UCLA School of Education & Information Studies
Department of Education

EDUC 231D
Advanced Quantitative Methods: Multilevel Analysis
Winter 2025

Multisite and Cluster Randomized Design

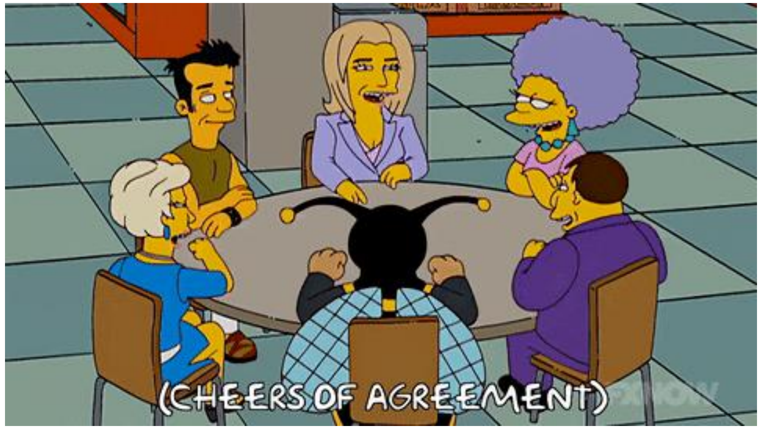
Lecture 10 Presentation Slides

February 11, 2025

Today’s Topics

- Reading discussion
- Sample size requirements for multilevel designs

Reading Discussion (in small groups)



Accelerating early math learning with research-based personalized learning games: A cluster randomized controlled trial

- Describe the general study design?
  - What is the primary outcome measure and at what level/unit was the outcome collected?
  - What is the level/unit of the treatment assignment?
- "Although the intraclass correlation coefficient (ICC) was 0.10, indicating a low variation across classrooms, we used HLM to control for the variability that may exist across schools (ICC = .03)." (Thai et al., 2022, p. 39)
  - What are the authors trying to say with this sentence? Does it make sense to you, and do you think the sentence achieves the intended purpose? Why or why not?

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- Define the following terms in the impact model on page 39:
  - π_{0jk}:
  - π_{1jk}:
  - β_{00k}:
  - β_{01k}:

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- Ignoring level 3 (school level), write-out a 2-level version of the model that has the following features:
  - *PreMath* is centered at level 1 so that π_{0j} represents the mean outcome score for students in class *j*
  - A class-mean version of *PreMath* is included at level 2 to adjust for the between-class relationship between pre- and post-test scores
  - There's a cross-level interaction to test whether the treatment effect differs based on a student's *PreMath* score

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- "… students who used *My Math Academy* in fall 2017 outperformed their control group peers on selected *TEMA-3* items by 5.71% at posttest (effect size = .23)." (Thai et al., 2022, p. 44)
    - Something in this sentence isn't stated correctly. What is it?

- What do you think are the main strengths of the study? The main limitations?

- If you were to conduct a new study of *My Math Academy* (or a similar intervention), in what ways would you change the study design? Why?

Sample Size Requirements for Multilevel Designs

Statistical Power and the Minimum Detectible Effect Size (MDES)

- When planning a randomized study, it is often helpful (and sometimes required) to get a sense of how large of a sample size you need to detect a meaningful effect

- Requires a "power analysis" that is (usually) based on a null hypothesis test of the average treatment effect

Commonly set at 0.05

	Probability to reject H_0	Probability to not reject H_0
If H_0 is true	α	$1-\alpha$
If H_1 is true	$1-\beta$ (power)	β

Commonly set at 0.80

Statistical Power and the Minimum Detectible Effect Size (MDES)

- Minimum detectible effect size (MDES) = the smallest effect (in standard deviation units) for which you can reject the null hypothesis
- Relationship between MDES and sample size for an individual random assignment design:

$$MDES = M_{(\alpha,\beta,df)} \sqrt{\frac{1 - R^2}{p(1-p)N}}$$

Proportion of variance explained by covariates

Total sample size

Hypothesis test multiplier given α, β, and degrees of freedom
M approximately 2.81 for a traditional two-tailed t-test with α = 0.05 and β = 0.20

Proportion of units in treatment group

Statistical Power and the Minimum Detectible Effect Size (MDES)

- For independent random assignment design, MDES depends on:
  - N : total sample size
  - p : proportion of units assigned to treatment (50/50 provides most power)
  - R^2 : proportion of variance explained by covariates

$$MDES = M_{(\alpha,\beta,df)}\sqrt{\frac{1-R^2}{p(1-p)N}}$$

Statistical Power and the Minimum Detectible Effect Size (MDES)

- For multisite randomized design where there's a site-level random effect for the treatment effect, the MDES formula is a little more complicated:

Proportion of between-site variance

Amount of between-site treatment effect variance

Proportion of between-site treatment effect variance explained by covariates

$$MDES = M_{(\alpha,\beta,df)}\sqrt{\underbrace{\frac{\rho\omega(1-R_{2t}^2)}{J}}_{\text{Level 2 error variance}}+\underbrace{\frac{(1-\rho)(1-R_1^2)}{p(1-p)Jn}}_{\text{Level 1 error variance}}}$$

Statistical Power and the Minimum Detectible Effect Size (MDES)

- For two-level cluster randomized design, the MDES formula is similar:

Proportion of between-site variance

Proportion of between-site variance explained by covariates

$$MDES = M_{(\alpha,\beta,df)}\sqrt{\frac{\rho(1-R_2^2)}{J}+\frac{(1-\rho)(1-R_1^2)}{p(1-p)Jn}}$$

Statistical Power and the Minimum Detectible Effect Size (MDES)

- For two-level cluster randomized design, MDES depends on:
  - *n* : average number of level-1 units per group
  - *J* : total number of groups at level-2
  - *p* : proportion of groups assigned to treatment (50/50 provides most power)
  - ρ : ICC
  - R_1^2 : proportion of level-1 variance explained by covariates
  - R_2^2 : proportion of level-2 variance explained by covariates

$$MDES = M_{(\alpha,\beta,df)}\sqrt{\frac{\rho(1-R_2^2)}{J}+\frac{(1-\rho)(1-R_1^2)}{p(1-p)Jn}}$$

Statistical Power and the Minimum Detectible Effect Size (MDES)

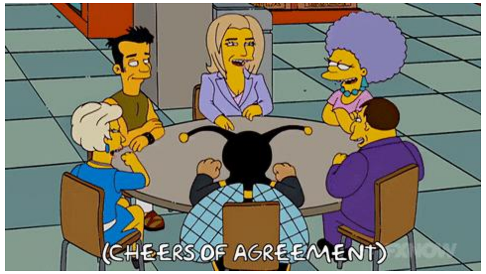
- Website with a lot more about power analysis:

  https://www.causalevaluation.org/power-analysis.html

- Online tool for power analysis:

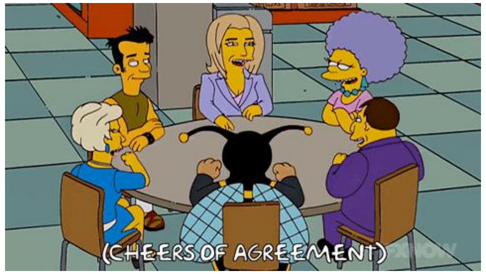
  https://powerupr.shinyapps.io/index/

Small group work



- Use the online PowerUp! tool to explore how the MDES of a multisite randomized design and a cluster randomized design changes based on different values for the following parameters:
  - J :
  - ρ :
  - R_1^2 :
  - R_2^2 :

Small group work



- Use the online PowerUp! tool to determine the number of sites (*J*) needed for a MDES = 0.20 for a 2-level multisite design with random treatment effects given the following conditions:
  - A two-tailed t-test with $\alpha = 0.05; \beta = 0.20$
  - $n = 25; p = 0.50; \rho = 0.20; R_1^2 = 0.30; g_2 = 2; \omega = 0.25; R_{2t}^2 = 0$

- Use the online PowerUp! tool to determine the number of sites (*J*) needed for a MDES = 0.20 for a 2-level cluster design given the following conditions:
  - A two-tailed t-test with $\alpha = 0.05; \beta = 0.20$
  - $n = 25; p = 0.50; \rho = 0.20; R_1^2 = 0.30; g_2 = 2; R_2^2 = 0.50$