STAT 216 Coursepack

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Montana State University

Melinda Yager
Jade Schmidt
Stacey Hancock

Preface

Placeholder

MODULE 1

Basics of Data and Sampling Methods

Placeholder

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1.1.2 Vocabulary

1.2 Activity 1: Intro to Data

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1.2.2 Terminology review

1.2.3 General information on the Coursepack

1.2.4 Steps of the statistical investigation process

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1.2.6 Additional notes

1.3 Video Notes: Intro to data and Sampling Methods

1.3.1 Course Videos

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Relationships between variables

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2.1.2 Vocabulary

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Probability

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3.1.2.1 Simulation-based inference for a single proportion

3.2 Video Notes: Exploratory Data Analysis of Categorical Variables

3.2.1 Course Videos

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Hypothesis Testing/Justice System

Null hypothesis

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Simulation-based method

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Simulation-based method

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Simulation-based methods

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3.3.2 Terminology review

3.3.3 Steps of the statistical investigation process

3.3.4 Helper-Hinderer

Ask a research question

Design a study and collect data

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Placeholder

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4.2.2 Concept Check

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4.3.2 Terminology review

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4.4 Activity 10: Confidence interval and what confidence means

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MODULE 5

Unit 1 Review

The following module contains both a list of key topics covered in Unit 1 as well as Module Review Worksheets that will be covered in Weekly Review Sessions.

5.0.1 Key Topics

Review the key topics for Unit 1 prior to the first exams. All of these topics will be covered in Modules 1–4.

5.0.2 Module Review

The following worksheets review each of the modules. These worksheets will be completed during Melinda's Study Sessions each week. Solutions will be posted on D2L in the Unit 1 Review folder after the study sessions.

5.1 Key Topics Exam 1

Descriptive statistics and study design

Hypothesis testing

5.1.1 Confidence intervals

5.1.2 Probability

5.2 Module 1 Review - Sampling Methods

5.3 Module 2 Review - Probability

5.4 Module 3 Review - Simulation Methods for a Single Proportion

5.5 Module 4 Review - Theory-based Methods for a Single Proportion

MODULE 6

Exploring Quantitative Data: Exploratory Data Analysis and Hypothesis Testing for a Single Quantitative Variable

Placeholder

6.1 Vocabulary Review and Key Topics

6.1.1 Key topics

6.1.2 Vocabulary

Sample statistics for a single quantitative variable

Plotting one quantitative variable

Hypothesis testing for a single mean

Simulation-based hypothesis testing

Theory-based hypothesis testing

6.2 Video Notes: Exploratory Data Analysis and Hypothesis Testing of Quantitative Variables

6.2.1 Course Videos

Summarizing quantitative data - Videos 5.2to5.4 and 5.5to5.6

Types of plots

Four characteristics of plots for quantitative variables

Robust statistics - Video 5.7

6.2.2 Video notes single quantitative variable inference

Hypothesis testing

Simulation-based method

Theory-based method

t-distribution

6.2.3 Concept Check

6.3 Activity 11: Summarizing Quantitative Variables

6.3.1 Learning outcomes

6.3.2 Terminology review

6.3.3 The Integrated Postsecondary Education Data System (IPEDS)

Identifying variables in a data set

Summarizing quantitative variables

Displaying a single quantitative variable

Robust statistics

6.3.4 Take-home messages

6.3.5 Additional notes

6.4 Activity 12: Hypothesis Testing of a Single Quantitative Variable

6.4.1 Learning outcomes

6.4.2 Terminology review

6.4.3 College student sleep habits

MODULE 7

Confidence Intervals for a Single Quantitative Variable

Placeholder

7.1 Vocabulary Review and Key Topics

7.1.1 Key topics

Simulation-based confidence interval

Theory-based confidence interval

Vocabulary

7.2 Video Notes: Theory-based Inference for a single quantitative variable

7.2.1 Course Videos

7.2.2 Single quantitative variable

Confidence interval

Simulation-based method

Theory-based method

t-distribution

7.2.3 Concept Check

7.3 Activity 14: Danceability of Songs

7.3.1 Learning outcomes

7.3.2 Terminology review

7.3.3 Danceability

Summarizing quantitative variables

Simulation methods to create a confidence interval

Theory-based methods to create a confidence interval

7.3.4 Take-home messages

7.3.5 Additional notes

7.4 Activity 15: Errors and Power

7.4.1 Learning outcomes

7.4.2 Terminology review

7.4.3 College textbook cost

7.4.4 Take-home messages

7.4.5 Additional notes

7.5 Module 6 and 7 Lab: Arsenic

7.5.1 Learning outcomes

7.5.2 Arsenic

Use statistical inferential methods to draw inferences from the data

MODULE 8

Exploratory Data Analysis and Simulation-based Hypothesis Testing for Two Categorical Variables

Placeholder

8.1 Vocabulary Review and Key Topics

8.1.1 Key topics

8.1.2 Vocabulary

Sample statistics for two categorical variables

Plotting two categorical variables

Hypotheses

Simulation-based hypothesis testing for a difference in proportions

Study design

8.1.2.1 Scope of inference

8.2 Video Notes: Inference for Two Categorical Variables using Simulation-based Methods

8.2.1 Course Videos

Observational studies, experiments, and scope of inference: Video 2.2to2.4

Study design

Scope of Inference

Summarizing two categorical variables - Video 4.1_TwoProp

Plots for two categorical variables - Video 4.2_TwoProp

Simpson's paradox - Video 4.4

Two categorical variables - Video 15.1

Hypothesis Testing

Summary statistics and plot

Simulation-based method

Confidence interval - Video 15.2

Simulation-based method

Relative Risk - Video RelativeRisk

Relative risk in the news

Testing Relative Risk

8.2.2 Concept Check

8.3 Activity 16: Study Design

8.3.1 Learning outcomes

8.3.2 Terminology review

8.3.3 Atrial fibrillation

8.3.4 Scope of Inference

8.3.5 Take-home messages

8.3.6 Additional notes

MODULE 9

Theory-based Hypothesis Testing and Simulation-based and Theory-based Confidence Intervals for Two Categorical Variables:

Placeholder

9.1 Vocabulary Review and Key Topics

9.1.1 Key topics

9.1.2 Vocabulary

Theory-based inference

Simulation-based confidence interval

9.2 Video Notes: Theoretical Inference for Two Categorical Variables

9.2.1 Course Videos

Hypothesis testing using theory-based methods - Video 15.4TheoryTests

Confidence interval - Video 15.3TheoryIntervals

Theory-based method for a two categorical variables

9.2.2 Concept Check

9.3 Activity 19: Winter Sports Helmet Use and Head Injuries — Theory-based Methods

9.3.1 Learning outcomes

9.3.2 Terminology review

9.3.3 Winter sports helmet use and head injury

Hypothesis test

Use statistical analysis methods to draw inferences from the data

How would an increase in sample size impact the p-value of the test?

9.3.4 Take-home messages

9.3.5 Additional notes

9.4 Activity 20: Diabetes

9.4.1 Learning outcomes

9.4.2 Glycemic control in diabetic adolescents

Simulation methods

Theory-based Methods

9.4.3 Take-home messages

9.4.4 Additional notes

9.5 Module 8 and 9 Lab: Poisonous Mushrooms

9.5.1 Learning outcomes

9.5.2 Poisonous Mushrooms

MODULE 10

Unit 2 Review

The following section contains both a list of key topics covered in Unit 2 as well as Module Review Worksheets.

10.0.1 Key Topics

Review the key topics for Unit 2 to review prior to the exams. All of these topics will be covered in Modules 6–9.

10.0.2 Module Review

The following worksheets review each of the modules. These worksheets will be completed during Melinda's Study Sessions each week. Solutions will be posted on D2L in the Unit 2 Review folder after the study sessions.

10.1 Key Topics Exam 2

Descriptive statistics and study design

Hypothesis testing

Confidence interval

10.2 Module 6 Review - One Mean Testing

10.3 Module 7 Review - One Mean Confidence Interval

10.4 Module 8 - 9 Review - Inference for Two Categorical Variables

MODULE 11

Exploratory Data Analysis and Inference for a Quantitative Response with Paired Samples

Placeholder

11.1 Vocabulary Review and Key Topics

11.1.1 Key topics

11.1.2 Vocabulary

Simulation-based inference for a paired mean difference

Theory-based inference for a paired mean difference

11.2 Video Notes: Inference for Paired Data

11.2.1 Course Videos

Single categorical, single quantitative variables Video Paired_Data

Paired vs. Independent Samples

Hypothesis testing

Simulation-based method

Confidence interval

Simulation-based method

Theory-based method - Video 18.3

t-distribution

11.2.2 Concept Check

11.3 Activity 21: Paired vs. Independent Samples

11.3.1 Learning outcomes

11.3.2 Terminology review

11.3.3 Paired vs. Independent Samples

11.3.4 Tattoo Effect on Sweat Rate

11.3.5 Exploring Paired Data

11.3.6 Additional notes

11.4 Activity 22: Snakes

11.4.1 Learning outcomes

11.4.2 Terminology review

11.4.3 Snake mazes

Ask a research question

Use statistical inferential methods to draw inferences from the data

Hypothesis test

MODULE 12

Exploratory Data Analysis and Inference for a Quantitative Response with Independent Samples

Placeholder

12.1 Vocabulary Review and Key Topics

12.1.1 Key topics

12.1.2 Vocabulary

Plotting two categorical variables

Hypotheses

Simulation-based inference for a difference in means

Theory-based inference for a difference in means

12.2 Video Notes: Inference for Independent Samples

12.2.1 Course Videos

Single categorical, single quantitative variable with independent samples

Hypothesis Testing

Simulation-based method

Confidence interval

Simulation-based method - Video 19.2

Theory-based method - Video 19.3TheoryTests

Confidence Interval - Video 19.3TheoryIntervals

12.2.2 Concept Check

12.3 Activity 24: Does behavior impact performance?

12.3.1 Learning outcomes

12.3.2 Terminology review

12.3.3 Behavior and Performance

Quantitative variables review

Ask a research question

Numerically Summarize the data

Use statistical inferential methods to draw inferences from the data

Hypothesis test

Confidence interval

12.3.4 Take-home messages

12.3.5 Additional notes

12.4 Activity 25: Moon Phases and Virtual Reality

12.4.1 Learning outcomes

12.4.2 Terminology review

12.4.3 Moon Phases and Virtual Reality

Use statistical inferential methods to draw inferences from the data

12.4.4 Take-home messages

12.4.5 Additional notes

12.5 Module 12 Lab: Trustworthiness

12.5.1 Learning outcomes

12.5.2 Trustworthiness

Use statistical inferential methods to draw inferences from the data

MODULE 13

Exploratory Data Analysis and Inference for Two Quantitative Variables

Placeholder

13.1 Vocabulary Review and Key Topics

13.1.1 Key topics

13.1.2 Vocabulary

Plotting two quantitative variables

Sample statistics for two quantitative variables

Hypotheses

Simulation-based inference for two quantitative variables

Theory-based methods for two quantitative variables

13.2 Video Notes: Regression and Correlation

13.2.1 Course Videos

Summary measures and plots for two quantitative variables - Videos 6.1 - 6.3

Type of plot

Correlation

Slope

Coefficient of Determination

Multivariable plots - Video Chapter7

13.2.2 Concept Check

13.2.3 Video Notes: Inference for Two Quantitative Variables

Hypothesis Testing - Video 21.1

Simulation-based method

Confidence interval - Video 21.3

Simulation-based method

Theory-based method - Video 21.4to21.5TheoryTests

Theory-based method

13.2.4 Concept Check

13.3 Activity 26: Moneyball — Linear Regression

13.3.1 Learning outcomes

13.3.2 Terminology review

13.3.3 Moneyball

Vocabulary review

Slope

Residuals

Correlation

13.3.4 Take-home messages

13.3.5 Additional notes

Hypothesis test

Confidence interval

Communicate the results and answer the research question

Multivariable plots

13.6.4 Take-home messages

13.6.5 Additional notes

13.7 Module 13 Lab: Big Mac Index

13.7.1 Learning outcomes

13.7.2 Big Mac Index

Summarize and visualize the data

Conditions for the least squares line

Ask a research question

Use statistical inferential methods to draw inferences from the data

Hypothesis test

Simulation-based confidence interval

Communicate the results and answer the research question

MODULE 14

Unit 3 Review

The following section contains both a list of key topics covered in Unit 3 as well as Module Review Worksheets.

14.0.1 Key Topics

Review the key topics for Unit 3 to review prior to the exams. All of these topics will be covered in Modules 11–13.

14.0.2 Module Review

The following worksheets review each of the modules. These worksheets will be completed during Melinda's Study Sessions each week. Solutions will be posted on D2L in the Unit 3 Review folder after the study sessions.

14.1 Key Topics Exam 3

Descriptive statistics and study design

Hypothesis testing

Confidence interval

14.2 Module 11 Review - Paired Data

14.3 Module 12 Review - Independent Samples

14.4 Module 13 Review - Regression

MODULE 15

Semester Review

Placeholder

15.1 Group Final Exam Review

15.2 Golden Ticket to Descriptive and Inferential Statistical Methods

In this course, we have covered descriptive (summary statistics and plots) and inferential (hypothesis tests and confidence intervals) methods for five different scenarios:

- one categorical response variable
- two categorical variables
- one quantitative response variable or paired differences in a quantitative variable
- two quantitative variables
- one quantitative response variable and one categorical explanatory variable

The "golden ticket" shown on the next page presents a visual summary of the similarities and differences across these five scenarios.

Scenario	One Categorical Response	Two Categorical Variables	One Quantitative Response or Paired Differences	Quant. Response and Categ. Explanatory (independent samples)	Two Quantitative Variables
Type of plot	Bar plot	Segmented bar plot, Mosaic plot	Dotplot, histogram, boxplot	Side-by-side boxplots, Stacked dotplots or histograms	Scatterplot
Summary measure	Proportion	Difference in proportions	Mean or Mean difference	Difference in means	Slope or correlation
Parameter notation	π	$\pi_1 - \pi_2$	μ or μ_d	$\mu_1 - \mu_2$	β_1 or ρ
Statistic notation	$\hat{p}$	$\widehat{p_1} - \widehat{p_2}$	$\bar{x}$ or $\bar{x}_d$	$\bar{x}_1 - \bar{x}_2$	b_1 or r
Null hypothesis	$H_0: \pi = \pi_0$	$H_0: \pi_1 - \pi_2 = 0$	$H_0: \mu = \mu_0$ or $H_0: \mu_d = 0$	$H_0: \mu_1 - \mu_2 = 0$	$H_0: \beta_1 = 0$ or $H_0: \rho = 0$
Conditions for simulation-based methods	Independent cases	Independent cases (within and between groups)	Independent cases	Independent cases (within and between groups)	Independent cases; Linear form
Simulation test (how to generate a null distn) p-value = proportion of null simulations at or beyond (H_A direction) the observed statistic	Spin spinner with probability equal to π_0, n times or draw with replacement n times from a deck of cards created to reflect π_0 as probability of success. Plot the proportion of successes. Repeat 10000 times. Centered at π_0	Label cards with response values from original data; mix cards together; shuffle into two new groups of sizes n_1 and n_2. Plot difference in proportion of successes. Repeat 10000 times. Centered at 0.	Shift the original data by adding $(\mu_0 - \bar{x})$ or $(0 - \bar{x}_d)$. Sample with replacement from the shifted data n times. Plot sample mean or sample mean difference. Repeat 10000 times. Centered at μ_0 for a single quantitative response or 0 for paired data.	Label cards with response variable values from original data; mix cards together; shuffle into two new groups of sizes n_1 and n_2. Plot difference in means. Repeat 10000 times. Centered at 0.	Separate the (x,y) pairs. Hold the x values constant; shuffle new y's to x's. Find the regression line for shuffled data; plot the slope or the correlation for the shuffled data. Repeat 10000 times. Centered at 0.
Bootstrap CI (how to generate a boot. distn) X% CI: $(\frac{1-X}{2}\%tile,$ $\left(X + \frac{1-X}{2}\right)\%tile)$	Label n cards with the original responses. Randomly draw with replacement n times. Plot the resampled proportion of successes. Repeat 10000 times. Centered at $\hat{p}$.	Label n_1 cards with the original responses from group 1 and n_2 cards with the original responses from group 2. Keep groups separate. Randomly draw with replacement n_1 times from group 1 and n_2 times from group 2. Plot the resampled difference in proportion of successes. Repeat 10000 times. Centered at $\widehat{p_1} - \widehat{p_2}$	Label n cards with the original responses. Randomly draw with replacement n times. Plot the resampled mean difference. Repeat 10000 times. Centered at $\bar{x}$ for a single quantitative response or $\bar{x}_d$ for paired data.	Label n_1 cards with the original responses from group 1 and n_2 cards with the original responses from group 2. Keep groups separate. Randomly draw with replacement n_1 times from group 1 and n_2 times from group 2. Plot the resampled difference in means. Repeat 10000 times. Centered at $\bar{x}_1 - \bar{x}_2$.	Label n cards with the original (explanatory, response) pairs. Randomly draw with replacement n times. Plot the resampled slope or correlation. Repeat 10000 times. Centered at b_1 for slope or r for correlation.
Theory-based distribution	Standard Normal	Standard Normal	*t*- distribution with $n - 1$ df	*t*- distribution with min of $n_1 - 1$ or $n_2 - 1$ df	*t*- distribution with $n - 2$ df
Conditions for theory-based hypothesis tests and confidence intervals	Independent cases; Number of successes and number of failures in the sample both at least 10.	Independence (within and between groups); Number of successes and number of failures in EACH sample all at least 10. (All four cell counts at least 10.)	Independent cases; $n < 30$ with no clear outliers OR $30 \le n < 100$ with no extreme outliers OR $n \ge 100$	Independent cases (within and between groups); In each sample, $n < 30$ with no clear outliers OR $30 \le n < 100$ with no extreme outliers OR $n \ge 100$	Linear form; Independent cases; Nearly normal residuals; Variability around the regression line is roughly constant.
Theory-based standardized statistic (test statistic)	$Z = \frac{\hat{p} - \pi_0}{SE_0(\hat{p})}$ $SE_0(\hat{p}) = \sqrt{\frac{\pi_0 \times (1 - \pi_0)}{n}}$	$Z = \frac{\widehat{p_1} - \widehat{p_2} - 0}{SE_0(\widehat{p_1} - \widehat{p_2})}$ $SE_0(\widehat{p_1} - \widehat{p_2}) = \sqrt{\widehat{p_{pool}} \times (1 - \widehat{p_{pool}}) \times \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$	$T = \frac{\bar{x} - \mu_0}{SE(\bar{x})}$ OR $T = \frac{\bar{x}_d - 0}{SE(\bar{x}_d)}$ $SE(\bar{x}) = \frac{s}{\sqrt{n}}, SE(\bar{x}_d) = \frac{s_d}{\sqrt{n}}$	$T = \frac{\bar{x}_1 - \bar{x}_2 - 0}{SE(\bar{x}_1 - \bar{x}_2)}$ $SE(\bar{x}_1 - \bar{x}_2) = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$	$T = \frac{b_1 - 0}{SE(b_1)}$ $SE(b_1)$ is the reported standard error (std. error) of the slope term in the lm() output from R.
Theory-based confidence interval	$\hat{p} \pm z^* \times SE(\hat{p})$ $SE(\hat{p}) = \sqrt{\frac{\hat{p} \times (1 - \hat{p})}{n}}$	$\widehat{p_1} - \widehat{p_2} \pm z^* \times SE(\widehat{p_1} - \widehat{p_2})$ $SE(\widehat{p_1} - \widehat{p_2}) = \sqrt{\frac{\widehat{p_1} \times (1 - \widehat{p_1})}{n_1} + \frac{\widehat{p_2} \times (1 - \widehat{p_2})}{n_2}}$	$\bar{x} \pm t^* \times SE(\bar{x})$ $\bar{x}_d \pm t^* \times SE(\bar{x}_d)$ $SE(\bar{x}) = \frac{s}{\sqrt{n}}, SE(\bar{x}_d) = \frac{s_d}{\sqrt{n}}$	$\bar{x}_1 - \bar{x}_2 \pm t^* \times SE(\bar{x}_1 - \bar{x}_2)$ $SE(\bar{x}_1 - \bar{x}_2) = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$	$b_1 \pm t^* \times SE(b_1)$ $SE(b_1)$ is the reported standard error (std. error) of the slope term in the lm() output from R.

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