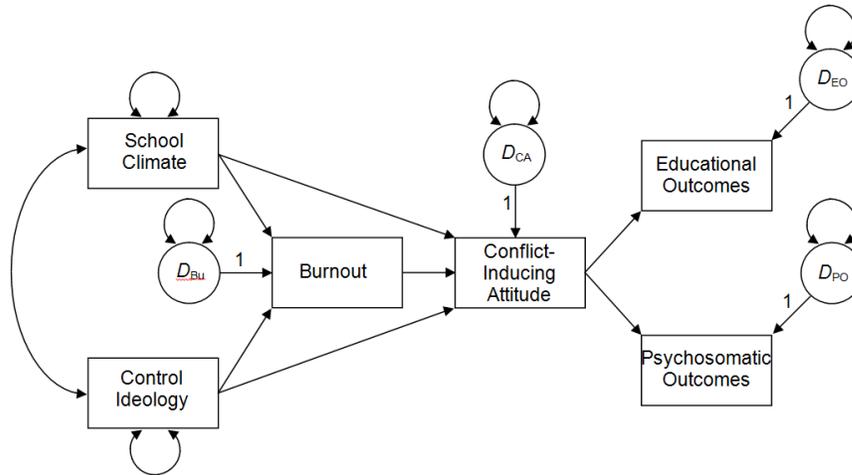
Shah & Goldstein (2006)

July 11 SR models, continued

July 12 Other kinds of analyses (optional)

Computer Practice

The task is to reproduce the path analysis of teacher and student variables by Sava (2002), the diagram of which is presented next in Reticular Action Modeling (RAM) format:



Practice 1

For computer practice 1, adapt the LISREL SIMPLIS syntax presented next for a four-variable path model by Nezu and Ronan (1989) for the six-variable path model by Sava (2002), as follows:

1. In the LISREL editor, select New | Syntax Only, and then save the empty syntax file as "sava.spl."
2. In SIMPLIS syntax, specify $N = 109$, and the input data will be the variance-covariance matrix in lower diagonal form reported in Table 3 of Sava (2002), shown below:

Variable	1	2	3	4	5	6
1. Control ideology (PCI)	69.009					
2. Burnout (MBI)	28.867	95.446				
3. School climate (CQ)	-22.427	-49.074	110.695			
4. Conflict inducing (PC_1)*	-3.361	.202	1.961	1.000		
5. Educational (EDUC)	-4.988	3.408	2.810	2.432	13.822	
6. Somatic (PSI)	-15.269	-.687	8.709	3.836	9.728	27.788

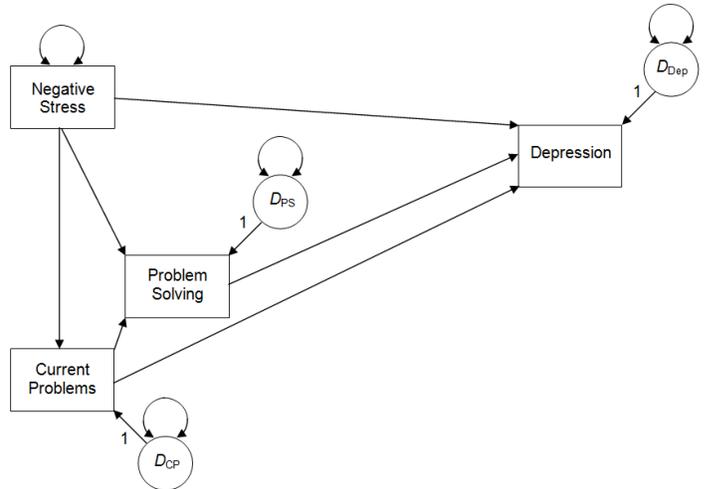
*Do not use the label "PC-1" in LISREL syntax because the hyphen character will be read as the minus operator, not as a character. Syntax in LISREL is also case sensitive.

- Note that LISREL syntax is case sensitive, and variable names are limited to eight characters. The hyphen character (“-”) is read in LISREL as a minus sign (i.e., an arithmetic operator), not as an alphanumeric character, so do not use it in a variable name. For example, use “PC_1” as a name instead of “PC-1,” which will cause an error. Run the syntax by clicking on the Run LISREL icon ().
- If the analysis is correctly specified, the model chi-square shown on screen will be $\chi^2(7) = 3.93$. This statistic is what is labeled in LISREL text output as the “Maximum Likelihood Ratio Chi-Square (C1).” Note that Sava (2002) reports error standard deviations, not error variances, which are listed in LISREL output.
- The syntax to be adapted is listed next along with its corresponding path model are presented next:

```

Nezu & Ronan (1989)
Observed Variables
  neg_str cur_prob prob_sol depress
Covariance Matrix
76.913
55.668 249.324
33.757 115.685 478.297
21.775 53.614 60.695 37.700
Sample Size is 205
Relationships
  cur_prob = neg_str
  prob_sol = neg_str cur_prob
  depress = neg_str cur_prob prob_sol
LISREL Output: ND = 3 SC RS MI
Path Diagram
End of Problem

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Practice 2

For computer practice 2, repeat the same analysis but now using the LISREL path diagram editor, as follows:

- Save the variance-covariance matrix for the Sava (2002) analysis from practice 1 in an external text (ASCII) file (e.g., create it in Windows Notepad), and name it “sava.dat.”
- In the LISREL editor, select New | Path Diagram, and save the empty diagram file as “sava.pth.”
- Next, use the Setup menu to specify the data file, variable names, and sample size before drawing the model on the screen. Check the boxes for the endogenous variables (Observed Y) before dragging and dropping the observed variables from the list to the drawing palette. Select View | Toolbars | Drawing Bar to display the shape tools, if not already visible.
- When finished drawing the model, generate the LISREL SIMPLIS syntax by selecting Build SIMPLIS Syntax under the Setup menu. Then run the syntax by clicking on the Run LISREL icon.
- The unstandardized path coefficients and error variances are initially shown in the path diagram. To see the standardized estimates, select Standardized Solution option from the Estimates pull-down menu of the diagram editor.