Philipps Universität Marburg

Simulation Studies for Methodological Research in Psychology

Björn S. Siepe[⋆], František Bartos, Tim P. Morris, Anne-Laure Boulesteix, Daniel Heck, Samuel Pawel

⋆ Psychological Methods Lab, Department of Psychology, University of Marburg

DagStat2025. Slides available at `htpps://bsiepe.github.io`

A multidisciplinary collaboration

Björn S. Siepe

František Bartoš

Daniel W. Heck

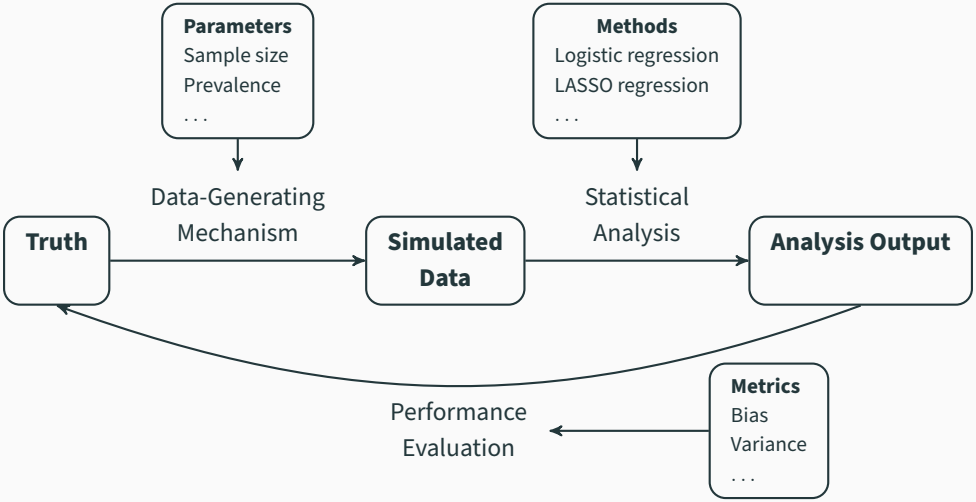
Tim P. Morris

Anne-Laure Boulesteix

Samuel Pawel

Simulation studies

Simulation studies



Simulation studies can have huge impact

A **simulation study** of the number of events per variable in logistic regression analysis

P **Peduzzi**, J Concato, E Kemper, TR Holford… - Journal of clinical …, 1996 - Elsevier

… In a **simulation study** of forward stepwise multiple linear regression, Freedman and Pee [3] demonstrated that the … In **simulation studies** of the effect of EPV on proportional … Peter **Peduzzi**. …

☆ Save 99 Cite Cited by 8827 Related articles All 9 versions

Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives

L **Hu**, PM **Bentler** - Structural equation modeling: a …, 1999 - Taylor & Francis

This article examines the adequacy of the "rules of thumb" conventional cutoff criteria and several new alternatives for various fit indexes used to evaluate model fit in practice. Using a 2-…

☆ Save 99 Cite Cited by 116305 Related articles All 9 versions

Collinearity: a review of methods to deal with it and a **simulation study** evaluating their performance

CF Dormann, J Elith, S Bacher, C Buchmann… - …, 2013 - Wiley Online Library

… In the fourth part we carry out a large **simulation study** to compare all reviewed methods. We provide complementary case studies on real data in Supplementary material Appendix 1.2. …

☆ Save 99 Cite Cited by 8455 Related articles All 30 versions

Deciding on the number of classes in latent class analysis and growth mixture modeling: A Monte Carlo **simulation study**

KL Nylund, T Asparouhov… - … equation modeling: A …, 2007 - Taylor & Francis

… This article presents the results of a **simulation study** that examines the performance of likelihood-based tests and the traditionally used Information Criterion (ICs) used for determining …

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Issues in simulation studies

> *"…extensive simulation studies show that the proposed method performs on par or* ***better than existing methods*** *…"*

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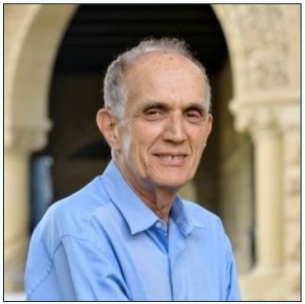
Issues in simulation studies

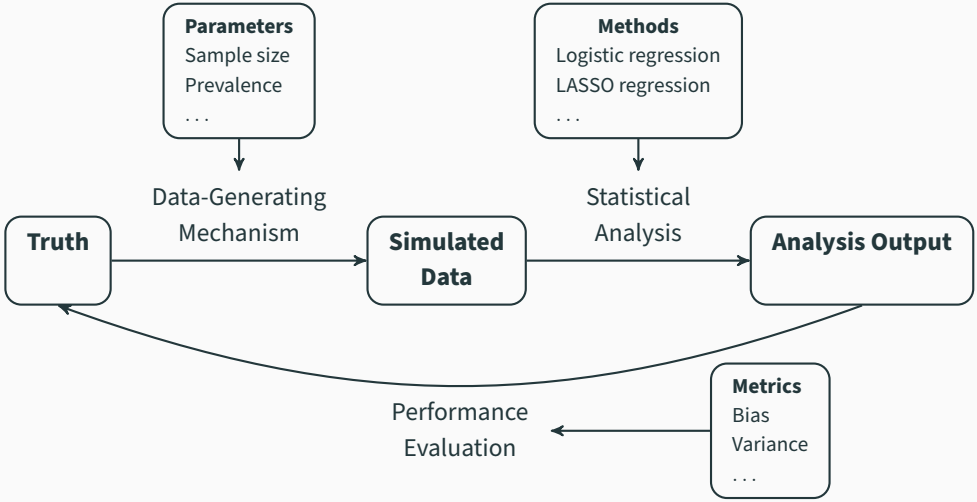
"*In fact it is* ***very difficult to run an honest simulation*** *comparison, and* ***easy to inadvertently cheat*** *by choosing favorable examples, or by not putting as much effort into optimizing the dull old standard as the exciting new challenger.*"

Brad Efron (2001)



https://statistics.stanford.edu/people/bradley-efron

Questionable research practices in simulation studies



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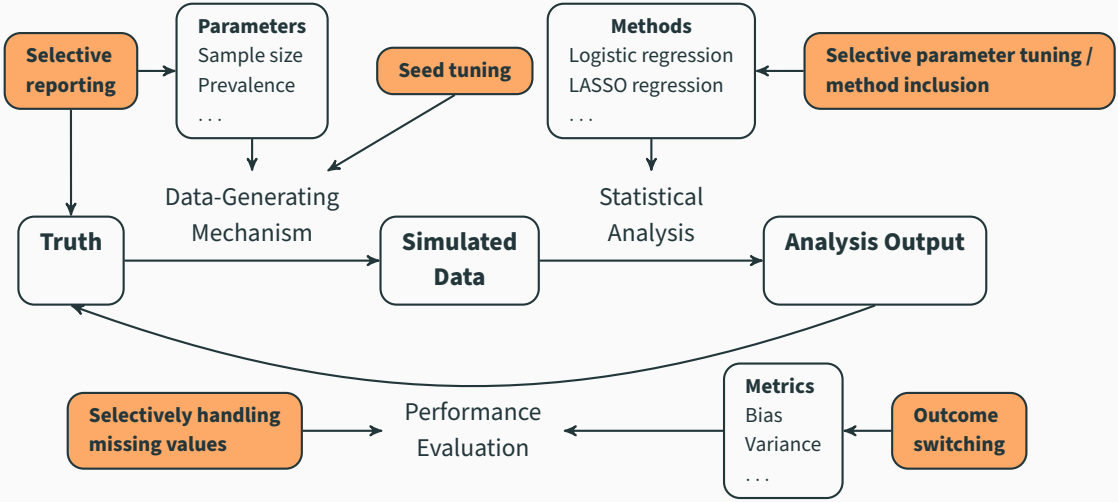


Questionable research practices in simulation studies

Received: 25 March 2022 | Revised: 5 January 2023 | Accepted: 9 January 2023

DOI: 10.1002/bimj.202200091

Biometrical Journal

RESEARCH ARTICLE

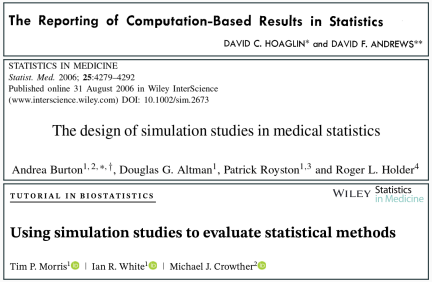
Pitfalls and potentials in simulation studies: Questionable research practices in comparative simulation studies allow for spurious claims of superiority of any method

Samuel Pawel | Lucas Kook | Kelly Reeve

"*By **deliberately using several QRPs**, we were able to **present a method with no expected benefits** […] **as an improvement** over […] well-established competitors.*"

Literature Review

"*Statisticians ... often pay too little attention to their own principles of design*"(Hoaglin & Andrews, 1975)



The Reporting of Computation-Based Results in Statistics

DAVID C. HOAGLIN* and DAVID F. ANDREWS**

STATISTICS IN MEDICINE
Statist. Med. 2006; **25**:4279–4292
Published online 31 August 2006 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sim.2673

The design of simulation studies in medical statistics

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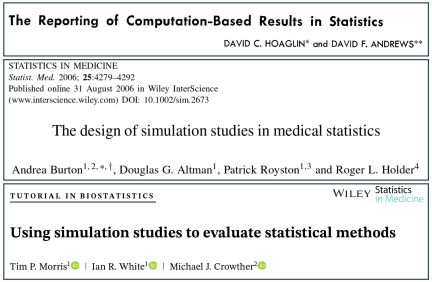

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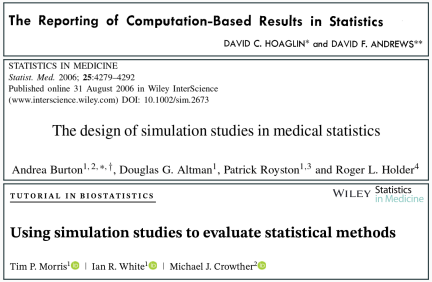

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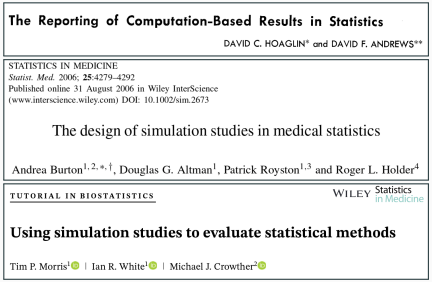

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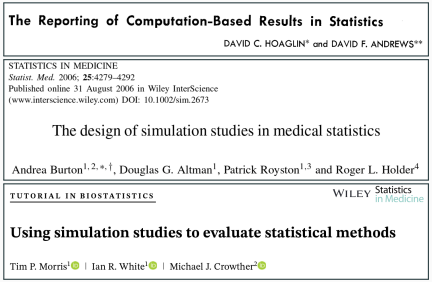

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- Coding of various aspects of reporting

Main Results

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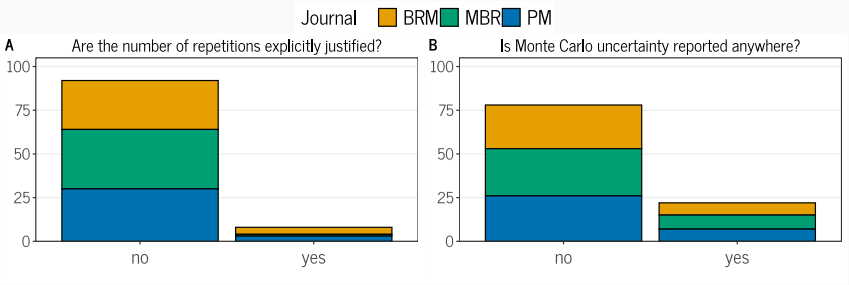

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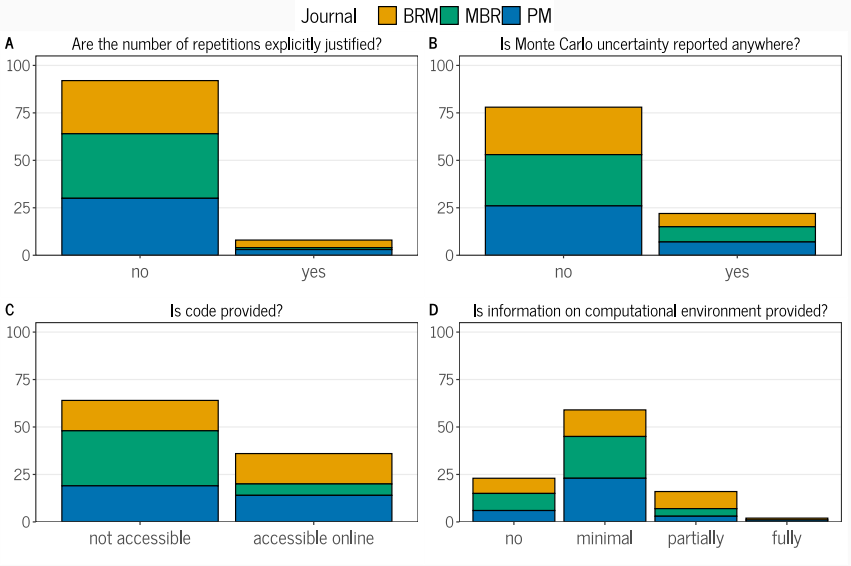

Simulation study protocols

Simulation study protocols

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The design of simulation studies in medical statistics

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"***When planning*** *a simulation study, it is* ***recommended that a detailed protocol be produced****, giving full details of how the study will be performed, analysed and reported.*"

Simulation study protocols

Advantages

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+ Planning and reporting

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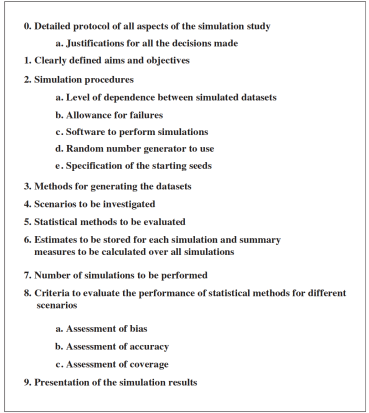
? Less/more work

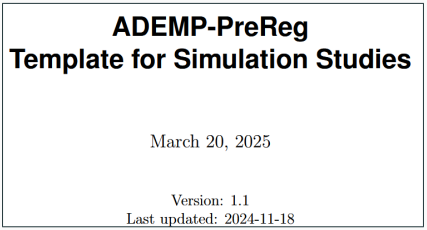
→ **How to structure protocol?**



0. Detailed protocol of all aspects of the simulation study
    a. Justifications for all the decisions made
1. Clearly defined aims and objectives
2. Simulation procedures
    a. Level of dependence between simulated datasets
    b. Allowance for failures
    c. Software to perform simulations
    d. Random number generator to use
    e. Specification of the starting seeds
3. Methods for generating the datasets
4. Scenarios to be investigated
5. Statistical methods to be evaluated
6. Estimates to be stored for each simulation and summary measures to be calculated over all simulations
7. Number of simulations to be performed
8. Criteria to evaluate the performance of statistical methods for different scenarios
    a. Assessment of bias
    b. Assessment of accuracy
    c. Assessment of coverage
9. Presentation of the simulation results

Proposal from Burton et al. (2006)

Towards improved reporting

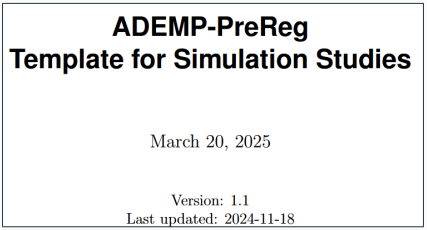


ADEMP-PreReg
Template for Simulation Studies

March 20, 2025

Version: 1.1
Last updated: 2024-11-18

Towards improved reporting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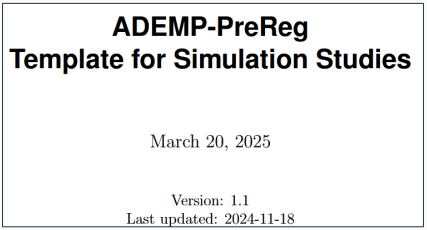
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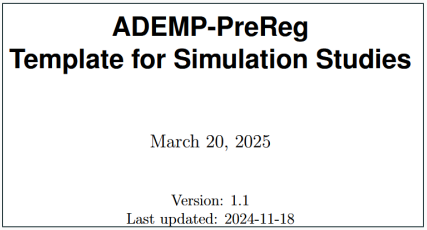

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- **Different versions**: LaTeX, Overleaf, MS/Libre office, Google docs
- **Living document**: https://github.com/bsiepe/ADEMP-PreReg

ADEMP: doi.org/10.1214/ss/1009213726, ADEMP-PreReg: doi.org/10.31234/osf.io/ufgy6

The ADEMP-PreReg template

1. Instructions
2. General information
3. **A**ims
4. **D**ata-generating mechanism
5. **E**stimands and targets
6. **M**ethods
7. **P**erformance Measures
8. Computational details

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7 Performance Measures

7.1 Which performance measures will be used?

Explanation: Please provide details on why they were chosen and on how these measures will be calculated. Ideally, provide formulas for the performance measures to avoid ambiguity. Some models in psychology, such as item response theory or time series models, often contain multiple parameters of interest, and their number may vary across conditions. With a large number of estimated parameters, their performance measures are often combined. If multiple estimates are aggregated, specify how this aggregation will be performed. For example, if there are multiple parameters in a particular condition, the mean of the individual biases of these parameters or the bias of each individual parameter may be reported.

Example

Our primary performance measures are the type I error rate (in conditions where the true effect is zero) and the power (in conditions where the true effect is non-zero) to reject the null hypothesis of no difference between the control and treatment condition. The null hypothesis is rejected if the p-value for the null hypothesis of no effect is less than or equal to the conventional threshold of 0.05. The rejection rate (the type I error rate or the power, depending on the data generating mechanism) is estimated by

$$\widehat{\text{RRate}} = \frac{\sum_{i=1}^{n_{\text{sim}}} 1(p_i \leq 0.05)}{n_{\text{sim}}}$$

where $1(p_i \leq 0.05)$ is the indicator of whether the p-value in simulation i is equal to or less than 0.05. We use the following formula to compute the MCSE of the rejection rate

$$\text{MCSE}_{\widehat{\text{RRate}}} = \sqrt{\frac{\widehat{\text{RRate}}(1 - \widehat{\text{RRate}})}{n_{\text{sim}}}}.$$

The ADEMP-PreReg template

Purposes

The ADEMP-PreReg template

Purposes

- Blueprint for **planning**, **reporting** & **reviewing** of simulation studies

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- **Preregistration** brings multiple benefits similar to other empirical research
  - Avoid QRPs
  - Increase transparency
  - Improve informativeness

Limitations

The ADEMP-PreReg template

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- Preregistration could be **faked**

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doi:10.5281/zenodo.7994221

Limitations

- Preregistration could be **faked**
- May **slow down** exploratory research

Conclusions

Simulation Studies for Methodological Research in Psychology:

A Standardized Template for Planning, Preregistration, and Reporting

Björn S. Siepe*[1], František Bartoš*[2], Tim P. Morris[3], Anne-Laure Boulesteix[4], Daniel W. Heck[1], and Samuel Pawel*[5]

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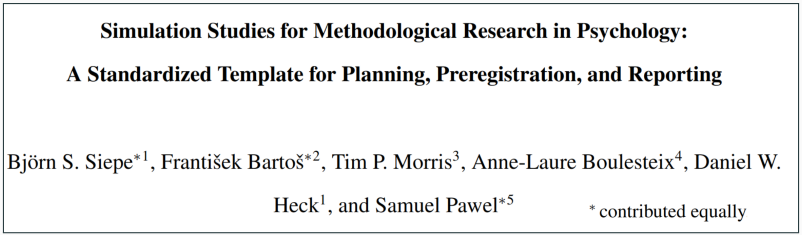

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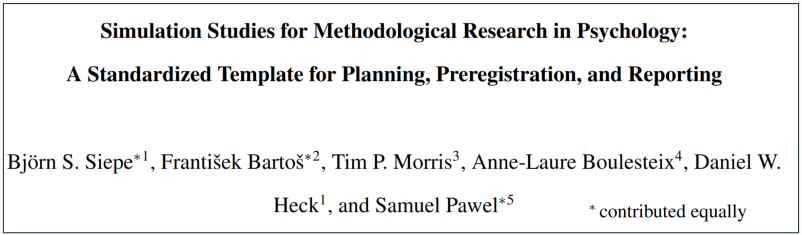

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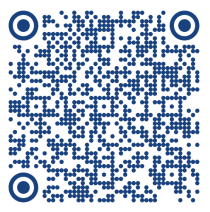
Get in touch:

- bjoern.siepe@uni-marburg.de
- Bluesky: bsiepe

Paper & Slides



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References ii

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