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Multi-level models for research policy and higher education studies

Introduction to Multilevel Modeling

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Overview

An introduction
- What is multi-level modeling?

Outline the motivations for the method
- Why multi-level modeling is useful?

A brief overview of estimation
- How to use multi-level models?

Considerations for your research
- When to use multi-level models?

Further reading suggestions
- Where to find out more about MLM?

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What is Multi-level Modeling?

Multi-level Modeling is

- an approach
- a methodology
- a statistical technique or tool

It is also known as

- hierarchical linear modeling
- mixed modeling
- random coefficient modeling
- variance component model

And is different from single-level methods such as

- OLS
- ANOVA

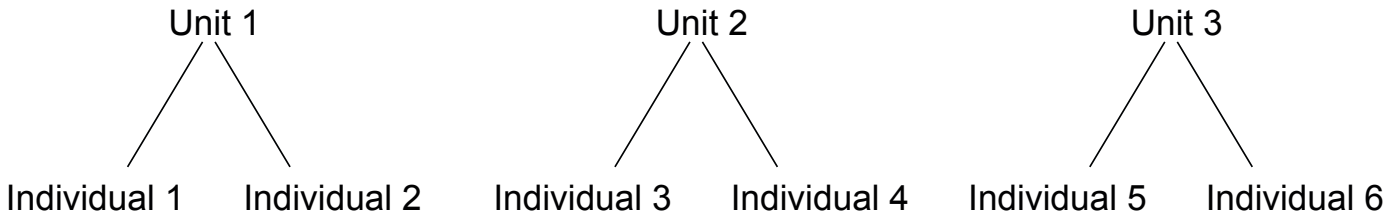
What is Multi-level Modeling?

The emergence of Multi-level Modeling

- education policy in the 1970s
- children within any one class/teacher are taught together tend to be similar in their performance than would have been the case if the same number of children had been taught separately (Aitkin, Anderson et al. 1981)
- differences in student performance depend on school systems, schools, classes, and student attributes
- interest in students AND educational contexts
- now burgeoned in other fields of social science, gaining wide acceptance

Why Multi-level Modeling

Multi-level addresses the notion of 'dependence': individuals nested within a social unit are more alike than a random sample



Some examples of nested data…

Macro Level	Micro Level
schools	teachers
classes	pupils
doctors	patients
universities	professors
companies	teams
judges	suspects

Why Multi-level Modeling

The term group can be interpreted in several ways:

Natural Grouping

- Intrinsically hierarchical clusters
- e.g. students in schools, children in families

Working Grouping

- Technical or bureaucratic groupings
- e.g. neighborhoods, health districts, electorates

Theoretical Grouping

- Clusters are theoretically conceived by scholars
- Boundaries and allocation are more fluid
- e.g. social context such as values or culture,

Why Multi-level Modeling

The type of variation of sub-groups within groups can be:

Homogenous

- takes the group as a whole
- group defined by a single characteristic that does not vary across members
- e.g. cohort, gender,

Independent

- sub-groups free of group influence
- focal identity is the individual
- e.g. manager's early career progress,

Heterogeneous

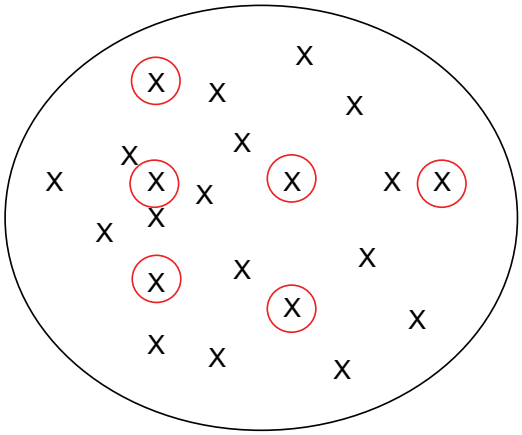
- individuals are seen as relative the rest of the group
- e.g. income brackets

Why Multi-level Modeling

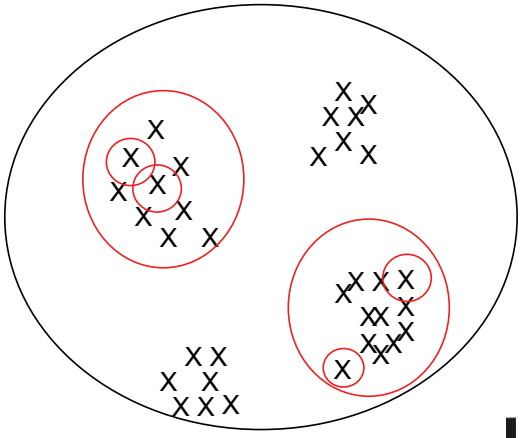
Dependence as a Nuisance

- most large-scale surveys not simple random samples
- dependence is inherent in research design

Simple Random Sample



Two-Stage Sample



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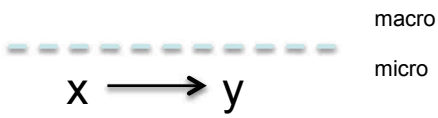
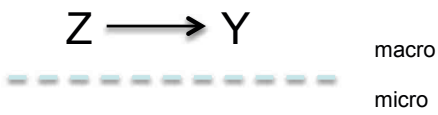
Why Multi-level Modeling

. Dependence as an interesting phenomenon

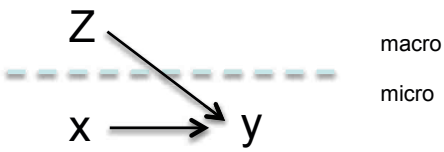
- Micro-level proposition: The effect of socio-economic status on pupil motivation



- Macro-level proposition: The effect of increased governmental spending on overall student performance



- Multi-level proposition: The effect of teacher efficacy (macro-level) on pupil motivation (micro-level)



Why Multi-level Modeling

1. Dependence as an interesting phenomenon

Sample research propositions across social science:

- Do girls in girls' schools do better or worse or the same compared with girls in mixed schools?
- Does the size of a firm impact an individual's earnings and does this differ depending on gender or occupation?
- What is the effect of leadership on the developmental progress of their employees?
- Does the workplace moral determine whether employees leave?
- What the effect of the size of a social network on emotional closeness in social relationships?
- Does a history of alcoholism in the family make individuals more predisposed to alcoholism?

Why is Multi-level Modeling Useful?

Durkheim's *Suicide* (1897)

- Early scholar to explain individual behavior through social phenomena and stress the importance of context
- Curious about why suicide rates vary across geographical units
- Observes that suicide rates in provinces of Prussia vary with the proportion of protestants
- Concludes suicide rates are not the result of thousands of solitary actions but due to social "interconnectedness"
- Conceptual distinction between the study of individual instances of suicide and the study of the frequency that it occurs within a group

Why is Multi-level Modeling Useful?

Why can't we just use group averages?

- Shifts meaning from micro to macro
- Aggregated variables are not a substitute for individual variables
- results in incongruence btw measurement and analysis
- Examples

Individual	Aggregate
employee values	organizational culture
unemployed	unemployment rate
family formation behavior	fertility rates
voter behavior	electorate behavior
male/female	team diversity

Why Multi-level Modeling

Why can't we just use group averages?

Ecological fallacy: transferring relationships across levels is a pitfall

Also known as the "Robinson effect"

The relationship between race and illiteracy from Robinson (1950)

- studies the relationship between illiteracy rates in the US in 1930
- A high correlation between the percentage of blacks living in a state and the state's illiteracy rates
- So, from this can we conclude that blacks are much likely than non-blacks to be illiterate?

Table 5. Percent Black and Percent Illiterate, South/Non-South: 1930 U.S.[a]

Region	Percent Black[b]	Percent Illiterate[b]
South	24.7	8.3
Non-South	3.0	2.7

[a] Source: U.S. Census, 1930.
[b] Population ten years and older.

Why Multi-level Modeling

Ecological Fallacy

Correlations for Foreign Born and Illiteracy

- Individual level analysis shows that there is a positive relationship between being foreign-born and illiterate
  - Logical conclusion since natives can have a better command of the language
- if aggregate this to the state level, you find that in states with more foreign born have lower illiteracy rates

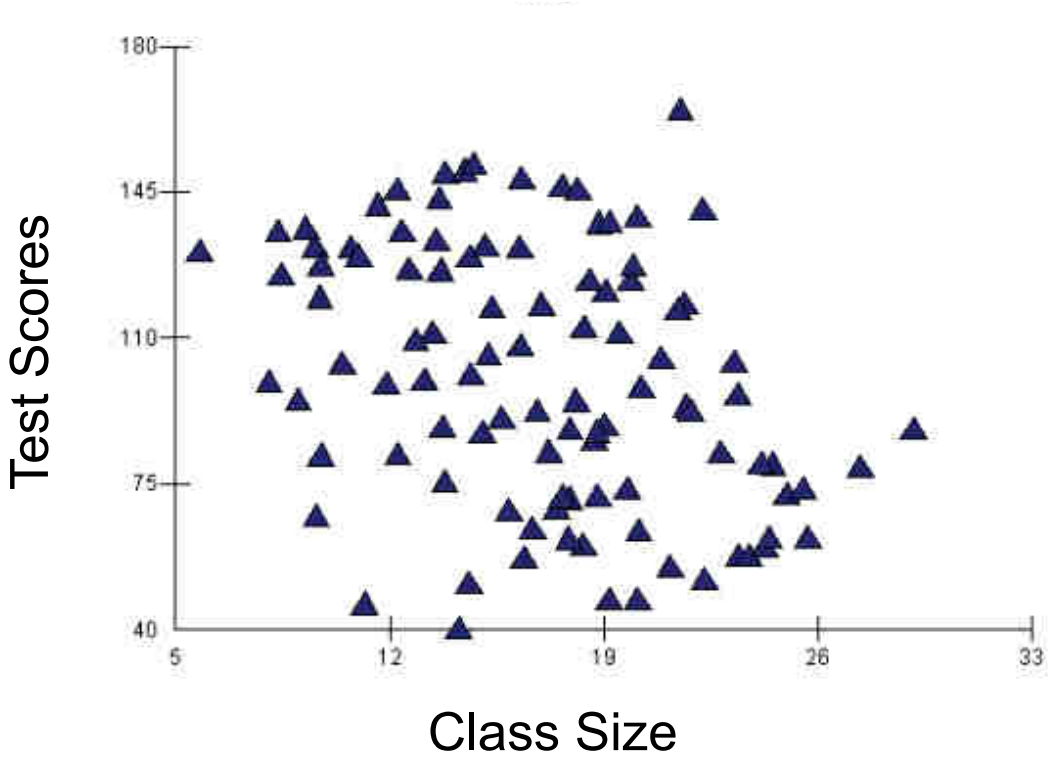
Why Multi-level Modeling

Atomistic Fallacy

- Associations between variables at the individual level may differ from associations between analogous variables measured at the group level
- e.g. increasing individual level income is associated with decreasing coronary heart disease mortality
- At the country level, increasing per capita income would be associated with decreasing coronary heart disease mortality
- But this is a fallacy!
  - across countries, increasing per capita income may actually be associated with *increasing* coronary heart disease mortality

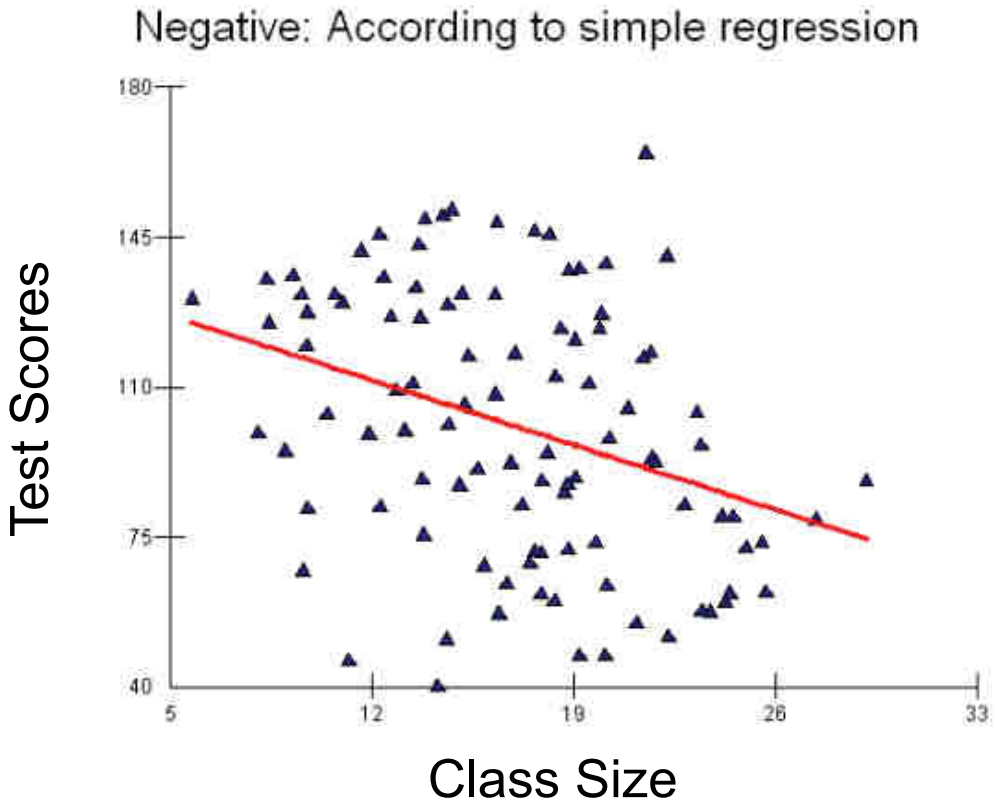
Why Multi-level Modeling

Example: Mean Math Test Scores in a School District



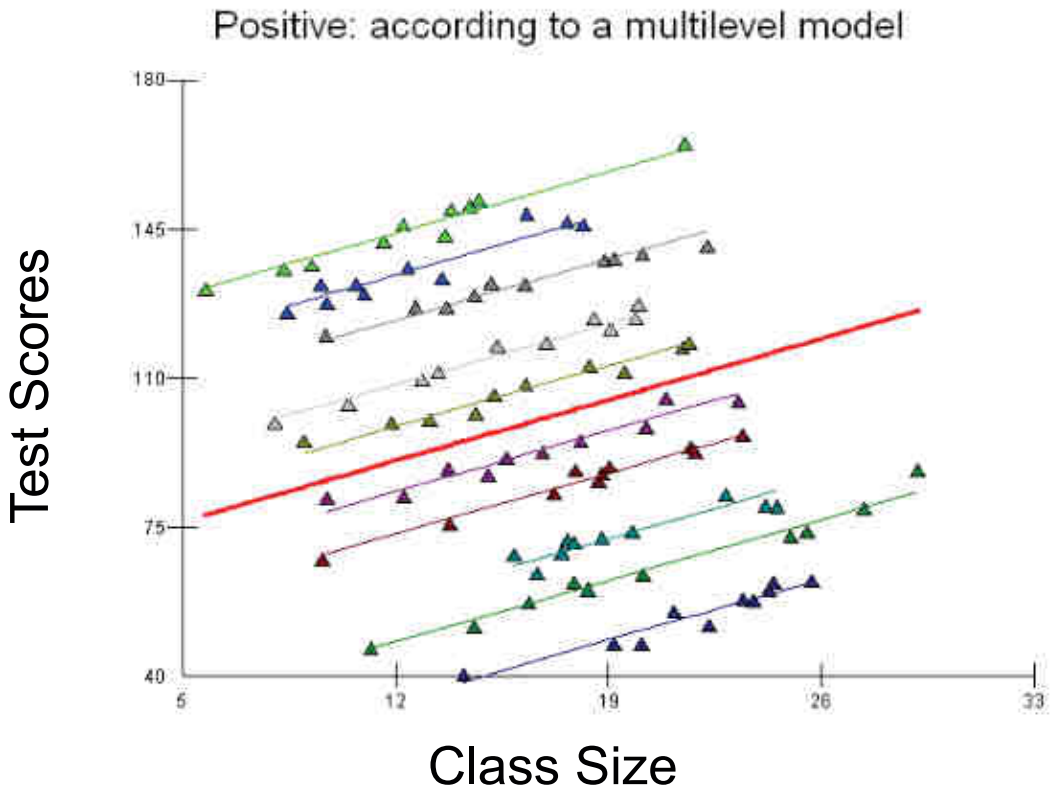
Why Multi-level Modeling

Example: Mean Math Test Scores in a School District



Why Multi-level Modeling

Example: Mean Math Test Scores in a School District



Why is Multi-level Modeling Useful?

Why can't we just use group averages?

Omits potential for Cross Level Interactions

- acknowledges group heterogeneity
- the individual's relative (rather than absolute) position in the group
- 'frog/pond effects'

Why is Multi-level Modeling Useful?

Example: Rafaeli and Sutton (1991) and the Good Cop/ Bad Cop Contrast Effect

- examine the performance of police interrogators to elicit confessions from suspects
- a “bad” cop seems more frightening when with a “good” cop
- contrast effect enhances the carrot and stick
- i.e. it is the individual’s relative (not absolute!) approach which determines performance

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How to use Multilevel Models

Background on Statistical Models

- explanatory, approximation of reality
- there are no ‘correct models’
- models are not ‘a kitchen sink’ approach
- must combine data with theoretical framework that frames the question
- Many models are better than one

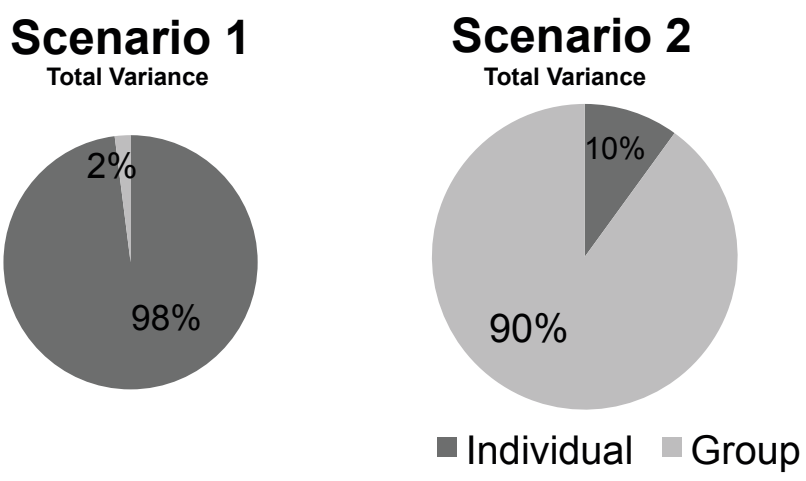
How to use Multilevel Models

Understanding your variance:

Compute the Interclass Correlation Coefficient (ICC)

$$\rho = \frac{\sigma_s^2}{\sigma_s^2 + \sigma_e^2}$$

Multilevel



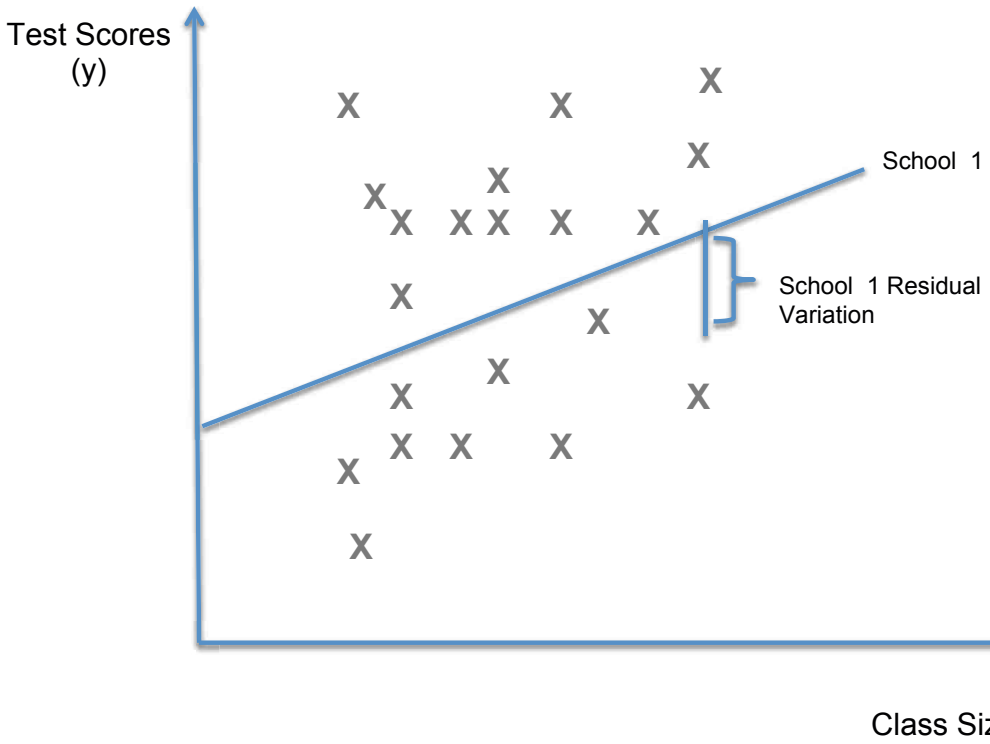
How to use Multilevel Models

Multi-level is a “Mixed Effect” Model

- Fixed Effect Component
  - intercepts/slopes describe whole population
- Random Effect Component
  - intercepts/slopes can vary across subgroups

How to use Multilevel Models

Level 1 Variation in Test Scores in One School



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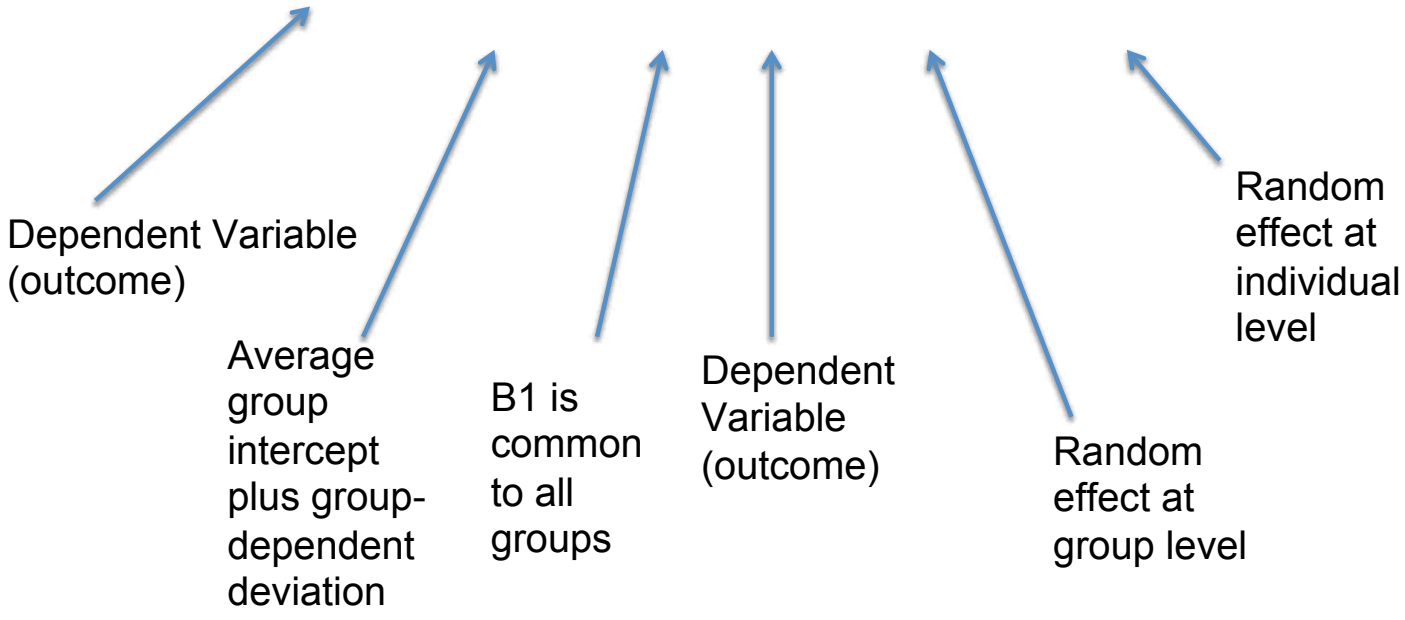
How to use Multilevel Models

Option 1: Random-Intercept Model

$$Y_{ij} = B_{0j} + B_1 x_{ij} + U_{0j} + R_{ij}$$



Note: *i* denotes the individual level, *j* denotes the group level

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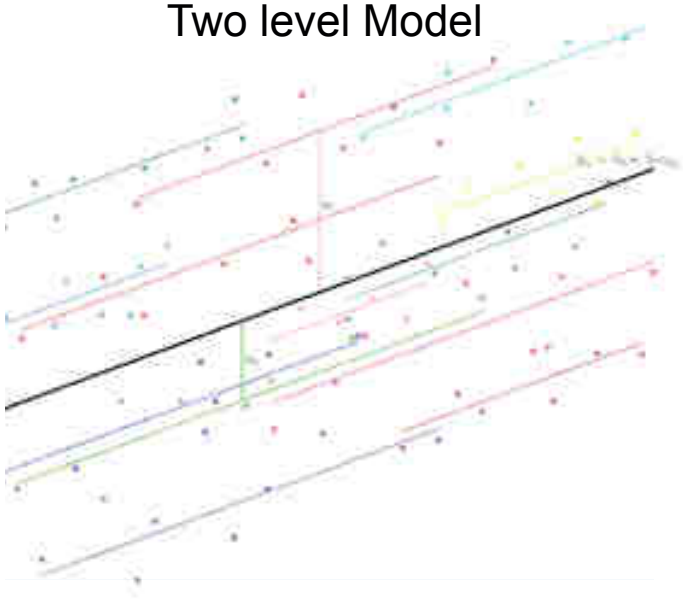
Residuals in Multilevel Models

A multilevel model has more than a set of residuals for each level

One level Model

Two level Model



How to use Multilevel Models

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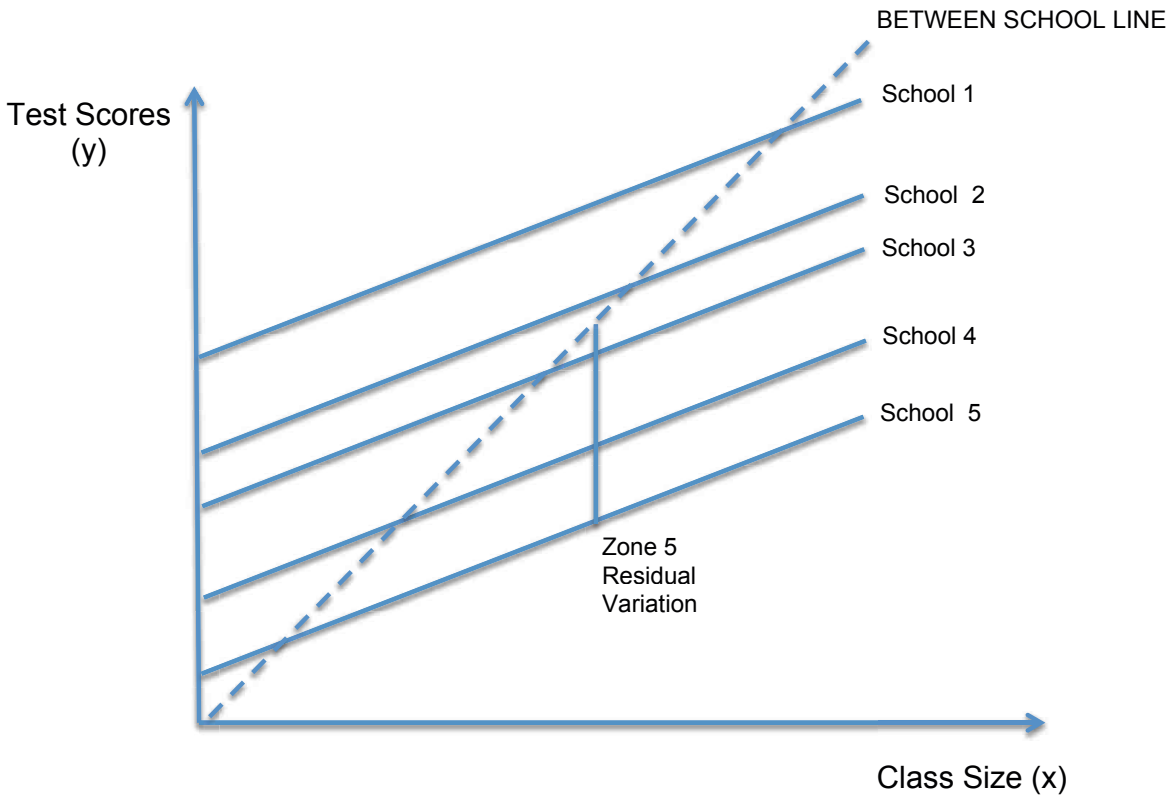


How to use Multilevel Models

Option 2: Random Coefficient Model

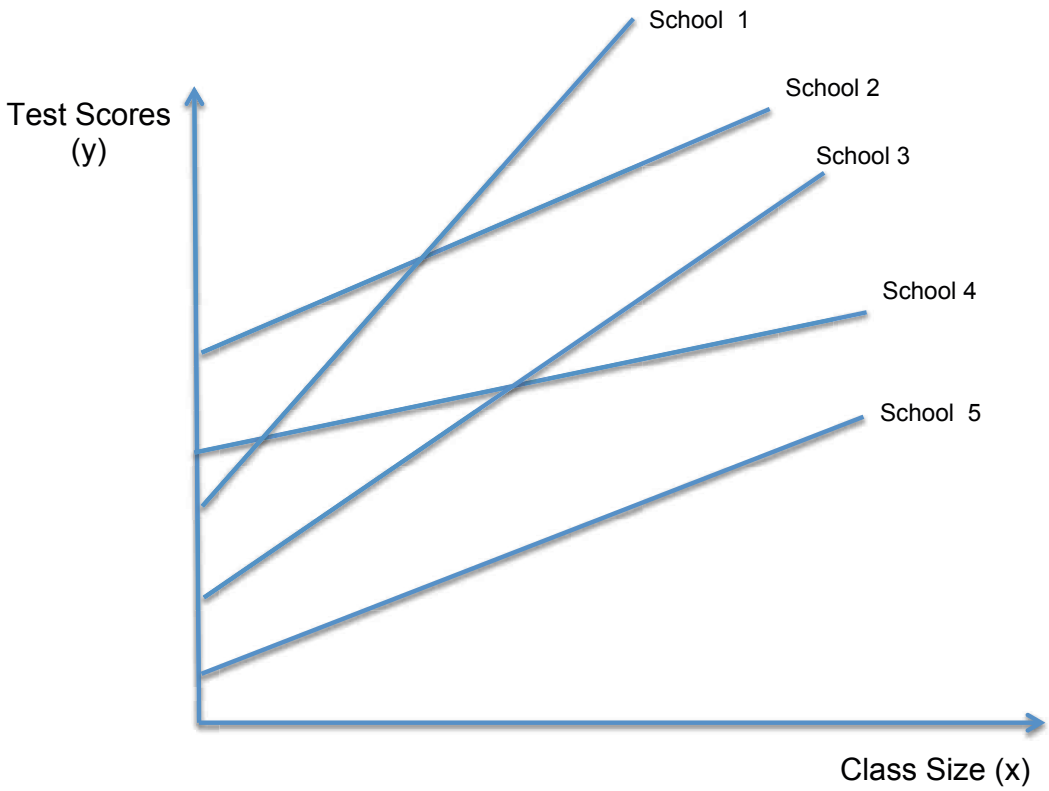
$$Y_{ij} = B_{0j} + B_1 x_{ij} + U_{0j} + U_{1j} x_{ij} + R_{ij}$$

Note: *i* denotes the individual level, *j* denotes the group level

- builds on the Random Intercept Model
- The added term is the "interaction between group and X"
- Indicates group-level deviations in the effect of x on y
- Example: The effect of IQ is positive in all schools but, the size of the effects varies across schools

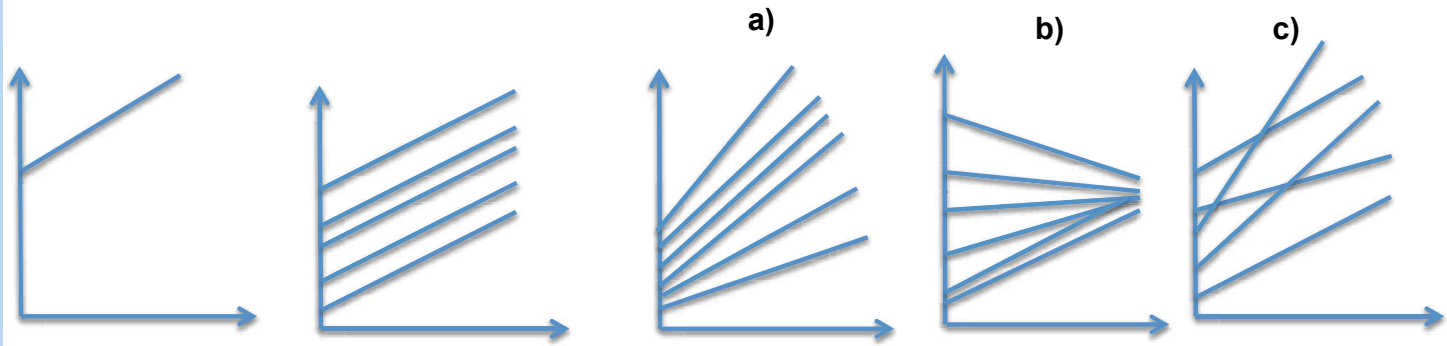
How to use Multilevel Models

Option 2: Random-Coefficient Model

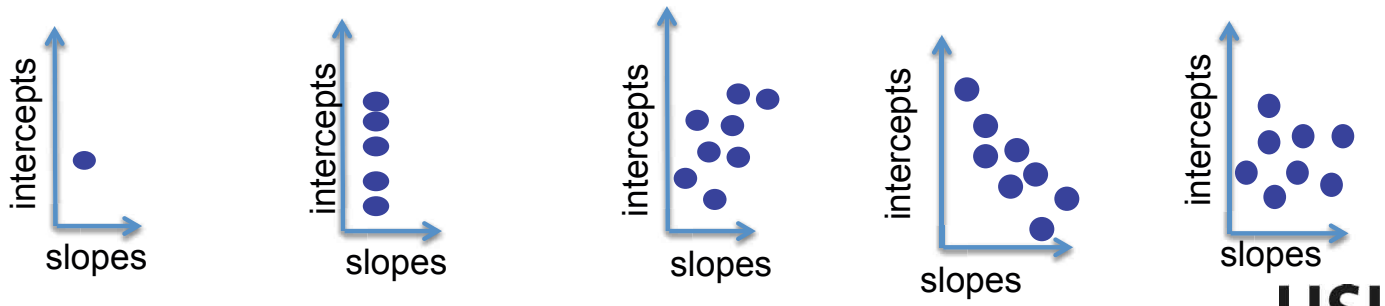


Types of Random Coefficient Patterns

Single Level **Random Intercept** **Random Slope**



Slope-Intercept Covariance



Estimation Strategies

- Maximum likelihood
  - frequentist procedure
  - Restricted maximum likelihood (REML)
- More advanced estimations use Bayesian simulation methods (Markov Chain Monte Carlo)
  - prior parameter distribution
  - more time-consuming but more flexible
  - better for more complex models

Model Diagnostics in Multilevel Modeling

- In OLS regression, the explained proportion of variance is captured by R-squared
- Calculating R-squared for each level is not intuitive to interpret
- So multilevel models can use the following diagnostics:
  - Estimated Variance Parameters
  - log pseduo-liklihood

How to use Multilevel Models

How is Multilevel different than Fixed Effects, dummy variables for each of the groups?

- Dummy variables introduced to absorb contextual differences are limited
  - Acknowledge group differences but treat it is a nuisance
  - cannot help us understand causal heterogeneity between groups
  - Do not exploit the theoretical opportunities of multi-level research propositions

How to use Multilevel Models

When building your multi-level model, you will need to tailor it to:

- type of response variable
- data structure
- variance structure

How to use Multilevel Models

Multi-level Models can be fitted for a variety of response variables:

- continuous
  - e.g. student test scores
- Binary
  - e.g. unemployed/employed
- nominal categorical
  - e.g. vote for party A, B, or C
- ordinal categorical
  - e.g. attitudinal scale (strongly disagree, disagree…)
- Counts (Poisson)
  - e.g. mortality rate
- Duration or Survival
  - e.g. duration of marriage or unemployment

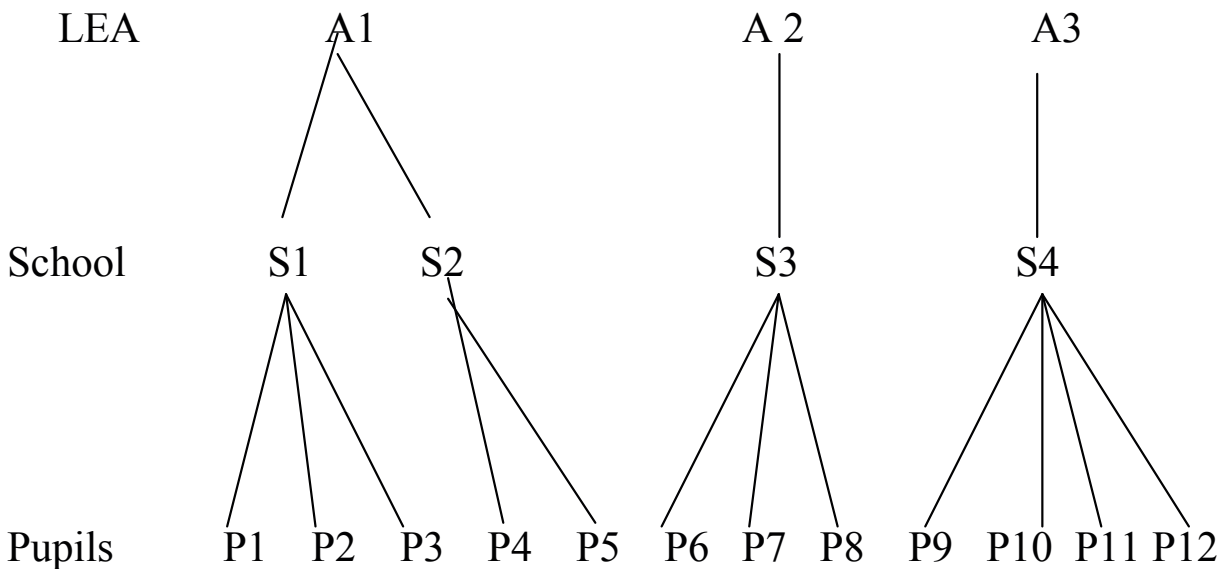
How to use Multilevel Models

Multi-level Models can be fitted for a variety of data structure:

- multivariate
- three-levels
- longitudinal
- small groups
- cross/multiple classification

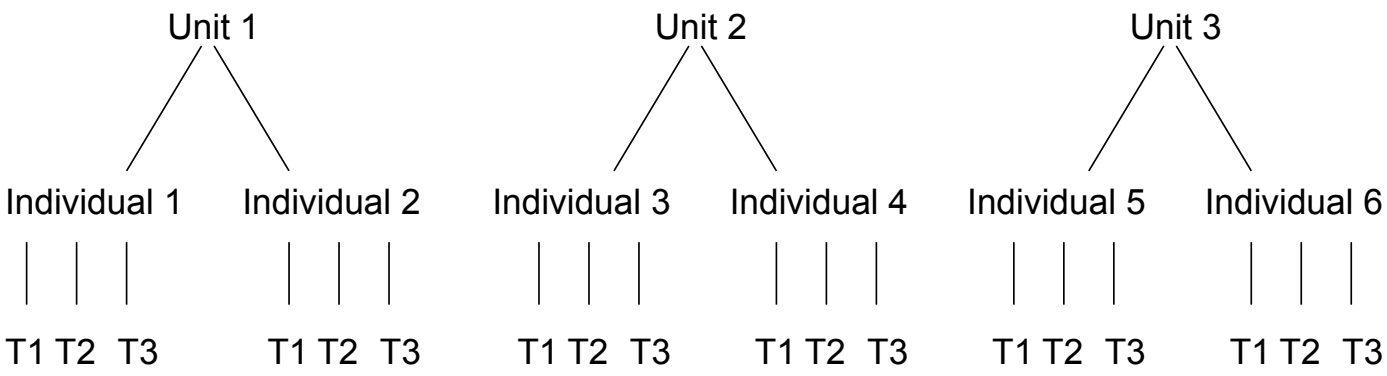
How to use Multilevel Models

data structure: three levels



How to use Multilevel Models

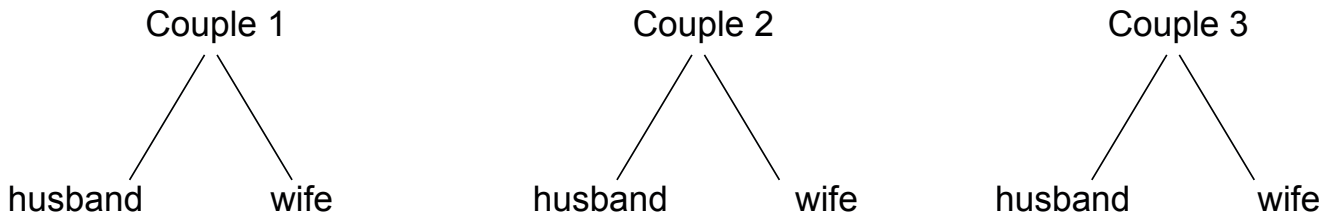
data structure: longitudinal



- all longitudinal analysis is a form of multilevel analysis
- time as a level nested within individuals

How to use Multilevel Models

data structure: small groups



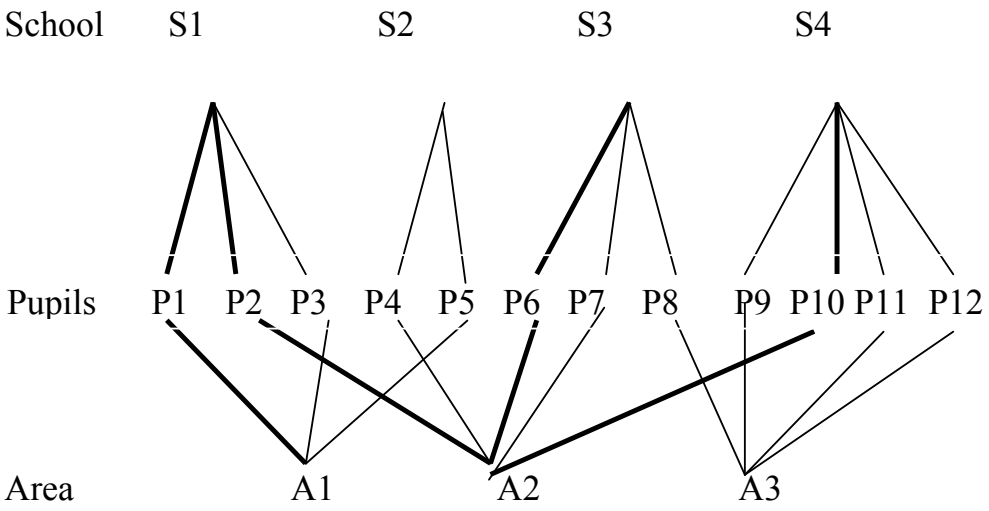
- Small groups often have high interclass correlation
- Some individuals small groups have high degree of homogeneity within the group (e.g. twins) while others can have high degrees of heterogeneity (e.g. marriages)
- Not all small groups are alike
  - Group effects can vary considerably across groups

How to use Multilevel Models

data structure: cross classified

Reasons for cross-classification analysis

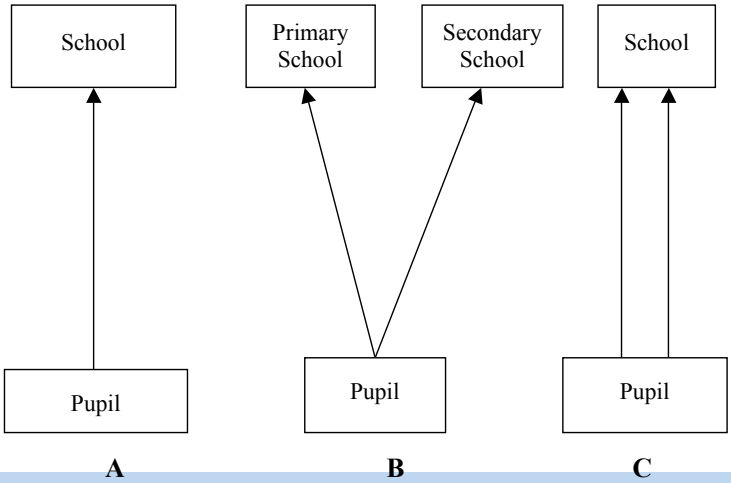
- individuals who belong to a sub-unit, may not all belong to same larger unit
- e.g. students, schools, and neighborhoods



How to use Multilevel Models

data structure: multiple classification

- individuals may not belong to more than one unit
- more intuitive to think about as classifications rather than levels
- e.g. students who have spent time at more than one school, employees for more than one company, individuals who change households, or move to another neighborhood



How to use Multilevel Models

Rules of Thumb

- Multilevel Proposition
- Number of Observations
- Variance
- Degrees of Freedom

How to use Multilevel Models

Emerging Multilevel Modeling:

-Structural Equations Modeling (SEM) or latent variable analysis

-factor analysis

-spatial data

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When to use Multilevel Models

Why multi-level modeling?

- necessity given multiple stage sampling design and nested structure of research production
- interest: Finding a multi-level research proposition
  - Decomposing the determinants of research performance across the levels
    - E.g. does higher funding at the group level improve individual publication records?
  - exploring time dynamics (e.g. career changes)

When to use Multilevel Models

In sum, can multi-level be an asset to your research?

This depends on…

- research proposition
  - theoretical justification
- structure of data
  - number of groups
  - variance across groups and individuals
- If interested, training is recommended for
  - model interpretation
  - Post-estimation tests

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Where to find out about Multilevel Modeling

Further references

Training

- Essex Course on MLM
- Online Tutorials

Software

- special multilevel: HLM or MLWin
- general: R, STATA, or SPSS

Introductory Books:

- Snijders and Bosker (2009) *An Introduction to Basic and Advanced Multilevel Modeling*
- Bickel (2007) *Multilevel Analysis for Applied Research: It's Just Regression!*