

# Experimental Design For Causal Inference Through An Optimization Lens

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## Abstract

The study of experimental design offers tremendous benefits for answering causal questions across a wide range of applications, including agricultural experiments, clinical trials, industrial experiments, social experiments, and digital experiments. Although valuable in such applications, the costs of experiments often drive experimenters to seek more efficient designs. Recently, experimenters have started to examine such efficiency questions from an optimization perspective, as experimental design problems are fundamentally decision-making problems. This perspective offers a lot of flexibility in leveraging various existing optimization tools to study experimental design problems. This manuscript thus aims to examine the foundations of experimental design problems in the context of causal inference as viewed through an optimization lens.

## 1. Introduction

The study of experimental design offers tremendous benefits for answering causal questions across a wide range of applications, including agricultural experiments, clinical trials, industrial experiments, social experiments, and digital experiments. Experimental design is probably one of the cleanest ways to answer causal questions, that is, to understand the causation behind some phenomenon. In such an experiment, the experimenter usually compares the standard offering of some existing policy (the “control”) to a new version of the policy (the “treatment”) by splitting the experimental units into the control and treatment groups. By comparing the outcomes from these two groups, the experimenter discovers the “treatment effect,” that is, the degree to which the newer version is better or worse than the standard version. See Examples 1 – 5 below for an illustration of experimental design terminology in the context of causal inference.

**Example 1 (Cochran et al. (1941). Agricultural Experiments).** During the winter of 1939 - 1940, the Iowa Agricultural Experiment Station (AES) conducted feeding experiments on their 18 Holstein cows to compare three feeding plans on milk yield. For simplicity, we drop one feeding plan from Cochran et al. (1941) and only compare two feeding plans in this example. We refer to the plan of feeding roughage (alfalfa hay and corn silage) as the control and the plan of feeding grain plus roughage as the treatment.

We present a simplified version of the experiment that Iowa AES conducted. On each day, Iowa AES randomly allocated these 18 Holstein cows into either the treatment or the control group. We refer to each cow as an experimental unit. At the end of each day, Iowa

Jinglong Zhao, Questrom School of Business, Boston University, [jinglong@bu.edu](mailto:jinglong@bu.edu). The author thanks Lihua Lei for sharing valuable perspectives that built the foundation of this manuscript and Alberto Abadie, David Anderson, Volodymyr Babich, Yuchen Hu, Stefanus Jasin, Ramesh Johari, Shuangning Li, Tu Ni, Chao Qin, Christopher Ryan, Nian Si, Johan Ugander, Ruoxuan Xiong, Ruohan Zhan, Bo Zhang, course participants at the National University of Singapore, and five anonymous referees for suggestions and feedbacks that significantly improved this manuscript. This manuscript builds on the author’s lecture notes taught at the National University of Singapore.

# Problems In Experimental Design And Inference

**R Sandford**



## **Problems In Experimental Design And Inference:**

**Problems in Experimental Design and Inference** Benton J. Underwood,1966      **Philosophical Problems of Statistical Inference** T. Seidenfeld,1979-08-31 Probability and inverse inference Neyman Pearson theory Fisherian significance testing The fiducial argument one parameter The fiducial argument several parameters Ian Hacking's theory Henry Kyburg's theory Relevance and experimental design      **Quasi-experimentation** Thomas D. Cook,Donald Thomas Campbell,1979 This book presents some quasi experimental designs and design features that can be used in many social research settings The designs serve to probe causal hypotheses about a wide variety of substantive issues in both basic and applied research Each design is assessed in terms of four types of validity with special stress on internal validity Although general conclusions are drawn about the strengths and limitations of each design emphasis is also placed on the fact that the relevant threats to valid inference are specific to each research setting Consequently a threat that is usually associated with a particular design need not invariably be associated with that design      **Using Propensity Scores in Quasi-Experimental Designs** William M. Holmes,2013-06-10 Using an accessible approach perfect for social and behavioral science students requiring minimal use of matrix and vector algebra Holmes examines how propensity scores can be used to both reduce bias with different kinds of quasi experimental designs and fix or improve broken experiments This unique book covers the causal assumptions of propensity score estimates and their many uses linking these uses with analysis appropriate for different designs Thorough coverage of bias assessment propensity score estimation and estimate improvement is provided along with graphical and statistical methods for this process Applications are included for analysis of variance and covariance maximum likelihood and logistic regression two stage least squares generalized linear regression and general estimation equations The examples use public data sets that have policy and programmatic relevance across a variety of social and behavioral science disciplines      **Handbook of Education Policy Research** Gary Sykes,Barbara Schneider,David N. Plank,2012-09-10 Co published by Routledge for the American Educational Research Association AERA Educational policy continues to be of major concern Policy debates about economic growth and national competitiveness for example commonly focus on the importance of human capital and a highly educated workforce Defining the theoretical boundaries and methodological approaches of education policy research are the two primary themes of this comprehensive AERA sponsored Handbook Organized into seven sections the Handbook focuses on 1 disciplinary foundations of educational policy 2 methodological perspectives 3 the policy process 4 resources management and organization 5 teaching and learning policy 6 actors and institutions and 7 education access and differentiation Drawing from multiple disciplines the Handbook's over one hundred authors address three central questions What policy issues and questions have oriented current policy research What research strategies and methods have proven most fruitful And what issues questions and methods will drive future policy research Topics such as early childhood education school choice access to higher education teacher

accountability and testing and measurement cut across the 63 chapters in the volume The politics surrounding these and other issues are objectively analyzed by authors and commentators Each of the seven sections concludes with two commentaries by leading scholars in the field The first considers the current state of policy design and the second addresses the current state of policy research This book is appropriate for scholars and graduate students working in the field of education policy and for the growing number of academic government and think tank researchers engaged in policy research For more information on the American Educational Research Association please visit <http://www.aera.net>

**MODA 5 - Advances in Model-Oriented Data Analysis and Experimental Design** Anthony C. Atkinson, Luc Pronzato, Henry P. Wynn, 2012-12-06 This volume contains the majority of the papers presented at the 5th International Workshop on Model Oriented Data Analysis held in June 1998 This series started in March 1987 with a meeting on the Wartburg Eisenach Germany The next three meetings were in 1990 St Kyrrik monastery Bulgaria 1992 Petrodvorets St Petersburg Russia and 1995 Spetses Greece The main purpose of these workshops was to bring together leading scientists from Eastern and Western Europe for the exchange of ideas in theoretical and applied statistics with special emphasis on experimental design Now that the separation between East and West has become less rigid this dialogue has in principle become much easier However providing opportunities for this dialogue is as vital as ever MODA meetings are known for their friendly atmosphere leading to fruitful discussions and collaboration especially between young and senior scientists Indeed many long term collaborations were initiated during these events This intellectually stimulating atmosphere is achieved by limiting the number of participants to around eighty by the choice of location so that participants can live as a community and of course through the careful selection of scientific direction made by the Programme Committee

**Experimental and Quasi-experimental Designs for Generalized Causal Inference** William R. Shadish, Thomas D. Cook, Donald Thomas Campbell, 2002 Sections include experiments and generalised causal inference statistical conclusion validity and internal validity construct validity and external validity quasi experimental designs that either lack a control group or lack pretest observations on the outcome quasi experimental designs that use both control groups and pretests quasi experiments interrupted time series designs regression discontinuity designs randomised experiments rationale designs and conditions conducive to doing them practical problems 1 ethics participation recruitment and random assignment practical problems 2 treatment implementation and attrition generalised causal inference a grounded theory generalised causal inference methods for single studies generalised causal inference methods for multiple studies a critical assessment of our assumptions

*Bayesian Calibration Experimental Designs Based on Linear Models* Sung Chul Kim, 1988 *Emerging Issues in Causal Inference for Intervention Trials* Qi Long, 2005

**Perception and Understanding in Young Children** Peter Bryant, 2017-03-31 Originally published in 1974 This book sets forth a theory of cognitive development based on simple but powerful processes of inference The theory is applied with great ingenuity and freshness to complex phenomena found

during intellectual development Dr Bryant has written an important and original book J S Bruner In this elegant timely and brief volume Dr Bryant produces strong experimental evidence which not only challenges Piaget s ideas but even more importantly synthesizes the old and new findings into a newer theory of perceptual development The importance of this book lies both in its demonstration of elegant experimental techniques in working with young children and in the optimism it will eventually bring to all concerned with their education Realizing that children can make deductive inferences at an early age educators will have to rethink some of their approaches to the teaching of young children The studies related to the understanding of number have crucial implications for the future teaching of mathematics This book will cause many people to take fresh thoughts on the subjects here dealt with and so it can be strongly recommended for all students of child development William Yule *British Journal of Psychiatry* *IEEE/ACM Transactions on Networking* ,2009 **Statistics; Probability, Inference, and Decision** William Lee Hays,Robert L. Winkler,1970 **Journal of the Royal Statistical Society** Royal Statistical Society (Great Britain),1962 **Notes on the Theory of Statistical Inference** Allan Birnbaum,1960 *Advances in Design Automation, 1988* S. S. Rao,1988 *Proceedings of the Tenth Industrial Waste Conference, May 9, 10 and 11, 1955* ,1956 **Statistics Catalog 2005** Neil Thomson,2004-09 **Experimental Design and Statistics** Steve Miller,Stephen Henry Miller,1984 The distinguishing feature of experimental psychology is not so much the nature of its theories as the methods used to test their validity The first edition of *Experimental Design and Statistics* provided a clear and lucid introduction to these methods and the statistical techniques which support them For this new edition the text has been revised the coverage of two sample tests has been extended and new sections have been added introducing one sample tests linear regression and the product moment correlation coefficient Problems associated with the applications of experimental design and how to use observations of behaviour in research are key questions for all introductory students of psychology **On the Evaluation of Social Action Programs by Theory Testing** Jonathan Shapiro,1980 **General Catalog - Texas Tech University** Texas Tech University,1971

The book delves into Problems In Experimental Design And Inference. Problems In Experimental Design And Inference is an essential topic that needs to be grasped by everyone, from students and scholars to the general public. This book will furnish comprehensive and in-depth insights into Problems In Experimental Design And Inference, encompassing both the fundamentals and more intricate discussions.

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## **Table of Contents Problems In Experimental Design And Inference**

1. Understanding the eBook Problems In Experimental Design And Inference
  - The Rise of Digital Reading Problems In Experimental Design And Inference
  - Advantages of eBooks Over Traditional Books
2. Identifying Problems In Experimental Design And Inference
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Problems In Experimental Design And Inference
  - User-Friendly Interface
4. Exploring eBook Recommendations from Problems In Experimental Design And Inference
  - Personalized Recommendations
  - Problems In Experimental Design And Inference User Reviews and Ratings
  - Problems In Experimental Design And Inference and Bestseller Lists
5. Accessing Problems In Experimental Design And Inference Free and Paid eBooks
  - Problems In Experimental Design And Inference Public Domain eBooks
  - Problems In Experimental Design And Inference eBook Subscription Services
  - Problems In Experimental Design And Inference Budget-Friendly Options
6. Navigating Problems In Experimental Design And Inference eBook Formats
  - ePub, PDF, MOBI, and More
  - Problems In Experimental Design And Inference Compatibility with Devices
  - Problems In Experimental Design And Inference Enhanced eBook Features
7. Enhancing Your Reading Experience

- Adjustable Fonts and Text Sizes of Problems In Experimental Design And Inference
  - Highlighting and Note-Taking Problems In Experimental Design And Inference
  - Interactive Elements Problems In Experimental Design And Inference
8. Staying Engaged with Problems In Experimental Design And Inference
    - Joining Online Reading Communities
    - Participating in Virtual Book Clubs
    - Following Authors and Publishers Problems In Experimental Design And Inference
  9. Balancing eBooks and Physical Books Problems In Experimental Design And Inference
    - Benefits of a Digital Library
    - Creating a Diverse Reading Collection Problems In Experimental Design And Inference
  10. Overcoming Reading Challenges
    - Dealing with Digital Eye Strain
    - Minimizing Distractions
    - Managing Screen Time
  11. Cultivating a Reading Routine Problems In Experimental Design And Inference
    - Setting Reading Goals Problems In Experimental Design And Inference
    - Carving Out Dedicated Reading Time
  12. Sourcing Reliable Information of Problems In Experimental Design And Inference
    - Fact-Checking eBook Content of Problems In Experimental Design And Inference
    - Distinguishing Credible Sources
  13. Promoting Lifelong Learning
    - Utilizing eBooks for Skill Development
    - Exploring Educational eBooks
  14. Embracing eBook Trends
    - Integration of Multimedia Elements
    - Interactive and Gamified eBooks

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