Multilevel Models II: Advanced Topics
ICPSR Summer Program
July 24-August 18
Lecture 1:00-3:00 M-F

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Course Description: This course is designed to extend the basic multilevel skills that participants receive from an introductory applied class to more sophisticated and complex models like nonlinear and non-hierarchical mixed effects models.

In the first week, we will review the basics of multilevel models and discuss more advanced topics like model tests and diagnostics, dealing with unmodeled or inconveniently structured data, and missing data. In the second week, we discuss complex non-hierarchical models and more technical details about generalized linear mixed models. In the third week, we will cover models for binary, multinomial choice, ordinal choice, survival, and count outcomes. In the final week, we will discuss some advanced topics relating to structural equation modeling, measurement error, and effect heterogeneity. We also spend a significant amount of time on the practical differences between and use of maximum likelihood, simulated/empirical likelihood, and Bayesian approaches to these nonlinear and non-hierarchical multilevel models.

The course will be pitched at around the technical level of other Track III courses, such as Advanced Topics in Maximum Likelihood. Prior exposure to maximum likelihood or basic categorical models as well as some previous background in either multilevel or longitudinal modeling as a prerequisite. Ideally, students will have had courses like the Maximum Likelihood Estimation I and Multilevel Models I classes at ICPSR prior to attending. The primary goal of the course will be to allow students to use advanced models and to understand how and when more sophisticated techniques will provide practical benefits.
**Readings:** There is no required book for purchase. Required and (some) recommended readings from book chapters and articles will be provided in the class shared drive. Despite the amount of material that we cover we will still omit many important topics. Below is a set of recommended books that will cover many of these advanced topics. You should probably buy at least some of these books for your library. I recommend Hox (2010) and/or Snijders and Bosker (2011) for basic references. For advanced references, the three handbooks of multilevel modeling: De Leeuw, Meijer, and Goldstein (2008) Hox and Roberts (2011) and Scott, Simonoff, and Marx. (2013) are all terrific. For broader (accessible) theories of how multilevel models fit into broader statistics, I strongly recommend Skrondal and Rabe-Hesketh (2004) and Hodges (2013).

**Strongly Recommended Software Books**

**Recommended Multilevel Books (Introductory/Intermediate):**

**Recommended Multilevel Books (Advanced/Specialized):**
Software: This class is designed to be somewhat agnostic to the kind of software that you want to use. Different people in different fields have different preferences and I’m not going to tell you what you should use. However, this is an advanced topics class and I guarantee that some topics are not practical in your preferred software. If you want to be able to do everything that this course covers, you’ll need to be flexible about the software that you use. Between the instructor and TA, we can help with R, Stata, and SAS. I’ve assigned some readings on specialized R packages mainly because they are useful for teaching concepts. Similar packages in Stata and SAS tend to be canned as part of the program and thus in the main documentation files.

Homework: The homework assignments are optional and designed to give you practical experience implementing the techniques in the class. You’ll be given notes on code to do these exercises in both R and Stata. Note that some techniques are currently unavailable in some software. Again, these are optional and designed so that you can figure out how to implement these models while you have the instructors available to help you troubleshoot problems. You don’t need to turn them in to us but you can come by and ask questions if you can’t figure something out.

Grades: Your grade for the class will be based on the analytical portion of a seminar paper using advanced methods covered in this course. If you have some other advanced multilevel model that is not covered in this course but is required for your analysis you will need to consult with me about it in person. Ideally, this is a paper that you have worked on previously where you want to build up the methods section but a new topic is fine. If you plan to get a grade, please submit the following milestones to me (by email) by the deadlines below.

Friday, August 4
- The initial topic
- Hypotheses
- Descriptive statistics
- A stab at an analytical plan

Wednesday, August 16
- A full draft of the analytical plan
- Model results with interpretation
- A stab at diagnostics

Friday, August 25
- Final draft due by noon
WEEK 1: INTRODUCTION TO MULTILEVEL MODELING

Monday: Introduction to the Class
- Introductions and Overview of the Class
- Basic Assumptions and the Problems of Correlated Data
  - Standard Error Problems
  - Cluster Confounding
  - Heterogeneous Effects Across Groups
- The Semantics of Fixed, Random, and Mixed Effects Models Across Fields

Required Readings

Tuesday: Multilevel Models
- Standard Error Corrections
- Fixed and Random Effects
- Hierarchical Linear Modeling
- Group-Mean and Grand-Mean Centering in 2 or More Levels
- Random Coefficients Models

Required Readings

RecommendedReadings

Wednesday: Likelihood, Simulated Likelihood, and Bayesian-flavored Multilevel Models
- The Machinery of Linear Models
- Points and Distributions
- Probability Theory
- Priors and Hyperpriors

Required Readings

Recommended Reading for Bayesian MLM

Comparing MLE and Bayes

**Thursday: Fit, Diagnostics, and Being Properly Paranoid about your Model**
- Residual and Random Effect Diagnostics
- The Hausman Test & the Mundlak Test
- Too Few Groups and Small Groups
- Large Numbers of Levels
- Outlier Diagnostics

Required Readings
https://cran.r-project.org/web/packages/DHARMa/vignettes/DHARMa.html

Recommended Readings


**Friday: Multilevel Missing Data Problems**

- MCAR, MAR and Thinking about your Missingness
- Listwise Deletion
- Ways You Should Not Impute Data
- Multiple Imputation through EM

**Required Reading**


**Recommended Reading**


➤ Documentation for the R Package mitml
WEEK 2: COMPLEX MODELS

Monday: Multilevel Longitudinal Models
- Fixed, Random and Mixed Effects Models with Time
- Temporal Autocorrelation
- Pattern Covariance Structures
- Cointegration Problems

Required Readings

Recommended Readings

Tuesday: Multilevel Spatial Models
- Spatial Correlation
- Hybrid Spatial Multilevel Models
- Diffusion
- Joint Exposure
- Group Misspecification
- Multilevel Diffusion Models
- Random Coefficients and Gravity Models

Required Readings

Recommended Readings
  - http://rpubs.com/INBOstats/spde


Wednesday: Multilevel Network Models

- Network Basics
- Egocentric Networks
- Multiple Membership Networks
- Cross-Classified Multiple Membership Networks
- Multilevel Exponential Random Graph Models

Required Readings


Recommended Readings


Thursday: Generalized Linear Mixed Models

- Review of Hierarchical Linear Modeling Assumptions
- General Method of Moments
- Maximum Likelihood Estimation with Link Functions
- Linearization as an alternative to Link Functions
- Integration as an alternative to Link Functions
Required Reading
➢ None

Recommended Readings

Friday: How Random Effects Are Estimated

- Linear Models
  o Swamy-Arora
  o Two Stage Least Squares
  o Maximum Likelihood (MLE)
  o Restricted Maximum Likelihood (REML)
- Non-Linear Models
  o Linearization
  o Laplace Approximation
  o Marginal Quasi Likelihood (MQL)/Penalized Quasi Likelihood (PQL)
  o Quadrature & Adaptive Quadrature
  o MCMC and Quasi-MCMC
  o Expectation Maximization (EM) and Variational Bayes

Required Readings
➢ None

Recommended Readings

WEEK 3: NONLINEAR MODELS

Monday: Multilevel Binary Outcomes I
- LPM, Probit, Logit, Clog-log, and Generalized Linear Mixed Models
- The Incidental Parameters Problem, Random Effects Misspecification, and other Nightmares
- What Likelihood, Simulated Likelihood, and Bayesian Variations Do Differently

Required Readings

Recommended Readings

Tuesday: Multilevel Binary Outcomes II
- Empirical Bayes Predictions, Predicted Probabilities, and Marginal Effects
- Multilevel Regression and Post-stratification (MRP)
- Multilevel Propensity Score Matching
- Multilevel Selection Models

Required Readings
- None

Recommended Readings (MRP)


Recommended Reading (Propensity Scores)
- Kim, J.S., & Steiner, P.M. Multilevel propensity score methods for estimating causal effects: A latent class modeling strategy. International Meeting of Psychometric Society Proceedings
- https://cran.r-project.org/web/packages/multilevelPSA/multilevelPSA.pdf

Recommended Reading (Selection Models)

Wednesday: Multilevel Item Response Theory

Required Reading

Recommended Readings

Thursday: Multilevel Event History Models
- Logit
- Cox Proportional Hazard
- Nonparametric Hazard Models
- Frailty Models
- What Likelihood, Simulated Likelihood, and Bayesian Models Do Differently

Required Readings

**Recommended Readings**

**Friday: Multilevel Ordered and Multinomial Choice Models**
- Generalizations of the Probit and Logit
- The Multiple Intercepts Problem
- Mixed Logit

**Required Readings**

**Recommended Readings**

**WEEK 4: ADVANCED TOPICS**

**Monday: Multilevel Structural Equation Modeling**
- The Generalized Latent Variable Framework
- Random Effects and Measurement Error
- Joint Outcomes for Linear Mixed Effects
- Joint Outcomes for Nonlinear Mixed Effects

**Required Reading**

**Recommended Readings**
Tuesday: Multilevel Count and Mixture Models
- Poisson and Negative Binomial Models
- Overdispersion as Multilevel Omitted Variable Bias
- What Likelihood, Simulated Likelihood, and Bayesian Models Do Differently

Required Readings

Recommended Readings

Wednesday: Multilevel Quantile Regression
- Fixed Effects Quantile Regression
- Random Effects Quantile Regression
- Random Effects in Generalized Additive Models for Location, Scale, and Shape

Required Reading

Recommended Reading

Thursday: Q&A
- Whatever participants want to discuss relating to multilevel models