

USING R FOR SIMULATION (MONTE CARLO) STUDIES

A BRIEF INTRODUCTION



Latent variables should remain as such: Evidence from a Monte Carlo study

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Pages 417-442 | Received 28 Oct 2018, Accepted 13 Mar 2019, Published online: 22 Apr 2019

Are fit indices used to test psychopathology structure biased? A simulation study.

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Greene, Ashley L., Eaton, Nic F., Markon, Kristian E., Waldner, Anna R., Fried, Eiko I., Ivanov

Skew t Mixture Latent State-Trait Analysis: A Monte Carlo **Simulation Study** on Statistical Performance

L Hohmann, J Holtmann, [M Eid](#) - *Frontiers in psychology*, 2018 - frontiersin.org

Standard errors and confidence intervals for correlations corrected for indirect range restriction: A **simulation study** comparing analytic and bootstrap methods

T Kennet-Cohen, D Klenner

and Statistical Psychology, 2010 - Wiley Online Library

The consequences of ignoring therapist effects in trials with longitudinal data: A **simulation study**.

[K Magnusson](#), [G Andersson](#)... - ... and *clinical psychology*, 2018 - psycnet.apa.org

STEPS IN CONDUCTING A SIMULATION STUDY

- Goals
 - What is the purpose/research question of the simulation study?
- Data Generation
 - How will the data be generated?
 - What factors will be held constant? What factors will vary?
 - How many simulations (datasets) will be generated?
- Tests, Methods
 - Which tests or procedures are being evaluated/compared?
- Outcomes
 - What are the important outcome variables from the study (% significant? bias? precision?)
- Conclusions

GOALS OF A SIMULATION STUDY

- There are many possible goals/research questions that can be addressed by a simulation study, including:
 - Evaluate a new or existing statistical method in terms of Type I error control, power, accuracy, etc.
 - E.g., evaluate the robustness of a statistic to violations of the normality assumption
 - Compare procedures in terms of statistical performance
 - E.g., is the Mann-Whitney procedure more powerful than the Student t test with platykurtic distributions?
 - Determination of an appropriate sample size given a specific model and data conditions
 - E.g., what sample size will we need to ensure that the width of a confidence interval on a standardized regression coefficient is less than .4 95% of the time

DATA GENERATION

- How are each of the variables in the study going to be generated?
 - How many levels of a categorical variable?
 - What is the distribution shape of continuous variables?
- Example distributions in R
 - `rnorm`: normally distributed variable
 - `rchisq`: chi-square distribution variable
 - `rbinom`: binomial variable
 - `rmvnorm`: multivariate normal variable
 - `rpois`: poisson distributed variable

DATA GENERATION

- How many simulations do I need?
 - There are many articles written on this topic, however generally the answer comes in terms of the standard error (or confidence interval) of the result
 - For example, let's say you are measuring the power of a statistical test (% rejections | H_0 is false)
 - The standard error of the proportion should be very small (e.g., $<.0001$)
 - Mundform et al. concluded that in most situations 7500 simulations is sufficient; however, sometimes the answer depends on the length of time required for one simulation

Number of Replications Required in Monte Carlo Simulation Studies: A Synthesis of Four Studies

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SOME IMPORTANT CONSIDERATIONS

- Have all variables been specified at the start of the file?
 - If not, this could lead to issues if you want to explore different conditions (e.g., change α), but this variable is specified throughout the file
- Will the simulation study be organized in one file or multiple files?
- In what manner will the results be summarized?
 - Descriptively
 - E.g., the power was 54% with a normal distribution and 27% with a positively skewed distribution
 - Percent of Variance
 - E.g., distribution shape explained 43% of the variance in rejection rates
- Have you explored a sufficient set of conditions over which to make a broad conclusion?
 - All simulation studies carry the limitation that they technically only apply to the conditions investigated

SIMULATION STUDY EXAMPLE: CAN OMNIBUS TESTS AND PAIRWISE COMPARISONS GIVE DISCREPANT RESULTS IN A ONE-WAY ANOVA SETTING?

- Background
 - There is often confusion regarding whether or not it is appropriate to explore post hoc tests when the omnibus test is not significant
 - E.g., Can we explore pairwise comparisons in an ANOVA setting when the omnibus test is not statistically significant? Can we explore individual predictors in a multiple regression if the omnibus F test is not statistically significant?
 - Note that these are highly related; e.g., dummy variables in regression

Relationship between Omnibus and Post-hoc Tests: An Investigation of performance of the F test in ANOVA

[Tian CHEN](#),^{1,*}

[Manfei XU](#),² [Justin TU](#),³ [Hongyue WANG](#),⁴ and [Xiaohui NIU](#)⁵

2018 Study!

SIMULATION STUDY EXAMPLE: CAN OMNIBUS TESTS AND PAIRWISE COMPARISONS GIVE DISCREPANT RESULTS IN A ONE-WAY ANOVA SETTING?

- There are many contradictory answers regarding this question

James, Witten, Hastie, & Tibshirani:

Given these individual p-values for each variable, why do we need to look at the overall F-statistic? After all, it seems likely that if any one of the p-values for the individual variables is very small, then *at least one of the predictors is related to the response*. However, this logic is flawed, especially when the number of predictors p is large.

Chen et al. conclusion:

Given our findings, it seems important to always perform pairwise group comparisons, regardless of the significance status of the omnibus test and report findings based on such group comparisons.