

Multi-level Research

I should venture to assert that the most pervasive fallacy of philosophic thinking goes back to neglect of context.
John Dewey, 1931

The Importance of Context

- › Early childhood development is strongly influenced by a whole host of environmental conditions: diet, amount of stimulation in the environment, presence of environmental pollutants, quality of relationship with mother, and so on.
- › The probability of teenagers engaging in risky behavior is related to being involved in structured activities with adult involvement.
- › A child's educational achievement is strongly affected by classroom, school, and school system characteristics.
- › **What does each example share in common?**

What is Multi-level Research?

- › Also known as mixed effects, random effects, Hierarchical linear models
- › Common in Education and Organizational Research
- › Nested data
 - › Hierarchically structured
- › Characteristics or processes occurring at a higher level of analysis are influencing characteristics or processes at a lower level.
- › Constructs are defined at different levels, and the hypothesized relations between these constructs operate across different levels.

Positivist Tradition

- › Emphasis on control over experimental and observational conditions
- › and
- › Reliance on control and comparison groups, and the use of modeling techniques that statistically “remove” or control for the effects of covariates
- › Combine to provide a lot of precision over inferences
- › But severely restrict the ability to measure or evaluate extra-individual, contextual effects.

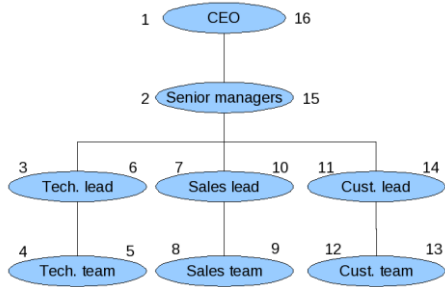
Positivism

- › Most effective at describing sciences that deal predominantly with closed systems
- › With open systems, by definition, it is impossible to control, restrict, or remove the effects of outside contextual influences.
- › Thus, it becomes important to be able to adequately measure and analyze those effects, using appropriate multilevel methods.

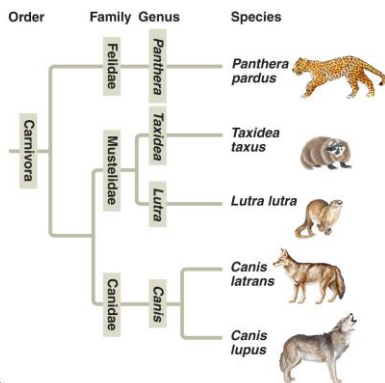
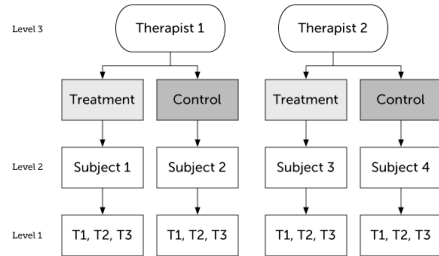
Why Multi-level analysis?

- › Data conceptualization and analyses map on to actual structure of data
- › Avoid conceptual fallacies due to misspecification of level of analysis
 - Better account for lack of independence of data points
 - Violation of independence assumption leads to wrong sample sizes, wrong SEs, misestimated precision and inaccuracy of inferences
- › Risk factors for CVD usually analyzed as individual variables (stress, smoking, diet...)
- › But
- › **Is lack of exercise an individual issue of personal choice, or is it an ecological issue of lack of access to opportunities for physical activity in the immediate neighborhood?**

Nested Data



Nested Data



Example

- ▶ Students
- ▶ Classes
- ▶ Schools

- ▶ Employees
- ▶ Work Groups/Teams
 - Employee job satisfaction – affected by employee personality (employee level), team size, average tenure (team level)
 - Job satisfaction may affect outcomes at various levels (intent to quit, team performance)
 - Variables at different levels may interact

Terms

- › Global variables
 - Measured at their natural level
- › Aggregation
 - Move upwards to higher level
- › Analytical Variables
 - Aggregated from variables at lower levels
- › Disaggregation
 - Move downwards to lower level
- › Contextual Variables
 - Disaggregated from variables at the higher levels

Compositional Effects

- › When inter-group (or inter-context) differences in an outcome (for example, disease rates) are attributable to differences in group composition (that is, in the characteristics of the individuals of which the groups are comprised) they are said to result from compositional effects

Contextual Effects

- › when group differences are attributable to the effects of GROUP LEVEL VARIABLES or properties
- › the effects of variables defined at a higher level (usually at the group level) on outcomes defined at a lower level (usually at the individual level) after controlling for relevant individual level (lower level) confounders.
- › most often used to refer to the effect of a DERIVED GROUP LEVEL VARIABLE (for example, mean neighbourhood income) on an individual level outcome (such as blood pressure) after controlling for its individual level namesake (for example, individual level income)

Fallacies of the Wrong Level

- › Ecological Fallacy
 - Making substantive conclusions at **lower level** from aggregated data analyzed at **higher level**
 - Ecological correlations – correlations made at aggregate level

Ecological Fallacy

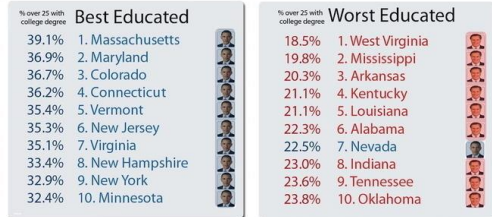
The Robinson effect

- ▶ A 1950 paper by William S. Robinson computed the illiteracy rate and the proportion of the population born outside the US for each of the 48 states + District of Columbia in the US as of the 1930 census. He showed that these two figures were associated with a negative correlation of -0.53
- ▶ in other words, the greater the proportion of immigrants in a state, the lower its average illiteracy. However, when individuals are considered, the correlation was $+0.12$
- ▶ immigrants were on average more illiterate than native citizens.
- ▶ Robinson showed that the negative correlation at the level of state populations was because immigrants tended to settle in states where the native population was more literate.

What can we conclude?

Top 10 Best (and Worst) Educated States, and How They Voted

ranked by percentage of residents 25 years of age or older with college degree or more



Research Statistics provided by factbusiness.com, based on education data from the U.S. Census Bureau's American Community Survey 2017. We identified the U.S. states with the largest and smallest percentage of residents 25 or older with a college degree or more. <https://www.factbusiness.com/research/education/2017/10/best-and-worst-educated-states/>

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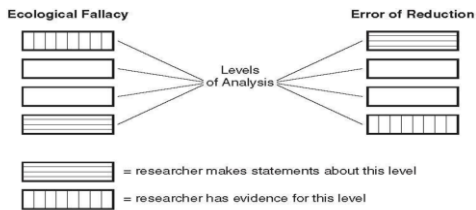
Atomistic/Individualistic Fallacy

- ▶ Making substantive conclusions at **higher level** from aggregated data analyzed at **lower level**
- ▶ Disaggregate class size and class mean exam scores to individual student level
- ▶ Individual level correlation between two disaggregated variables will be much larger than the corresponding higher level correlation
 - For example, it might be true that there is no correlation between infant mortality and family income at the city level, while still being true that there is a strong relationship between infant mortality and family income at the individual level.
 - All aggregate statistics are subject to compositional effects, so that what matters is not only the individual-level relationship between income and infant mortality, but also the proportions of low, middle, and high income individuals in each city.

Atomistic/Individualistic Fallacy

- ▶ For example, a study of individuals may find that increasing individual level income is associated with decreasing coronary heart disease mortality. If it is inferred from these data that at the country level, increasing per capita income is associated with decreasing coronary heart disease mortality, the researcher may be committing the atomistic fallacy (because across countries, increasing per capita income may actually be associated with *increasing* coronary heart disease mortality)

Fallacies



Psychologicistic Fallacy

- ▶ An inferential fallacy that may arise from the failure to consider group characteristics in drawing inferences regarding the causes of variability across individuals
 - E.g., assuming that individual level outcomes can be explained exclusively in terms of individual level characteristics.
 - Although the level at which data are collected may fit the conceptual model being investigated (that is, individual level), important facts pertaining to other levels (that is, group level) may have been ignored.
 - E.g., a study based on individuals might find that immigrants are more likely to develop depression than natives. But suppose this is only true for immigrants living in communities where they are a small minority. A researcher ignoring the contextual effect of community composition might attribute the higher overall rate in immigrants to the psychological effects of immigration or to genetic factors, ignoring the importance of community level factors and thus committing the psychologicistic fallacy

Sociologicistic Fallacy

- ▶ An inferential fallacy that may arise from the failure to consider individual level characteristics in drawing inferences regarding the causes of variability across groups.
 - Although the level at which data are collected may fit the conceptual model being investigated (that is, group level), important facts pertaining to other levels (that is, the individual level) may have been ignored.
 - Suppose a researcher finds that communities with higher rates of transient population have higher rates of schizophrenia, and he/she concludes that higher rates of transient population lead to social disorganisation, breakdown of social networks, and increased risk of schizophrenia among all community inhabitants. But suppose that schizophrenia rates are only increased for transient residents (because transient residents tend to have fewer social ties, and individuals with few social ties are at greater risk of developing schizophrenia).
 - I.e., rates of schizophrenia are high for transient residents and low for non-transient residents, regardless of whether they live in communities with a high or a low proportion of transient residents. If this is the case, the researcher would be committing the sociologicistic fallacy in attributing the higher schizophrenia rates to social disorganisation affecting all community members rather than to differences across communities in the percentage of transient residents.

Statistical Challenge

- ▶ One approach has been to disaggregate group-level information to the individual level so that all predictors in a multiple regression model are tied to the individual unit of analysis.
 - All contextual info ends up pooled in individual error term
 - But individuals belonging to shared context have correlated error variance
 - Ignoring context implies that regression coefficients apply equally to all contexts

ANOVA or ANCOVA approach

- › In the case where there are many groups, these models will have many more parameters, resulting in greatly reduced power and parsimony.
- › Second, these group parameters are often treated as fixed effects, which ignores the random variability associated with group-level characteristics



Violation of Statistical Assumptions

- › Suppose data set of 50 classes, total $N = 2000$
- › If we disaggregate class size to student level and run typical regression at student level
- › Class size is now..... contextual variable
 - True sample size for variable class size is 50
 - But sample size has now been inflated to 2000
 - 2000 values on class size treated as independent
- Problems?



Violation of Statistical Assumptions

- › Large sample size increases what?
 - Type I error
- › Artificial reduction of standard errors – why?
 - SE decreases as sample size increases
- › Results in:
 - Overestimation of precision of parameters



Violation of Statistical Assumptions

- › Predict exam scores from class size
- › Aggregate exam score data to class level
- › Class mean exam scores are now an analytic variable
- › Regress mean exam scores on class size
- › Problems?



Violation of Statistical Assumptions

- › Information on lower levels (e.g., different values of intelligence in each class) is lost
- › Sample size reduced
- › Leads to?
 - › Increased standard errors
 - › Reduced statistical power which = ?
 - › Higher probability of committing Type II error



How?

- › Conceptualization should drive statistical application!
 - › Don't use multi-level analyses just b/c you know how!
 - › Specify functional relationships between constructs at different levels



Typology of Composition Models

- › Provides organizing framework for existing focal constructs
- › Provides conceptual framework for developing and validating new focal constructs
- › Enhances confidence that researchers are referring to same construct when it is explicated according to same form of composition



Analysis

- › Multilevel latent variable models
- › Multilevel regression
 - › Traditional regression models with additional variance terms to represent variables specifically associated with hierarchical nature of multilevel data



Multilevel regression

- › Lower level observations within a group are typically not independent b/c they share some similar characteristics or are exposed to same effects by virtue of being in same group
- › So, errors from observations are correlated with group membership
- › Independence assumption is violated



Multilevel regression

- › Line of best fit defined by regression equation no longer represents sources of variance in y adequately
- › Source of variance from group membership not represented
- › Source of variance from between-group differences in x - y relationship is not represented
 - Regular regression specifies only one x - y relationship



Multilevel data set example

- › J = Group membership (class)
- › I = lower level (students)
- › y = math performance
- › X = gender of student (lower level)
 - = teacher experience (higher level)
 - Do classes differ in mean math performance (different intercepts)
 - And
 - Does gender predict math performance differently across classes? (different slopes)
 - **Can we use teacher experience to predict class differences in the gender-math performance relationship?**



Multilevel regression

- › Also called random coefficient models
- › Allow intercepts and slopes to vary randomly across groups
- › Introduce teacher experience at higher level to predict or explain class differences in mean math performance (variance in intercepts) and the class differences in gender-math performance relationship (variance in slopes)



Multilevel regression

- › Moderator relationship
 - Teacher experience moderates relationship between gender and math performance
 - E.g., gender effect on math performance larger in classes with more (positive regression coefficient) or less teacher experience (negative regression coefficient)
 - Fixed (not random) coefficients – not assumed to vary across groups (classes)



Fixed Versus Random Effects

- › Fixed
 - Regression coefficients (intercepts or covariate effects) that are not allowed to vary randomly across higher level units
 - One option is to include a dummy variable for each classroom. In this case the classroom coefficients are modelled as fixed
- › Random
 - are allowed to vary randomly across higher level units
 - Another option is to assume that the classes in the sample are a random sample of a larger population of classes (school) and that the coefficients for the “classroom effect” vary randomly around an overall mean



Multilevel regression

- › Cross levels effect – effect of higher order variables (teacher experience) on lower level variable (math performance)
- › Cross levels interaction effect – interaction of lower-level variable (gender) and higher-level variable (teacher experience) on a lower-level variable (math performance)



Multilevel latent variable models

- › Do not assume perfect measurement of constructs
- › Take measurement error into account when estimating parameters
- › Can specify all criterion and predictor variables and their relationships in a single model
- › Can specify direct and indirect effects



Other types

- › One-to-many repeated measures
 - Performance appraisal
 - Many reports nested within supervisors
- › Longitudinal
 - Multiple measures over time nested within individuals
 - Models intraindividual change over time
 - E.g., Daily measures of stress and SE
 - Individual traits predict response to particular events



Potential Pitfalls

- › Allowing techniques to drive research
- › Failure to use theory to guide formulation and application of composition models
- › Multimodality in distribution of scores within a group indicates subgroups may exist within the group with low individual differences in each subgroup
 - Graph group distribution
 - Match modality to grouping boundaries



Potential Pitfalls

- › Failure to attend to number of higher-level units
 - Power of tests of significance of higher-level and cross-level interaction effects depends on # of higher level units
 - If groups < 5, SEs for fixed parameters are biased downward

