Monte Carlo Simulation for Quantitative Research
ED PSYCH 506-001 – Fall 2025

Lecture	Mondays, 9:00 – 11:00 a.m.
Room	Noland 123
Credits	3 credits[1]
Instruction	Face-to-face

Instructor	Dr. James E. Pustejovsky (pronounced "PUHS-tea-UV-ski" or "Pusto" for short)
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Course Description

Monte Carlo simulations are computational experiments that involve using random number generators to study the behavior of statistical or mathematical models. Simulations allow the analyst to control the data-generating process and therefore fully know the truth—something that is almost always uncertain when analyzing real, empirical data. Thus, simulation studies provide a clean and controlled environment for testing out data analysis approaches before putting them to use with real empirical data, making them an essential tool of inquiry for quantitative methodologists, data analysts, and students of statistics. This course provide an introduction to the logic, mechanics, analysis, and interpretation of Monte Carlo simulation studies. The primary focus is on simulation studies for formal methodological research and for informing the design of empirical studies (e.g., power analysis), although other uses of simulation (such as bootstrapping and permutation inference) will be discussed as well. Course activities will include hands-on, collaborative programming activities, presentations of contemporary research that uses simulation, and discussions of contemporary scholarship covering issues in the design, analysis, and interpretation of simulation.

[1] This class meets for one, 150-minute class periods each week over the Spring semester and carries the expectation that students will work on course learning activities (reading, writing, problem sets, studying, etc) for about six hours out of the classroom for every class period.

Pre-requisites

- Experience with writing scripts/programming in R. You should be comfortable doing the following:
    - Cleaning, manipulating, and transforming datasets.
    - Calculating summary statistics.
    - Computing and interpret the output of statistical models.

Course Learning Outcomes

By the end of this course, students will be able to:

- Describe the strengths and core limitations of simulation studies for quantitative methods research.
- Write code to implement and run simulations using the R programming language.
- Use tabular, graphical, and statistical methods to interpret the results of methodological simulations.
- Critically evaluate the design, implementation, and findings from methodological simulation studies.

Readings

- Miratrix and Pustejovsky (2024). *Designing Monte Carlo Simulations in R*. Available online at https://jepusto.github.io/Designing-Simulations-in-R/.
- Journal articles and other materials available through the course Canvas site.

Additional Recommended Resources

- Wickham, H., Cetinkaya-Rundel, M., & Grolemund, G. (2023). *R for Data Science* (2nd Ed.). O'Reilly. R for Data Science (2e)

Topics and Readings

2025-09-08 – Course Introduction

- DMCSR Chapters 1, 2, and 3

2025-09-15 – Structure of Simulations

- DMCSR Chapters 4 and 5
- Morris, T. P., White, I. R., and Crowther, M. J., (2019). Using simulation studies to evaluate statistical methods. *Statistics in Medicine*. https://doi.org/10.1002/sim.8086

2025-09-22 –Models, Methods, and Data Analysis Techniques

- Class presentations on statistical models and methods

2025-09-29 – Data-Generating Models

- DMCSR Chapter 6

2025-10-06 – Data-Analysis Procedures

- DMCSR Chapter 7
- DiRenzo, G. V., Hanks, E., & Miller, D. A. W. (2023). A practical guide to understanding and validating complex models using data simulations. *Methods in Ecology and Evolution*, *14*(1), 203–217. https://doi.org/10.1111/2041-210X.14030

2025-10-13 – Running Simulation Processes

- DMCSR Chapter 8
- Siepe, B. S., Bartoš, F., Morris, T. P., Boulesteix, A.-L., Heck, D. W., & Pawel, S. (2024). Simulation studies for methodological research in psychology: A standardized template for planning, preregistration, and reporting. *Psychological Methods. Advance online publication*. https://doi.org/10.1037/met0000695
- Williams, C., Yang, Y., Lagisz, M., Morrison, K., Ricolfi, L., Warton, D. I., & Nakagawa, S. (2024). Transparent reporting items for simulation studies evaluating statistical methods: Foundations for reproducibility and reliability. *Methods in Ecology and Evolution, 15*(11), 1926–1939. **https://doi.org/10.1111/2041-210X.14415**

2025-10-20 – Performance Criteria, part 1

- DMCSR Chapter 9
- Koehler, E., Brown, E., and Haneuse, S. J.-P. (2009). On the assessment of Monte Carlo error in simulation-based statistical analyses. *The American Statistician, 63*(2),155–162.

2025-10-27 – Performance Criteria, part 2

- Pawel, S., Bartoš, F., Siepe, B. S., & Lohmann, A. (2025). *Handling Missingness, Failures, and Non-Convergence in Simulation Studies: A Review of Current Practices and Recommendations* (No. arXiv:2409.18527). arXiv. https://doi.org/10.48550/arXiv.2409.18527
- Boos, D. D., & Osborne, J. A. (2015). Assessing variability of complex descriptive statistics in Monte Carlo studies using resampling methods. *International Statistical Review, 83*(2), 228–238. https://doi.org/10.1111/insr.12087

2025-11-03 – Multifactor Simulations

- DMCSR Chapters 10 and 19
- Heinze, G., Boulesteix, A.-L., Kammer, M., Morris, T. P., White, I. R., & Initiative, the S. P. of the S. (2024). Phases of methodological research in biostatistics—Building the

evidence base for new methods. *Biometrical Journal*, *66*(1), 2200222. https://doi.org/10.1002/bimj.202200222

- Skrondal, A. (2000). Design and Analysis of Monte Carlo Experiments: Attacking the Conventional Wisdom. *Multivariate Behavioral Research*, *35*(2), 137–167. https://doi.org/10.1207/S15327906MBR3502_1

2025-11-10 – Presenting Simulation Results

- DMCSR Chapters 11 and 12
- Gelman, A., Pasarica, C., & Dodhia, R. (2002). Let's practice what we preach: Turning tables into graphs. *The American Statistician* 56(2), 121–30.
- Harwell, M., Kohli, N., & Peralta-Torres, Y. (2018). A Survey of Reporting Practices of Computer Simulation Studies in Statistical Research. *The American Statistician*, *72*(4), 321–327. https://doi.org/10.1080/00031305.2017.1342692

2025-11-17 – Computational Considerations

- White, I., Pham, T. M., Quartagno, M., & Morris, T. (2023). *How to check a simulation study*. OSF. https://doi.org/10.31219/osf.io/cbr72
- DMCSR Chapters 15 and 18

2025-11-24 – Bootstrapping

- Boos, D. D. (2003). Introduction to the bootstrap world. *Statistical Science, 18*(2). **https://doi.org/10.1214/ss/1063994971**
- Boos, D. D., & Zhang, J. (2000). Monte Carlo evaluation of resampling-based hypothesis tests. *Journal of the American Statistical Association, 95*(450), 486–492. https://doi.org/10.1080/01621459.2000.10474226

2025-12-01 – Potential Outcomes

- DMCSR Chapter 21
- Schreck, N., Slynko, A., Saadati, M., and Benner, A. (2024). Statistical plasmode simulations–Potentials, challenges and recommendations. *Statistics in Medicine, 43*(9), 1804–25.
- Ress, V. and Wild, E.-M. (2024). Comparing methods for estimating causal treatment effects of administrative health data: A plasmode simulation study. *Health Economics, 33*(12), 2757–2777.

2025-12-08 – Possible Further Topics

- Pawel, S., Kook, L., & Reeve, K. (2024). Pitfalls and potentials in simulation studies: Questionable research practices in comparative simulation studies allow for spurious claims of superiority of any method. *Biometrical Journal*, *66*(1), 2200091. https://doi.org/10.1002/bimj.202200091

- Kelter, R. (2024). The Bayesian simulation study (BASIS) framework for simulation studies in statistical and methodological research. *Biometrical Journal*, *66*(1), 2200095. https://doi.org/10.1002/bimj.202200095
- Luijken, K., Lohmann, A., Alter, U., Claramunt Gonzalez, J., Clouth, F. J., Fossum, J. L., Hesen, L., Huizing, A. H. J., Ketelaar, J., Montoya, A. K., Nab, L., Nijman, R. C. C., Penning de Vries, B. B. L., Tibbe, T. D., Wang, Y. A., & Groenwold, R. H. H. (2024). Replicability of simulation studies for the investigation of statistical methods: The RepliSims project. *Royal Society Open Science*, *11*(1), 231003. https://doi.org/10.1098/rsos.231003
- Kueppers, S., Rau, R., & Scharf, F. (2024). Using Monte Carlo Simulation to Forecast the Scientific Utility of Psychological App Studies: A Tutorial. *Multivariate Behavioral Research*, *59*(4), 879–893. https://doi.org/10.1080/00273171.2024.2335411

Evaluation

- Problem sets (25%)
- Course participation (20%)
- Presentations (25%)
- Course project (30%)

Grading Scale

A tentative scale for assignment of final grades is listed below. Square brackets correspond to ≤ or ≥; rounded parentheses to < or >.

A	[90, 100]	C	[65, 70)
A/B	[85, 90)	C/D	[60, 65)
B	[75, 85)	D	[50, 60)
B/C	[70, 75)	F	[0, 50)

Problem sets

- Students will complete problem sets involving writing and running R code for implementing pieces of simulation studies.
- Problem sets must be submitted through Canvas.
- Problem set submissions will be evaluated for responsiveness and for providing an honest attempt at a solution, ***not for correctness***. Student responses to problem sets will form the basis of discussion during the subsequent class meeting, and so must be submitted by the due date.

Course participation

- Students are expected to prepare for and participate actively in class activities, including in-class paired programming exercises, small-group and full-group discussions, and other assigned tasks.

- Preparation and active participation in class is demonstrated by
    - Asking questions related to the readings.
    - Discussing your solution to an assigned problem with other students or offering suggestions to other students about their solutions.
    - Sharing your attempted solution to a problem during full-group discussion.
    - Relating concepts and topics from class discussions to material from other Quantitative Methods or Statistics courses.

Presentations

- Each student will give an oral presentation on a statistical model, data analysis technique, or methodological issue that could be investigated through Monte Carlo simulation. Presentations should cover a) contexts where the method could be used, b) types or examples of question(s) addressed by the method, and c) explicit and implicit assumptions of the method.
    - Undergraduate expectations: Presentations should be 5 – 8 minutes in length and can cover any statistical model, technique, or issue of interest.
    - Graduate expectations: Presentations should be 10 – 15 minutes in length and should cover a model, technique, or issue that is *not typically covered* in the core Quantitative Methods courses. Examples of ineligible topics include: linear or logistic regression, factor analysis, hierarchical linear models, random effects meta-analysis, propensity score matching for a binary treatment. Examples of eligible topics: boosted regression trees, hierarchical linear models with sampling weights, generalized linear mixed models, energy balancing methods for propensity score analysis, generalized additive models.
- Each student will give an oral presentation and lead discussion on one assigned article. Presentations should be 10 – 15 minutes in length. Articles will be assigned at the beginning of the semester, with presentations spaced out over the course of the semester.
    - Additional graduate expectation: the presenter should prepare 15-20 minutes of discussion questions or activities directly related to the assigned article

Course Project

There are two options for the course project:

- Option 1: Find a published Monte Carlo simulation study that evaluates a statistical method or compares a set of methods, but for which replication code is not available. Create R code to replicate the main results of the paper. Critically assess the design and findings of the original study.
    - Additional graduate expectation: Extend the study by using an alternative data-generating process, adding further estimation methods, or applying the simulation design to other parameter values not considered in original study.

- Option 2: Conduct a Monte Carlo simulation study on a novel topic of interest. Submit a paper presenting the results of the study and covering: the research questions and rationale, simulation methods, results, and conclusions. Code for reproducing the simulation should be submitted as an appendix. You are free to choose any topic you like.

Respectful Learning Environment

Courses in Educational Psychology are venues for the free, open, and respectful exchange of ideas. Class members are expected to respect others and to contribute to a healthy learning environment in all course activities. Concerns in this regard should be brought to the attention of the course instructor.

Diversity & Inclusion Statement

Diversity is a source of strength, creativity, and innovation for UW-Madison. We value the contributions of each person and respect the profound ways their identity, culture, background, experience, status, abilities, and opinion enrich the university community. We commit ourselves to the pursuit of excellence in teaching, research, outreach, and diversity as inextricably linked goals. The University of Wisconsin-Madison fulfills its public mission by creating a welcoming and inclusive community for people from every background – people who as students, faculty, and staff serve Wisconsin and the world.

The School of Education recognizes that our desire to be an anti-racist, unbiased, and inclusive academic community is ongoing and involves shared commitment, responsibility, action, and accountability. We believe that diversity, equity, inclusion, and inclusive excellence, the four essential pillars of our approach to generating positive and lasting change, build upon our scholarship and the School's reputation as a leading educational institution. Read the full statement for values and commitments supporting the School's efforts.

Academic Integrity Statement

By virtue of enrollment, each student agrees to uphold the high academic standards of the University of Wisconsin-Madison. Students are expected to maintain absolute integrity and a high standard of individual honor in scholastic work. Assignments and projects must be completed with the utmost honesty, which includes acknowledging the contributions of other sources to your scholastic efforts; avoiding plagiarism; and completing assignments independently unless expressly authorized otherwise. ***Homework assignments or exam responses containing any plagiarized material will not be accepted.*** Cheating, fabrication, plagiarism, unauthorized collaboration, and helping others commit these previously listed acts are examples of academic misconduct, which may result in disciplinary action. Violations of University of Wisconsin policies on academic honesty will not be tolerated and will be dealt with in accordance with University policies. Examples of disciplinary action include, but are not limited to, failure on the assignment/course, written reprimand, disciplinary probation, suspension, or expulsion. For further information on these policies, students may consult this website: https://www.students.wisc.edu/doso/academic-integrity/

Accommodations for Students with Disabilities Statement

The University of Wisconsin-Madison supports the right of all enrolled students to a full and equal educational opportunity. The Americans with Disabilities Act (ADA), Wisconsin State Statute (36.12), and UW-Madison policy (Faculty Document 1071) require that students with disabilities be reasonably accommodated in instruction and campus life. Reasonable accommodations for students with disabilities is a shared faculty and student responsibility.

Students are expected to inform faculty [me] of their need for instructional accommodations by the end of the third week of the semester, or as soon as possible after a disability has been incurred or recognized. Faculty [I], will work either directly with the student [you] or in coordination with the McBurney Center to identify and provide reasonable instructional accommodations. Disability information, including instructional accommodations as part of a student's educational record, is confidential and protected under FERPA. (See: McBurney Disability Resource Center)