Applied Structural Equation Modeling
Psychology 368, Fall 2007
Class meeting: Thursday 1:15-3:45, 312A Soc/Psych
Lab meeting: Friday 10:00-11:30, 229 Social Sciences

Course Instructor:

Rick Hoyle
318 Sociology/Psychology Building
660.5791 (office)
rhoyle@duke.edu
Office hours: Mon 3-4 and by appt.

Lab Instructor:

Chongming Yang
B137 Erwin Mill Building
668.3023 (office)
cy29@duke.edu
Office hours: Mon, Tue, Wed, & Fri 2-5

Course Web site: http://www.duke.edu/~rhoyle/teaching/psy368/

Readings

Required:

Hoyle, R. H. (1995). *Structural equation modeling: Concepts, issues, and applications*. Thousand Oaks, CA: Sage Publications.

Kline, R. B. (2005). *Principles and practice of structural equation modeling* (2nd ed). New York: Guilford Press.

Additional readings listed in the course outline.

Primary Goals of the Course

- familiarize graduate students in psychology with the language, logic, and implementation of structural equation modeling;
- compare and contrast structural equation modeling with more commonly used statistical procedures such as analysis of variance, multiple regression analysis, and factor analysis;
- learn the criteria associated with decisions that must be made at each phase of a structural equation modeling analysis;
- consider the philosophical and statistical criticisms of structural equation modeling as an approach to research design and data analysis;
- provide firsthand experience reviewing research reports that feature structural equation modeling and writing up the results of structural equation modeling analyses.

Elements of the Course

Readings

The readings for the course come from two required textbooks as well as edited books and journals in which advances in structural equation modeling are published. The reading requirement is heavy at times, but the readings are carefully chosen and a vital element of the learning that will take place in the course. Make every effort to complete the readings before the class meeting for which they are assigned. Bring questions inspired by the readings with you to the class meeting or, if you prefer, send them to me by email prior to the class meeting. Readings outside the textbooks will be made available to you for download from the course website, typically two weeks before the class meeting during which they will be covered.

Lab Meetings

Lab meetings are scheduled for a 90 minute block each Friday beginning at 10:00. Attendance is mandatory. The purpose of lab meetings is fourfold: (1) to provide opportunities for deeper exploration of material covered in class meetings; (2) to provide training in the use of Mplus for structural equation modeling analyses; (3) to prepare for examinations through discussion of homework assignments; (4) for administration of exams. Lab meetings will be convened by the lab instructor.

Quiz

During the third lab meeting (September 14) there will be a one-hour quiz on material covered during the first two class meetings. Primarily, the quiz will cover the relation between the general linear model and the structural equation model, basic vocabulary associated with structural equation modeling, Greek alphabet representation of parameters, and aspects of path diagrams.

Exams

You will complete two written examinations during the course; the first exam (Friday, September 28), which covers measurement models, will contribute 15%, and the second exam (Friday, October 19), on steps in executing a structural equation modeling analysis, will contribute 20% toward your grade for the course. The exams will include multiple choice and short answer items.

Presentation

You will give a 9-minute presentation in which you describe and evaluate a published application of structural equation modeling. You are to choose an article published since 2002 in a major journal in your field of interest. The article you choose to present must be approved by the course or lab instructor. In the presentation, you are to do the following:

1. State the primary research question.
2. Describe the data (e.g., *N*, missing data problems, measures, distributions)
3. Describe how structural equation modeling was used to address the primary research question.

4. Critique the presentation of the results (e.g., tables, figures, details about the analyses).
5. State whether, in your opinion, structural equation modeling was appropriately chosen and why. Note any alternative analyses not described in the article that might shed additional light on the primary research question.

You will present on November 15. Your grade on the presentation will contribute 10% toward your grade for the course.

Application Project

The primary product of the course will be a paper in which you describe an application of structural equation modeling that is typical of research in your area. The paper can be either a proposal for an application or a write-up of an actual application of structural equation modeling.

Proposal. The goal of the proposal is to provide full information regarding a *planned* application of structural equation modeling to a set of data that is typical of research in your research area or discipline. Ideally, you would refer to an actual data set that you will, at some point, analyze. If you are unable to pinpoint such a data set, then you may propose the collection of an appropriate set of data. In either case, you must describe in detail the data and your plan to analyze the data. Proposals are to include the following.

1. a *brief* statement of the research question and hypotheses,
2. a detailed method section,
3. a detailed plan of analysis section,
4. a *brief* limitations section.

Write-up. The goal of the write-up is to provide full information regarding an *actual* application of structural equation modeling to a set of data of your choosing. (Note: Pursuing this option requires that you have a suitable set of data and that you have access to appropriate software such as Mplus, EQS, LISREL, or AMOS.) Reports are to include the following:

1. a *brief* statement of the research question and hypotheses,
2. a detailed method section,
3. a detailed results section,
4. a *brief* conclusion section.

In either case, about one-third of the way into the course you will be asked to provide a basic description of the data set that you will either propose to analyze, propose to gather and analyze, or actually analyze.

Near the midpoint of the course you will be asked to prepare a document in which you specify the names and characteristics of the variables your project will include and the strategy you will use in applying structural equation modeling to your data.

About two-thirds of the way into the course you will be asked to meet outside of class with another member of the class to discuss your data and plan of analysis and to exchange feedback on your project.

Two weeks before the write-ups are due, *at the beginning of the class meeting* on Thursday, November 29, you will provide a copy of a draft to two members of the class, and you

will receive copies of two drafts from other class members. You will provide written reviews (details will be provided in a handout) for the authors of the two drafts you receive (and copies for me); you will receive two reviews of your draft. The reviews, which will be graded and contribute 5% toward your grade for the course, are due one week later, on Thursday, December 6, one week before the final draft of the paper is due.

The final draft of the paper is due *before noo*n on Thursday, December 13. The paper will count 35% toward your grade for the course.

Course Grade

To summarize, course grades will be based on the average percentage of points obtained from seven sources, weighted as follows:

Quiz: 5%
Exam 1: 15%
Exam 2: 20%
Homework: 10%
Presentation: 10%
Reviews: 5%
Application project: 35%

Grades will be distributed according to the following scale:

A: 89.5%-100%
B: 79.5%-89.4%
C: 69.5%-79.4%
F: < 69.5%

Course Outline*

August 30 introduction and overview

Optional background readings:

Chapter 1 in Tucker, L. R., & MacCallum, R. C. (1997). *Exploratory factor analysis.*

Comrey, A. L. (1988). Factor-analytic methods of scale development in personality and clinical psychology. *Journal of Consulting and Clinical Psychology, 56*, 754-761.

Darlington, R. B. (1968). *Multiple regression in psychological research and practice. Psychological Bulletin, 69*, 161-182.

http://www2.chass.ncsu.edu/garson/pa765/regress.htm—description of multiple regression analysis from the Quantitative Research in Public Administration Web site at NC State University

http://www.statsoft.com/textbook/stmulreg.html—basic description of multiple regression analysis from the Statistica Web site

http://elsa.berkeley.edu/sst/regression.html—a more technical description of multiple regression analysis from the Statistical Software Tools Web site at Berkeley

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*All readings available for download at http://www.duke.edu/~rhoyle/teaching/psy368/reading.html

September 6 "nuts and bolts"

Kline: Chapters 1-4 (Chapter 3 optional)
Hoyle: Chapter 1
Hoyle: Chapter 2, pp. 16-27
Bollen, K. A. (1989). Model notation, covariances, and path analysis. Chapter 2 in *Structural equations with latent variables*. New York: Wiley.
*pp. 10-20 on notation; pp. 32-34 on path diagrams; pp. 36-39 on decomposing effects

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September 13 simple measurement models

Hoyle, R. H. (2007). Applications of structural equation modeling in personality research. In R. Robins, C. Fraley, & R. Krueger (Eds.), *Handbook of research methods in personality psychology* (pp. 444-460). New York: Guilford Publications.
DeShon, R. P. (1998). A cautionary note on measurement error corrections in structural equation models. *Psychological Methods, 4*, 412-423.
Steiger, J. H. (2002). When constraints interact: A caution about reference variables, identification constraints, and scale dependencies in structural equation modeling. *Psychological Methods, 7*, 210-227.
Bollen, K. A., & Lennox, R. D. (1991). Conventional wisdom on measurement: A structural equation perspective. *Psychological Bulletin, 110*, 305-314.
Edwards, J. R., & Bagozzi, R. P. (2000). On the nature and direction of relationships between constructs and measures. *Psychological Methods, 5*, 155-174.

Optional:

Little, T. D., Lindenberger, U., & Nesselroade, J. R. (1999). On selecting indicators for multivariate measurement and modeling with latent variables: When "good" indicators are bad and "bad" indicators are good. *Psychological Methods, 4*, 192-211.
MacCallum, R. C., & Browne, M. W. (1993). The use of causal indicators in covariance structure models: Some practical issues. *Psychological Bulletin, 114*, 533-541.

September 20 complex measurement models

Kline: Chapter 7, section 7.8
Hoyle: chapter 10, pp. 177-187
Little, T. D., Cunningham, W. A., Shahar, G., & Widaman, K. F. (2002). To parcel or not to parcel: Exploring the question, weighing the merits. *Structural Equation Modeling, 9*, 151-173.
Zautra, A. J., Marbach, J. J., Raphael, K. G., Dohrenwend, B. P., Lennon, M. C., & Kenny, D. A. (1995). The examination of myofascial face pain and its relationship to psychological distress among women. *Health Psychology, 14*, 223-231.
Byrne, B.M., Shavelson, R. J., & Muthen, B. (1989). Testing for the equivalence of factor covariance and mean structures: The issue of partial measurement invariance. *Psychological Bulletin, 105*, 456-466.

Optional:

Lance, C. E., Noble, C. L., & Scullen, S. E. (2002). A critique of the correlated trait-correlated method and correlated uniqueness models for multitrait-multimethod data. *Psychological Methods, 7*, 228-244.

Hoyle, R. H., & Duvall, J. L. (2004). Determining the number of factors in exploratory and confirmatory factor analysis. In D. Kaplan (Ed.), *Handbook of quantitative methodology for the social sciences* (pp. 301-315). Thousand Oaks, CA: Sage Publications.

Kenny, D. A., & Zautra, A. (1995). The trait-state-error model for multiwave data. *Journal of Consulting and Clinical Psychology, 63*, 52-59.

Cole, D. A., Martin, N. C., & Steiger, J. H. (2005). Empirical and conceptual problems with longitudinal trait-state models: Introducing a trait-state-occasion model. *Psychological Methods, 10*, 3-20.

September 27 specification and estimation

Hoyle: Chapter 2, re-read pp. 16-27
Kline: Chapter 5, sections 5.2-5.4, and Chapter 7, sections 7.1-7.2
Hoyle: Chapters 3 (pp. 37-46) and 4
Kline: Chapter 5, sections 5.6-5.7

Hoyle, R. H. (2000). Confirmatory factor analysis. In H. E. A. Tinsely & S. D. Brown (Eds.), *Handbook of applied multivariate statistics and mathematical modeling* (pp. 465-497). New York: Academic Press.

October 4 omnibus fit indices; model modification

Kline: Chapter 6, section 6.2

MacCallum, R. C. (2003). Working with imperfect models. *Multivariate Behavioral Research, 38*, 113-139.

Widaman, K. F., & Thompson, J. S. (2003). On specifying the null model for incremental fit indices in structural equation modeling. *Psychological Methods, 8*, 16-37.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin, 107*, 238-246.

Browne, M. W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen & J. S. Long (Eds.), *Testing structural equation models* (pp. 136-162). Newbury Park, CA: Sage.

Hoyle: Chapter 2, pp. 31-35

Jöreskog, K. G. (1993). Testing structural equation models. In K. A. Bollen & J. S. Long (Eds.), *Testing structural equation models* (pp. 294-316). Thousand Oaks, CA: Sage Publications.

MacCallum, R. C., Roznowski, M., & Necowitz, L. B. (1992). Model modifications in covariance structure analysis: The problem of capitalization on chance. *Psychological Bulletin, 111*, 490-504.

Optional:

Browne, M. W., MacCallum, R. C., Kim, C.-T., Andersen, B. L., & Glaser, R. (2002). When fit indices and residuals are incompatible. *Psychological Methods, 7*, 403-421.

Hu, L.-T., & Bentler, P. M. (1998). Fit indices in covariance structure modeling: Sensitivity to underparameterized model misspecification. *Psychological Methods, 3*, 424-453.

October 11 tests of parameters, non-normal & non-continuous data, statistical power

Gonzalez, R., & Griffin, D. (2001). Testing parameters in structural equation modeling: Every "one" matters. *Psychological Methods, 6*, 258-269.

Finney, S. J., & DiStefano, C. (2006). Non-normal and categorical data in structural equation modeling. In G. R. Hancock & R. O. Mueller (Eds.), *Structural equation modeling: A second course* (pp. 269-314). Greenwich, CT: Information Age Publishing.

Hoyle: Chapter 6

Hancock, G. R. (2006). Power analysis in covariance structure modeling. In G. R. Hancock & R. O. Mueller (Eds.), *Structural equation modeling: A second course* (pp. 69-115). Greenwich, CT: Information Age Publishing.

MacCallum, R. C, Browne, M. W., & Sugawara, H. M. (1996). Power analysis and determination of sample size for covariance structure modeling. *Psychological Methods, 1*, 130-149.

Muthén, L. K., & Muthén, B. O. (2002). How to use a Monte Carlo study to decide on sample size and determine power. *Structural Equation Modeling, 9*, 599-620.

October 18 cross-sectional structural models

Hoyle, R. H., & Kenny, D. A. (1999). Sample size, reliability, and tests of mediation. In R. H. Hoyle (Ed.), *Statistical strategies for small sample research* (pp. 195-222). Thousand Oaks, CA: Sage Publications.

McClelland, G. H., and Judd, C. M. (1993). Statistical difficulties of detecting interactions and moderator effects. *Psychological Bulletin, 114*, 376-390.

Jaccard, J., & Wan, C. K. (1995). Measurement error in the analysis of interaction effects between continuous predictors using multiple regression: Multiple indicator and structural equation approaches. *Psychological Bulletin, 117*, 348-357.

Marsh, H. W., Wen, Z., & Hau, K.-T. (2004). Structural equation models of latent interactions: Evaluation of alternative estimation strategies and indicator construction. *Psychological Methods, 9*, 275-300.

October 25 autoregressive longitudinal models; latent growth curve models

Farrell, A. D. (1994). Structural equation modeling with longitudinal data: Strategies for examining group differences and reciprocal relationships. *Journal of Consulting and Clinical Psychology, 62*, 477-487.

Hays, R. D., Marshall, G. N., Wang, E. Y. I., & Sherbourne, C. D. (1994). Four-year cross-lagged associations between physical and mental health in the Medical Outcomes Study. *Journal of Consulting and Clinical Psychology, 62*, 441-449.

Willett, J. B., & Sayer, A. G. (1994). Using covariance structure analysis to detect correlates and predictors of individual change over time. *Psychological Bulletin, 116*, 363-381.

Optional:

Newcomb, M. D. (1994). Drug use and intimate relationships among women and men: Separating specific from general effects in prospective data using structural equation models. *Journal of Consulting and Clinical Psychology, 62,* 463-476.

November 1 latent growth curve models (cont.); other structured means models

Llabre, M. M., Spitzer, S. B., Saab, P. G., & Schneiderman, N. (2001). Piecewise latent growth curve modeling of systolic blood pressure reactivity and recovery from the cold pressor test. *Psychophysiology, 38,* 951-960.

Kline, Chapter 10, sections 10.1-10.4

Thompson, M. S., & Green, S. B. (2006). Evaluating between-group differences in latent variable means. In G. R. Hancock & R. O. Mueller (Eds.), *Structural equation modeling: A second course* (pp. 119-169). Greenwich, CT: Information Age Publishing.

Optional:

Curran, P. J. (2003). Have multilevel models been structural equation models all along? *Multivariate Behavioral Research, 38,* 529-569.

Curran, P. J., Bauer, D. J., & Willoughby, M. T. (2004). Testing main effects and interactions in latent curve analysis. *Psychological Methods, 9,* 220-237.

November 8 missing data methods

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

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

Graham, J. W., Olchowski, A. E., & Gilreath, T. D. (2002). How many imputations are really needed? Some practical clarifications of multiple imputation theory. *Prevention Science, 8,* 206-213.

Optional:

Collins, L. M., Schafer, J. L., & Kam, C.-M. (2001). A comparison of inclusive and restrictive strategies in modern missing data procedures. *Psychological Methods, 6,* 330-351.

Sinharay, S., Stern, H. S., & Russell, D. (2001). The use of multiple imputation for the analysis of missing data. *Psychological Methods, 6,* 317-329.

November 15 presentations

Optional readings on reporting SEM results:

Boomsma, A. (2000). Reporting analyses of covariance structures. *Structural Equation Modeling, 7,* 461-483.

Hoyle: Chapter 9

McDonald, R., & Ho, M.-H. R. (2002). Principles and practice in reporting structural equation analyses. *Psychological Methods, 7,* 64-82.

Raykov, T., Tomer, A. & Nesselroade, J. R. (1991). Reporting structural equation modeling results in psychology and aging: Some proposed guidelines. *Psychology and Aging, 6,* 499-503.

November 29 **limitations and criticisms**
rough drafts due

Hoyle: Chapter 7

Kline: Chapter 12

Breckler, S. J. (1990). Applications of covariance structure modeling in psychology: Cause for concern? *Psychological Bulletin, 107,* 260-273.

MacCallum, R. C., Wegener, D. T., Uchino, B. N., & Fabrigar, L. R. (1993). The problem of equivalent models in applications of covariance structure analysis. *Psychological Bulletin, 114,* 185-199.

Optional:

Meehl, P. E., & Waller, N. G. (2002). The path analysis controversy: A new statistical approach to strong appraisal of verisimilitude. *Psychological Methods, 7,* 283-300.

Responses to Meehl & Waller (2002) in *Psychological Methods,* Vol. 7, No. 3.

December 6 **reviews due by noon**

December 13 **final drafts due by noon**

Lab Meetings

August 31	exploratory factor analysis (EFA)
September 7	introduction to Mplus and data preparation
September 14	**quiz**
September 21	confirmatory factor analysis (CFA) & complex measurement models
September 28	**Exam 1**
October 5	multiple group CFA and invariance testing
October 12	power and sample size calculation with Monte Carlo simulation
October 19	**Exam 2**
October 26	full structural equation models; mediation and moderation
November 2	latent growth models
November 9	latent growth model (continued)
November 16	multiple imputation and using multiply-imputed data for SEM
November 30	additional topics

Note. Some lab meetings will be held in B140 Erwin Mill Building.