## Chapter 1

A central function of multilevel modeling is to separate within-group individual effects from between-group aggregate effects.

**Within-Group Effects** = unexplained variance / residual variance component in MLM after controlling for the effects of the grouping variable

**Multilevel models** adjust estimates of the intercept (mean) of one or more dependent variables at level 1, and/or the slope of one or more of the level 1 predictors based on grouping (clustered) variables at level 2.

1. **Fixed Effects** – Similar interpretation as OLS regression parameters (e.g., intercept, slope)
2. **Random Effects** – The variance of the above parameters (fixed effects) across the higher-level groups/clusters

Multilevel Models use **Maximum Likelihood** instead of Least Squares

**Five Types of Multilevel Data**

1. Hierarchical Data
2. Repeated measures Data
3. Random effects Data
4. Cross-classified Data
5. Multiple outcome Data

**Six Types of Multilevel Models**

1. Null Model (Unconditional Random Intercept Model)
2. Random Intercept Model
3. Random Coefficient Model
4. Random Intercept Regression Model
5. Random Intercept ANCOVA Model
6. Random Coefficient ANCOVA Model

Questions

1. What’s the difference between MLM and OLS Assumptions?

* Independence of Error

1. What is one of the two mathematically equivalent tests which indicate whether a multilevel model is needed?

* Null / Baseline Model
  + Random Effect (Significant or not) of the grouping variable
  + ICC (>0.05)

1. A multilevel model can be done with non-linear relationships

* True

1. A multilevel model can have more than 2 levels

* True

## Chapter 2

**Assumptions of Multilevel Modeling**

* Sample Size (It depends)
  + Research Purpose, Statistical Power, Number of Parameters
  + In general, ML requires **large** sample size
* Regression Assumptions
  + Linearity (for Linear MLM)
  + No extreme outliers
  + No multicollinearity
  + Residuals OK
    - Normally distributed
    - Linearity with DV
    - Homogeneity of Variance
* Other relevant issues and Convergence problems
* Covariance Structure Assumptions
  + Variance Component (VC): Random effects are independent (Covariance = 0)
  + Diagonal (DIAG): for repeated measures models
  + Unstructured (UN): All variance & covariance are estimated

Questions

1. Not taking into account the clustering of multilevel data can drastically inflate which type of error? Why?
   1. Type I error (False Positive)
   2. Makes the standard error smaller
2. Multicollinearity inflates the likelihood of which type of error?

* Type II error (False Negative)

1. What are some common reasons for convergence issues in MLM?
   1. Random effects approaching 0
   2. Correlation between random effects approaching 1
   3. Small sample sizes
2. Grand Mean centering is when the overall mean is subtracted from each value
3. What is the primary reason centering is generally recommended in multilevel modeling?

* Centered variables are easier to interpret

1. What is the independence of error assumption violated in MLM?

* Residuals at level 1 are not independent of the grouping variable at level 2

1. In multilevel modeling, Level 2 sample size is more important (True)

## Chapter 3

**The Null Model** is used to see

1. Degree of clustering (if MLM is indeed needed)
   1. If the grouping variable at level 2 (or higher) significantly affects the intercept (mean) of the dependent variable (DV) at level 1.
   2. While finding a not a significance rules out the need for a random intercept model, it doesn’t rule out the need for a random slope model
2. A baseline model for comparison

**ICC** means the proportion of variance in DV accounted for by the random intercept

-2LL = deviance; No cutoff; Heavily influenced by sample size and model complexity

**Likelihood Ratio Tests (LRT)**

* Models must be nested
* Use ML (instead of REML) if different fixed effects
* Sample sizes of models should be the same

**AIC / BIC** is used when comparing non-nested models

Questions

1. If the ICC test is significant, then ANOVA will also be significant. Yet significant ANOVA results do not necessarily indicate the ICC test will be significant.

* True

1. When comparing two models with very different sample sizes, the result of the likelihood ratio may be misleading.

* True

1. Which of the following is a common use of the likelihood ratio test?

* The comparison of the null model to a nested model with one variable added to determine the importance of the specific variable in the model.

## Chapter 4

Why use Multilevel Modeling?

* Uses REML / ML rather than least squares estimate
* No need to dummy-code (can have dozens or hundreds of clusters)
* Better handle unbalanced groups

1. **ML** is good

* For comparing nested models
* Models with different parameterizations (e.g., raw vs transformed measures)
* Models with different fixed effects

1. **REML** is good in some situations

* Less influenced by outliers
* Better dealing with high correlations in the model
* Smaller sample sizes

When **NOT** to use

|  |  |
| --- | --- |
| Maximum Likelihood (ML) | Restricted Maximum Likelihood (REML) |
| Small Sample Size | Comparing nested Model |
| DV has sever non-normality | Comparing nested Model with different parametrizations |
|  | Comparing nested Model with different Fixed Effects |

Other Estimation Methods

1. Bayesian Estimation
   1. Monte Carlo Markov Chain (MCMC)
2. Generalized Least Squares (GLS)
3. Bootstrap methods
   1. Non-normal data
   2. Smaller sample size
4. Asymptotically distribution free (ADF)
5. Weighted Least Squares (WLS)

**Robust vs. Cluster-Robust Standard Errors**

Robust SEs adjust estimates for violations of assumptions (e.g., non-normality, outliers, heteroskedasticity) – Huber-White SEs

Questions

1. The \_\_\_\_\_\_ portion of multilevel output for a multilevel model includes both between-group and residual effects.

* Random effects

## Chapter 5

**-2LL** = Model deviance/Model Chi-square/Likelihood Ratio

**LRT** = Likelihood Ratio Tests

* Compare Nested Model
* Prefers ML estimation (rather than REML)

Information Criterion Measures – AIC & BIC

* Compare non-nested models
* Measures of model fit that modify model deviance with some penalty term

**AIC** – Akaike Information Criterion

* AIC prioritizes good prediction over true model
* Selects more complex model as n becomes large
* Use when Smaller Sample

Small Sample = Number of estimated param is larger than 30% of the sample size

OR sample size is less than the square of the number of parameters

**BIC** – Bayes Information Criterion

* BIC is stricter and aims to find the true model
* Selects simpler model
* Use when Larger Sample (Level 2)

Effect Size Measures

**PRV** = Proportional Reduction in Variance

* Estimates change in variance explained in DV when predictors are added to model.
* Covariance Structure 🡪 VC
* Estimation Method 🡪 ML

**𝐵𝐺−𝑃𝑅𝑉** = (𝑉𝑎𝑟𝐿𝑒𝑣𝑒𝑙𝑁𝑢𝑙𝑙−𝑉𝑎𝑟𝐿𝑒𝑣𝑒𝑙𝐹𝑢𝑙𝑙) / 𝑉𝑎𝑟𝐿𝑒𝑣𝑒𝑙𝑁𝑢𝑙𝑙

**𝑊𝐺−𝑃𝑅𝑉** = (𝑅𝑒𝑠𝑖𝑑𝑁𝑢𝑙𝑙−𝑅𝑒𝑠𝑖𝑑𝐹𝑢𝑙𝑙) / 𝑅𝑒𝑠𝑖𝑑𝑁𝑢𝑙𝑙

**R2 & Pseudo R2 estimates**

Percentage of variance explained for a full model with level-1 fixed effects included

Questions

1. Which of the following is NOT one of the reasons why R2 is not used with multilevel modeling

* Slopes of fixed effects in multilevel modeling do not have the same type of interpretation as in single-level OLS regression.

1. When determining which model to use for a particular dataset, the AIC model may be viewed as the \_\_\_\_\_\_ model and the BIC model as the \_\_\_\_\_\_ model

* Maximum, minimum

1. All statistical packages use the same formula for calculating BIC

* False

1. What significant ICC indicates about the need for MLM?

* Need for a multilevel modeling as the grouping variable has a significant effect

1. Model chi-square penalizes for lack of model parsimony

* False

1. Within-group PRV us used to determine whether effects should be added at level \_1\_\_ . In constrast, between group PRV is used to determine whether effects should be added at level\_\_2\_\_.
2. For the random intercept model – there is no adjustment for the slope.
3. Random intercept is the adjustment of what \_\_\_?

* the DV; adjusting to see on the average for the DV, take into account.

1. It is not possible to partition the variance and compute PRV measures for exchangeable or unstructured models because of which of the following.

* Random effects are correlated

1. The residual variance component may be influenced by effects at which level

* Both level 1 and 2 (higher group effects that impact the individual scores as well)

## Chapter 6

**Random Slopes Model**: A multilevel regression model with at least one slope coefficient allowed to vary across groups/cluster

* The fixed effect slope can be seen as the average (mean) slope across the entire sample
* The random effect slope is the variance of this effect across the groups/clusters

Questions

1. A random coefficient model has additional effects on top of the random intercept model. What are those additional effects?

* The slope, or B coefficient, **at least one fixed** effect at a lower level by the variation associated with a higher-level grouping variable

1. When comparing a random coefficient model to its corresponding random intercept model, if the RC model is found to have a better model fit, improvement is due to modeling one or more slopes by higher-level random effects.

* TRUE

1. Random coefficient models model the rate by which at least one predictor variable affects the values of the \_\_\_\_\_\_\_ variable

* Outcome/DV

1. Level 1 slopes are interpreted the same in OLS & multilevel models

* TRUE

1. In a well-fitting multilevel linear model, residuals need not be normally distributed

* FALSE

1. In a random intercept model, the slope of a level 1 predictor reflects which of the following

* How values of the outcome variable change based on different values of a predictor variable

1. When making a decision about what covariance structure assumption to choose, the selection should ideally be made primarily based on \_\_\_\_\_, and secondarily based on \_\_\_\_\_.

* Theory, Parsimony