

**Studying Power Via Simulation**

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**Learning Objectives**

Describe how to simulate power.

Describe how long simulation takes.

Learn why simulations can be wrong.

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**We discuss the computational steps behind power simulation**

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

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

Power simulations are frequently programmed in SAS or R.

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**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).

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**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.

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**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).

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**Empirical power is a proportion**

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

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**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.

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**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 <sup>-4</sup> )	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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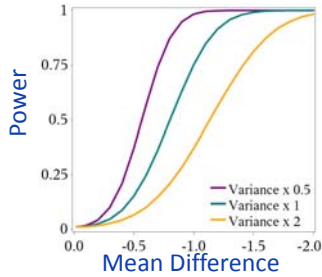
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**Creating complex power graphs takes much longer than calculating power at a single point**



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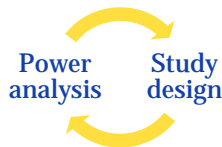
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**Power analysis is an iterative process**

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

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**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.

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**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  
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**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**.

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**GLIMPSE has been validated by comparison to published values and to simulations**

MAD for GLIMPSE vs. Published Values ( $\times 10^{-2}$ )	MAD for GLIMPSE 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 Summary**

- A power simulation is a statistical program developed to estimate power under hypothetical conditions
- The margin of error is no more than 0.01 with 10,000 replications
- Power simulations take time, and each round of power simulations also requires extensive effort to validate

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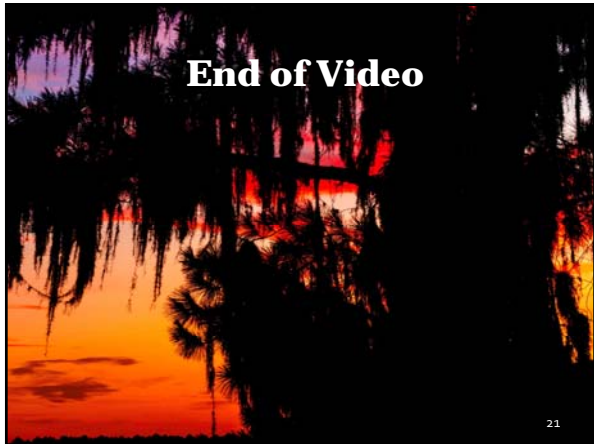
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