Tools for computationally efficient power and sample size determination for mediation models

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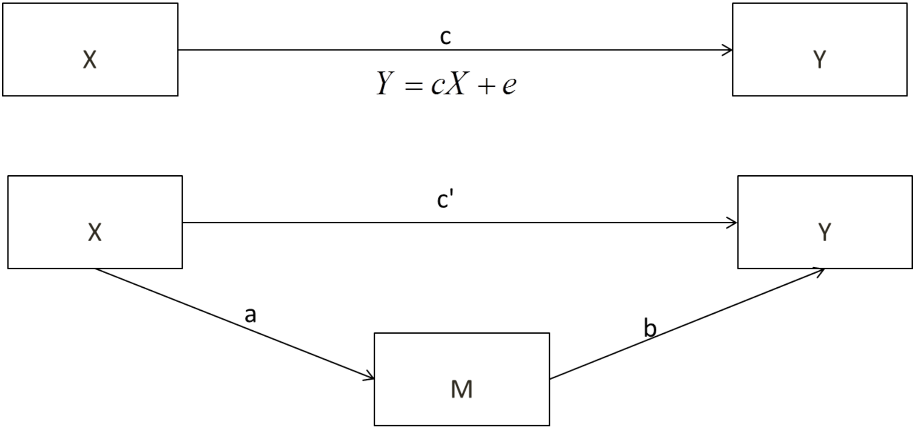
M3 2017

Overview

- Power in Mediation Models
- Monte Carlo Power Analysis
    - Monte Carlo CI for inference
    - Varying N power analysis
    - GUI for computations

Basic Mediation



$$Y = bM + c'X + e$$

$$M = aX + e$$

Testing the indirect effect: Power

- Methods of testing the indirect effect have different power for the same data (e.g. Fritz & MacKinnon, 2007, MacKinnon, Lockwood, & Williams, 2004)
  - Difference in coefficients method has extremely low power (especially when c is small)
  - Distribution of the product, bootstrap CI and Monte Carlo CI have higher power
    - Power for these methods is generally comparable

Testing the indirect effect: Power

- What else affects power to detect an indirect effect?
  - Sample size
  - Effect size
    - Effect size of both the a and b path

Determing power for an indirect effect

- Methods of power analysis should match methods of analysis
- Seperately determining power for a and b paths and picking the smaller value systematically underestimates power
- No analytic method of power analysis for popular methods of testing the indriect effect, e.g., bootstrap CI or Monte Carlo CI
- We need to use a Monte Carlo power analysis

Monte Carlo Power Analysis

- General steps in a Monte Carlo Power Analysis
  1. Specify all population parameters
  2. Create a sample of size N, based on population parameters
  3. Analyze sample data from Step 2 with chosen statistical method(s)
  4. Repeat steps 2 and 3 for each of *r* replications (often $r > 1000$)
  5. The proportion of replications with a significant parameter is an estimate of power (for all parameters not equal to 0)

Monte Carlo Power Analysis

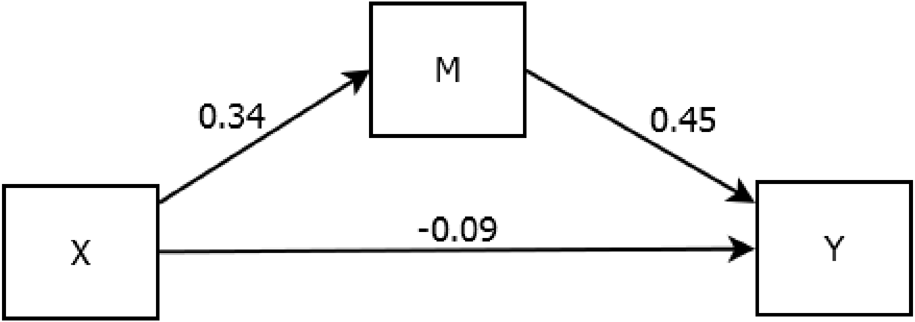
- Best practice approach for assessing power in mediation models (Zhang, 2014)
  - Can utilize any method of testing the indirect effect
- Two main limitations to Monte Carlo Power Analysis for mediation models
  - Limited, user friendly software (e.g. Mplus, bmem, simsem)
  - Very time consuming (especially with bootstrapping!)

Monte Carlo Power Analysis

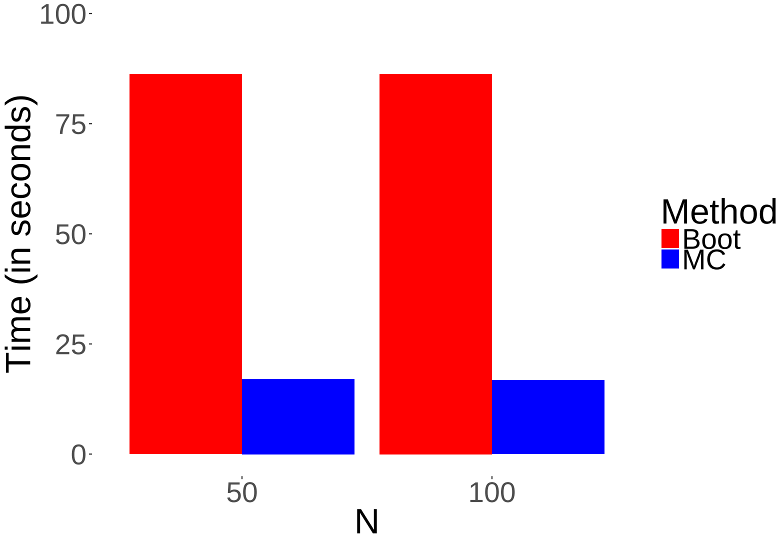
- Overcoming limitations
  - Use Monte Carlo CI to test indirect effects
    - Faster than bootstrapping
    - Estimates of power are similar or slightly higher than bootstrapping (Tofighi & MacKinnon, 2016)
    - Simulation study comparing power analyses. Run 500 power analyses using Monte Carlo CI and Bootstrapped CI for each sample size
    - Sample sizes range from 10 to 200 (in increments of 10)
    - Compare time to completion and estimated power for each method

Monte Carlo Power Analysis

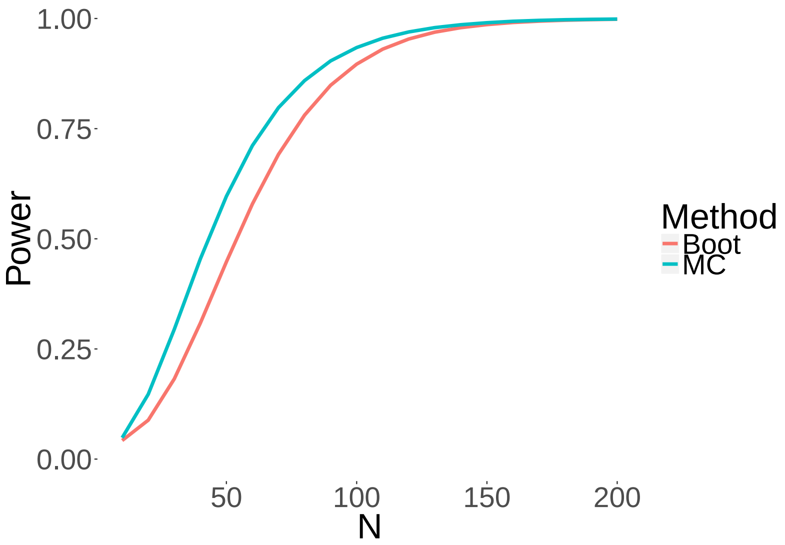
- Example (from Hayes, 2013):



Monte Carlo Power Analysis



Monte Carlo Power Analysis



Monte Carlo Power Analysis

- Overcoming limitations
  - Use Monte Carlo CI to test indirect effects
    - Faster than bootstrapping
    - Estimates of power are extremely similar
  - Use varying N for sample size determination (Schoemann, Miller, Pornprasertmanit, & Wu, 2014)

Monte Carlo Power Analysis: Varying N

- Determine range of samples sizes of interest
- Vary sample size across replications within a single simulation
  - Example: N ranges from 100 to 500 within a simulation with 10 replications at each sample size (4000 total replications)
- Analyze results with logistic regression
  - Regress significance of a parameter on N
  - From this model the predicted probability for a given sample size is the estimate of power.

Monte Carlo Power Analysis: Varying N

- Example (from Hayes, 2013):
  - Run power analysis varying N between 15 and 300
    - ~ 1000 total replications (1144 actual replications)
    - Predicted probability for a given N:

$$p = \frac{e^{-2.211+0.053N}}{1 + e^{-2.211+0.053N}}$$

Monte Carlo Power Analysis: Varying N

- Example (from Hayes, 2013):
    - Target N for power of .80 is 68 with estimated power of 0.801
    - Run power analysis (again) with $N = 68$ and 1000 replications
    - Estimated power is 0.78

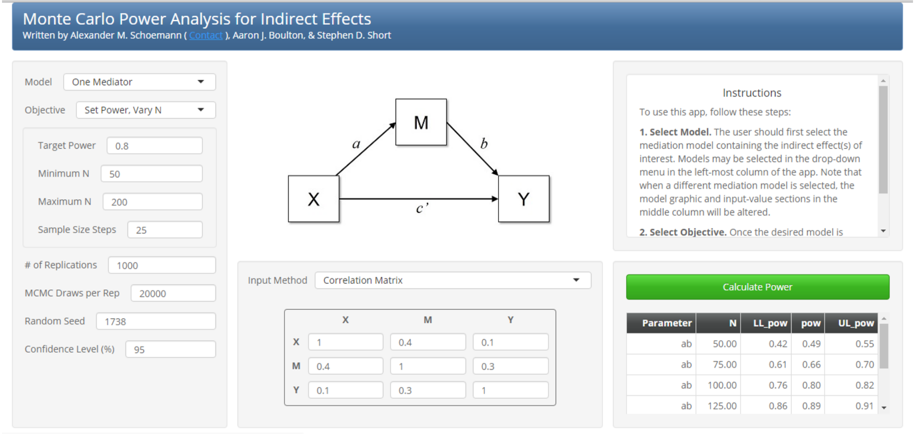
Monte Carlo Power Analysis

- Overcoming limitations
  - Use Monte Carlo CI to test indirect effects
    - Faster than bootstrapping
    - Estimates of power are extremely similar
  - Use varying N for sample size determination
  - Create user friendly software
    - Shiny app for simple mediation models

Power estimation app

- Available from `http://MARlab.org`
  - Further details are in Schoemann, Boulton, & Short (in press)
- Web based or run locally on your computer
  - Requires R is installed on a computer (it helps if RStudio is too)
- Population parameters are entered as correlations
- Multiple mediation models included
  - Simple mediation model and multiple (parallel) mediation models currently available

Power estimation app



Power estimation app

- Demonstration
- Population Values

	X	M	Y
X	1		
M	.340	1	
Y	.064	.417	1
SD	1.43	0.72	1.25

Future directions

- Best practice recommendations for varying N power analysis
  - Number of replications, distribution of N, optimal meta-model, grid search for optimal N
- Extend methods and Shiny app to complex data and mediation models
  - Other methods of entering population values
  - Longitudinal mediation, moderated mediation
  - Missing data, non-normal data, nested data

Thank you!

- Slides and Shiny app from today at: `http://MARlab.org/Supplemental_Materials/`
- email: `schoemanna@ecu.edu`

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