Vanguard University
School for Professional Studies
Degree Program

"INTRODUCTION TO STATISTICAL METHODS"
PSYD 265

Student Guide

7/10

REQUIRED TEXT

Gravetter, F. J., & Wallnau, L. B. (2011). *Essentials of statistics for the behavioral sciences* (7th ed.). Pacific Grove, CA: Brooks/Cole Publishing Company. ISBN-13 9780495812203

[Note: Solutions for odd-numbered end-of-chapter questions are provided in Appendix C.]

CATALOG DESCRIPTION

Introduction to Statistical Methods is a course in basic statistical concepts and methods of collecting, summarizing, presenting, and interpreting data in the behavioral sciences: including descriptive statistics (use of graphs and charts), normal distribution curve, measures of central tendency, deviation and dispersion, hypothesis testing, statistical fallacies, correlation and topics in probability. Students are advised to take Math 093 and Math 104 or Math 120 in preparation for this course.

COURSE DESCRIPTION

Introduction to Statistical Methods is a course in basic statistical concepts and methods of collecting, summarizing, presenting, and interpreting data in the behavioral sciences; including descriptive statistics (use of graphs and charts), normal distribution curve, measures of central tendency, deviation and dispersion, hypothesis testing, statistical fallacies, correlation, and topics in probability.

OVERVIEW

The purpose of this Course is to provide the student with an introductory survey of basic statistical concepts and methods of collecting, summarizing, presenting, and interpreting data in the social and behavioral sciences. Among the topics covered are graphing, measures of central tendency and variability, normal curve, hypothesis testing, correlation and regression, and topics in probability. The focus of the Course will be on a conceptual understanding of the topics covered, rather than a “cookbook” memorization of formulas. Computation of statistics using “definitional” formulas will assist in the development of a conceptual understanding of the topics.

WEB RESOURCES

In order to make use of the following Web sites, students will need Internet access. In addition, each student will need to have an e-mail address by which the instructor can contact the student throughout the weeks of the class. Any student who does not have Internet access and/or an e-mail address should notify the instructor the first week of the class in order to allow alternative arrangements to be explored.

Text "Companion Site"
http://www.thomsonedu.com/psychology/gravetter

Your ongoing use of the resources of the text "companion site" throughout the five weeks is strongly encouraged. To get to these resources, click on Student "Companion Sites" for your text, select the chapter you are studying, and select the resource you'd like to use.

VassarStats: Web Site for Statistical Computation
http://faculty.vassar.edu/lowry/VassarStats.html

VassarStats is a Web site that allows you to enter data and perform statistical calculations with a click of a button. It will enable you to check your work on assessment problems that require computation.

STUDENT LEARNING OUTCOMES

1. Knowledge Base in Psychology

- ***Understand the range of research strategies employed in psychology***
    - Students will be able to demonstrate, on weekly quizzes and assessments, an understanding of the different purposes of correlational and experimental research.

2. Research Methods in Psychology

- ***Understand and apply the principles of empirical research***
    - Students will understand the uses of basic descriptive statistical measures and will be able to calculate these measures of central tendency and variability on weekly quizzes and assessments.
    - Students will be able to use the normal curve to solve problems involving z-scores, probability, and the normal curve on weekly quizzes and assessments.
    - Students will understand the logic of hypothesis testing for one or more independent samples and will be able to conduct hypothesis tests on weekly quizzes and assessments.
    - Students will be able to calculate correlations on weekly quizzes and assessments and will understand the purposes and limitations of correlational data.
- ***Acquire skill in evaluating the research of others***
    - Students will be able to interpret statistical summary statements in published empirical research articles and will demonstrate their understanding on weekly quizzes and assessments.

3. Critical Thinking Skills in Psychology

- ***Think critically and evaluate evidence rationally***
    - Students will be able to critically evaluate appropriate and inappropriate uses of descriptive statistical measures and utilize this ability to solve problems on weekly assessments.

4. Communication Skills

- ***Acquire skill in written communication***
    - Students will be able to appropriately summarize and communicate the results of hypothesis testing on weekly assessments.

STUDENT EVALUATION

Percentages	Points	Grade	Significance	GPA
93-100%	930-1000	A	Exceptional	4.00
90-92.9%	900-929	A-		3.67
87-89.9%	870-899	B+		3.33
83-86.9%	830-869	B	Good	3.00
80-82.9%	800-829	B-		2.67
77-79.9%	770-799	C+		2.33
73-76.9%	730-769	C	Satisfactory	2.00
70-72.9%	700-729	C-		1.67
67-69.9%	670-699	D+		1.33
63-66.9%	630-669	D	Poor	1.00
60-62.9%	600-629	D-		0.67
00-59.9%	000-599	F	Failure	0.00

Students in this course will be evaluated by the university's 4.0 grading system. Grades will be assigned based on the points earned in the class as follows:

Classroom Attendance (40 pts per week, weeks 1–5):	200 points
Weekly In-Class Quizzes (25 pts per week, weeks 2-5):	100 points
Weekly Assessments (125 pts per week, weeks 2–5):	500 points
In-Class Exam (200 pts, week 5):	200 points
Total:	1000 points

Weekly Quizzes: Within the first hour of class on Weeks 2-5, a quiz covering material from the previous week will be given. The quizzes may include multiple-choice, true/false, fill-in-the-blank, and short-answer essay questions. To prepare for the weekly quizzes, students are encouraged to review class lecture material and use the text resources on the "Companion Site" (http://www.thomsonedu.com/psychology/gravetter).

Weekly Assessments: Learning assessments are due in class from Week 2 through Week 5. Assessments are to be typed, although handwritten responses to computational problems and graphs will be accepted. In your Assessment Word file, include each question followed by your answer. (You can "copy and paste" the Assessment questions from the PDF Student Guide file, using the "Text Select" tool; however, if you do this, please note that some symbols may not copy correctly. You should use the printed Student Guide for the official Assessment questions.)

Although the assessments are to be done individually, you are encouraged to study together to better learn the concepts and procedures. If you meet with other students to study together, please observe the following: for computational problems on your assessments, feel free to work through similar problems from the text. Solutions to odd-numbered end-of-chapter questions from *Essentials of Statistics for the Behavioral Sciences* are provided in Appendix C. The actual computational questions on the assessments are to be done individually.

Most of the conceptual questions on the assessments are addressed directly in the *Essentials of Statistics for the Behavioral Sciences* text. You are welcome (and even encouraged!) to “lift” answers directly from the texts, using quotation marks and APA reference style. For example, Question #3 on Assessment 1 asks, “Under what circumstances should you use a grouped frequency distribution rather than an ungrouped frequency distribution?” Your response could be as follows:

> “When a set of data covers a wide range of values, it is unreasonable to list all the individual scores in a frequency distribution table” (Gravetter & Wallnau, 2011, p. 39). In this circumstance, similar scores can be grouped together. For example, if we were summarizing the distribution of ages of VUSC students, we might identify the number of students between the ages of 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-60, 60-64, 65-69, etc. This would result in a more manageable number of age intervals and would better convey general information about the distribution of ages.

Exam: On Week 5, a 50-question objective (multiple-choice) exam worth 200 points will be given during the final two hours of class. All major topics covered in class will be represented on the exam. The exam will include both conceptual and computational questions. All formulas needed to answer the questions will be provided. Students will need to have a basic calculator (which includes a square root function), a No. 2 pencil, and the text (for access to tables). ScanTron forms will be provided.

LOGISTICS CHART

Hour	Week 1	Week 2	Week 3	Week 4	Week 5
1	Introductions And Student Expectations Overview of Course	Interpreting Scores: z Scores (ch. 5) Quiz 1	Intro to Hypothesis Testing (ch. 8) Quiz 2	Hypothesis Testing: Analysis of Variance (ch. 13) Quiz 3	Quiz 4 Review for Exam
2	Organizing Data: Frequency Distributions (ch 1,2)	Probability and the Normal Distribution (ch. 6)	Intro to the t Statistic (ch. 9)	Correlation and Regression (ch. 15)	
3	Describing Distributions: Shape and Central Tendency (ch. 3)	Probability and Samples (ch. 7)	Hypothesis Testing: Two Independent Samples (ch. 10)	The Chi-Square Statistic (ch. 16)	Exam
4	Describing Distributions: Variability (ch. 4)	Review and Practice	Review and Practice	Review and Practice	

WEEK ONE

Assignments:

Read:

Gravetter & Wallnau, Essentials of Statistics, Chapter 1, "Introduction to Statistics."

Gravetter & Wallnau, Essentials of Statistics, Chapter 2, "Frequency Distributions."

Gravetter & Wallnau, Essentials of Statistics, Chapter 3, "Central Tendency."

Gravetter & Wallnau, Essentials of Statistics, Chapter 4, "Variability."

Bring: Basic Calculator

Learning objectives:

The student will demonstrate a competent knowledge base in the following areas.

1. Understand the purposes of descriptive and inferential statistics.
2. Understand the key characteristics of correlational, experimental, and quasi-experimental research.
3. Understand the important characteristics of any distribution of scores.
4. Understand the basic shapes of distributions.
5. Understand the different measures of central tendency that are commonly used.
6. Understand and be able to calculate the mean.
7. Understand and be able to calculate "standard deviation."

Class activities:

1. Introductions (professor and students)
2. Review Student Guide
3. Discuss real-life benefits of a course in Statistics
4. Overview of descriptive and inferential statistics
5. Discuss types of studies
6. Discuss types of variables
7. Discuss statistical notation
8. Discuss frequency distributions
9. Discuss graphing
10. Discuss shapes of distributions
11. Discuss central tendency
12. Discuss variability

WEEK TWO

Assignments:

Read:

Gravetter & Wallnau, Essentials of Statistics, Chapter 5, “z-scores”

Gravetter & Wallnau, Essentials of Statistics, Chapter 6, "Probability”

Gravetter & Wallnau, Essentials of Statistics, Chapter 7, "Probability and Samples”

Bring: Calculator

Complete: Assessment #1

Instructions: Answer each question fully. In answering questions, use information from the text and from classroom presentations, as appropriate. 125 points total are possible. Point values of each question are indicated in parentheses following the question number.

1 (4). What are the basic purposes of descriptive and inferential statistics?

2 (4). Define and give an example of a discrete variable and a continuous variable.

3 (4). Under what circumstances should you use a grouped frequency distribution rather than an ungrouped frequency distribution?

4 (4). If the median selling price of single-family homes in Orange County is reported as $400,000 and the mean selling price is reported as $625,000, what do these two statistics reveal about the *shape* of the distribution of selling prices?

5 (4). Under what circumstances is the mean the preferred measure of central tendency? Under what circumstances is the median the preferred measure of central tendency?

6 (4). A developmental psychologist conducts a research study comparing vocabulary skills for 5-year-old boys and 5-year-old girls. Is this study an *experiment*? Explain why or why not.

7 (5). How does the correlational method differ from the experimental method?

8. A researcher would like to evaluate the claim that large doses of vitamin C can help prevent the common cold. One group of research participants is given a large dose of the vitamin (500 mg per day), and a second group is given a placebo (sugar pill). The researcher records the number of colds each individual experiences during the 3-month winter season.

a (4). Identify the dependent variable for this study.
b (4). Is the "number of colds" variable continuous or discrete? Explain.
c (4). Identify the independent variable for this study.
d (4). What research method is being used (experimental or correlational)?

9. For the following hypothetical data of ages of a sample of 50 SPS psychology majors, do the following:

32	68	43	36	34	32	57	43	36	35
32	55	44	36	35	27	55	39	38	35
27	48	39	37	35	28	50	39	33	30
28	45	40	33	31	24	42	40	34	26
24	42	36	34	32	24	42	36	34	25

a. (4) What is the mean age of these fifty SPS psychology majors? Round your final answer to one decimal (e.g., 29.7).
b. (4) Clearly explain why the *median* age might be preferred over the *mean* age as a summary measure for this sample.
c. (10) Make the grouped frequency distribution, using i = 3 with a top interval of 66-68. Include all intervals (even if there is a zero frequency in an interval) down to the interval containing the youngest student.
d. (10) Create the histogram from the i = 3 grouped frequency distribution, labeling midpoints of intervals on the "age" axis. On each axis, include both the appropriate numbers and a label for what those numbers represent.
e. (4) How would you describe the *shape* of the distribution? Explain your answer.

10. (4) In a certain unimodal, symmetrical distribution, six scores are added to the distribution, three of which are extremely larger and three extremely smaller than any scores of the original distribution. How would the standard deviation of the new distribution compare with that of the original? Would the new standard deviation be larger, smaller, or unchanged? Explain your answer.

11. (4) A population has $\mu = 100$ and $\sigma = 20$. If you select a single score from this population, on the average, how close would it be to the population mean? Explain your answer.

12. (4) In general, what does it mean for a sample to have a standard deviation of zero? Make up a set of five scores on a 10-point quiz such that the standard deviation of the five scores is zero.

13. (4) A professor administers a 5-point quiz to a class of 40 students. The professor calculates a mean of 4.2 for the quiz with a standard deviation of 11.4. Although the mean is a reasonable value, you should realize that the standard deviation is not. Explain in your own words why it appears that the professor made a mistake in computing the standard deviation.

14. (4) The standard deviation of IQs is 6 for one class of seventh-grade pupils and 12 for another. The mean IQ for both classes is 105. How might a knowledge of this difference between the classes affect how the teacher would choose to teach these two classes?

15. (4) A professor gave an exam that resulted in a mean score of 65 (out of 100 points possible) and a standard deviation of 15. Because the professor felt that the exam was unusually difficult, she added five points to each student's score. What is the mean and standard deviation of the new, adjusted score distribution?

16. (10) Consider the following hypothetical data of ages of a sample of SPS psychology majors: 32, 68, 43, 36, 36. The mean age is 43. What is the standard deviation of the ages? Show your work, using the formulas discussed in class, and round off your final answer to one decimal.

17. (4) For the previous question, what does the standard deviation you obtained mean?

18. (6) What are the three important characteristics of any distribution of scores?

19. (4) In the introductory example in your Student Guide (graph of number of murder offenders by age), explain why the graph is potentially misleading.

Learning objectives:

The student will demonstrate a competent knowledge base in the following areas.

1. Understand, calculate, and “z scores” in interpreting individual scores.

2. Understand and use appropriately the normal curve.

3. Understand the purpose and limitations of sampling.

4. Understand the use of the distribution of sample means.

Class activities:

1. Take Quiz 1.

2. Discuss the use of percentile ranks and z-scores in interpreting individual scores

3. Discuss the basic rules of probability

4. Discuss the characteristics of normal curves

5. Discuss the nature of sampling error and the use of the distribution of sample means

WEEK THREE

Assignments:

Read:

Gravetter & Wallnau, Essentials of Statistics, Chapter 8, “Introduction to Hypothesis Testing”

Gravetter & Wallnau, Essentials of Statistics, Chapter 9, “Introduction to the *t* Statistic”

Gravetter & Wallnau, Essentials of Statistics, Chapter 10, "The *t* Test For Two Independent Samples”

Bring: Calculator

Complete: Learning Assessment #2

Instructions: Answer each question fully. In answering questions, use information from the text and from classroom presentations, as appropriate. 125 points total are possible. Point values of each question are indicated in parentheses following the question number.

1. (5) What does a z-score of zero ($z = 0.00$) mean?

2. (8) Explain in your own words how to interpret a z-score.

3. (4) For a distribution of raw scores, $\mu = 45$. The z-score for $X = 55$ is computed, and a value of $z = –2.00$ is obtained. Regardless of the value for the standard deviation, why must this z-score be incorrect?

4. (8) Bob is 6'2" tall (74 inches) and weighs 200 pounds. For a representative sample of men Bob's age, the mean height is 5'10" (70 inches) and the standard deviation is 3 inches. The mean weight for this sample is 150 pounds with a standard deviation of 30 pounds. Assume that both height and weight are distributed normally. What can you say about Bob’s weight relative to his height? Use z-scores to explain your answer.

5. (4) The height distribution for a large representative sample of 21-year-old American men is approximately normal. With reference to this sample, a certain man's height z-score is +3.50. Which of the following characterizes this individual: extremely tall; tall; medium height; short; extremely short? Another man has a height z-score of -0.30. In which of the above categories would you classify this individual?

6. (8) The population of heights of American women between the ages of 18 and 24 is approximately normal with a mean of 65.5 inches ($\mu = 65.5$) and a standard deviation of 2.5 inches ($\sigma = 2.5$). What is the proportion of American women between these ages over six feet tall? Show your work.

7. (8) In October, 1981, the mean and standard deviation for the scores of all people taking the Graduate Record Exam (GRE) were 489 and 126, respectively. Assuming that the scores were normally distributed, what percentage of them would be expected to lie below 500? Show your work.

8. (8) If one's IQ must be in the upper two percent of the population to qualify to be in MENSA, what IQ is needed to qualify? Assume that IQ scores are distributed normally with $\mu = 100$ and $\sigma = 16$. Show your work.

9. (8) If IQ scores are distributed normally with $\mu = 100$ and $\sigma = 16$, what proportion of IQ scores are within one standard deviation of the mean (between 84 and 116)? Show your work.

10. (8) The distribution of SAT scores is normal with $\mu = 500$ and $\sigma = 100$. What SAT score, X value, separates the top 10% from the rest of the distribution? Show your work.

11. (8) For each of the following, assume that the sample was selected from a population with $\mu = 75$ and $\sigma = 20$.

    a. What is the expected value of M for a sample of n = 4 scores?
    b. What is the standard error of M for a sample of n = 4 scores?
    c. What is the expected value of M for a sample of n = 25 scores?
    d. What is the standard error of M for a sample of n = 25 scores?

12. (8) The distribution of SAT scores is normal with $\mu = 500$ and $\sigma = 100$.

    a. If you selected a random sample of n = 4 scores from this population, how much error would you expect between the sample mean and the population mean? Show your work.
    b. If you selected a random sample of n = 25 scores, how much error would you expect between the sample mean and the population mean? Show your work.
    c. How much error would you expect for a sample of n = 100 scores? Show your work.

13. (8) A normal population has $\mu = 70$ and $\sigma = 12$.

    a. Sketch the population distribution. What proportion of the <u>scores</u> have values greater than X = 73? Show your work.

b. Sketch the distribution of sample means for samples of size n = 16. What proportion of the sample means have values greater than 73? Show your work.

14. (8) Suppose that Vanguard University claims that the SAT scores of its students are normally distributed with a mean of 580 and a standard deviation of 100. A local newspaper questions the claim and selects a random sample of 25 VUSC students and discovers that the mean SAT score for this sample is 565. If the university's claims are true, how likely would it be to obtain a sample mean of 565 or lower with a random sample of n = 25? Show your work.

15. (8) In the example of the "Principal and the Superintendent," what are the two possible explanations for obtaining a low sample mean IQ (for example, 90)?

16. (8) What does the "standard error of *M*" represent?

17. (8) What can a researcher control to reduce the magnitude of the standard error?

Learning objectives:

The student will demonstrate a competent knowledge base in the following areas.

1. Understand the logic of hypothesis testing.

2. Understand the use of the t statistic.

3. Understand and be able to conduct hypothesis testing utilizing two independent samples.

Class activities:

1. Take Quiz 2.

2. Discuss the logic of hypothesis testing.

3. Discuss the basic steps involved in hypothesis testing.

4. Discuss the kinds of errors that are possible in hypothesis testing.

5. Discuss the *t* statistic.

6. Discuss the independent-measures *t* statistic.

WEEK FOUR

Assignments:

Read:

Gravetter & Wallnau, Essentials of Statistics, Chapter 13, “Introduction to Analysis of Variance”

Gravetter & Wallnau, Essentials of Statistics, Chapter 15, "Correlation and Regression”

Gravetter & Wallnau, Essentials of Statistics, Chapter 16, "The Chi-Square Statistic”

Bring: Calculator

Complete: Assessment #3

Instructions: Answer each question fully. In answering questions, use information from the text and from classroom presentations, as appropriate. 125 points total are possible. Point values of each question are indicated in parentheses following the question number.

1. (4) In the example of the “Principal and the Superintendent,” why was it necessary to employ hypothesis testing? In other words, why didn’t they simply test everyone and find out for sure whether the students in the principal’s school were below average in intelligence?

2. (4) In the example of the “Principal and the Superintendent,” what was the “population”?

3. (4) Explain in some detail what the “null hypothesis” is.

4. (4) Is the null hypothesis testing something about the population or something about the sample?

5. (8) In your own words, briefly explain what each of the four steps of hypothesis testing does.

6. (4) In general (whether you are performing a “z” test or a “t” test), where does one find the critical value of the test statistic (step 2 in hypothesis testing)?

7. (4) What does the term “statistically significant” mean?

8. (8) Discuss the errors that can be made in hypothesis testing.

   a. What is a Type I error? Why might it occur?
   b. What is a Type II error? Why might it occur?

9. (4) Briefly explain the advantage of using an alpha level of .01 versus a level of .05. What is the disadvantage of using a smaller alpha level?

10. (4) The term *error* is used two different ways in the context of a hypothesis test. First, there is the concept of standard error, and second, there is the concept of a Type I error.

    a. What factor can a researcher control that will reduce the risk of a Type I error?
    b. What factor can a researcher control that will reduce the standard error?

11. (15) A researcher is trying to assess some of the physical changes that occur in addicts during drug withdrawal. For the population, suppose that the mean body temperature is $\mu = 98.6$ degrees and $\sigma = 0.56$. Assume that in the population the temperatures are normally distributed. The following data consist of the body temperatures of a sample of heroin addicts during drug withdrawal: 98.6, 99.0, 99.4, 100.1, 98.7, 99.3, 99.9, 101.0, 99.6, 99.5, 99.4, 100.3. Is there a significant change in body temperature during withdrawal? Test at the .01 level of significance for two tails. Round all computations to two decimals. Include the four steps of hypothesis testing and the statistical summary statement. Show your work.

12. (15) For the past two years the vending machine in the psychology department has charged 70 cents for a soft drink. During this time, company records indicate that the population mean number of soft drinks sold each week was $\mu = 185$. The distribution was approximately normal with $\sigma = 23$. Recently, the company increased the price to 80 cents a can. The weekly sales for the first 8 weeks after the price increase are as follows: 148, 135, 142, 181, 164, 159, 192, 173. Do these data indicate that there was a significant change in sales after the price increase? Test at the .05 level of significance for two tails. Include the statistical summary statement. Show your work.

13. (4) What factor determines whether you should use a z-statistic or a t-statistic for a hypothesis test?

14. (8) The following sample was obtained from a population with unknown parameters.

    Scores: 9, 1, 13, 1

    a. Compute the sample mean and sample standard deviation. (Note that these are descriptive values that summarize the sample data.)
    b. Compute the estimated standard error (s_M). (Note that this is an inferential value that describes how accurately the sample mean represents the unknown population mean.)

15. (8) A major corporation in the Northeast noted that last year its employees averaged $\mu = 5.8$ absences during the winter season (December to February). In an attempt to reduce absences, the company offered free flu shots to all employees this year. For a sample of $n = 100$ people who took the shots, the average number of absences this winter was $M = 3.6$ with $SS = 396$. Do these

data indicate a significant decrease in the number of absences? Use a one-tailed test with $\alpha = .05$. Show all four steps of hypothesis testing and include the statistical summary statement.

16. (8) For a single-sample study, the following statistical summary statement was reported in the published article: $t(15) = +2.22, p < .05$, two tailed.

    a. How many participants were used in the study?
    b. What decision was made about the null hypothesis?
    c. What type of error could have been made?
    d. What is the probability that the decision reached was in error?

17. (4) What happens to the value of the independent-measures t statistic as the difference between the two sample means increases? What happens to the t value as the variability of the scores in the two samples increases?

18. (15) Siegel (1990) found that elderly people who owned dogs were less likely to pay visits to their doctors after upsetting events than those that did not own pets. Similarly, consider the following hypothetical data. A sample of elderly dog owners is compared to a similar group (in terms of age and health) who do not own dogs. The researcher records the number of visits to the doctor during the past year for each person. For the following data, is there a significant difference in the number of doctor visits between dog owners and control subjects? Use the .01 level of significance (two tailed), show your computational work, and include the four steps of hypothesis testing and the statistical summary statement. Assume that the assumptions underlying the use of the independent-measures t-test have been met.

Control Group (n = 7)	Dog Owners (n = 5)
12	6
10	5
6	9
9	4
15	6
12	
13	

Learning objectives:

The student will demonstrate a competent knowledge base in the following areas.

1. Understand and be able to conduct hypothesis testing for more than two independent samples.

2. Understand the purpose and limitations of correlational data.

3. Understand the relation between correlation and regression.

4. Understand and be able to calculate the Pearson correlation coefficient.

5. Understand and be able to calculate the linear regression equation.

6. Understand and be able to conduct chi-square analyses.

Class activities:

1. Take Quiz 3.

2. Discuss analysis of variance.

3. Discuss correlation and regression.

4. Discuss the chi-square test.

WEEK FIVE

Assignments:

Review all chapters to prepare for Exam

Bring: Calculator, #2 pencil

Complete: Assessment #4

Instructions: Answer each question fully. In answering questions, use information from the text and from classroom presentations, as appropriate. 125 points total are possible. Point values of each question are indicated in parentheses following the question number.

1. (4) In an experiment, a researcher observes that participants' interest in a lecture increases as a function of whether they are paid $1, $5, or $25 to listen to it. What would the null hypothesis be for this experiment?

2. (4) Describe the general characteristics of a research study for which ANOVA would be the appropriate test statistic.

3. (3) Explain why you should use ANOVA instead of several t tests to evaluate mean differences when an experiment consists of three or more treatment conditions.

4. (4) Describe *when* and *why* post hoc tests are used. Explain why you would not need to do post hoc tests for an experiment with only $k = 2$ treatment conditions.

5. (15) A study was conducted to compare the effectiveness of different rewards that might be used in teaching retarded children. Twenty retarded children, ages five to seven, were randomly assigned to four independent groups. Each child was shown five common objects and five cards, each showing the printed name of one of the objects. The child's task was to match each object correctly with its name card. Whenever a correct match was made, the experimenter rewarded the child. Children in the first group were rewarded with candy; children in the second group were rewarded with tokens that could later be exchanged for candy; children in the third group were rewarded with tokens that could later be exchanged for attention from the experimenter (playing games, reading to the child); children in the fourth group were rewarded with verbal praise. The experimenter recorded the number of trials required before a child could correctly match all five pairs. The scores were as follows:

Candy	**Tokens/Candy**	**Tokens/Attention**	**Praise**
9	4	8	11
7	7	3	8
6	8	7	8
7	7	6	6
6	9	6	7

Test the null hypothesis that the type of reward did not affect the children's performance (let $\alpha = .01$). Include the four steps of hypothesis testing and the statistical summary statement. Show your work and complete the ANOVA table.

Source	**SS**	**df**	**MS**	**F**
Total				
Between				
Within				

6. (8) In the preceding problem, identify the independent and dependent variables.

7. (8) Explain what a Pearson "r" of +.85 between variables X and Y means. Describe in words (do not sketch) how the scatterplot would look.

8. It is well-known that similarity in attitudes, beliefs, and interests plays an important role in interpersonal attraction. Thus, correlations for attitudes between married couples should be strong. Suppose a researcher developed a questionnaire that measures how liberal or conservative one's attitudes are. Low scores indicate that the person has liberal attitudes, while high scores indicate conservatism. The following hypothetical data are scores for married couples:

	Attitude Scores	
Couple	X (Wife)	Y (Husband)
A	11	14
B	6	7
C	18	15
D	4	7
E	1	3
F	10	9
G	5	9
H	3	3

a. (10) Draw the scatterplot, carefully labeling the axes.

b. (15) Calculate Pearson "r." Show your work.

c. (8) Calculate the regression equation for predicting the husband's score given the wife's score. What is the predicted husband's score if the wife's score is 10?

9. (8) Explain why "correlation does not necessarily imply causation." Give an example of two variables that are strongly correlated, where it is obvious that the relationship between the variables is not cause-and-effect.

10. (4) Explain what "r^2" reveals about the relationship between two variables.

11. (15) An advertising researcher is trying to determine the criteria that people use when choosing a new car. The researcher selects a sample of n = 100 people and asks each person to select what they consider to be the "most important factor in selecting a new car" from a list of alternatives. The data are as follows:

Cost	30
Styling	10
Performance	20
Reliability	40

On the basis of these observed frequencies, can the researcher conclude that there is any specific factor (or factors) that is most often cited as being important? Test at the .05 level of significance, include each of the four steps of hypothesis testing and a statistical summary statement. Show your work.

12. (15) Friedman and Rosenman (1974) have suggested that personality type is related to heart disease. Specifically, Type A people who are competitive, driven, pressured, and impatient, are more prone to heart disease. On the other hand, Type B individuals, who are less competitive and more relaxed, are less likely to have heart disease. Suppose an investigator would like to examine the relationship between personality type and disease. For a random sample of individuals, personality type is assessed with a standardized test.. These individuals are then examined and categorized according to the type of disorder they have. The observed frequencies are as follows:

Type of Disorder				
	Heart	**Vascular**	**Hypertension**	**None**
Type A	$f_o = 38$	$f_o = 29$	$f_o = 43$	$f_o = 60$
Type B	$f_o = 18$	$f_o = 22$	$f_o = 14$	$f_o = 126$

Is there a relationship between personality type and type of disorder? Test at the .01 level of significance, include each of the four steps of hypothesis testing and a statistical summary statement. Show your work.

13. (4) Pearson "r" and the Test of Independence χ^2 both assess relationship between two variables. Identify a key difference between these two measures.

Class activities:

1. Take Quiz 4.

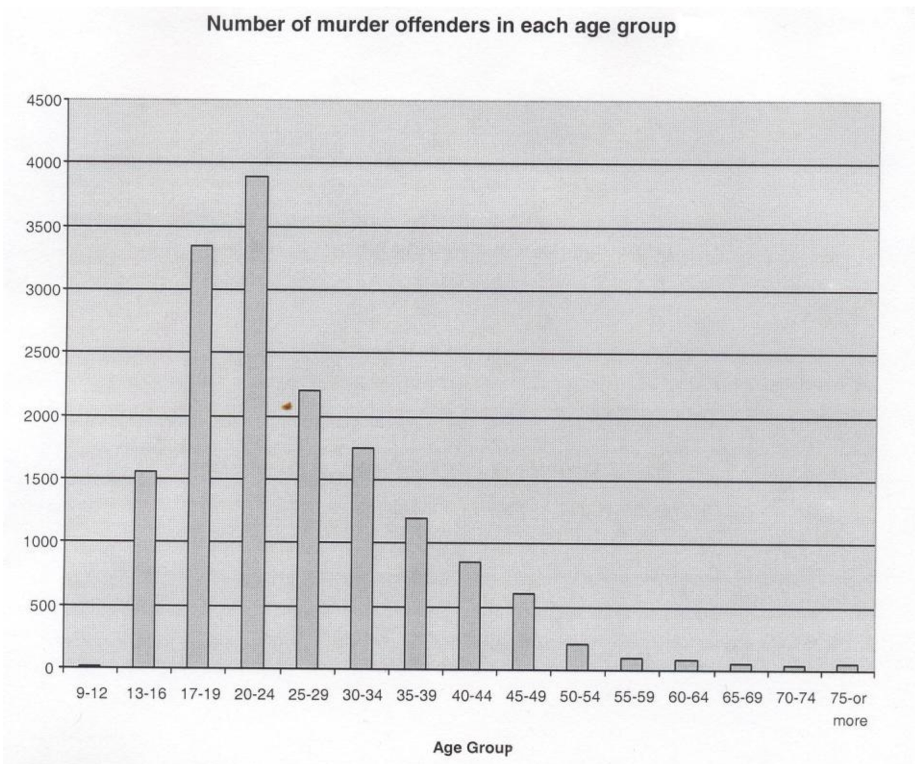
2. Review for in-class Exam.

3. Take in-class Exam.

WEEK ONE LECTURE

Introductory Example

Consider the following graph ("Number of murder offenders in each age group: 1994"). How would you summarize to a friend what the graph shows? In what age range are there the most murder offenders? Do you see any particular problems with the presentation of the information?



Purpose of Statistics

1. Descriptive statistics:

2. Inferential statistics:

Population:

Sample:

Representativeness and random sampling:

A key characteristic of a sample is that it is representative of the population from which it came. One procedure designed to result in a representative sample is random sampling, or random selection, in which each person in the population has the same chance of being selected.

Types of Studies

Correlational study: examines the relationship between two variables; no control of a variable; cannot assess causal (cause-and-effect) relationships.

Experimental study: because a variable is controlled, causal (cause-and-effect) relationships between variables can be assessed.

Independent variable: controlled or manipulated by the researcher (usually by having the experimenter randomly assign participants to conditions or groups)

Dependent variable: measured to assess the effect of the independent variable

Quasi-experimental study: no control or manipulation of an independent variable; often looks at already existing groups.

Types of variables

Discrete variables

Continuous variables

Interval size (i)
Real limits
Midpoint

Statistical notation

Σ = summation
ΣX = sum of the x scores
ΣX^2; $(\Sigma X)^2$; N; n

Organizing Data: Ungrouped Frequency Distribution

1. List from high to low all possible score values.

2. Identify frequency of each score.

Organizing Data: Grouped Frequency Distributions

Purpose?

Terms:

interval size (i)

real limits

apparent limits

midpoint

Graphing

1. Histogram

   A. Height of bar is frequency.

   B. Width of bar is interval size.

   C. Sides of bar come down at real limits of the interval.

   D. Midpoints of intervals typically labeled.

2. Frequency polygon

   A. Points placed directly over midpoints.

   B. Height of point is the frequency.

   C. Midpoints of intervals labeled.

Characteristics of Distributions (shape, central tendency, variability)

1. Shape

   symmetrical

   unimodal

   bimodal

   skewed (positively and negatively)

2. Central Tendency

   Mode: most frequently occurring score.

   Median: fiftieth percentile (P_{50}): score below which 50% of the scores fall.

   Mean: responds to every score in a distribution.

   Population mean: $\mu = \frac{\sum X}{N}$

   Sample mean: $M = \frac{\sum X}{n}$

   Characteristics of the Mean

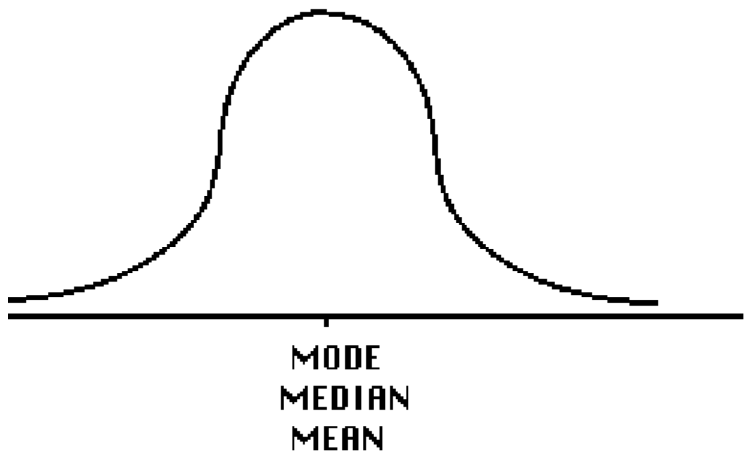
   Mean is the "balance point" of the distribution.

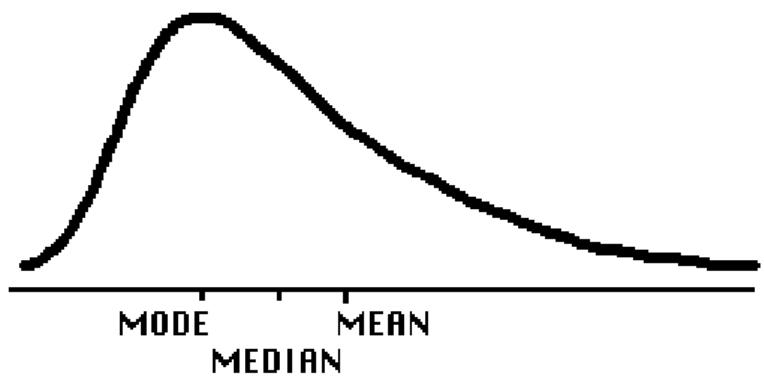
   Because the mean (unlike the mode or median) responds to each score, it balances the distribution, taking into account how far away each score is.

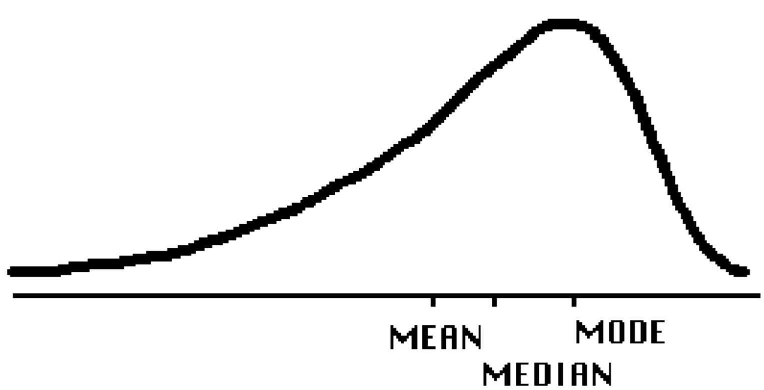
   Sum of the deviations from the mean equals zero.

   $$\sum(X - \mu) = 0$$

Relationship between shape and central tendency







Shape and Central Tendency Example

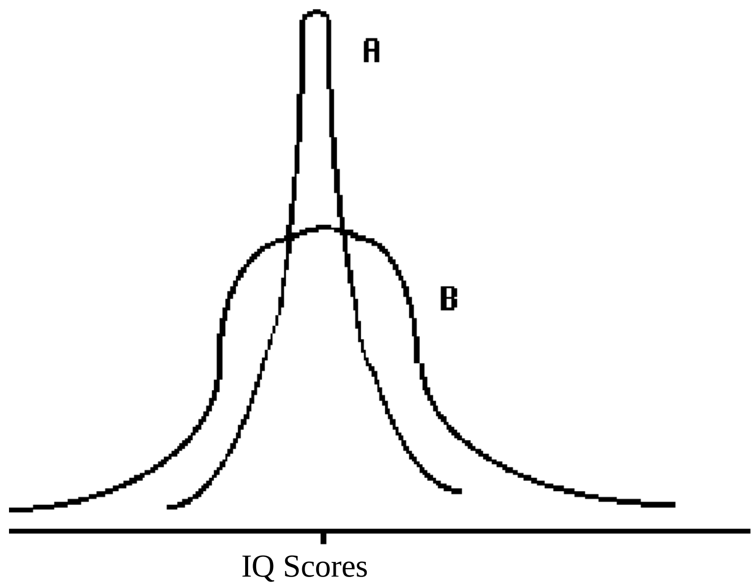
The L.A. Times (April 7, 1999) reported the following as the salaries for all the Dodgers:

Kevin Brown	10,714,286
Gary Sheffield	9,916,667
Raul Mondesi	9,000,000
Eric Karros	5,500,000
Todd Hundley	5,325,000
Mel Rojas	4,583,333
Eric Young	4,500,000
Ismael Valdes	4,275,000
Jeff Shaw	3,383,333
Jose Viscaino	3,000,000
Devon White	2,500,000
Carlos Perez	2,333,333
Chan Ho Park	2,300,000
Dave Mlicki	2,250,000
Darren Dreifort	1,900,000
Mark Grudzielanek	1,900,000
Alan Mills	1,250,000
Antonio Osuna	1,050,000
Todd Hollandsworth	850,000
Dave Hansen	450,000
Pedro Borbon	375,000
Tripp Cromer	285,000
Rick Wilkins	270,000
Jacob Brumfield	240,000
Adrian Beltre	220,000
Alex Cora	200,000
Paul LoDuca	200,000
Onan Masaoka	200,000
Steve Montgomery	200,000

How would you respond to the reporting of $2,730,033 as the "average" salary? Who would choose to use this average, player representatives negotiating a raise or a team owner? How would you describe this distribution? Is $2,730,033 the mode? median? mean?

Variability

Variability refers to the dispersion, or spread, of the scores in a distribution.



These two distributions have the same basic shape and cannot be differentiated on the basis of measures of central tendency; yet clearly they differ. They differ in terms of the "spread" of scores. Distribution A is much less variable than distribution B.

The measures of variability that we will be looking at are distance measures, not scores.

1. Range = URL Xmax - LRL Xmin

2. Semi-interquartile range (Q)

$$Q = \frac{Q_3 - Q_1}{2}$$

3. Standard deviation and variance

$$SS = \sum(X - \mu)^2 \qquad SS = \sum(X - M)^2$$

Population variance: $\sigma^2 = \frac{SS}{N}$

Population standard deviation: $\sigma = \sqrt{\frac{SS}{N}}$

Sample variance: $s^2 = \frac{SS}{n-1}$

Sample standard deviation: $s = \sqrt{\frac{SS}{n-1}}$

WEEK TWO LECTURE

Interpretation of Individual Scores

1. Percentile Ranks

The percentile rank of a score is the percentage of scores below that score.

2. z-scores

z-scores specify the precise location of scores within a distribution, using the mean and standard deviation.

The numerical value of the z-score specifies the score's distance from the mean, using the standard deviation as the basic unit of distance.

$$z = \frac{x - \mu}{\sigma}$$

To find a raw score (X) given a z-score:

$$X = \mu + (z)(\sigma)$$

Uses of z-scores

Probability

Probability of an outcome can be represented as a proportion:

$$p(A) = \frac{n_A}{N}$$

If one card is picked at random from a well-shuffled deck of cards (52 cards), what is the probability that the card will be a heart?

Normal Curve and Probability

Normal curve

1. Unimodal
2. Symmetric
3. Always has the same proportion of area between the mean and some point a certain number of standard deviations from the mean.

Inferential Statistics

Using data from a sample to reach conclusions about a population

population: parameters: μ, σ
sample: statistics: M, s

Difference between a sample and its population is sampling error. The problem is that we don't usually know the population and thus we don't know how much sampling error has occurred.

Example: The Principal and the Superintendent

In their 1960 book *Elementary Statistical Methods*, Blommors and Lindquist introduced an example of the use of the standard error of the mean that has become a classic. They tell of an elementary school principal who goes to his superintendent requesting that his school be given more money per pupil than the other elementary schools in the system because the children in his school are not as intelligent as the children in the other schools. He points out that his graduates have done less well in middle school than graduates of other schools.

The principal argues that since the pupils in his school are less intelligent than the pupils in the other schools he needs additional money for compensatory education: additional teachers in order to have a smaller teacher-pupil ratio, special equipment, and so on.

The superintendent agrees that if indeed the children in the principal's school are below average it would be appropriate to give him the additional money he requested. However, there are no data available to indicate how intelligent the children are. It is possible that the intelligence of the children in the principal's school is average. In that case it would be inappropriate to give his school more money than the other schools in the system. It is also possible that the children in the principal's school are above average. If this is the case perhaps something is wrong with the principal or his faculty or both. If the children are above average in intelligence, yet do less well than children from other schools when they go on to middle school, perhaps the best course would be to fire the principal and send in a new person to straighten things out.

The superintendent has no faith in any of the group intelligence scores commonly administered in schools. She will only accept Binet IQ test scores as a legitimate definition of intelligence. The Binet must be individually administered at a cost of about twenty dollars per child. Therefore, it would be prohibitively expensive to test every pupil in the principal's school. However, the school district does have a couple of psychometricians who have some spare time. The superintendent decides to have them test 36 pupils randomly selected from the principal's school.

Sampling distributions help us by allowing us to compare our sample with a theoretical distribution of statistics obtained by selecting all possible samples of a specific size from a population.

Central limit theorem: for any population (μ, σ), the distribution of sample means for sample size n will approach a normal distribution with a mean of μ ($\mu_M = \mu$) and a standard deviation of $\frac{\sigma}{\sqrt{n}}$ ($\sigma_M = \frac{\sigma}{\sqrt{n}}$)

The distribution of sample means will be approximately normal if either of the following is true:

1. The population is normal
2. The sample size is relatively large (30 or more)

The standard deviation of the distribution of sample means is called the standard error of the mean and is symbolized σ_M (or SE or SEM). The standard error provides a measure of how much error, on average, we should expect in our sample mean (on average, how far would a sample mean be away from the true population mean).

$$\sigma_M = \frac{\sigma}{\sqrt{n}}$$

Example: principal & superintendent

$\mu = 100$, $\sigma = 16$
sample of n=36 taken

What is the mean & standard deviation of the sampling distribution?

What is the probability of getting a sample mean less than 95?

WEEK THREE LECTURE

Hypothesis Testing

Remember the example of "The Principal and the Superintendent"? In that scenario, the superintendent must establish cut-off points which specify possible decisions: "If the sample data are below point 'X' then we will give the school the money."

The area beyond the cut-off point is called the critical region and is commonly set at .05 or .01 (5% or 1%). This area is also referred to as the level of significance and is symbolized by alpha ($\alpha = .05$).

Steps in hypothesis testing

1. State null hypothesis, alternative hypothesis, and level of significance.
2. Set the criteria for a decision: How large a value of the test statistic is necessary to reject the null hypothesis (the "critical value" of the test statistic)?
3. Calculate your test statistic from the sample data.
4. Reach a decision about the null hypothesis (reject it or fail to reject it).

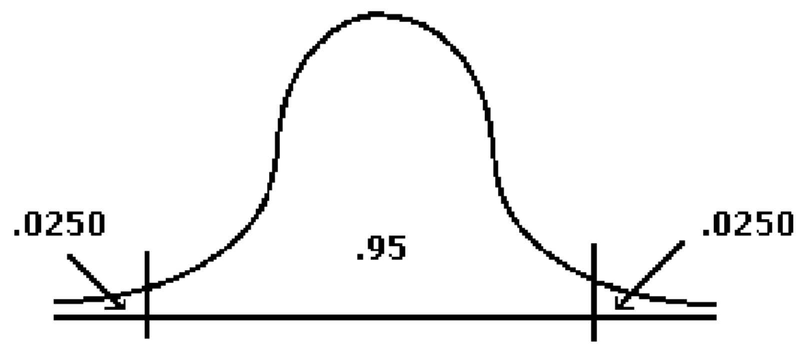
1. State the null hypothesis (H_0) which in general predicts that there will be no difference or no effect, the alternative hypothesis (H_1) which predicts that there will be a difference or an effect, and select the level of significance. Hypotheses always refer to population parameters (e.g., μ rather than *M*).

   H_0: $\mu = 100$
   H_1: $\mu \neq 100$
   $\alpha = .05$

2. How large a value of the test statistic is necessary to reject the null hypothesis (what is the "critical value" of the test statistic)? Usually this comes from a table.

   Example: What values of z correspond to the cut-off points below defining the middle 95% of the distribution ($\alpha = .05$)?

   critical z = +1.96 and -1.96



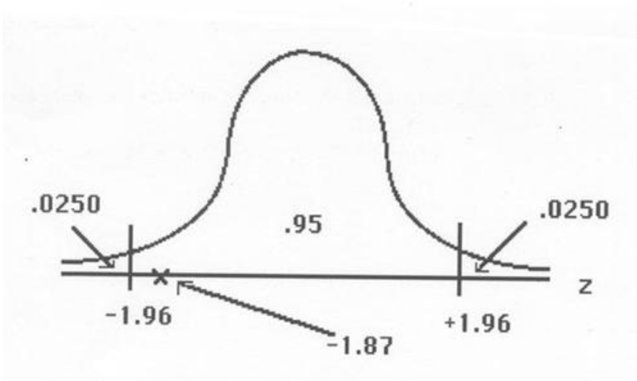
3. Calculate the test statistic from the sample data.

   Example: if n = 36 $M = 95$, $\mu = 100$, $\sigma = 16$

$$z = \frac{M - \mu_M}{\sigma_M} \qquad \sigma_M = \frac{\sigma}{\sqrt{n}}$$

$$z = \frac{95-100}{2.67} = \frac{-5}{2.67} = -1.87$$

4. Reach a decision about the null hypothesis.



Decision: fail to reject H_0

The consequence of this decision would be that the principal would not get the money, but neither would anyone be fired.

Statistical summary statement:

$z = -1.87$, $p > .05$

p > .05: "If the null hypothesis is true, the probability of getting a test statistic like we got (-1.87) is relatively high (greater than .05)."

Consider our decision if we had, in Step 3, obtained a calculated z of -2.18. The decision would have been to reject H_0, and the statistical summary statement would have been "$z = -2.18$, $p < .05$." (If the null hypothesis is true, the probability of getting a test statistic like we obtained (-2.18) is relatively rare– less than .05.) What would the practical consequence of this decision have been?

Possible types of errors

If H_0 is rejected, a Type I error is possible. A Type I error is made if the H_0 is rejected when it is actually true.

If the decision is to fail to reject the H_0, a Type II error is possible. A Type II error is made when you fail to reject the H_0 when it is really false.

		Actual Situation	
		H_0 True	H_0 False
Decision Made	Reject H_0	Type I Error	Correct Decision
	Fail to Reject H_0	Correct Decision	Type II Error

"t" statistic (single sample)

For the "z" statistic, the population standard deviation (σ) must be known. When (σ) is unknown, we can use the sample standard deviation (s) and a "t" statistic.

$$t(n=1) = \frac{M - \mu_M}{s_M}$$

"degrees of freedom" for the single-sample t-statistic: n - 1

s_M is the estimated standard error.

$$s_M = \frac{s}{\sqrt{n}}$$

$$s = \sqrt{\frac{SS}{n-1}}$$

"t" statistic (independent measures)

"t" test for two independent samples: Is there a difference between two groups (conditions)?

Assumptions:

1. The two populations are normal or the sample sizes are $>$ 30.
2. The two populations are approximately equally variable (homogeneity of variances).

$$t(n_1 + n_2 - 2) = \frac{(M_1 - M_2)}{s_{(M_1 - M_2)}}$$

$$s_{(M_1 - M_2)} = \sqrt{\frac{s_p^2}{n_1} + \frac{s_p^2}{n_2}}$$

$$s_p^2 = \frac{SS_1 + SS_2}{n_1 + n_2 - 2}$$

$$SS_1 = \sum (X - M_1)^2$$

$$SS_2 = \sum (X - M_2)^2$$

Ho states that there are no differences between the population means:

$H_o : \mu_1 - \mu_2 = 0$ (or) $H_o : \mu_1 = \mu_2$

A two-tailed alternative hypothesis states that the population means are different:

$H_1 : \mu_1 - \mu_2 \neq 0$ (or) $H_1 : \mu_1 \neq \mu_2$

Independent-Measures t statistic Example

A psychologist studying human memory would like to examine the process of forgetting. One group of participants is required to memorize a list of words in the evening just before going to bed. Their recall is tested 10 hours later in the morning. Participants in the second group memorize the same list of words in the morning, and then their memories are tested 10 hours later after being awake all day. The psychologist hypothesizes that there will be a difference in average recall for these two groups. The recall scores for two samples of college students are as follows:

Asleep Scores	**Awake Scores**
15, 16, 16, 13, 15, 15, 14, 16, 17, 14, 15, 14	15, 14, 13, 13, 13, 13, 14, 11, 12, 12, 12, 14

Use the independent-measures t statistic to determine whether there is a significant difference between the two treatments. Conduct the two-tailed test with $\alpha = .01$.

1. $H_o : \mu_{\text{asleep}} = \mu_{\text{awake}}$
   $H_1 : \mu_{\text{asleep}} \neq \mu_{\text{awake}}$
   $\alpha = .01$

2. critical t (22) = ± 2.819

3. t (22) = +4.35

$$SS = \sum (X - \mu)^2$$
$$SS_1 = 14$$
$$SS_2 = 14$$

$$s_p^2 = \frac{SS_1 + SS_2}{n_1 + n_2 - 2} = 1.27$$

$$s_{(M_1 - M_2)} = \sqrt{\frac{s_p^2}{n_1} + \frac{s_p^2}{n_2}} = .46$$

$$t(n_1 + n_2 - 2) = \frac{(M_1 - M_2)}{s_{M_1 - M_2}} = \frac{15 - 13}{.46} = +4.35$$

4. reject H_0; $t\ (22) = +4.35$, $p < .01$

WEEK FOUR LECTURE

Analysis of variance

Are there any significant differences among the three (or more) groups?

Assumptions:
1. Random samples
2. Normal populations
3. Homogeneity of variance

$$H_O : \mu_1 = \mu_2 = \mu_3 \ldots$$

H_1 : Not H_O (at least one mean is different)

$$F = \frac{MS_{Between}}{MS_{Within}}$$

$$F = \frac{\text{variability between groups}}{\text{variability within groups}}$$

$$F = \frac{\text{independent variable effect} + \text{individual differences} + \text{error}}{\text{individual differences} + \text{error}}$$

$$F = \frac{MS_B}{MS_W} \qquad MS_B = \frac{SS_B}{df_B} \qquad MS_W = \frac{SS_W}{df_W}$$

Source	**SS**	**df**	**MS**	**F**
Total				
Between				
Within				

$SS_T = \Sigma X^2 - \frac{G^2}{N}$, where G is the overall ("G"rand) total

$SS_B = \Sigma \frac{T^2}{n} - \frac{G^2}{N}$, where T is a condition total

$SS_W = SS_T - SS_B$

$SS_B + SS_W = SS_T$

$df_T = N - 1$

$df_B = k - 1$, where k is the number of groups

$df_W = N - k$

Analysis of Variance Example

A study was conducted to examine the effects of different types of water on the growth of bean plants. Four bean seedlings were randomly assigned to each of four water conditions: tap water, bottled water, rain water, and pond water. The number of centimeters of growth after four weeks was recorded:

Tap	Bottled	Rain	Pond
5	4	8	2
7	7	11	3
4	6	12	1
4	7	13	2

1. $H_o : \mu_{tap=}\mu_{bottled} = \mu_{rain} = \mu_{pond}$

H_1 : Not H_o

$\alpha = .01$

2. critical F(3,12) = 5.95

3. F(3,12) = 24.03

4. reject Ho; F (3,12) = 24.03, p < .01

$$SS_T = \Sigma X^2 - \frac{G^2}{N} = 772 - \frac{96^2}{16} = 772 - 576 = 196$$

$$SS_B = \Sigma \frac{T^2}{n} - \frac{G^2}{N} = \left[\frac{20^2}{4} + \frac{24^2}{4} + \frac{44^2}{4} + \frac{8^2}{4} \right] - 576 = 744 - 576 = 168$$

$$SS_W = SS_T - SS_B = 196 - 168 = 28$$

$$MS_B = \frac{SS_B}{df_B} \qquad MS_W = \frac{SS_W}{df_W} \qquad F = \frac{MS_B}{MS_W}$$

Source	**SS**	**df**	**MS**	**F**
Total	196	15		
Between	168	3	56	24.03
Within	28	12	2.33	

If the overall "F" is significant, a post hoc test can identify which mean(s) are significantly different from each other. Commonly used post hoc tests include the Scheffé test and Tukey's HSD test.

Correlation

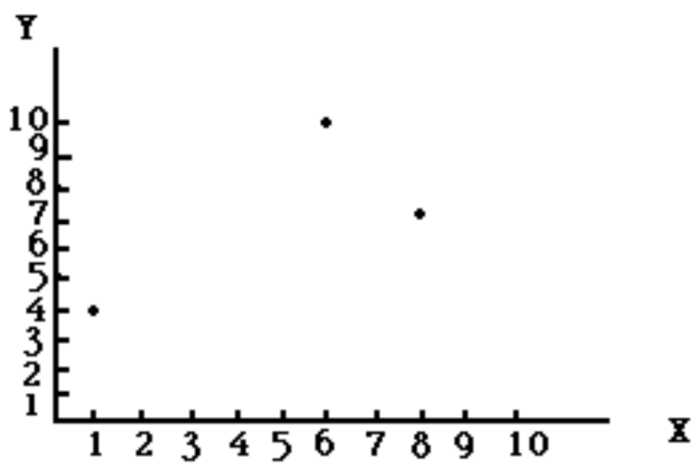
Allows the assessment of a relationship between two variables.

A health psychologist is interested in the relationship between regular exercise and general health. Three individuals are interviewed to determine how much exercise each person gets in an average week, and each person undergoes a physical exam to determine general health. A 10-point scale is used to rate both health and exercise, with higher scores indicating better health and more exercise.

	X (Exercise)	Y (Health)
Joe	8	7
Jane	6	10
Jack	1	4

Correlations assess
1. direction of the relationship (positive or negative).
2. magnitude of the relationship (between -1.00 and +1.00).

Graph called a scatterplot allows an estimate of the relationship.



$$r = \frac{\text{degree to which X and Y vary together}}{\text{degree to which X and Y vary separately}}$$

$$r = \frac{SP}{\sqrt{(SS_X)(SS_Y)}}$$

$$SS_X = \sum (X - M_X)^2$$

$$= (8-5)^2 + (6-5)^2 + (1-5)^2 = 26$$

$$SS_Y = \sum (Y - M_Y)^2$$

$$= (7-7)^2 + (10-7)^2 + (4-7)^2 = 18$$

$$SP = \Sigma (X - M_X)(Y - M_Y)$$

$$= (8-5)(7-7) + (6-5)(10-7) + (1-5)(4-7) = 0 + 3 + 12 = 15$$

$$r = \frac{SP}{\sqrt{(SS_X)(SS_Y)}} = \frac{15}{\sqrt{(26)(18)}} = \frac{15}{\sqrt{468}} = +0.69$$

Regression

When two variables are correlated, it is possible to predict an individual's score on one variable (Y) given that individual's score on the other variable (X).

The goal of regression is to find the equation of the straight line which best fits the scatterplot. The line is sometimes called the "prediction line," or the "regression line," or the "least-squares line."

The regression equation (the equation of the straight line that best fits the points in the scatterplot) allows one to predict an individual's score on one variable (typically the "Y" variable) based on that individual's score on a second variable (typically the "X" variable).

	X (Exercise)	Y (Health)
Joe	8	7
Jane	6	10
Jack	1	4

The "best fitting" line is defined as the line which minimizes the sum of the squared vertical deviations of the points from the line: $\sum (Y - \hat{Y})^2$

The regression equation for the line is $\hat{Y} = bX + a$ (where b is the slope of the line and a is the y-intercept)

$$b = \frac{SP}{SS_X} = \frac{15}{26} = .58$$

$$a = M_Y - (b)(M_X) = 7 - (.58)(5) = 4.1$$

$$\hat{Y} = bX + a$$

$$\hat{Y} = .58X + 4.1$$

Non-parametric Tests

Statistical tests examined so far (z,t,F) are parametric tests (testing hypotheses about population parameters). These tests require numerical scores for each individual (interval or ratio data).

Chi-square (χ^2) is an example of a nonparametric test. The data used are not individual scores but frequencies (how many people fall into mutually exclusive categories).

Chi-square compares frequencies observed (f_o) with frequencies expected (f_e) according to the null hypothesis.

A. Goodness of fit chi-square

Example: a food processor has developed three blends of coffee (A,B,C). Ninety people are asked which blend they prefer.

1. H_o: In the population, there is no difference in preference for blends A,B,C.
   H_1 : in the population, there is a difference in preference for blends A,B,C.
   $\alpha = .05$

2. df = c - 1 (where c is the number of categories)
   critical $\chi^2 = 5.99$

3. $\chi^2 = \Sigma \frac{(f_o - f_e)^2}{f_e}$

	f_o	f_e	f_o-f_e	$(f_o-f_e)^2$	$\frac{(f_o - f_e)^2}{f_e}$
A	26	30	-4	16	.53
B	38	30	8	64	2.13
C	26	30	-4	16	.53
					3.19

$\chi^2 = 3.19$

4. Fail to reject H_o

B. Chi-square test of independence

Example: is there a relationship between level of teaching and opinion about forming a teachers' union?

	Elem.	Middle	Sec.	Jr.Col.	
Yes	4	18	24	40	**86**
No	36	20	10	10	**76**
	40	**38**	**34**	**50**	**162**

1. H_0: for the population, opinion about union and level of teaching are <u>independent</u>.
   H_1: for the population, opinion about union is <u>dependent</u> on level of teaching.
   $\alpha = .05$

2. df = (r-1)(c-1) = (1)(3) = 3
   critical $\chi^2 = 7.81$

3. $\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e}$ $\qquad f_e = \frac{f_c f_r}{n}$

	Elem.	Middle	Sec.	Jr.Col.	
Yes	**21.23** 4 **13.98**	**20.17** 18 **.23**	**18.05** 24 **1.96**	**26.54** 40 **6.83**	**86**
No	**18.77** 36 **15.82**	**17.83** 20 **.26**	**15.95** 10 **2.22**	**23.46** 10 **7.72**	**76**
	40	**38**	**34**	**50**	**162**

$\chi^2 = 13.98 + .23 + 1.96 + 6.83 + 15.82 + .26 + 2.22 + 7.72 = 49.02$

4. Reject H_0

Restrictions for use of chi square

1. f_e for each cell should be > 4
2. df should be > 1

WEEK FIVE

1. Quiz 4
2. Topics from Weeks 1-4 will be reviewed in preparation for the comprehensive exam.
3. In-class Exam