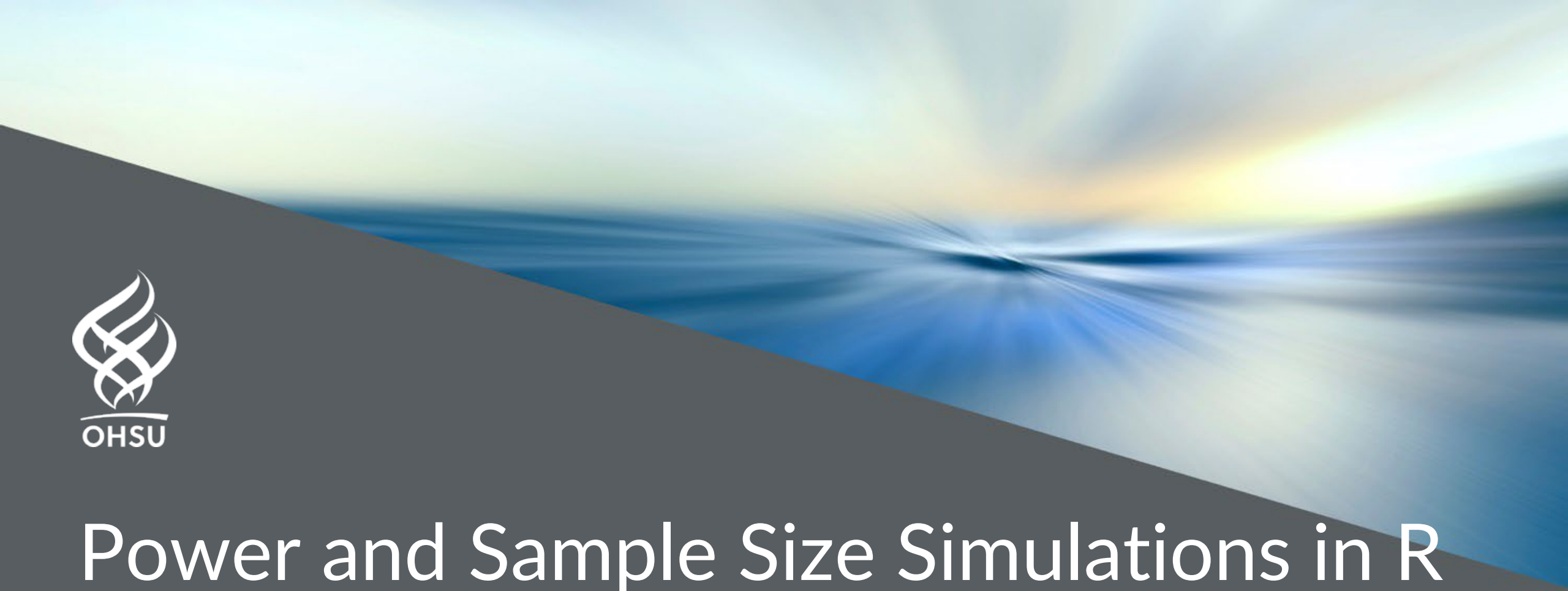


Power and Sample Size Simulations in R

OCTRI Research Forum

DATE: November 21, 2024 PRESENTED BY: ROBIN BAUDIER, MSPH, MFA, STAFF BIOSTATISTICIAN WITH THE BDP

Topics Covered

Very brief overviews of

- Power and Sample Size (PSS) concepts
- PSS simulations
  - When – only when you have to
  - What – Monte Carlo Simulations
  - How – 4 basic steps & inputs

How to perform PSS simulations in R

- Simulating variables
- Using loops
- Looping tests on simulated datasets to calculate power
- 4 Examples of PSS simulations
  - Simple T-test
  - Correlated covariates
  - Repeated measures
  - Survival
- Packages that can make things a little easier

Topics NOT Covered

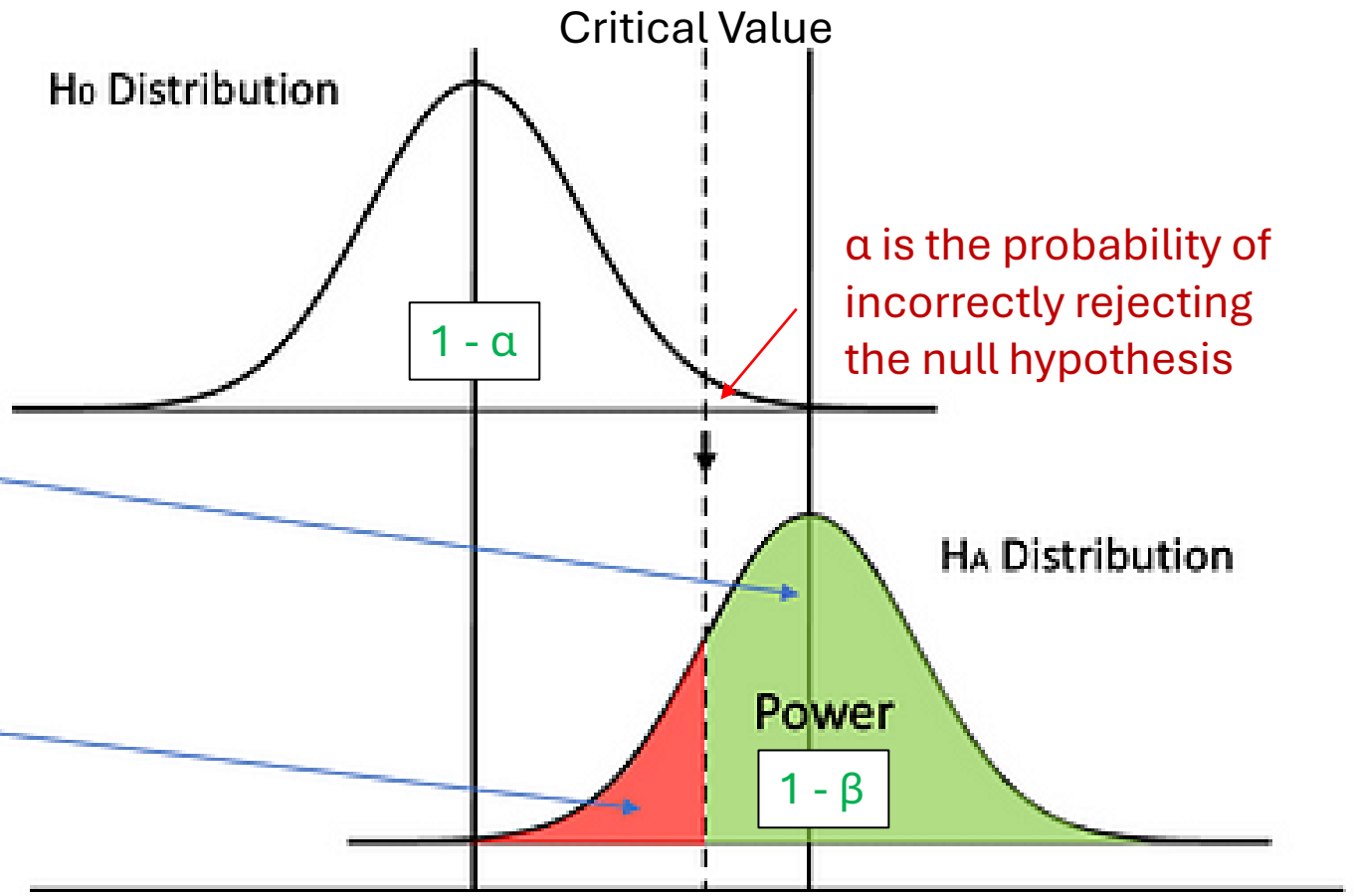
- Basics of R
- Basics of PSS calculations
  - Check out the OCTRI PSS 101 Seminar, co-developed by Meike Niederhausen, PhD and Alicia Johnson, MPH, and presented most recently by Alicia Johnson in July:
    - RECORDING: https://echo360.org/media/03e6d606-6fa4-4861-a1d0-dd00e925a330/public
    - SLIDES: https://drive.google.com/file/d/1bVBj7QpeBY8KwKXsgzp6IMUaKCtCrdVV/view

Power & Sample Size Concepts

A very brief overview

What is power?

	H_0 is True	H_A is True
Reject H_0	Type I Error False Positive α (alpha)	Correct True Positive 1-β (power)
Fail to reject H_0	Correct True Negative 1-α	Type II Error False Nagative β (beta)



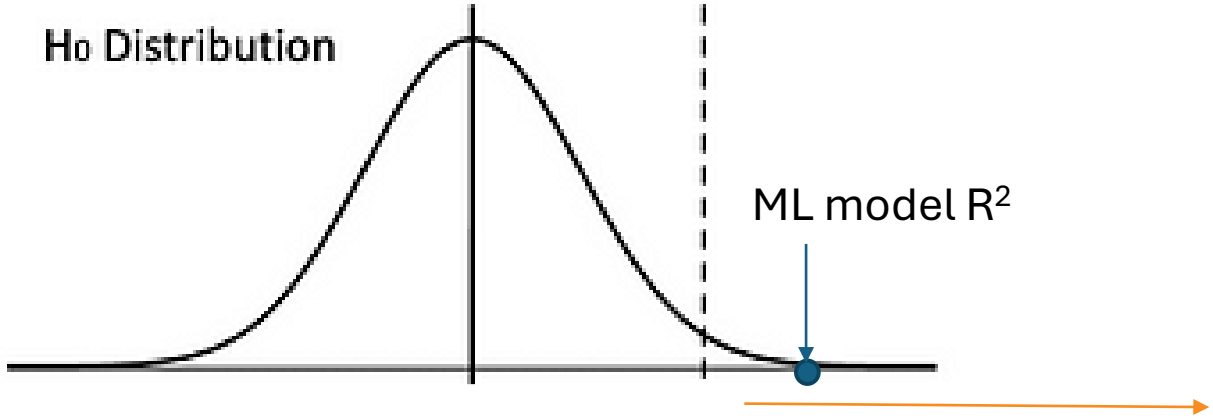
Power is the probability of correctly rejecting the null hypothesis

Image adapted from: https://towardsdatascience.com/5-ways-to-increase-statistical-power-377c00dd0214

Simulating the null hypothesis

	H_0 is True	H_A is True
Reject H_0	Type I Error False Positive α (alpha)	Correct True Positive 1-β (power)
Fail to reject H_0	Correct True Negative 1-α	Type II Error False Nagative β (beta)

H_0: $R^2 = 0$
H_A: $R^2 > 0$



Reject H_0 if proportion of random R^2 less than model R2 **≥95% (for α = 0.05)**

How do you determine if a machine learning (ML) model performs better than chance? You can create a null distribution by randomly permuting the outcome variable on your dataset a large number of times (e.g., 999) and run ML model on each dataset.

1 – (proportion of random R^2 < real data model R^2) = p-value

Image adapted from: https://towardsdatascience.com/5-ways-to-increase-statistical-power-377c00dd0214

Simulating the alternative hypothesis

To calculate power in PSS simulations, you can simulate the H_A distribution a large number of times and assess what proportion of statistical tests performed on simulated data are able to detect the effect of interest

	H_0 is True	H_A is True
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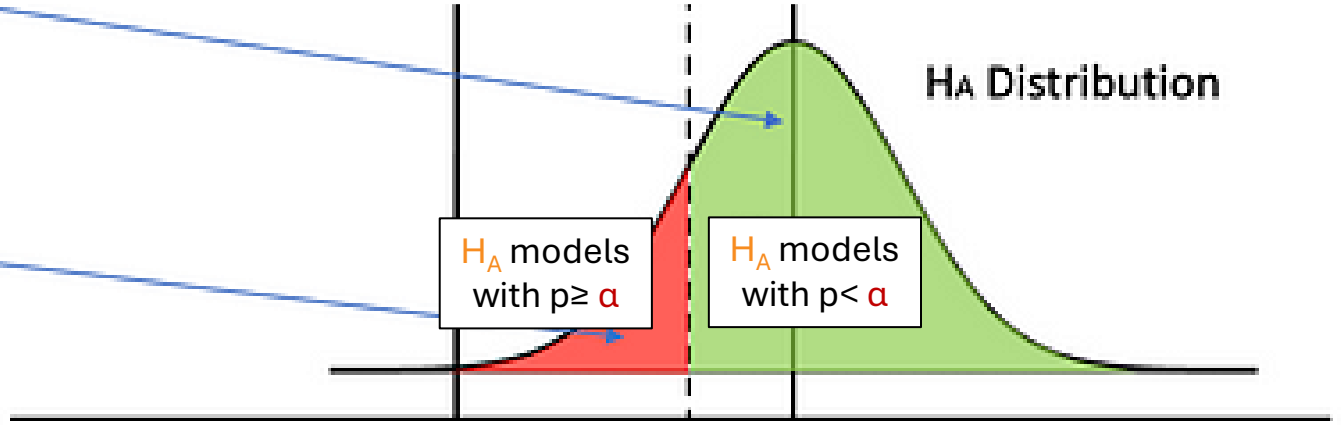


What is the probability of correctly rejecting the null hypothesis (power) with the specified effect size, N, and α?

Power = proportion of models (performed on data simulated with H_A distributions) with p-values <α

Image adapted from: https://towardsdatascience.com/5-ways-to-increase-statistical-power-377c00dd0214

PSS SIMULATIONS

When, What & How

When should you use a PSS simulation?

- When there isn’t an easier way. Before you start down the road of power simulations, check whether any R packages exist for the power simulation you want to perform!

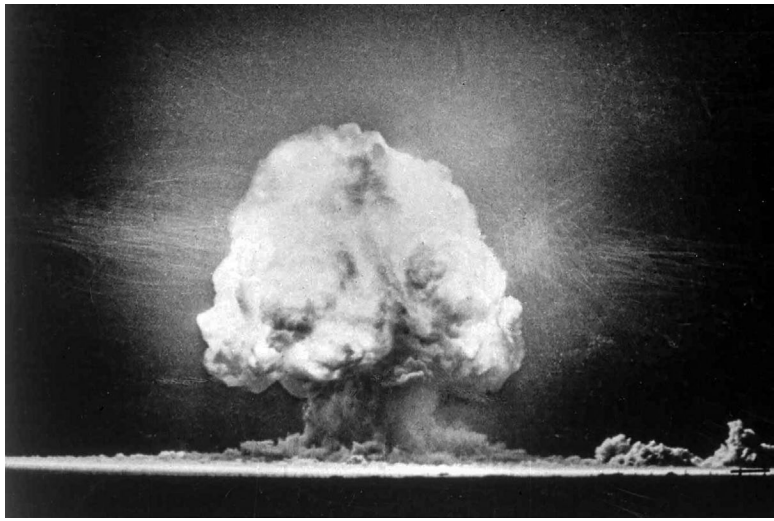
#	Name of Test	in R?	Package	Function
1	One Mean T-test	Yes	pwr	pwr.t.test
2	Two Means T-test	Yes	pwr	pwr.t.test
3	Paired T-test	Yes	pwr	pwr.t.test
4	One-way ANOVA	Yes	pwr	pwr.anova.test
5	Single Proportion Test	Yes	pwr	pwr.p.test
6	Two Proportions Test	Yes	pwr	pwr.2p.test
7	Chi-Squared Test	Yes	pwr	pwr.chisq.test
8	Simple Linear Regression	Yes	pwr	pwr.f2.test
9	Multiple Linear Regression	Yes	pwr	pwr.f2.test
10	Correlation	Yes	pwr	pwr.r.test
11	One Mean Wilcoxon Test	Yes*	pwr	pwer.t.test + 15%
12	Mann-Whitney Test	Yes*	pwr	pwer.t.test + 15%
13	Paired Wilcoxon Test	Yes*	pwr	pwer.t.test + 15%
14	Kruskal Wallace Test	Yes*	pwr	pwr.anova.test + 15%
15	Repeated Measures ANOVA	Yes	WebPower	wp.rmanova
16	Multi-way ANOVA (1 Category of interest)	Yes	WebPower	wp.kanova
17	Multi-way ANOVA (>1 Category of interest)	Yes	WebPower	wp.kanova
18	Non-Parametric Regression (Logistic)	Yes	WebPower	wp.logistic
19	Non-Parametric Regression (Poisson)	Yes	WebPower	wp.poisson
20	Multilevel modeling: CRT	Yes	WebPower	wp.crt2arm/wp.crt3arm
21	Multilevel modeling: MRT	Yes	WebPower	wp.mrt2arm/wp.mrt3arm
22	GLMM	Yes^	Simr & lme4	n/a

*-parametric test with non-parametric correction
^-detailed in future Module

PSS R packages

What is a Monte Carlo simulation?

- Monte Carlo Simulations were invented during WWII to model nuclear fission and develop atomic bombs by estimating the possible outcomes of an uncertain event



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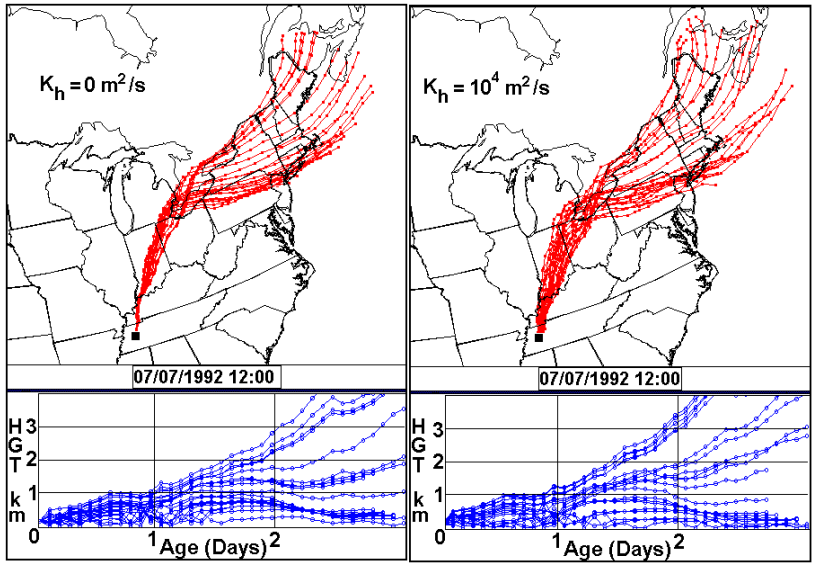
- Monte Carlo Simulations were invented during WWII to model nuclear fission and develop atomic bombs by estimating the possible outcomes of an uncertain event
- It's named Monte Carlo after the well-known casino district in Monaco because of the element of chance being modeled
- They are used in a wide range of fields and applications, including financial risk assessment and long-term forecasting, estimating the duration or cost of projects, analyzing weather patterns, traffic flow, and in a wide swath of applications in biomedical research.



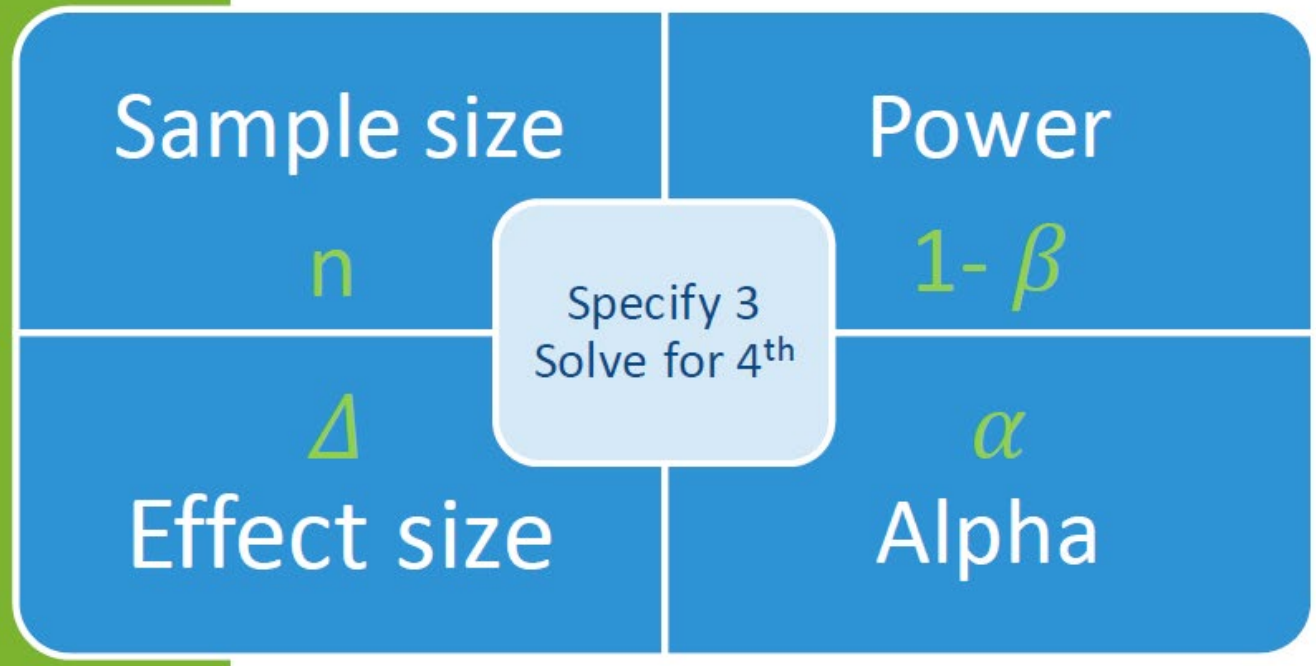
How does a Monte Carlo PSS Simulation Work?

- Four basic steps:
  - Specify probability distributions of the independent and dependent variables (effect size, variation, range, correlations, etc) based on your hypothesized relationship between variables.
  - Simulate datasets (e.g., 1000) with random variation from these specified distributions
  - Perform a statistical test on each simulated dataset.
  - Calculate proportion of your simulated results correctly detected the true relationship between the variables you have simulated. This is your power.

  If you're happy with your power from the previous step, you're done. If you're not, change inputs (e.g., N, effect size, distributions) until you achieve sufficient power.

PSS inputs

4 components to a power analysis



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Yes, but How Do you Actually do this in R?

- The rest of this seminar will be taking place in the R Studio environment. Code and data used is available on dropbox here: https://bit.ly/PSS_simulations_R_2024

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