

STAT 490 — Experimental Design

Fall 2016

Credit Hours: 3

Lectures: Tuesday & Thursday / 10:30 - 11:45 AM / REC 114

Professor: Arman Sabbaghi, PhD

Office: MATH 204

Office Hours: M 4:00 - 5:00 PM, T Th, 1:30 - 3:30 PM, W 3:00 - 5:00 PM

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Course website: Blackboard ([mycourses.purdue.edu](#))

Required Textbooks: Imbens G.W., Rubin D.B. (2015). *Causal Inference for Statistics, Social, and Biomedical Sciences*. Cambridge University Press. ISBN 978-0-521-88588-1.

Wu C.F.J., Hamada M.S. (2009). *Experiments: Planning, Analysis, and Optimization (2nd ed.)*. Wiley Series in Probability and Statistics. ISBN 978-0-471-69946-0.

Course Description: Experimental design is a fundamental component of any investigation on the causal effects of treatment factors on a response. Statistics 490 will provide a unique treatment of the design and analysis of experiments based on the modern Rubin Causal Model, and the classical contributions of Sir Ronald Aylmer Fisher and Jerzy Neyman. This distinct perspective forms the foundation for conventional inferential techniques, and more importantly, can be effectively applied to address complex real-life problems that are not amenable to standard techniques. Topics include: randomization inference, completely randomized and randomized block designs, Latin square designs and the Neyman-Fisher controversy of 1935, rerandomization, factorial and fractional factorial designs, and the analysis of experiments with noncompliance. Specific topics and the course outline are subject to change as the semester progresses. All topics will be motivated by real-life problems from the physical, life, social, and management sciences, as well as engineering. Conceptual understanding, not memorization or theoretical derivations, is required and emphasized throughout the course.

Course/Learning Objectives:

- Acquire fluency in the principles and techniques of experimental design.
- Apply experimental design techniques to solve real-life causal inference problems.
- Utilize R for statistical computation, visualization, and analysis of experiments.
 - R is freely available for download [here](#). Free manuals are available [here](#).
 - Assistance for R is available at the help desk in MATH G175.
- Discuss what is learned in lecture and assignments through oral and written presentations.

Prerequisite: At least one introductory statistics course, such as STAT 301, 350, or 511, or permission of the instructor. Upper-division undergraduate statistics courses, in particular STAT 416 or STAT 417, are strongly recommended.

Course Outline:

- **Week 1:** Introduction to designed experiments, the Rubin Causal Model, assignment mechanisms, and R (Chapters 1 – 3 of IR, Chapter 1 of WH).
 - **Lecture 1 (8-23-2016):** Overview of the powerful role of designed experiments, and causal inference under the potential outcomes framework.
 - **Handout (Due 8-25-2016):** Background survey.
 - **Lecture 2 (8-25-2016):** The potential outcomes framework and assignment mechanisms. Bernouilli trials. Random sampling of treatment assignment vectors via R.
 - **Homework 1 (Due 9-1-2016):** Problems based on Chapters 1 – 3 in IR.
- **Week 2:** Completely randomized designs for one treatment factor with two levels (Chapters 4 – 6 of IR, Chapter 2 of WH).
 - **Lecture 3 (8-30-2016):** Introduction to completely randomized designs and the Fisherian approach for hypothesis testing in experiments. Implementation via R.
 - **Lecture 4 (9-1-2016):** The Neymanian repeated sampling approach for the analysis of experiments. Implementation via R.
 - **Homework 2 (Due 9-8-2016):** Problems based on Chapters 4 – 6 in IR, Chapter 2 of WH.
- **Week 3:** Completely randomized designs for one treatment factor with more than two levels (Chapter 2 of WH).
 - **Lecture 5 (9-6-2016):** ANOVA and its geometric interpretation as an orthogonal decomposition of variability for potential outcomes. Inference via the Fisherian and Neymanian approaches.
 - **Lecture 6 (9-8-2016):** Contrasts of potential outcomes, and their relation to ANOVA.
 - **Homework 3 (Due 9-15-2016):** Problems based on Chapter 2 of WH.
- **Week 4:** Randomized block and paired comparison designs (Chapters 9 – 10 of IR, Chapter 3 of WH).
 - **Lecture 7 (9-13-2016):** Randomized complete block design for one treatment factor with more than two levels.
 - **Lecture 8 (9-15-2016):** Randomized block designs, and paired comparison designs for one treatment factor with two levels.
 - **Homework 4 (Due 9-22-2016):** Problems based on Chapters 9 – 10 in IR, Chapter 3 of WH.
- **Week 5:** Two dilemmas in design (Chapter 3 of WH)
 - **Lecture 9 (9-20-2016):** Latin square designs and the Neyman-Fisher controversy of 1935.
 - **Lecture 10 (9-22-2016):** [Rerandomization to improve covariate balance in randomized experiments](#).
 - **Project Description: Due 9-29-2016.**
- **Week 6:** Midterm I.
 - **Review Lecture (9-27-2016):** Review of Lectures 1 - 10.

- **Midterm I (9-29-2016, in class)**: Fisherian and Neymanian inference, ANOVA, completely randomized designs, randomized complete block designs, randomized block designs.
- **Week 7:** Introduction to 2^2 factorial experiments (Chapter 4 in WH).
 - **Lecture 11 (10-4-2016)**: The Science of the 2^2 factorial design.
 - **Lecture 12 (10-6-2016)**: Inference for factorial effects in the 2^2 factorial design.
 - **Homework 5 (Due 10-13-2016)**: Problems based on Chapter 4 in WH.
- **Week 8:** 2^K factorial experiments (Chapter 4 in WH).
 - **October Break (10-11-2016)**: No class.
 - **Lecture 13 (10-13-2016)**: An introduction to the 2^K full factorial design.
 - **Homework 6 (Due 10-20-2016)**: Problems based on Chapter 4 in WH.
- **Week 9:** 2^K factorial experiments (Chapter 4 in WH).
 - **Lecture 14 (10-18-2016)**: Screening for active effects in the 2^K full factorial design.
 - **Lecture 15 (10-20-2016)**: Blocking the 2^K full factorial design.
 - **Homework 7 (Due 10-27-2016)**: Problems based on Chapter 4 in WH.
- **Week 10:** Two-level fractional factorial experiments (Chapter 5 in WH).
 - **Lecture 16 (10-25-2016)**: The 2^{K-1} fractional factorial design.
 - **Lecture 17 (10-27-2016)**: Effect aliasing in the 2^{K-P} design.
 - **Homework 8 (Due 11-3-2016)**: Problems based on Chapter 5 in WH.
- **Week 11:** Foldovers, resolution, and aberration (Chapter 5 in WH).
 - **Lecture 18 (11-1-2016)**: Foldovers of fractional factorials.
 - **Lecture 19 (11-3-2016)**: Maximum resolution and minimum aberration designs.
 - **Homework 9 (Due 11-10-2016)**: Problems based on Chapter 5 in WH.
 - **Project Progress Report: Due 11-10-2016**.
- **Week 12:** Multi-armed bandit experiments.
 - **Lecture 20 (11-8-2016)**: [Multi-armed bandit experiments in the online service economy](#).
 - **Lecture 21 (11-10-2016)**: Presentations on progress of projects and continuation of multi-armed bandit experiments.
- **Week 13:** Midterm II
 - **Review Lecture (11-15-2016)**: Review of Lectures 11 - 20.
 - **Midterm II (11-17-2016, in class)**: Design and analysis of experiments for two-level full and fractional factorial designs.
- **Week 14:** Another dilemma in design: non-compliance (Chapter 23 in IR).
 - **Lecture 22 (11-22-2016)**: Instrumental variables analysis of randomized experiments with one-sided noncompliance.
 - **Thanksgiving Break (11-24-2016)**: No class.
 - **Homework 10 (Due 12-2-2016)**: Problems based on Chapter 23 in IR.

- **Week 15:** Project presentations
 - **Lecture 23 (11-29-2016):** Analysis of randomized experiments with two-sided noncompliance.
 - **Lecture 24 (12-1-2016):** Project presentations.
- **Week 16:** Review for Final Exam
- **Week 17:** Final Exam

Course Work and Requirements:

Percentage of Grade	
Homework	15%
Group Project	20%
Midterm I	15%
Midterm II	15%
Final Exam	35%

- *Homework* will generally be posted on a Thursday, and due the following Thursday (**before lecture begins**). There will be 10 homework assignments accounting for 15% of your course grade. No late homework will be accepted. The lowest homework score will be dropped.
- *Group projects* will be due at the end of the semester. Specific details on the project will be given in a separate handout.
- The two *midterms* will be written exams during the regular class period, and each will account for 15% of the course grade. There will be no retaking of exams. On the rare occasion when a student is sick for an exam, or other extenuating circumstances, the student *must* contact Professor Sabbaghi *before* the exam begins, or accept a zero as the grade for that test.
- The *final exam* will constitute 35% of the course grade. Please do not make plans to leave campus before the scheduled final.
- Exams are based primarily on lecture and designated reading material. You are responsible for what is discussed in class. All midterms are closed book and closed notes. While exam questions vary in difficulty, the answers are generally quite brief given time constraints on the exams.

Course Policies

Addressing Questions via E-mail: Please feel free to e-mail questions to the instructor, but reserve those that involve extensive computation or mathematical expressions for office hours.

Incompletes: Incompletes will only be given under emergency circumstances, e.g., a serious auto accident, death of family member, etc. (see the grief absence policy for further information). Incompletes will not be given to students failing the course.

Grading: The grading scale is predetermined so as to eliminate competition with other students, and to ensure that you always know your grade in the class. Your grade is based upon *your* performance only. Grades will not be curved.

Grade	Numerical range
A	90.00-100.00
B	80.00-89.99
C	70.00-79.99
D	60.00-69.99
F	0.00-59.99

Evaluation: Student feedback is essential for any course to be successful. Feedback questionnaires will be included in each week's assignment. These evaluations should be taken seriously, and will be addressed directly by the instructor.

Re-grading: All grade disputes are to be made on paper, and submitted *directly* to Professor Sabbaghi. Discussions or arguments for re-grades will *not* be done in person. A student has until one week after receiving his/her grade to dispute the grade (in writing). Handling re-grades in this manner eliminates the “end of the semester” digging for points.

When disputing a grade, you should state the question, the dispute, and the number of points you feel you should have received for the question. If you do not state the number of points you think are reasonable for the re-grade, zero points will be give as the re-grade. Please note that when you ask for a question to be re-graded, the entire assignment may be re-graded, and there is a possibility of losing points.

Dropping the Course: I reserve the right to *not* sign anyone out of the course once the deadline for dropping without the instructors signature has passed. Please take care to pay attention to these dates.

Attendance and Participation: Students: You are expected to attend lectures. You are expected to arrive on time, or before. You are expected to stay until the end of lecture unless you have asked in advance to leave early. You are expected to be prepared and participate. On the rare occasion that a student is extremely close to the cut-off value between letter grades, attendance and class participation may help.

When conflicts or absences can be anticipated, such as for many University sponsored activities and religious observations, you should inform the instructor of the situation as far in advance as possible. For unanticipated or emergency absences when advance notification is not possible, you should contact the instructor as soon as possible by e-mail, or the Department of Statistics main office. When you are unable to make direct contact with the instructor and unable to leave word with the Department of Statistics because of circumstances beyond your control, and in cases of bereavement, you or your representative should contact the Office of the Dean of Students. Links to the complete attendance policy and implications can be found at www.purdue.edu/odos/sac/attendance-and-absence/ and www.purdue.edu/studentregulations/regulations_procedures/classes.html.

Professor: You can expect that I will attend lectures. I will arrive in the lecture room prior to the start of lecture, and will end lecture on time. You can expect that I will be prepared for lecture, try my best to convey the information for the course, and show respect for all students.

If I am unable to attend lecture you will know in advance, and I will either cancel class or provide a guest instructor. I will be present for my office hours, and available for scheduled appointments.

The amount of material covered in each lecture is governed by the speed with which we complete the material. Every group of students is different, and I would rather teach the material well (and have you learn it) than speed through the topics for the purpose of covering a preset number of topics. Accordingly, the course outline is subject to change as the course progresses.

Grief Absence Policy for Students: Purdue University recognizes that a time of bereavement is very difficult for a student. The University therefore provides the following rights to students facing the loss of a family member through the Grief Absence Policy for Students (GAPS). Students will be excused for funeral leave and given the opportunity to earn equivalent credit and to demonstrate evidence of meeting the learning outcomes for missed assignments or assessments in the event of the death of a member of the student's family.

University Emergency Information: A safety briefing will be conducted on the first day of class. In the event of a major campus emergency or temporary suspension of classes, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. You can get information about changes in this course by means of the course web page, or contacting the instructor via e-mail or phone. You are expected to read your Purdue e-mail on a frequent basis.

Violent Behavior Policy: Purdue University is committed to providing a safe and secure campus environment for members of the university community. Purdue strives to create an educational environment for students and a work environment for employees that promote educational and career goals. Violent behavior impedes such goals. Therefore, violent behavior is prohibited in or on any University Facility or while participating in any university activity. See the following website for more details: www.purdue.edu/policies/pages/facilities_lands/i_2_3.shtml.

Academic Dishonesty: Purdue prohibits "dishonesty in connection with any University activity. Cheating, plagiarism, or knowingly furnishing false information to the University are examples of dishonesty." [Part 5, Section III-B-2-a, University Regulations] Furthermore, the University Senate has stipulated that "the commitment of acts of cheating, lying, and deceit in any of their diverse forms (such as the use of substitutes for taking examinations, the use of illegal cribs, plagiarism, and copying during examinations) is dishonest and must not be tolerated. Moreover, knowingly to aid and abet, directly or indirectly, other parties in committing dishonest acts is in itself dishonest." [University Senate Document 72-18, December 15, 1972]. **Use of instructor solution manuals or related resources will not be tolerated, and may result in an automatic failure in the course.** For more information, please refer to Purdue's student guide for academic integrity (www.purdue.edu/odos/osrr/academic-integrity-brochure). **Instances of cheating will be reported to the Office of Student Rights and Responsibilities (www.purdue.edu/odos/osrr/report-an-incident), and may result in an automatic failure in the course.** Bonus points will be given to students who report instances of cheating.

Use of Copyrighted Materials: Among the materials that may be protected by copyright law are the lectures, notes, and other material presented in class or as part of the course. Always assume the materials presented by an instructor are protected by

copyright unless the instructor has stated otherwise. Students enrolled in, and authorized visitors to, Purdue University courses are permitted to take notes, which they may use for individual/group study or for other non-commercial purposes reasonably arising from enrollment in the course or the University generally.

Notes taken in class are, however, generally considered to be “derivative works” of the instructor’s presentations and materials, and they are thus subject to the instructor’s copyright in such presentations and materials. No individual is permitted to sell or otherwise barter notes, either to other students or to any commercial concern, for a course without the express written permission of the course instructor. To obtain permission to sell or barter notes, the individual wishing to sell or barter the notes must be registered in the course or must be an approved visitor to the class. Course instructors may choose to grant or not grant such permission at their own discretion, and may require a review of the notes prior to their being sold or bartered. If they do grant such permission, they may revoke it at any time, if they so choose.

Students with Disabilities: Purdue University is required to respond to the needs of the students with disabilities as outlined in both the Rehabilitation Act of 1973 and the Americans with Disabilities Act of 1990 through the provision of auxiliary aids and services that allow a student with a disability to fully access and participate in the programs, services, and activities at Purdue University.

If you have a disability that requires special academic accommodation, please make an appointment to speak with the instructor within the first three (3) weeks of the semester in order to discuss any adjustments. It is important to talk about this at the beginning of the semester. It is the student’s responsibility to notify the Disability Resource Center (<http://www.purdue.edu/drc>) of an impairment/condition that may require accommodations and/or classroom modifications.

Nondiscrimination: Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life.

Purdue University prohibits discrimination against any member of the University community on the basis of race, religion, color, sex, age, national origin or ancestry, genetic information, marital status, parental status, sexual orientation, gender identity and expression, disability, or status as a veteran. The University will conduct its programs, services and activities consistent with applicable federal, state and local laws, regulations and orders and in conformance with the procedures and limitations as set forth in Executive Memorandum No. D-1, which provides specific contractual rights and remedies. Any student who believes they have been discriminated against may visit www.purdue.edu/report-hate to submit a complaint to the Office of Institutional Equity. Information may be reported anonymously.