Planning Cluster Randomized Trials with Adequate Power

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Outline

- Software Options
- Designs
- Examples
  - 2-level HLM (Traditional and Plus version)
  - 3-level HLM
  - 3-level Randomized Block Design
  - 4-level Randomized Block Design
- Writing up a Power Analysis

Software Options

- Three widely used options
  - *CRT Power* (Borenstein & Hedges)
  - *Optimal Design Plus* (Raudenbush, Spybrook, Congdon, Liu, Martinez, Bloom, & Hill)
  - *PowerUp!* (Maynard & Dong)

- Plus a new option ☺
  - The Generalizer plus Power (Tipton, Spybrook, & Miller)

Software Options

- Key to keep in mind:
  - Much of the work is done before you get to the software ☺
  - All programs yield same results
  - Know the program you are using
    - Different programs require different parameters
    - Document the program and parameters

Software Options

- Use the program that works for you ☺
  - Design options
  - Binary outcomes
  - MDES
  - Tabular output
  - Graphical output
  - Pricing
  - Computers

Designs

- Be specific in naming a design
- Cluster randomized trial does NOT define the design
  - Consider three design elements
    - Number of levels
    - Level of random assignment
    - Level outcome data measured

	Multisite Trial (MST) or Randomized Block Design (RBD)
Number of Levels	2
Level of Random Assignment	1
Level Outcome Data Measured	1
Example of Level Structure	L1: Students L2: Schools

	Multisite Trial (MST) or Randomized Block Design (RBD)	2-level Cluster Randomized Trial (2-level CRT)
Number of Levels	2	2
Level of Random Assignment	1	2
Level Outcome Data Measured	1	1
Example of Level Structure	L1: Students L2: Schools	L1: Students L2: Schools

	Multisite Trial (MST) or Randomized Block Design (RBD)	2-level Cluster Randomized Trial (2-level CRT)	3-level Cluster Randomized Trial (3-level CRT)
Number of Levels	2	2	3
Level of Random Assignment	1	2	3
Level Outcome Data Measured	1	1	1
Example of Level Structure	L1: Students L2: Schools	L1: Students L2: Schools	L1: Students L2: Teachers L3: Schools

	Multisite Trial (MST) or Randomized Block Design (RBD)	2-level Cluster Randomized Trial (2-level CRT)	3-level Cluster Randomized Trial (3-level CRT)	3-level Multisite Cluster Randomized Trial with Treatment at Level 2 (3-level MSCRT or 3-level RBD)
Number of Levels	2	2	3	3
Level of Random Assignment	1	2	3	2
Level Outcome Data Measured	1	1	1	1
Example of Level Structure	L1: Students L2: Schools	L1: Students L2: Schools	L1: Students L2: Teachers L3: Schools	L1: Students L2: Teachers L3: Schools

	Multisite Trial (MST) or Randomized Block Design (RBD)	2-level Cluster Randomized Trial (2-level CRT)	3-level Cluster Randomized Trial (3-level CRT)	3-level Multisite Cluster Randomized Trial with Treatment at Level 2 (3-level MSCRT or 3-level RBD)	4-level Multisite Cluster Randomized Trial with Treatment at Level 3 (4-level MSCRT or 4-level RBD)
Number of Levels	2	2	3	3	4
Level of Random Assignment	1	2	3	2	3
Level Outcome Data Measured	1	1	1	1	1
Example of Level Structure	L1: Students L2: Schools	L1: Students L2: Schools	L1: Students L2: Teachers L3: Schools	L1: Students L2: Teachers L3: Schools	L1: Students L2: Teachers L3: Schools L4: Districts

2-level Cluster Randomized Trial (2-level HLM) Example

Program: A new math curriculum for 3rd graders. The curriculum is implemented at the school level. The researchers plan to randomly assign schools to the treatment or control condition.

Research question: Is the new math curriculum more effective than the traditional one?

Standardized math tests scores used as outcome measure. Based on previous research, 18% percent of the variation lies between schools. Researchers have access to last years test scores and expect the school level covariate explains 60 % of the variability in test scores.

2-level Cluster Randomized Trial (2-level HLM) Example

- Scenario A
  - Researchers expect the new curriculum to boost test scores by 0.25 standard deviations. Assuming 90 students per school, how many schools do they need to detect an effect of 0.25 with power of 0.80?
- Scenario B
  - Researchers have access to a total of 38 schools. What is the MDES?

2-level Cluster Randomized Trial (2-level HLM) Example

- How many levels are in this study?
- What is the unit of randomization?
- What is the unit where outcome data is measured?
- What are good estimates of the intraclass correlation? Percent variance explained by covariate(s)?

2-level Cluster Randomized Trial (2-level HLM) Example

Design Parameters

Probability of Type I Error	(α)
One or Two-tailed Hypothesis Testing	
Effect Size	(δ)
Number of Students (Level 1) per School (Level 2)	(n)
Number of Schools (Level 2)	(J)
Proportion of units randomly assigned to treatment condition	(P)
Proportion of variance in the outcome between schools (Level 2) (ICC_2)	(ρ_2)
Proportion of Level 1 variance explained by covariates	(R_1^2)
Proportion of Level 2 variance explained by covariates	(R_2^2)
Number of covariates at Level 2	(g_2)

3-level Cluster Randomized Trial (3-level HLM) Example

Program: Third grade math curriculum implemented at the school level (group-level intervention). 40 schools are randomized. There are 6 teachers within each school and 25 kids per teacher.

Research question: Is the new math curriculum more effective than the traditional one?

Standardized math tests scores used as outcome measure. Based on previous research. 9% percent of the variation lies between classes. 15% of the variation lies between schools. School level covariate explains 50 percent of the variation in test scores.

3-level Cluster Randomized Trial (3-level HLM) Example

- Scenario A
  - What is the MDES?
- Scenario B
  - What is the power to detect an effect size of 0.20?

3-level Cluster Randomized Trial (3-level HLM) Example

- How many levels are in this study?
- What is the unit of randomization?
- What is the unit where outcome data is measured?
- What are good estimates of the intraclass correlations? Percent variance explained by covariates?

3-level Cluster Randomized Trial (3-level HLM)

Design Parameters

Probability of Type I Error	(α)
One or Two-tailed Hypothesis Testing	
Effect Size	(δ)
Number of Students (Level 1) per Teacher (Level 2)	(n)
Number of Teachers (Level 2) per School (Level 3)	(J)
Number of Schools (Level 3)	(K)
Proportion of units randomly assigned to treatment condition	(P)
Proportion of variance in the outcome between teachers (Level 2) (ICC_2)	(ρ_2)
Proportion of variance in the outcome between schools (Level 3) (ICC_3)	(ρ_3)
Proportion of Level 1 variance explained by covariates	(R_1^2)
Proportion of Level 2 variance explained by covariates	(R_2^2)
Proportion of Level 3 variance explained by covariates	(R_3^2)
Number of covariates at Level 3	(g_3)

3-level Multi-site Cluster Randomized Trial (RBD) Example

- Two types of blocking
  - "Naturally blocked" For example:
    - Randomization at classroom level, with schools as sites
    - Randomization at school level, with cities as sites
  - "Blocking embedded" For example:
    - Blocks of schools are created based on percentage of free/reduced lunch
    - Blocks of communities are created based on SES

3-level Multi-site Cluster Randomized Trial (RBD) Example

Program: The following will be repeated across districts. 4 schools will be randomly assigned to either the new 3rd grade math curriculum or the regular curriculum. 100 students will be tested in each school.

Research question: Is the new math curriculum more effective than the traditional one?

Standardized math tests scores used as outcome measure. Based on previous research, within districts, 12% percent of the variation lies between schools within districts and 8% of the variance lies between districts. A school level covariate explains 48 % of the variability in test scores.

3-level Multi-site Cluster Randomized Trial (RBD) Example

- Scenario A
  - Assuming 6 districts are willing to participate, what is the MDES?
- Scenario B
  - Assuming 16 districts are willing to participate, what is the MDES?

3-level Multi-site Cluster Randomized Trial (RBD) Example

- How many levels are in this study?
- What is the unit of randomization?
- What is the unit where outcome data is measured?
- Given that there is blocking:
  - How are blocks being treated – as fixed or random effects? If random effects, what is the variance of treatment effect across blocks/sites?

3-level Multi-site Cluster Randomized Trial (RBD) (fixed effects case)

Design Parameters

Probability of Type I Error	(α)
One or Two-tailed Hypothesis Testing	
Effect Size	(δ)
Number of Students (Level 1) per School (Level 2)	(n)
Number of Schools (Level 2) per District (Level 3)	(J)
Number of Districts (Level 3)	(K)
Proportion of units randomly assigned to treatment condition	(P)
Proportion of variance in the outcome between schools (Level 2) (ICC_2)	(ρ_2)
Proportion of variance in the outcome between districts (Level 3) (ICC_3)	(ρ_3)
Proportion of Level 1 variance explained by covariates	(R_1^2)
Proportion of Level 2 variance explained by covariates	(R_2^2)
Number of covariates at Level 2	(g_2)

3-level Multi-site Cluster Randomized Trial (RBD) (random effects case)

Design Parameters

Probability of Type I Error	(α)
One or Two-tailed Hypothesis Testing	
Effect Size	(δ)
Number of Students (Level 1) per School (Level 2)	(n)
Number of Schools (Level 2) per District (Level 3)	(J)
Number of Districts (Level 3)	(K)
Proportion of units randomly assigned to treatment condition	(P)
Proportion of variance in the outcome between schools (Level 2) (ICC_2)	(ρ_2)
Proportion of variance in the outcome between districts (Level 3) (ICC_3)	(ρ_3)
Effect size variability as the ratio of the treatment effect variance between districts (Level 3) to the total variance in the outcome.	(esv_3)
Proportion of Level 1 variance explained by covariates	(R_1^2)
Proportion of Level 2 variance explained by covariates	(R_2^2)
Proportion of treatment effect variance among districts (Level 3) explained by the districts (Level 3) covariates	(R_3^2)
Number of covariates at Level 3	(g_3)

Effect Size Variability

TABLE 3
Intervals Around the Main Effect of Treatment of 0.20 for Different Effect Size Variances

Effect size variability	*Lower bound*	*Upper bound*	*Span*
0.01	0.000	0.400	0.40
0.03	−0.146	0.546	0.70
0.05	−0.247	0.647	0.90
0.10	−0.432	0.832	1.06

Note. Bounds based on $0.20 \pm 1.96\sqrt{ESV}$.

Spybrook, J. (2014). Detecting intervention effects across context: An Examination of the Power of Cluster Randomized Trials. *Journal of Experimental Education*, *82(3), 334-357*.

4-level Multi-site Cluster Randomized Trial (RBD) Example

Program: The following will be repeated across 5 districts. 8 elementary schools will be randomly assigned to a new 5th science curriculum or the current curriculum. There are 4 classrooms per school and 25 kids per classroom.

Research question: Is the new curriculum more effective than the traditional one?

Standardized math tests scores used as outcome measure. Based on previous research, 6 % of the variance in the outcome is between classrooms within schools,12% percent is between schools within districts and 8% is between districts. A school level covariate explains 48 % of the variability in test scores.

4-level Multi-site Cluster Randomized Trial (RBD) Example

- Scenario A
  - Assuming science achievement as the outcome, what is the MDES?

4-level Multi-site Cluster Randomized Trial (RBD)

- How many levels are in this study?
- What is the unit of randomization?
- What is the unit where outcome data is measured?
- Given that there is blocking:
  - How are blocks being treated – as fixed or random effects? If random effects, what is the variance of treatment effect across blocks/sites?

4-level Multi-site Cluster Randomized Trial (RBD) (fixed effects case)

Design Parameters

Probability of Type I Error	(α)
One or Two-tailed Hypothesis Testing	
Effect Size	(δ)
Number of Students (Level 1) per Teacher (Level 2)	(n)
Number of Teachers (Level 2) per School (Level 3)	(J)
Number of Schools (Level 3) per District (Level 4)	(K)
Number of Districts (Level 4)	(L)
Proportion of units randomly assigned to treatment condition	(P)
Proportion of variance in the outcome between teachers (Level 2) (ICC_2)	(ρ_2)
Proportion of variance in the outcome between schools (Level 3) (ICC_3)	(ρ_3)
Proportion of variance in the outcome between districts (Level 4) (ICC_4)	(ρ_4)
Proportion of Level 1 variance explained by covariates	(R_1^2)
Proportion of Level 2 variance explained by covariates	(R_2^2)
Proportion of Level 3 variance explained by covariates	(R_3^2)
Number of covariates at Level 3	(g_3)

4-level Multi-site Cluster Randomized Trial (RBD) (random effects case)

Design Parameters

Probability of Type I Error	(α)
One or Two-tailed Hypothesis Testing	
Effect Size	(δ)
Number of Students (Level 1) per Teacher (Level 2)	(n)
Number of Teachers (Level 2) per School (Level 3)	(J)
Number of Schools (Level 3) per District (Level 4)	(K)
Number of Districts (Level 4)	(L)
Proportion of units randomly assigned to treatment condition	(P)
Proportion of variance in the outcome between teachers (Level 2) (ICC_2)	(ρ_2)
Proportion of variance in the outcome between schools (Level 3) (ICC_3)	(ρ_3)
Proportion of variance in the outcome between districts (Level 4) (ICC_4)	(ρ_4)
Effect size variability as the ratio of the treatment effect variance between districts (Level 4) to the total variance in the outcome.	(esv_4)
Proportion of Level 1 variance explained by covariates	(R_1^2)
Proportion of Level 2 variance explained by covariates	(R_2^2)
Proportion of Level 3 variance explained by covariates	(R_3^2)
Proportion of treatment effect variance among districts (Level 4) explained by the districts (Level 4) covariates	(R_4^2)
Number of covariates at Level 4	(g_4)

Writing up a Power Analysis

- Differs depending on the design
- Differs depending on software
- Critical to identify your design and software
- TG Plus Power provides report template