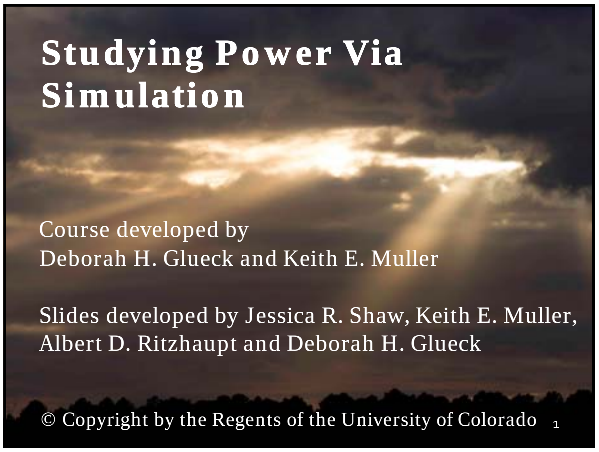

Learning Objectives

Describe how to simulate power.

Describe how long simulation takes.

Learn why simulations can be wrong.

2

We discuss the computational steps behind power simulation

We will not discuss programming or details of how to implement a power simulation.

3

A power simulation is a statistical program developed to estimate power under hypothetical conditions

Power simulations are frequently programmed in SAS or R.

4

A power simulation involves the following steps

1. Set the Type I error rate.
2. Specify the experimental design, data analysis, hypothesis.
3. Specify how many times to repeat the simulated experiment (i.e., 10,000 times, the number of replications).

5

A power simulation involves the following steps

4. Simulate data using an appropriate random number generator.
5. Conduct the hypothesis test.
6. Determine whether to reject the null hypothesis.

Repeat steps 4-6 for each replication.

6

A power simulation runs the following steps a specified number of times

7. Count the number of rejections
8. Divide the number of rejections by the total number of times the experiment was run.

The resulting fraction is the empirical power (simulated power).

7

Empirical power is a proportion

$$\text{Empirical power} = \frac{\text{\# of rejections}}{\text{\# of replications}}$$

8

The number of replications is chosen to limit the error in the empirical power

The margin of error for empirical power is largest when power = 0.50.

The margin of error is half the width of the confidence interval.

9

The margin of error is no more than 0.01 with 10,000 replications

For 95% confidence interval,

$$\text{Margin of error} \approx 1.96\sqrt{\frac{p(1-p)}{\#\text{ of replications}}}$$

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The goal of simulation may be to specify power +/- 0.01

Simulated power is 0.92 when true power is 0.93 is typically acceptable.

Simulated power of 0.80 when true power is 0.90 is unacceptable.

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Simulations are time consuming

Example	Mean GLIMMPSE CPU Time (sec. × 10^{-4})	Mean Simulation CPU Time (sec.)
1	4.1	0.17
2	< 0.1	0.15
3	1.8	0.17
4	< 0.1	0.18
5	1.1	0.32
6	1.9	0.81
7	< 0.1	0.57
8	0.9	15.12
9 MB	< 0.1	0.61
9 MEST	< 0.1	0.61

Kreidler et al., 2013

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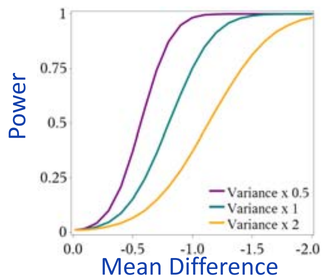
Creating complex power graphs takes much longer than calculating power at a single point



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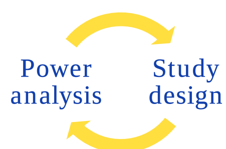
Power analysis is an iterative process

Design changes are made in response to initial power analysis, which requires new power analyses to be conducted.



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The total time required for a power analysis is even longer

Total time = Time to write the simulation

\+ Time to debug the simulation

\+ Time to run the simulation to generate an entire curve

Kreidler et al., 2013

15

Each round of power simulations requires extensive effort to validate

Validation efforts may include code review, writing another simulation to validate the original, and having another person write a simulation to provide a comparison.

Further errors can occur at any step in the validation process, making it difficult to confidently reach a conclusion.

16

Simulations can produce incorrect empirical power

Reasons include

- Mistakes in coding,
- Mistakes in initial assumptions,
- Mistakes in calculations, or
- Mistakes in output.

Kreidler et al., 2013

17

Mathematical calculation of power also requires extensive validation

Strategies include analytic derivation, comparison to simulation, comparison to other calculations, and peer review.

All apply to GLIMMPSE.

18

GLIMMPSE has been validated by comparison to published values and to simulations

MAD for GLIMMPSE vs. Published Values ($\times 10^{-2}$)	MAD for GLIMMPSE vs. Simulation
0.004	0.047
0.003	0.047
0.063	0.032
0.061	0.033
7.300	0.095
7.300	0.094
7.300	0.071
7.300	0.072

Maximum absolute deviation (MAD) is the maximum difference observed over many values.

Kreidler et al., 2013

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REVIEW OF LEARNING OBJECTIVES

What four ways can a simulation be wrong?

Mistakes in coding.
Mistakes in initial assumptions.
Mistakes in calculations.
Mistakes in output.

Kreidler et al., 2013

21

Compared to power calculations, how long do simulations take?

- Simulations usually take longer
- Simulations take the same amount of time.
- Simulations are faster.

Kreidler et al., 2013

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