## Course Mechanics


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| Course Website: | http://www.mayowilson.org/Statistics.htm |


## Course Description

Although statistical techniques are employed in virtually every scientific discipline, there are still several unresolved debates concerning the foundations of statistics. For example, there is considerable disagreement about the value of random sampling and whether the rule for terminating an experiment ought to affect the interpretation of its results. This course is an introduction to these issues and others concerning proper experimental design and norms for statistical/inductive inference. We will focus on the differences between the so-called "frequentist" and "Bayesian" paradigms and the arguments offered in favor of each.

Because philosophical discussions of statistical techniques often presuppose a particular interpretation of probability, we will begin by reviewing two common interpretations of probability: subjective and propensity. For the remainder of the semester, we will discuss a number of issues that concern the debate between so-called Bayesians and Frequentists. Topics will include the likelihood principle, exchangeability, Bayesian convergence theorems, the value of randomization in experimental design, and stopping rules.

## Course Goals

The course has two central goals. Namely, by the end of the semester, students should be able to (1) describe the differences between frequentist and Bayesian methods, and (2) evaluate the arguments offered in favor of (and against) each. By acquiring these two skills, students should be better able to evaluate the strength of various everyday inductive arguments (e.g., those appearing in newspapers) and rudimentary (but common) statistical arguments appearing in scientific journals.

## Requirements

Philosophical thinking is a skill, not unlike playing the piano, riding a bike, or dancing. Learning a new skill requires practice, and the best way to practice philosophical thinking is to write and engage in spirited (but polite) debates with other philosophers. Thus, the central requirement of this course is to write three short papers (between five and seven

pages in length) in which you summarize an argument from the readings and defend it from potential objections. More details about the topics of the three papers can be found on the course website.

Additionally, before four of the fourteen classes, you must write a one-page summary of the assigned readings. Please bring both the assigned readings and your summaries with you to class. Some students view frequent assignments/assessments as "busy work" or as an instructor's attempt to gauge which students are working hardest. That is is not my intention at all. The philosophy of statistics is a complex subject, and consequently, many of the assigned readings are somewhat difficult. When faced with hard-to-understand texts, it is easy to become discouraged and to give up. One of my central duties, as an instructor, is to ensure that you do not give up when concepts and/or arguments are initially difficult to understand. The purpose of the one-page summaries is threefold: (i) to force you to read the assigned texts closely and actively, (ii) to prepare you for class discussions in which we will clarify and build upon the readings, and (iii) to provide *me* with feedback about which concepts are most difficult for students to understand.

Finally, one cannot study the philosophy of statistics without knowing a bit about its mathematics. Unfortunately, I cannot teach you statistics and philosophy at the same time, and so if you have not studied elementary statistics recently (or at all), I ask that you to review a bit of basic probability theory and statistics during the course of the semester. I will spend only one class reviewing concepts from a first semester statistics class. On the reading schedule below, I have recommended sections of an introductory statistics book (Larry Wasserman's *All of Statistics*) that discusses topics with which you should be familiar. These readings are not required, but I will presume knowledge of basic probability theory and elementary classical statistics after a few weeks. In particular, by the end of the first unit, you should able to define basic terms of probability theory (e.g., random variable, conditional probability, independence, expectation, etc.) and to employ these concepts in (very) short calculations and proofs. Discussions during the second and third units of the course will assume that you can define the following terms from elementary (frequentist) statistics: p-value, confidence interval, power, and consistency. Because many students are not introduced to Bayesian methods in introductory statistics courses, I assume no knowledge of such methods for this course.

## Grading

Your final grade will be calculated via a weighted average using the following weights:

- Papers 1 and 2 (about 5-7 pages): Each is worth 25 %
- Paper 3 (about 5-7 pages): 30%
- Four one-age Summaries: Each is worth 5%.

Percentages will be translated into grades as follows: 95 % or higher = 1,0; $90 - 94\%$ = 1,3; $85 - 90\%$ = 1,7; $80 - 85\%$ = 2,0; and so on.

## Reading Schedule

### Interpretations of Probability

8/4 - Criteria for Interpretations of Probability and Kolmogorov's Axioms
*Recommended Readings:*

- Introduction and Sections 1 and 2 of Alan Hajek. Interpretations of probability, 2003. URL `http://plato.stanford.edu/entries/probability-interpret/`.
- Chapter 1 of Rudolf Carnap. *Logical Foundations of Probability*. University of Chicago Press, second edition, 1962.
- Chapter 3. Pages 51-70 of Patrick Suppes. *Representation and Invariance of Scientific Structures*. CSLI Publications Stanford, 2002.

15/4 - Subjective Probability: Dutch Books, Comparative Probability, de Finetti's Theory of Previsions (both pragmatic and epistemic interpretations)
*Required Readings:*

- Section 1.1 of Joseph B. Kadane. *Principles of uncertainty*, volume 92. Chapman & Hall, 2011.
- Pages 97-104 of Bruno De Finetti. Foresight: its logical laws in subjective sources. In H.E. Kyburg and H.E. Smokler, editors, *Studies in Subjective Probability*. 1937.
- J.M. Joyce. A nonpragmatic vindication of probabilism. *Philosophy of Science*, 65 (4):575–603, 1998.
- Pages 1-26 of L. J. Savage. *The foundation of statistics*. Dover publications, 1972.

*Recommended/Optional:*

- Peter C. Fishburn. The axioms of subjective probability. *Statistical Science*, 1(3): 335–358, 1986. URL `http://projecteuclid.org/euclid.ss/1177013611`.
- Chapters 3 - 3.7, 4, and 5.0 – 5.9 (inclusive) of Dennis V. Lindley. *Understanding uncertainty*. Wiley-Interscience, 2006.
- Chapter 2. Section "Why Proper Scoring Rules are Proper." of Bruno De Finetti and Alberto Mario Mura. *Philosophical lectures on probability*, volume 340. Springer Science+ Business Media, 2008.

*Mathematical Background:* Chapter 1 of Larry Wasserman. *All of statistics: a concise course in statistical inference*. Springer, 2004.

22/4 - No Class

29/4 - Subjective Probability: Representation Theorems of Savage, Von Neumann and Morgenstern, and Anscombe and Aumann
*Required Readings:*

- Pages 27-40 of Savage [1972].
- Chapter 3 of John Von Neumann and Oskar Morgenstern. *Theory of Games and Economic Behavior*. Princeton University Press, third edition, 1953.
- Francis J. Anscombe and Robert J. Aumann. A definition of subjective probability. *Annals of mathematical statistics*, 34(1):199–205, March 1963.

*Mathematical Background:* Wasserman. Chapters 2 and 3-3.5

6/5 - Arguments for Conditionalization: Dynamic Dutch Books and Savage's Theorem
**First summary due.**
*Required Readings:*

- Sections 1, 2, 5.1, and 6 of Brian Skyrms. Dynamic coherence and probability kinematics. *Philosophy of Science*, 54(1):1–20, 1987.
- Pages 193-204 (you may stop at the word "untenable") of Isaac Levi. The demons of decision. *The Monist*, 70(2):193–211, 1987.
- Pages 43-44 of Savage [1972].

13/5 - The Propensity Interpretation
**Second summary Due.**
*Required Readings:*

- Chapter 5. Section 6. Pages. 202-225 of Patrick Suppes. *Representation and Invariance of Scientific Structures*. CSLI Publications Stanford, 2002.
- Michael Strevens. Inferring probabilities from symmetries. *Nous*, 32(2):231–246, June 1998.
- Jan Von Plato. The method of arbitrary functions. *British Journal for the Philosophy of Science*, 34(1):37–47, March 1983.

*Recommended*: Sections 6.1, 6.2, & 6.4 of Jan Von Plato. *Creating modern probability: Its mathematics, physics and philosophy in historical perspective*. Cambridge University Press, 1998.
*Mathematical Background:* Wasserman. Chapters 5.

## Frequentist Methodology

20/5 - Bayesian and Frequentist Methodology

- Chapter 6 and Sections 10.1-10.2 of Larry Wasserman. *All of statistics: a concise course in statistical inference*. Springer, 2004.
- Sections 6-6.4 of Morris H. DeGroot. *Probability and Statistics*. Addison-Wesley, second edition, January 1986.

27/5 - Criticisms of Frequentist Methodology
**First Paper Due**.
*Required Readings:*

- Steven N. Goodman. Toward evidence-based medical statistics. 1: The p value fallacy. *Annals of internal medicine*, 130(12):995–1004, June 1999.
- Chapter 5 of Colin Howson and Peter Urbach. *Scientific reasoning: the Bayesian approach*. Open Court, Chicago, 2005.

3/6 - More Criticisms of Frequentist Methodology
*Required Readings:*

- Chapter 2 of James Orvis Berger and Robert L. Wolpert. The likelihood principle. In *Ims Lecture Notes-Monograph*, volume 6. Institute of Mathematical Statistics, 1988.
- Allan Birnbaum. On the foundations of statistical inference. *Journal of the American Statistical Association*, 57(298):269–306, 1962.

10/6 - No Class

17/6 - Frequentism Defended
**Third Summary Due.**
*Required Readings:*

- Sections 1 and 2. Pages 153-183 of D. Mayo and Aris Spanos. Error statistics. In M. Forster and Prasanta S Bandyopadhyay, editors, *Philosophy of statistics*, number 7 in Handbook of the Philosophy of Science, pages 153—198. 2011.

## Bayesian Methodology

24/6 - Bayesian Inference
*Required Readings:* Jose M. Bernardo. Modern bayesian inference: Foundations and objective methods. In M. Forster and Prasanta S Bandyopadhyay, editors, *Philosophy of Statistics*, number 7 in Handbook of the Philosophy of Science, pages 263—306. 2011.

*Important Note:* Much of what Bernardo says about "reference priors" is highly controversial, even among Bayesians.
*Recommended:*

- Chapter 15 of Savage [1972].
- Chapter 5, Pages 88-90 of Colin Howson and Peter Urbach. *Scientific reasoning: the Bayesian approach*. Open Court, Chicago, 2005.
- Sections 1 and 2 of Sandy L. Zabell. Symmetry and its discontents. In *Causation, chance and credence*, pages 155–190. Springer, 1988.

1/7: Randomization
**Second Paper Due.**
*Required Readings:*

- Chapter 2 of R. A. Fisher. *The design of experiments*, volume xi. Oliver & Boyd, Oxford, England, 1935.
- Joseph B. Kadane and Teddy Seidenfeld. Randomization in a bayesian perspective. *Journal of statistical planning and inference*, 25(3):329–345, 1990.

8/7: Stopping Rules
**Fourth Summary Due.**
*Required Readings:*

- Pages 183-193 of D. Mayo and Aris Spanos. Error statistics. In M. Forster and Prasanta S Bandyopadhyay, editors, *Philosophy of statistics*, number 7 in Handbook of the Philosophy of Science, pages 153—198. 2011.
- Joseph B. Kadane, Mark J. Schervish, and Teddy Seidenfeld. When several bayesians agree that there will be no reasoning to a foregone conclusion. *Philosophy of Science*, pages S281–S289, 1996.

29/7: **Final Paper Due.**

## References


Francis J. Anscombe and Robert J. Aumann. A definition of subjective probability. *Annals of mathematical statistics*, 34(1):199–205, March 1963.

James Orvis Berger and Robert L. Wolpert. The likelihood principle. In *Ims Lecture Notes-Monograph*, volume 6. Institute of Mathematical Statistics, 1988.

Jose M. Bernardo. Modern bayesian inference: Foundations and objective methods. In M. Forster and Prasanta S Bandyopadhyay, editors, *Philosophy of Statistics*, number 7 in Handbook of the Philosophy of Science, pages 263—306. 2011.

Allan Birnbaum. On the foundations of statistical inference. *Journal of the American Statistical Association*, 57(298):269–306, 1962.

Rudolf Carnap. *Logical Foundations of Probability*. University of Chicago Press, second edition, 1962.

Bruno De Finetti. Foresight: its logical laws in subjective sources. In H.E. Kyburg and H.E. Smokler, editors, *Studies in Subjective Probability*. 1937.

Bruno De Finetti and Alberto Mario Mura. *Philosophical lectures on probability*, volume 340. Springer Science+ Business Media, 2008.

Morris H. DeGroot. *Probability and Statistics*. Addison-Wesley, second edition, January 1986.

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R. A. Fisher. *The design of experiments*, volume xi. Oliver & Boyd, Oxford, England, 1935.

Donald Gillies. Varieties of propensity. *The British journal for the philosophy of science*, 51(4):807–835, 2000.

Steven N. Goodman. Toward evidence-based medical statistics. 1: The p value fallacy. *Annals of internal medicine*, 130(12):995–1004, June 1999.

Alan Hajek. Interpretations of probability, 2003. URL `http://plato.stanford.edu/entries/probability-interpret/`.

Colin Howson and Peter Urbach. *Scientific reasoning: the Bayesian approach*. Open Court, Chicago, 2005.

J.M. Joyce. A nonpragmatic vindication of probabilism. *Philosophy of Science*, 65(4): 575–603, 1998.

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Joseph B. Kadane and Teddy Seidenfeld. Randomization in a bayesian perspective. *Journal of statistical planning and inference*, 25(3):329–345, 1990.

Joseph B. Kadane, Mark J. Schervish, and Teddy Seidenfeld. When several bayesians agree that there will be no reasoning to a foregone conclusion. *Philosophy of Science*, pages S281–S289, 1996.

Isaac Levi. The demons of decision. *The Monist*, 70(2):193–211, 1987.

Dennis V. Lindley. *Understanding uncertainty*. Wiley-Interscience, 2006.

D. Mayo and Aris Spanos. Error statistics. In M. Forster and Prasanta S Bandyopadhyay, editors, *Philosophy of statistics*, number 7 in Handbook of the Philosophy of Science, pages 153—198. 2011.

L. J. Savage. *The foundation of statistics*. Dover publications, 1972.

Brian Skyrms. Dynamic coherence and probability kinematics. *Philosophy of Science*, 54 (1):1–20, 1987.

Michael Strevens. Inferring probabilities from symmetries. *Nous*, 32(2):231–246, June 1998.

Patrick Suppes. *Representation and Invariance of Scientific Structures*. CSLI Publications Stanford, 2002.

John Von Neumann and Oskar Morgenstern. *Theory of Games and Economic Behavior*. Princeton University Press, third edition, 1953.

Jan Von Plato. The method of arbitrary functions. *British Journal for the Philosophy of Science*, 34(1):37–47, March 1983.

Jan Von Plato. *Creating modern probability: Its mathematics, physics and philosophy in historical perspective*. Cambridge University Press, 1998.

Larry Wasserman. *All of statistics: a concise course in statistical inference*. Springer, 2004.

Sandy L. Zabell. Symmetry and its discontents. In *Causation, chance and credence*, pages 155–190. Springer, 1988.