



## Module 1: Introduction to Statistics

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# Module 1 Overview



- ▶ **The Role of Statistics**
- ▶ **The Research Process**
  - ▶ Threats to Validity
- ▶ **Statistical Terminology**
- ▶ **Scales of Measurement**
- ▶ **Introduction to Descriptive and Inferential Statistics**

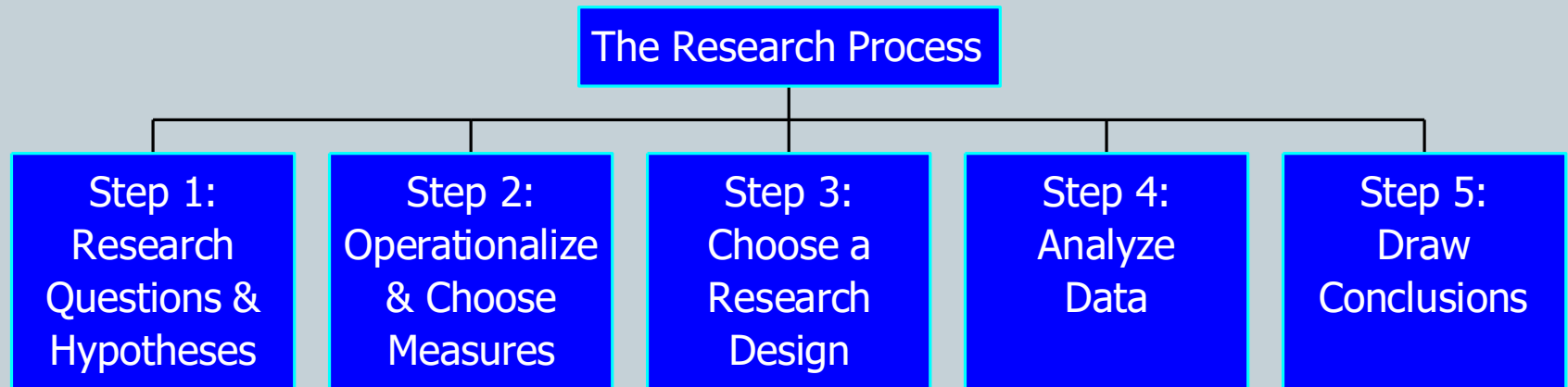
# The Role of Statistics



- ▶ The goal of virtually all quantitative research studies is to identify and describe relationships among constructs.
- ▶ Data are collected in a very systematic manner and conclusions are drawn based on the data.
- ▶ At a basic level, statistical techniques allow us to aggregate and summarize data in order for researchers to draw conclusions from their study.

# The Typical Research Process

- ▶ The typical quantitative study involves a series of steps, one of which is statistical analysis.
- ▶ Note: These are steps in the research process and NOT sections of the dissertation.



# Step 1: Research Questions



- ▶ Research questions reflect the problem that the researcher wants to investigate.
- ▶ Research questions can be formulated based on theories, past research, previous experience, or the practical need to make data-driven decisions in a work environment.
- ▶ Research questions are **vitaly** important because they, in large part, dictate what type of statistical analysis is needed as well as what type of research design may be employed.

# Examples of Research Questions



- ▶ How is financial need related to retention after the freshman year of college?
- ▶ What types of advertising campaigns produce the highest rates of inquiries among prospective applicants at NSU?
- ▶ How do males and females differ with respect to statistics self-efficacy?
- ▶ How does a body image curriculum improve body image in college females?

# Hypotheses



- ▶ While research questions are fairly general, hypotheses are specific predictions about the results, made **prior** to data collection.
  - ▶ As financial need increases, the likelihood of retention decreases.
  - ▶ Personalized letters result in more inquiries than brochures.
  - ▶ Males have higher levels of self-efficacy than females.
  - ▶ Body image will improve as a result of the new curriculum.

# Step 2: Operationalize & Choose Measures

- ▶ Many variables of interest in education and psychology are abstract concepts that cannot be directly measured.
- ▶ This doesn't preclude us from studying these things, but requires that we clearly define the specific behaviors that are related to the concept of interest.



# Measuring Abstract Concepts



- ▶ How does one measure retention, inquiry rate, statistics self-efficacy, and body image?
- ▶ The process of defining variables and choosing a reliable and accurate measurement tool is called operationalizing your variables.
- ▶ Good measurement is **vital** to the trustworthiness of your results!

## Step 3: Choose a Research Design

- ▶ In Step 3, we develop a plan for collecting the data we need (i.e., a “blueprint” for the study)
- ▶ This is called **research design**, and includes things such as:
  - ▶ Who will participate in the study?
  - ▶ Who will receive the intervention?
  - ▶ Will there be a “control group”?
  - ▶ Will data be collected longitudinally?
  - ▶ What instrument will be used to collect data?
  - ▶ What type of data will be collected?

# Threats to Validity



- ▶ **Internal Validity**

- ▶ Problems associated with the experimental procedures or experiences of participants

- ▶ **External Validity**

- ▶ Problems that affect the generalizability of the results

- ▶ **The choice of design impacts the validity of your final results**

# Step 4: Analyze The Data



- ▶ Once the data have been collected, the results must be organized and summarized so that we can answer the research questions.
- ▶ This is the purpose of statistics
- ▶ The choice of analysis at this stage depends **entirely** on two prior steps:
  - ▶ The research questions
  - ▶ How the variable is measured

## Step 5: Draw Conclusions



- ▶ After analyzing the data, we can make judgments about our initial research questions and hypotheses.
- ▶ Are these results consistent with previous studies?
- ▶ The conclusions drawn from a study may provide a starting point for new research.

# The Role of Statistics

- ▶ Despite the anxiety usually associated with statistics, data analysis is a relatively small piece of the larger research process.
- ▶ There is a misconception that the trustworthiness of statistics is independent of the research process itself.
- ▶ This is **absolutely** incorrect!
- ▶ A statistical analysis can in **no way** compensate for a poorly designed study!!!!



# Statistical Terminology

# Population



- ▶ A population is the **entire** set of individuals that we are interested in studying.
- ▶ This is the group that we want to generalize our results to.
- ▶ Although populations can vary in size, they are usually quite large.
- ▶ Thus, it is usually not feasible to collect data from the entire population.



# Sample



- ▶ A sample is a **subset** of individuals selected from the population.
- ▶ In the best case, the sample will be representative of the population.
- ▶ That is, the characteristics of the individuals in the sample will mirror those in the population.

# Parameters vs. Statistics



- ▶ In most studies, we wish to quantify some characteristic of the population.
- ▶ Example:
  - ▶ The retention rate, inquiry rate, average level of self-efficacy, average level of body image
- ▶ This is the population parameter
- ▶ Parameters are generally unknown, and must be estimated from a sample
- ▶ The sample estimate is called a statistic

# Variables



- ▶ A characteristic that takes on different values for different individuals in a sample is called a variable.
- ▶ Examples:
  - ▶ Retention (yes/no)
  - ▶ Inquiry about NSU (yes/no)
  - ▶ Self-efficacy (score on self-efficacy questionnaire)
  - ▶ Body image (score on body image questionnaire)

# Independent Variables (IV)

- ▶ The “explanatory” variable
- ▶ The variable that attempts to explain or is purported to cause differences in a second variable.
- ▶ In experimental designs, the intervention is the IV.
- ▶ Example:
  - ▶ Does a new curriculum improve body image?
  - ▶ The curriculum is the IV

# Dependent Variables (DV)



- ▶ The “outcome” variable
- ▶ The variable that is **thought to be influenced** by the independent variable
- ▶ Example:
  - ▶ Does a new curriculum improve body image?
  - ▶ Body image is the DV

# Examples



- ▶ Do students prefer learning statistics online or face to face?
  - ▶ What is the IV? DV?
- ▶ How do students who have never had statistics compare to students who have previously had statistics in terms of their anxiety levels?
  - ▶ What is the IV? DV?

# Confounding Variables

- ▶ Researchers are usually only interested in the relationship between the IV and DV.
- ▶ Confounding variables represent unwanted sources of influence on the DV, and are sometimes referred to as “nuisance” variables.
- ▶ Example:
  - ▶ Does a new curriculum improve body image?
  - ▶ Such things as heredity, family background, previous counseling experiences, etc. can also impact the DV.

# Controlling Confounding Variables



- ▶ Typically, researchers are interested in excluding, or controlling for, the effects of confounding variables.
- ▶ This is generally **not** a statistical issue, but is accomplished by the research design.
- ▶ Certain types of designs (e.g., experiments) better control the effects of confounding variables.
- ▶ If an experiment or an equivalent control group is not possible → ANCOVA





# Scales of Measurement

# Variable Measurement Scales

- ▶ For any given variable that we are interested in, there may be a variety of measurement scales that can be used:
  - ▶ What is your annual income? \_\_\_\_\_
  - ▶ What is your annual income?
    - a. 10,000-20,000
    - b. 20,000-30,000
    - c. 30,000-40,000
    - d. 40,000-50,000
    - e. 50,000 or above
- ▶ Variable measurement is the second factor that influences the choice of statistical procedure.

# Scales of Measurement



- ▶ **Nominal**
- ▶ **Ordinal**
- ▶ **Interval**
- ▶ **Ratio**

# Nominal Scale

- ▶ Observations fall into different **categories** or groups.
- ▶ Differences among categories are **qualitative**, not quantitative.
- ▶ Examples:
  - ▶ Gender
  - ▶ Ethnicity
  - ▶ Counseling method (cognitive vs. humanistic)
  - ▶ Retention (retained vs. not retained)

# Ordinal Scale



- ▶ Categories can be rank ordered in terms of amount or magnitude.
- ▶ Categories possess an inherent order, but the amount of difference between categories is unknown.
- ▶ Examples:
  - ▶ Class standing
  - ▶ Letter grades (A,B,C,D,F)
  - ▶ Likert-scale survey responses (SD, D, N, A, SA)

# Interval Scale

- ▶ Categories are ordered, but now the intervals for each category are exactly the same size.
- ▶ That is, the distance between measurement points represent equal magnitudes (e.g., the distance between point A and B is the same as the distance between B and C).
- ▶ Examples:
  - ▶ Fahrenheit scale of measuring temperature
  - ▶ Chronological scale of dates (1997 A.D.)
  - ▶ Standard scores (z-scores)

# Ratio Scale

- ▶ Same properties as the interval scale, but with an additional feature
- ▶ Ratio scale has an absolute 0 point.
- ▶ Absolute 0 point permits the use of ratios (e.g., A is “twice as large” as B).
- ▶ Examples:
  - ▶ Number of children
  - ▶ Weight
  - ▶ Annual income

# Categorical vs. Continuous Variables

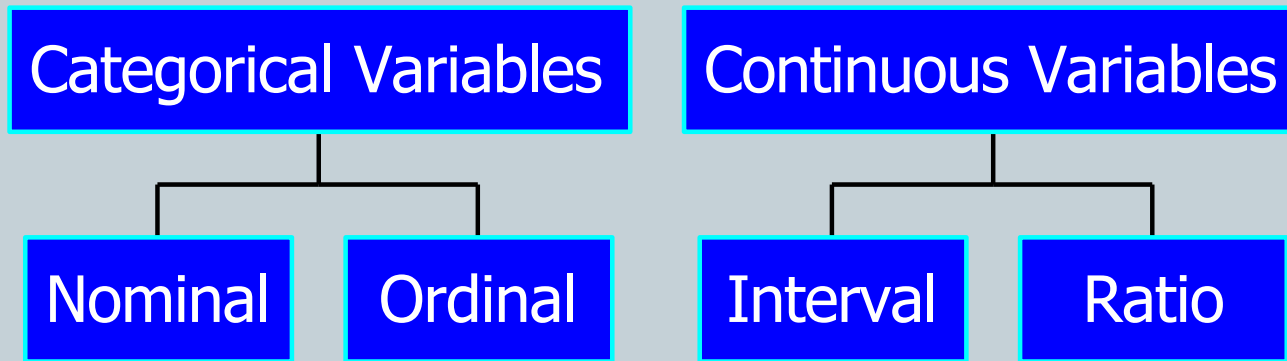


- ▶ In practice, it is not usually necessary to make such fine distinctions between measurement scales.
- ▶ Two distinctions, categorical and continuous are usually sufficient.
- ▶ Categorical variables consist of separate, indivisible categories (i.e., men/women).
- ▶ Continuous variables yield values that fall on a numeric continuum, and can (theoretically) take on an infinite number of values.



# Level of Measurement Summary

- ▶ In practice, the four levels of measurement can usually be classified as follows:



- ▶ Continuous variables are generally preferable because a wider range of statistical procedures can be applied

# Examples

- ▶ What is the level of measurement of
  - ▶ Temperature<sup>°C</sup>?
  - ▶ Color?
  - ▶ Income of professional baseball players?
  - ▶ Degree of agree (1 = Strongly Disagree, 5 = Strongly Agree)?

# Descriptive Statistics

- ▶ Procedures used to **summarize, organize, and simplify** data (data being a collection of measurements or observations) taken from a sample (i.e., mean, median, mode).
- ▶ Examples:
  - ▶ The average score on the Rosenberg Self-Esteem Scale was 7.5
  - ▶ 63% of the sample described themselves as Caucasian

# Inferential Statistics



- ▶ Techniques that allow us to make inferences about a population based on data that we gather from a sample.
- ▶ Study results will vary from sample to sample strictly due to random chance (i.e., sampling error).
- ▶ Inferential statistics allow us to determine how likely it is to obtain a set of results from a single sample.
- ▶ This is also known as testing for “statistical significance.”

# Module 1 Summary



- ▶ **The Role of Statistics**
- ▶ **Statistical Terminology**
- ▶ **Scales of Measurement**
- ▶ **Introduction to Descriptive and Inferential Statistics**

# Review Activity and Quiz



- ▶ Please complete the Module 1 Review Activity: Statistical Terminology located in Module 1.
- ▶ Upon completion of the Review Activity, please complete the Module 1 Quiz.
- ▶ Please note that all modules in this course build on one another; as a result, completion of the Module 1 Review Activity and Module 1 Quiz are required before moving on to Module 2.
- ▶ You can complete the review activities and quizzes as many times as you like.

# Upcoming Modules



- ▶ Module 1: Introduction to Statistics
- ▶ Module 2: Introduction to SPSS
- ▶ Module 3: Descriptive Statistics
- ▶ Module 4: Inferential Statistics
- ▶ Module 5: Correlation
- ▶ Module 6: *t*-Tests
- ▶ Module 7: ANOVAs
- ▶ Module 8: Linear Regression
- ▶ Module 9: Nonparametric Procedures

# Module 2: Introduction to SPSS

The Applied Research Center



# Module 2 Overview

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- ▶ Steps for Analyzing Data
- ▶ Using SPSS for Windows
  - ▶ Entering Data
  - ▶ Managing Data

# Steps for Analyzing Data

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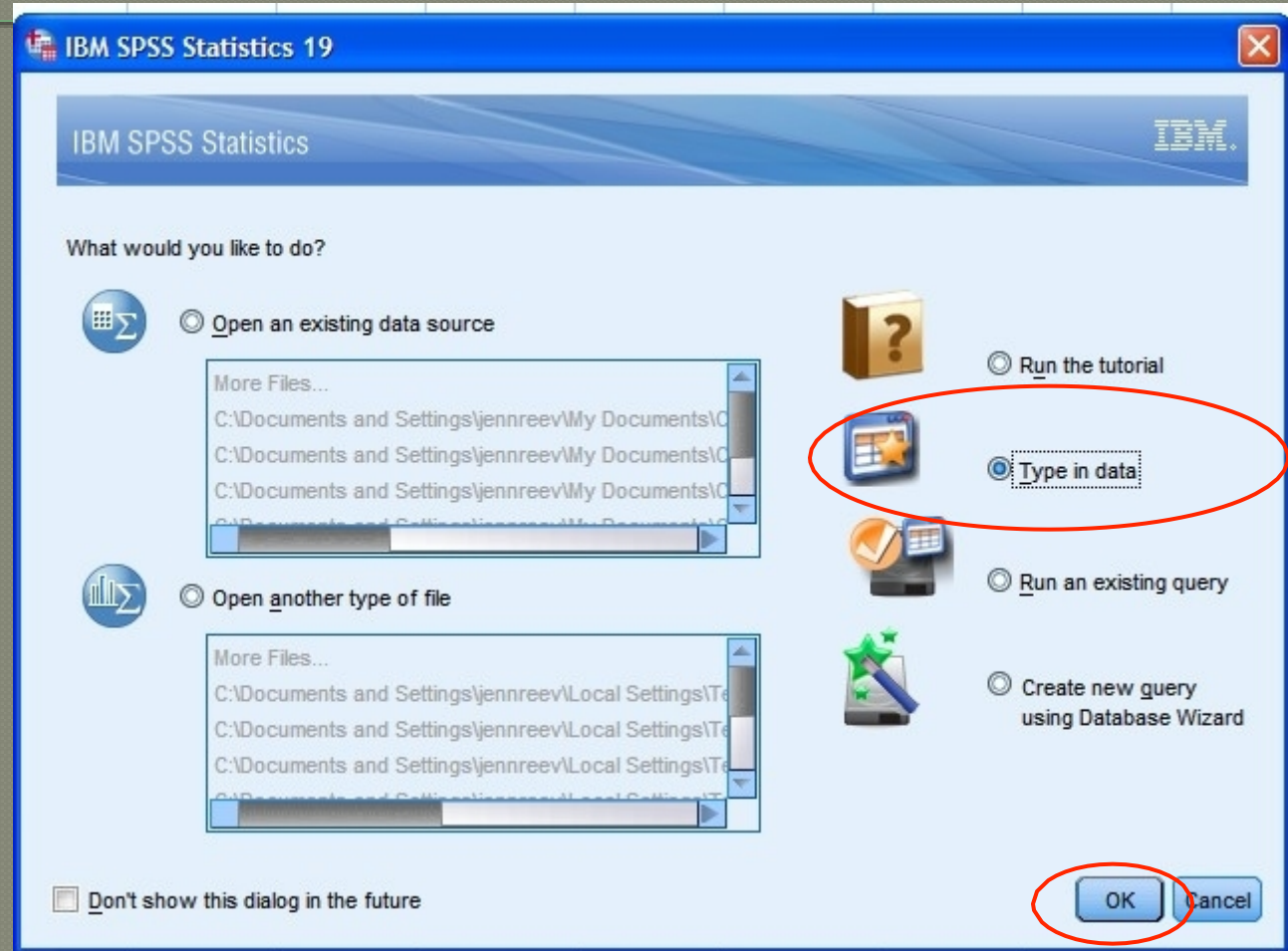
- ▶ Enter the data
- ▶ Select the procedure and options
- ▶ Select the variables
- ▶ Run the procedure
- ▶ Examine the output

# Using SPSS© for Windows - Data Procedures

- ▶ Entering Data
  - ▶ Ways to Enter Data
  - ▶ Entering Data Directly
  - ▶ Defining Variable Properties
- ▶ Managing Data
  - ▶ Viewing Data
  - ▶ Computing New Variables
  - ▶ Selecting Cases

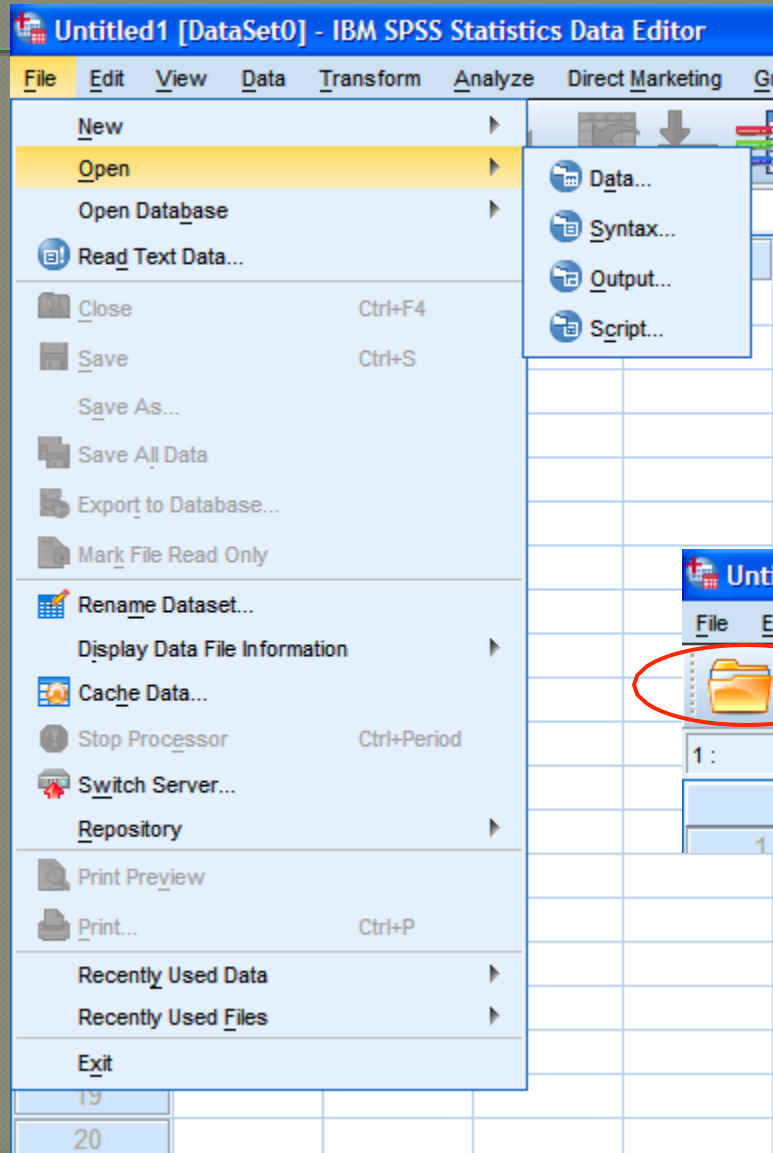
# Ways to Enter the Data

- ▶ Create a new data file
- ▶ Opening an existing data file
- ▶ Import data
  - ▶ Database file
  - ▶ Spreadsheet file (.xls)
  - ▶ ASCII text file

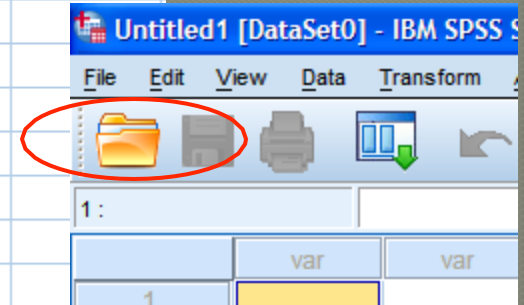


# Ways to Enter the Data

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  - ▶ Spreadsheet file (.xls)
  - ▶ ASCII text file

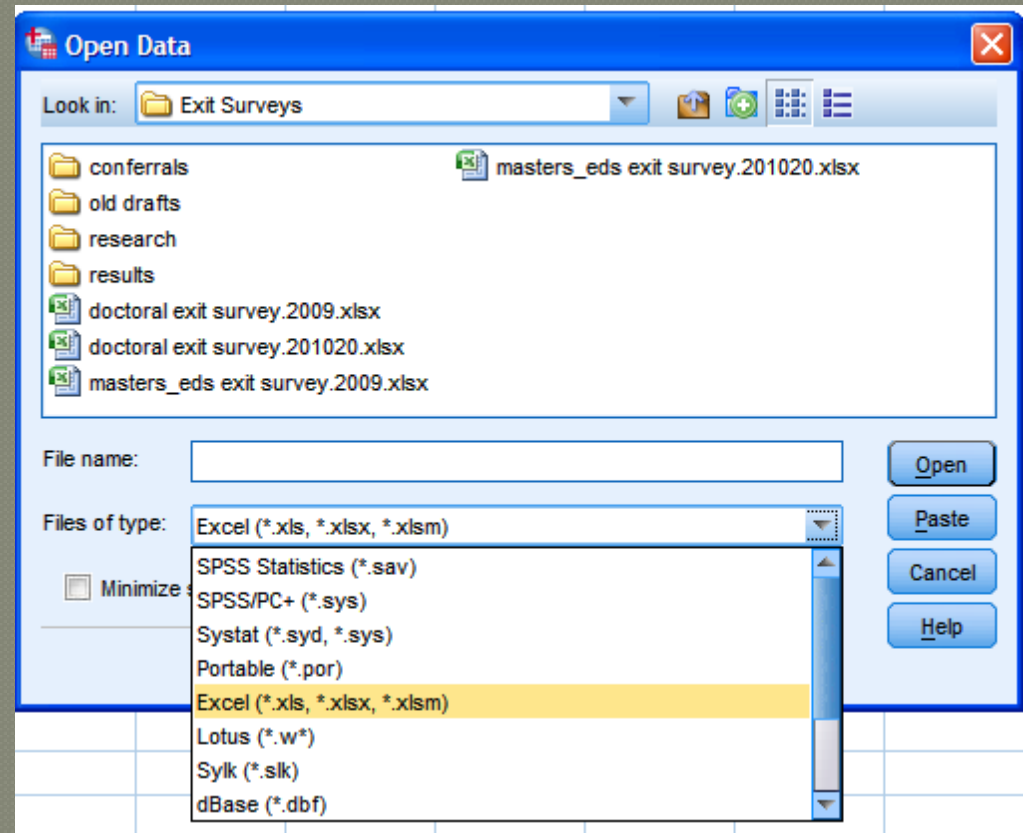
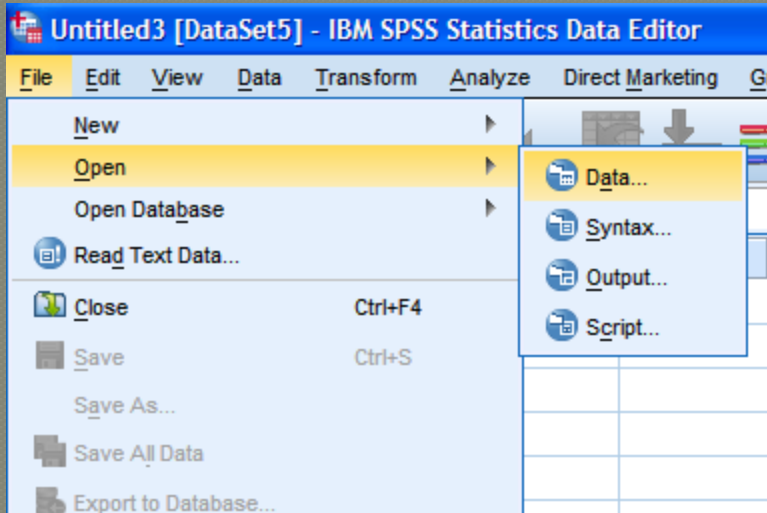


OR



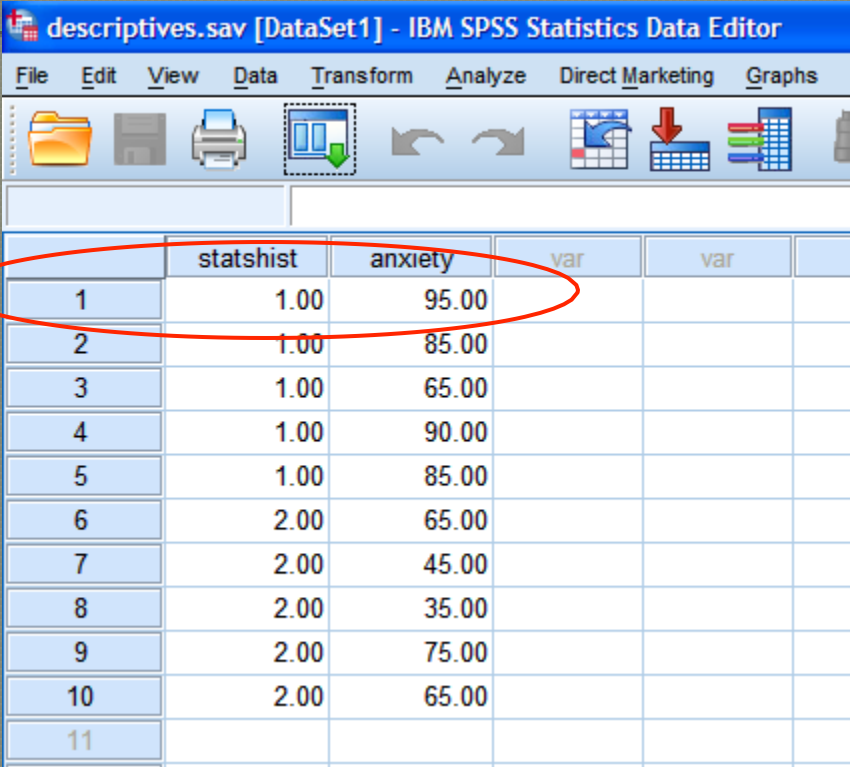
# Ways to Enter the Data (cont'd)

## ▶ Import data



# Directly

- ▶ Each row is a case (e.g., a participant).
- ▶ Enter the value for each variable.
- ▶ Press <Tab> key or right arrow key to move to next variable.
- ▶ Leave blank if no value/ data
- ▶ Press Enter key to move to the next case.



descriptives.sav [DataSet1] - IBM SPSS Statistics Data Editor

	statshist	anxiety	var	var
1	1.00	95.00		
2	1.00	85.00		
3	1.00	65.00		
4	1.00	90.00		
5	1.00	85.00		
6	2.00	65.00		
7	2.00	45.00		
8	2.00	35.00		
9	2.00	75.00		
10	2.00	65.00		
11				





# Labeling Variables

descriptives.sav [DataSet1] - IBM SPSS Statistics Data Editor

File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help

	Name	Type	Width	Decimals	Label	Values	M
1	statshist	Numeric	8	2		{1.00, no}...	None
2	anxiety	Numeric	8	2		None	None
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							

**Value Labels**

Value Labels

Value: 2

Label: yes

1.00 = "no"

Add

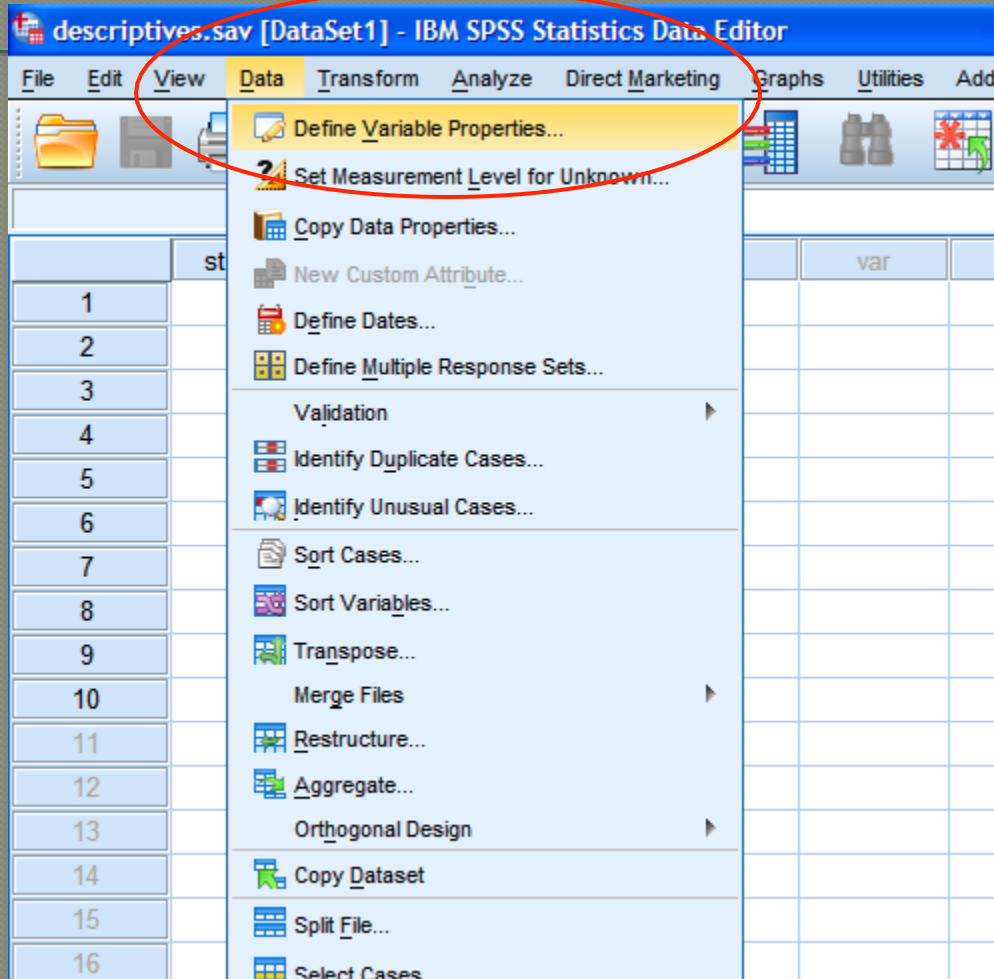
Change

Remove

Spelling...

OK Cancel Help

# Define Variable Properties Menu



# Define

**Define Variable Properties**


Use this facility to label variable values and set other properties after scanning the data.

Select the variables to scan. They should be categorical (nominal or ordinal) for best results. You can change the measurement level setting in the next panel.

**Variables:**

- statshist
- anxiety

**Variables to Scan:**



Limit number of cases scanned to:

Limit number of values displayed to:

**Define Variable Properties**


Use this facility to label variable values and set other properties after scanning the data.

Select the variables to scan. They should be categorical (nominal or ordinal) for best results. You can change the measurement level setting in the next panel.

**Variables:**

**Variables to Scan:**

- statshist
- anxiety



Limit number of cases scanned to:

Limit number of values displayed to:

# Labeling Variables

- Type labels in boxes under Label column

**Define Variable Properties**

Scanned Variable List

Un...	Me...	Role	Variable
<input type="checkbox"/>			statshist
<input checked="" type="checkbox"/>			anxiety

Current Variable: statshist    Label:

Measurement Level: Scale    Suggest    Type: Numeric   

Role: Input    Width: 8    Decimals: 2

Unlabeled values: 0   

Value Label grid: Enter or edit labels in the grid. You can enter additional values at the bottom.

	Changed	Missing	Count	Value	Label
1	<input type="checkbox"/>	<input type="checkbox"/>	5	1.00	no
2	<input type="checkbox"/>	<input type="checkbox"/>	5	2.00	yes
3	<input type="checkbox"/>	<input type="checkbox"/>			

# Value Labels

- Data entered as numeric codes can be displayed as value labels by clicking the “Value Labels” icon.

The screenshot shows the IBM SPSS Statistics Data Editor interface. The title bar reads "\*descriptives.sav [DataSet1] - IBM SPSS Statistics Data Editor". The menu bar includes File, Edit, View, Data, Transform, Analyze, Direct Marketing, Graphs, Utilities, Add-ons, Window, and Help. The toolbar contains various icons, with the "Value Labels" icon (a small window with a green arrow) circled in red. Below the toolbar, two data tables are displayed. The first table shows the original data with numeric codes for the 'statshist' variable. The second table shows the same data with value labels (1.00 and 2.00) for the 'statshist' variable, also circled in red.

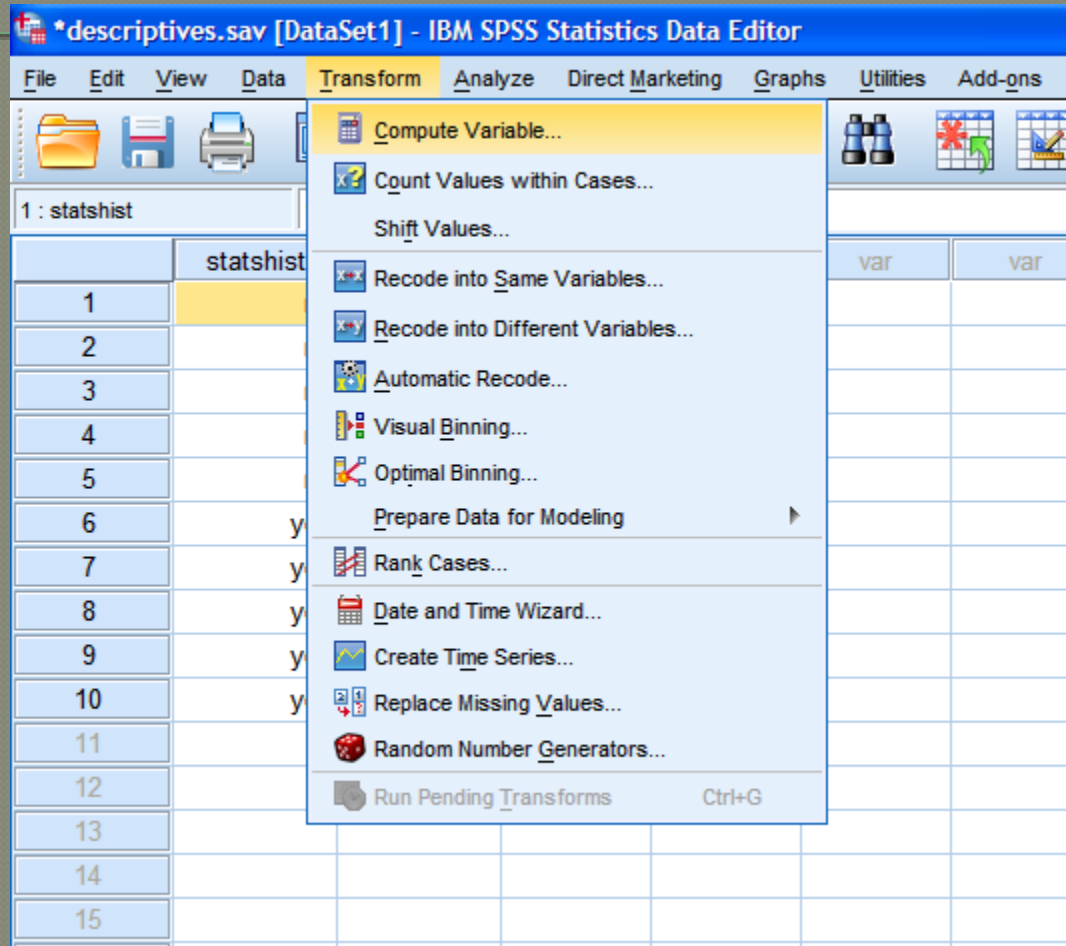
	statshist	anxiety	var
1	no	95.00	
2	no	85.00	
3	no	65.00	
4	no	90.00	
5	no	85.00	
6	yes	65.00	
7	yes	45.00	
8	yes	35.00	
9	yes	75.00	
10	ves	65.00	

	statshist	anxiety	var
1	1.00	95.00	
2	1.00	85.00	
3	1.00	65.00	
4	1.00	90.00	
5	1.00	85.00	
6	2.00	65.00	
7	2.00	45.00	
8	2.00	35.00	
9	2.00	75.00	
10	2.00	65.00	

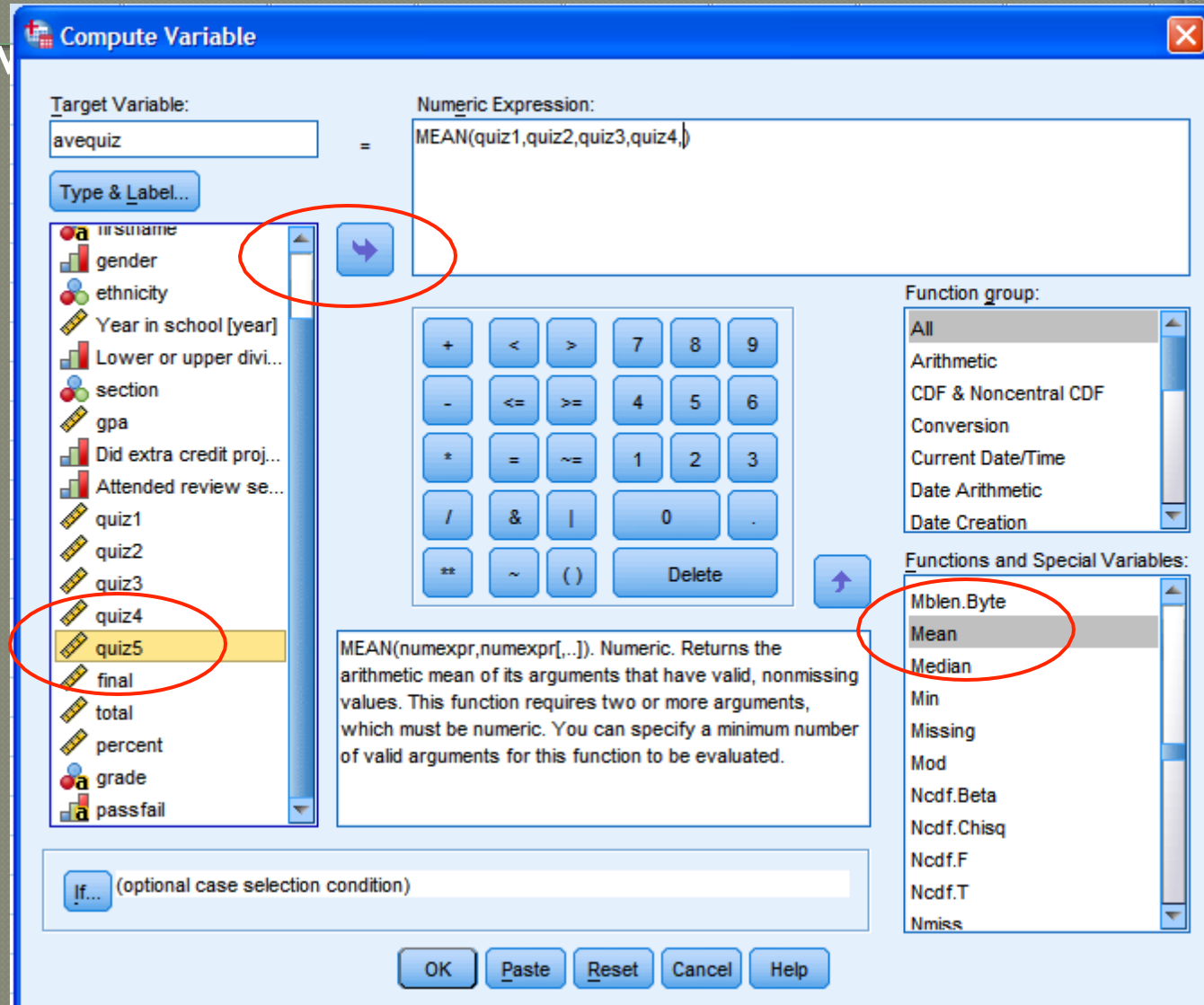
# Compute Procedure

- ▶ Compute is used to create a new variable.



# Compute Procedure (cont'd)

- ▶ Name the new variable
- ▶ Choose the type of computation
- ▶ Select the appropriate variables to add to the numeric expression



# Compute Procedure (cont'd)

\*grades.sav [DataSet3] - IBM SPSS Statistics Data Editor

File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help

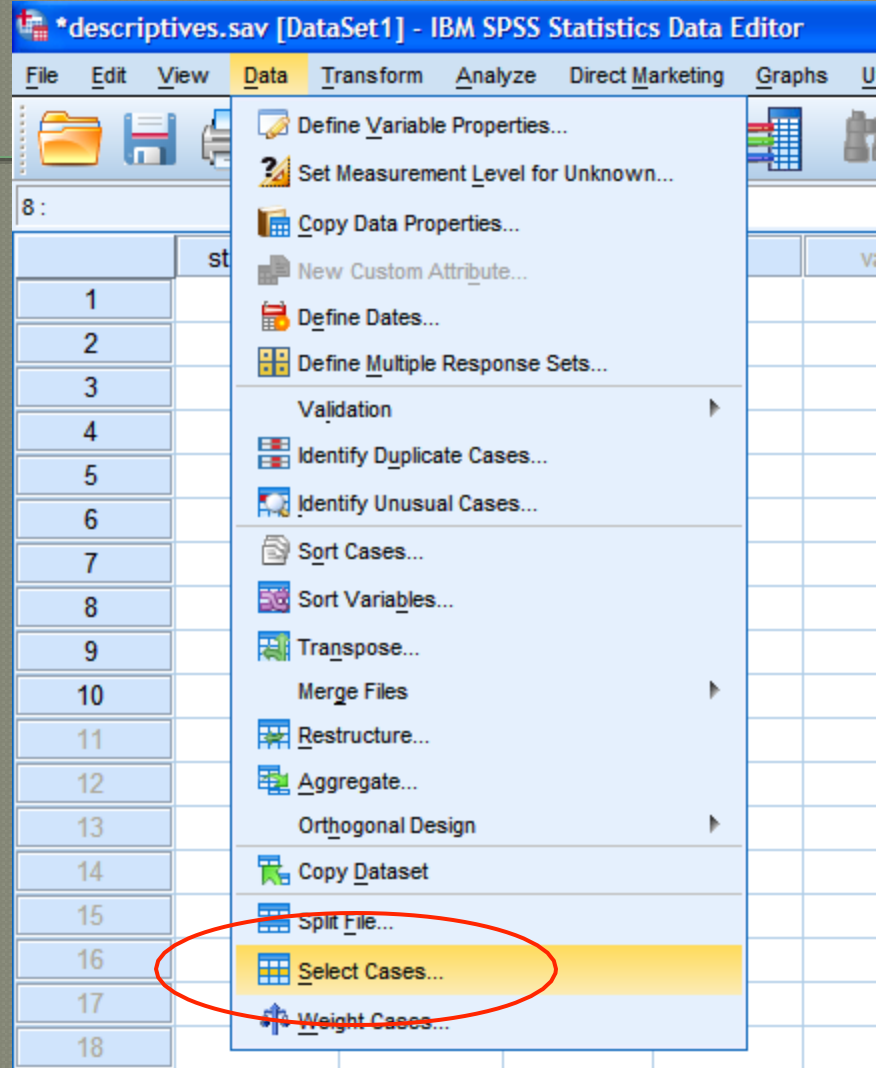
1 : avequiz 5.40

	quiz1	quiz2	quiz3	quiz4	quiz5	avequiz	var
1	6	5	7	6	3	5.40	
2	10	10	7	6	9	8.40	
3	10	7	8	9	7	8.20	
4	7	8	7	7	6	7.00	
5	7	8	9	8	10	8.40	
6	10	10	10	9	9	9.60	
7	10	9	10	10	10	9.80	
8	10	9	10	10	10	9.80	
9	10	10	10	10	9	9.80	
10	10	10	9	10	10	9.80	
11	7	8	6	7	10	7.60	
12	8	10	10	10	9	9.40	
13	8	8	10	10	6	8.40	
14	3	8	4	6	8	5.80	
15	5	5	7	6	4	5.40	
16	5	8	6	4	10	6.60	
17	5	7	4	7	6	5.80	



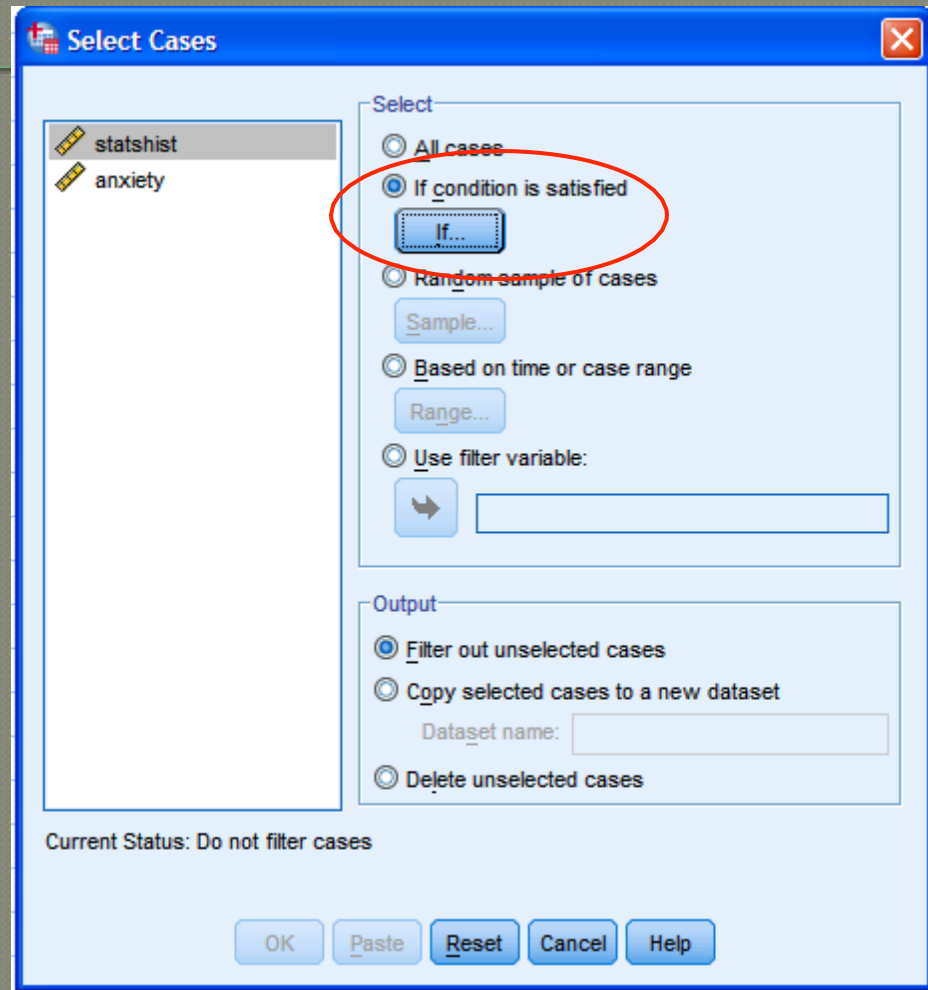
# Select Cases

- ▶ For a subset of the data file, use Select Cases



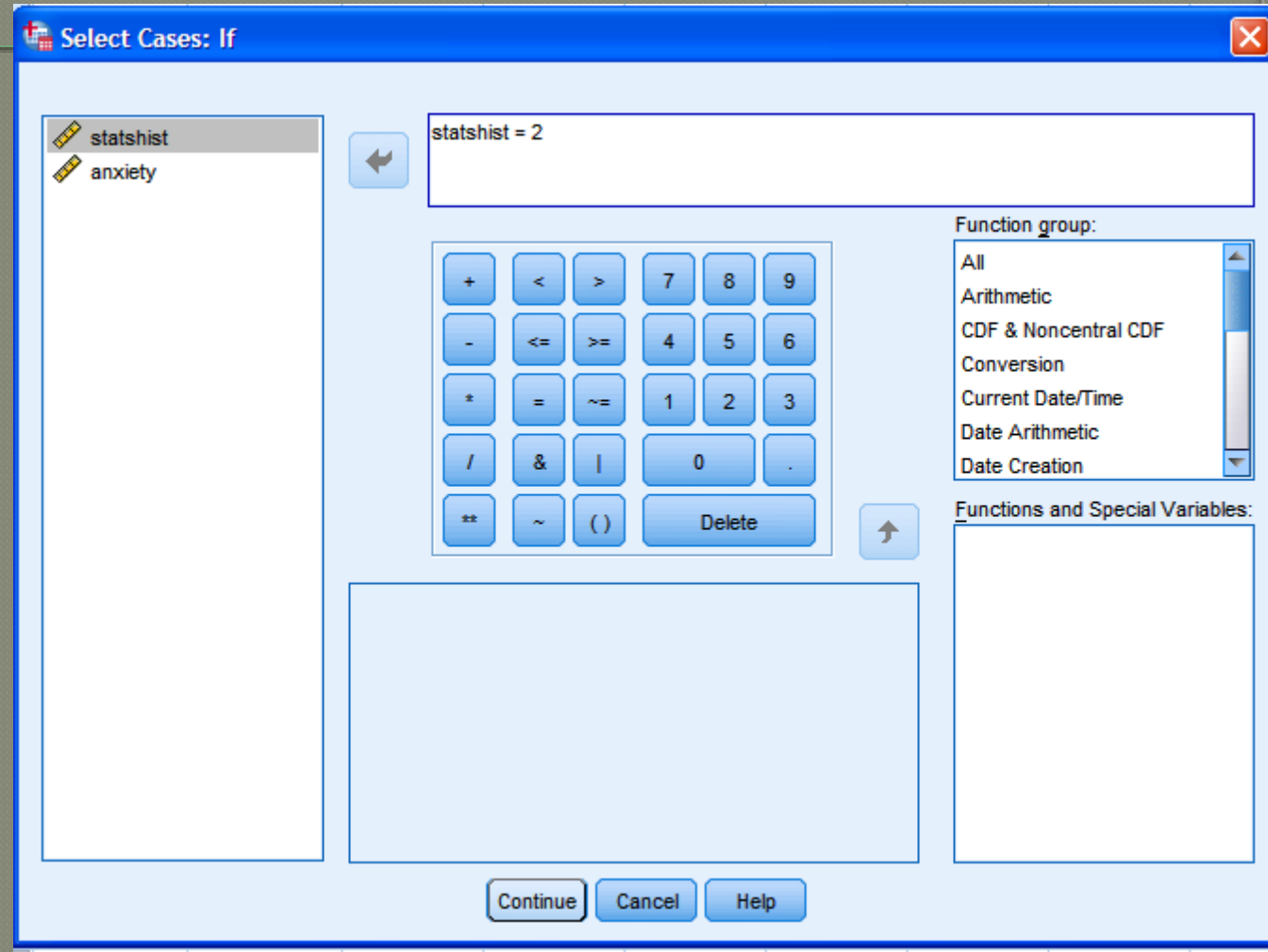
# Select Cases

- ▶ To select only those cases which meet certain criteria, choose the If option.



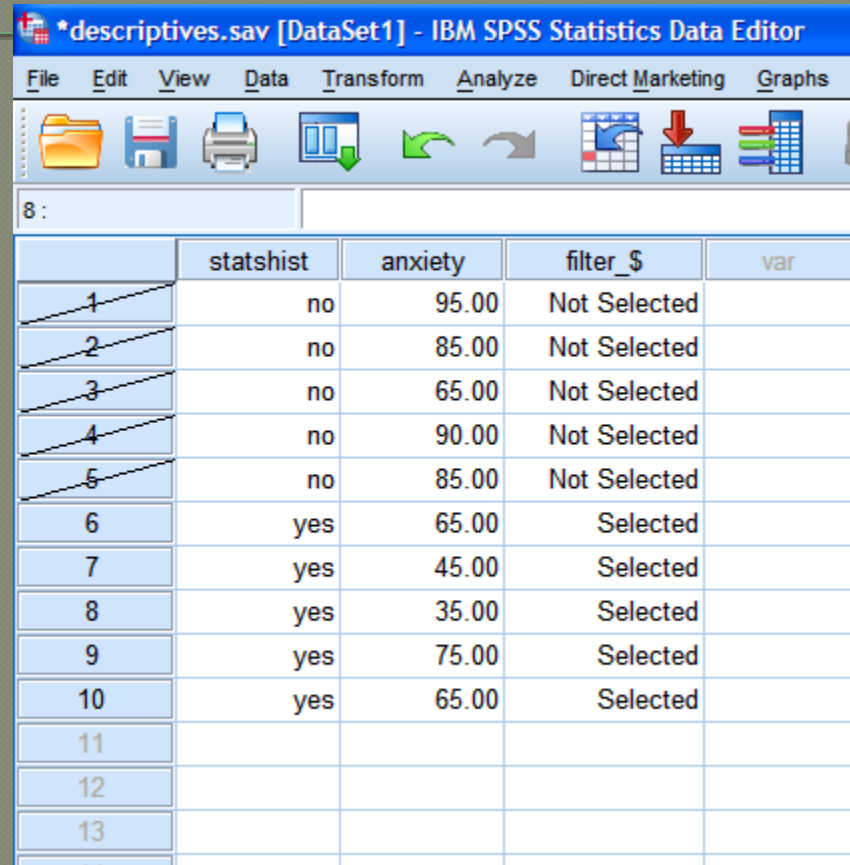
# Select Cases (cont'd)

- ▶ Enter the expression that will determine which cases will be selected



# Select Cases (cont'd)

- ▶ Only those cases selected will be used in the analysis



The screenshot shows the IBM SPSS Statistics Data Editor window for a file named 'descriptives.sav [DataSet1]'. The window displays a data table with the following columns: 'statshist', 'anxiety', 'filter\_\$', and 'var'. The rows are numbered 1 through 13. Rows 1 through 5 are crossed out with diagonal lines, indicating they are not selected. Rows 6 through 10 are highlighted in blue, indicating they are selected. The 'filter\_\$' column shows 'Not Selected' for rows 1-5 and 'Selected' for rows 6-10. The 'anxiety' column shows values ranging from 35.00 to 95.00. The 'statshist' column shows 'no' for rows 1-5 and 'yes' for rows 6-10. The 'var' column is empty for all rows.

	statshist	anxiety	filter_\$	var
<del>1</del>	no	95.00	Not Selected	
<del>2</del>	no	85.00	Not Selected	
<del>3</del>	no	65.00	Not Selected	
<del>4</del>	no	90.00	Not Selected	
<del>5</del>	no	85.00	Not Selected	
6	yes	65.00	Selected	
7	yes	45.00	Selected	
8	yes	35.00	Selected	
9	yes	75.00	Selected	
10	yes	65.00	Selected	
11				
12				
13				

# Select Cases (cont'd)

- Select “All cases” to analyze all cases in the data file.

	statshist	anxiety
1	no	95.00
2	no	85.00
3	no	65.00
4	no	90.00
5	no	85.00
6	yes	65.00
7	yes	45.00
8	yes	35.00
9	yes	75.00
10	yes	65.00
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		

**Select Cases**

Select

- All cases
- If condition is satisfied  
If... statshist = 2
- Random sample of cases  
Sample...
- Based on time or case range  
Range...
- Use filter variable:  
[ ]

Output

- Filter out unselected cases
- Copy selected cases to a new dataset  
Dataset name: [ ]
- Delete unselected cases

Current Status: Do not filter cases

OK Paste Reset Cancel Help

# Module 2 Summary

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- ▶ Steps for Analyzing Data
- ▶ Using SPSS for Windows
  - ▶ Entering Data
  - ▶ Managing Data

# Review Activity and Quiz

- ▶ Please complete the Module 2 Review Activity: 5 Steps for Analyzing Data located in Module 2.
- ▶ Upon completion of the Review Activity, please complete the Module 2 Quiz.
- ▶ Please note that all modules in this course build on one another; as a result, completion of the Module 2 Review Activity and Module 2 Quiz are required before moving on to Module 3.
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# Upcoming Modules

- ▶ Module 1: Introduction to Statistics
- ▶ Module 2: Introduction to SPSS
- ▶ Module 3: Descriptive Statistics
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- ▶ Module 8: Linear Regression
- ▶ Module 9: Nonparametric Procedures





# Module 3: Descriptive Statistics

The Applied Research Center

# Module 3 Overview

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- ▶ Measures of Central Tendency
- ▶ Measures of Variability
- ▶ Frequency Distributions
- ▶ Running Descriptive Statistics



# Measures of Central Tendency

- ▶ Three measures of central tendency are available
  - ▶ The Mean
  - ▶ The Median
  - ▶ The Mode
- ▶ Unfortunately, no single measure of central tendency works best in all circumstances
  - ▶ Nor will they necessarily give you the same answer



# Example

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- ▶ SAT scores from a sample of 10 college applicants yielded the following:
  - ▶ Mode: 480
  - ▶ Median: 505
  - ▶ Mean: 526
- ▶ Which measure of central tendency is most appropriate?



# The Mean

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- ▶ The mean is simply the arithmetic average
- ▶ The mean would be the amount that each individual would get if we took the total and divided it up equally among everyone in the sample
- ▶ Alternatively, the mean can be viewed as the balancing point in the distribution of scores (i.e., the distances for the scores above and below the mean cancel out)



# The Median

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- ▶ The median is the score that splits the distribution exactly in half
- ▶ 50% of the scores fall above the median and 50% fall below
- ▶ The median is also known as the 50th percentile, because it is the score at which 50% of the people fall below



# Special Notes

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- ▶ A desirable characteristic of the median is that it is **not** affected by extreme scores
- ▶ Example:
  - ▶ Sample 1: 18, 19, 20, 22, 24
  - ▶ Sample 2: 18, 19, 20, 22, 47
- ▶ Thus, the median is not distorted by skewed distributions



# The Mode

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- ▶ The mode is simply the most common score
- ▶ There is no formula for the mode
- ▶ When using a frequency distribution, the mode is simply the score (or interval) that has the highest frequency value
- ▶ When using a histogram, the mode is the score (or interval) that corresponds to the tallest bar

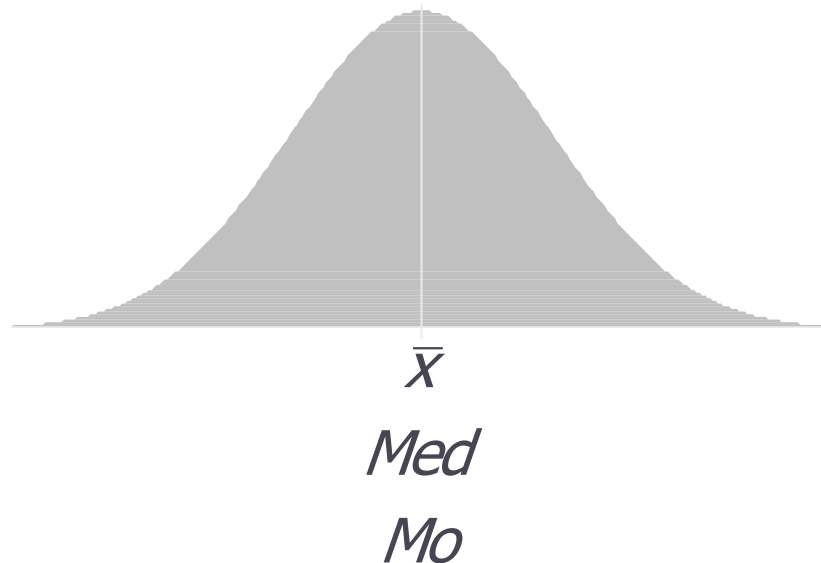




# Distribution Shape and Central Tendency

---

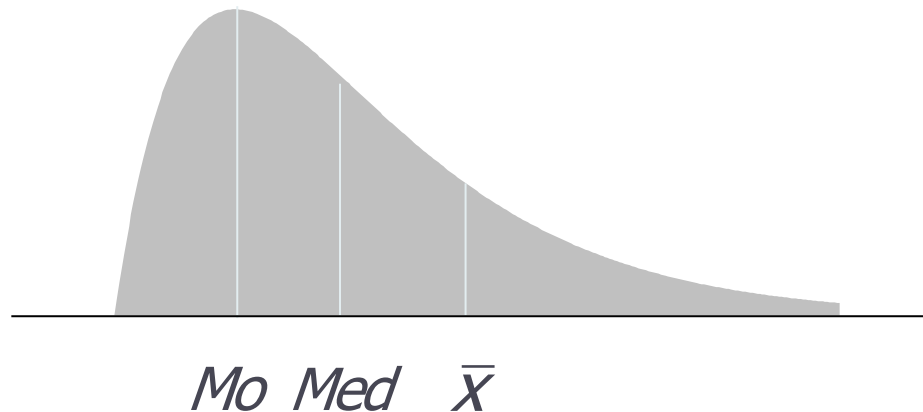
- ▶ In a normal distribution, the mean, median, and mode will be approximately equal



# Skewed Distribution

---

- ▶ In a skewed distribution, the mode will be the peak, the mean will be pulled toward the tail, and the median will fall in the middle



# Choosing the Proper Statistic

---

- ▶ **Continuous data**

- ▶ Always report the mean
- ▶ If data are substantially skewed, it is appropriate to use the median as well

- ▶ **Categorical data**

- ▶ For nominal data you can only use the mode
- ▶ For ordinal data the median is appropriate (although people often use the mean)



# Example

---

- ▶ SAT scores from a sample of 10 college applicants yielded the following:
  - ▶ Mode: 480
  - ▶ Median: 505
  - ▶ Mean: 526
- ▶ Which measure of central tendency is most appropriate?



# Measures of Variability

---

- ▶ The fluctuation of scores about a central tendency is called “variability.”
- ▶ We can use measures of variability to compare two sets of scores.
- ▶ Although the means may be the same, the distribution may be different.
- ▶ Measure of Variability
  - ▶ Range
  - ▶ Standard Deviation
  - ▶ Variance

# Range

---

- ▶ Range is the distance between two extreme scores.
- ▶ It informs us about the dispersion of our distribution.
- ▶ The larger the range the larger the dispersion from the mean value.
- ▶ Although the mean of the scores of two distributions can be identical their ranges may be different.

# Drawbacks to the Range

---

- ▶ Good preliminary measure, but one single extreme value can influence the range significantly.
- ▶ The calculation of the range is derived from the highest and lowest values and doesn't tell us anything about the variability of the different values.



# Standard Deviation

---

- ▶ Defined as the variability of the scores around the mean
- ▶ Each score in a distribution varies from the mean by a greater or lesser amount, except when the score is the same as the mean.
- ▶ Deviations from the mean can be noted as either positive or negative deviations from the mean.
- ▶ The average of these deviations would equal “zero.”





# Standard Deviation (cont'd)

- ▶ Large SD



- ▶ Small SD



# Variance

---

- ▶ The variance and the closely-related standard deviation are measures of how **spread** out a distribution is.



# Frequency Distribution Tables

# Overview

---

- ▶ After collecting data, researchers are faced with pages of unorganized numbers, stacks of survey responses, etc.
- ▶ The goal of descriptive statistics is to aggregate the individual scores (datum) in a way that can be readily summarized
- ▶ A frequency distribution table can be used to get “picture” of how scores were distributed



# Frequency Distributions

---

- ▶ A frequency distribution displays the number (or percent) of individuals that obtained a particular score or fell in a particular category
- ▶ As such, these tables provide a picture of where people respond across the range of the measurement scale
- ▶ One goal is to determine where the **majority** of respondents were located



# When To Use Frequency Tables

- ▶ Frequency distributions and tables can be used to answer **all** descriptive research questions
- ▶ It is important to **always** examine frequency distributions on the IV and DV when answering comparative and relationship questions



# Three Components of a Frequency Distribution Table

---

## ▶ Frequency

- ▶ the number of individuals that obtained a particular score (or response)

## ▶ Percent

- ▶ The corresponding percentage of individuals that obtained a particular score

## ▶ Cumulative Percent

- ▶ The percentage of individuals that fell at or below a particular score (not relevant for nominal variables)



# Example

---

- ▶ What are the ages of students in an online course?
- ▶ Are students likely to recommend the course to others?
  
- ▶ Step 1: Input the Data into SPSS

Age	Recommend
31	2
26	3
32	4
37	5
18	4
31	5
38	4
49	2
35	4
37	3
43	4
41	5
49	4
40	2



## Example (cont'd)

---

- ▶ Step 2: Run the Frequencies
- ▶ Analyze → Descriptive Statistics → Frequencies
- ▶ Move variables to the Variables box (select the variables and click on the arrow).
- ▶ Click OK.

# Example

---

- ▶ Frequency distribution showing the ages of students who took th

		Age			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18.00	1	7.1	7.1	7.1
	26.00	1	7.1	7.1	14.3
	31.00	2	14.3	14.3	28.6
	32.00	1	7.1	7.1	35.7
	35.00	1	7.1	7.1	42.9
	37.00	2	14.3	14.3	57.1
	38.00	1	7.1	7.1	64.3
	40.00	1	7.1	7.1	71.4
	41.00	1	7.1	7.1	78.6
	43.00	1	7.1	7.1	85.7
	49.00	2	14.3	14.3	100.0
	Total	14	100.0	100.0	

## Example (cont'd)

---

- ▶ Student responses when asked whether or not they would recommend the online course to others

**Recommend**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Probably Would Not	3	21.4	21.4	21.4
	May or May Not	2	14.3	14.3	35.7
	Probably Would	6	42.9	42.9	78.6
	Definitely Would	3	21.4	21.4	100.0
	Total	14	100.0	100.0	

- ▶ Most would recommend the course



# Running Descriptive Statistics

# Example

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- ▶ Are there differences in the anxiety levels of students who have had statistics before versus students who have never had statistics?

# Example (cont'd)

---

- ▶ Step 1: Input the data into SPSS

Stats History	Anxiety Score
1	95
1	85
1	65
1	90
1	85
2	65
2	45
2	35
2	75
2	65

## Example (cont'd)

---

- ▶ **Step 2: Run the descriptive statistics**
  - ▶ Analyze → Compare Means → Means
  - ▶ Anxiety = Dependent List
  - ▶ Stats History = Independent List
  - ▶ Click Options
    - ▶ Move Median over
    - ▶ Move Minimum over
    - ▶ Move Maximum over
  - ▶ Click Continue
  - ▶ Click OK



# Example (cont'd)

---

## Report

anxiety

statshist	Mean	N	Std. Deviation	Median	Minimum	Maximum	Range	Variance
no	84.0000	5	11.40175	85.0000	65.00	95.00	30.00	130.000
yes	57.0000	5	16.43168	65.0000	35.00	75.00	40.00	270.000
Total	70.5000	10	19.50071	70.0000	35.00	95.00	60.00	380.278





## Example (cont'd)

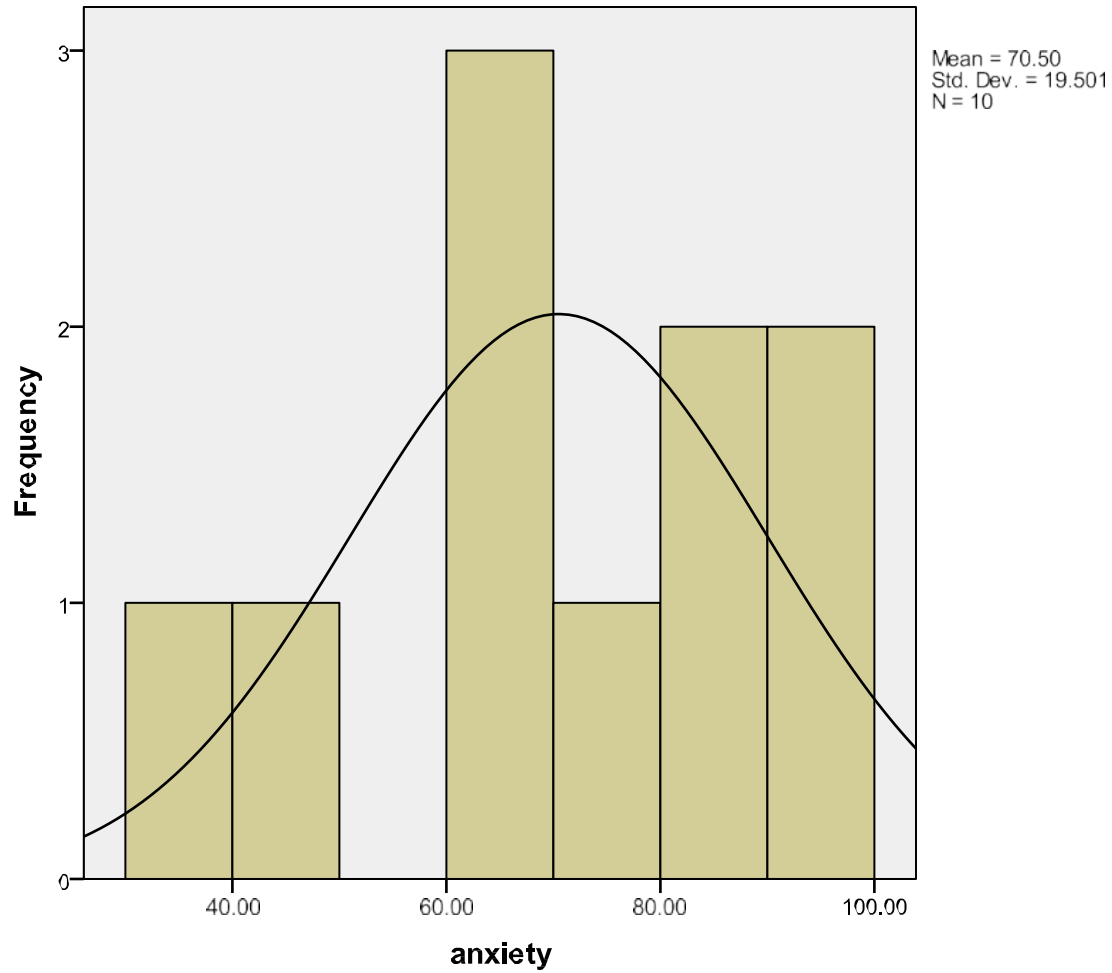
---

- ▶ **Step 3: Create a Histogram for Anxiety with a normal curve option**
  - ▶ Graphs → Legacy Dialogs → Histogram
  - ▶ Variable = anxiety
  - ▶ Check the “Display normal curve” check box
  - ▶ Click Ok



# Histogram for Anxiety

---



## Example (cont'd)

---

- ▶ **Step 4: Write up the results**
  - ▶ Descriptive statistics revealed that students who had previous experience with statistics ( $M = 57.00$ ,  $SD = 16.43$ ) had lower anxiety at the beginning of the semester than students who did not have any previous experience with statistics ( $M = 84.00$ ,  $SD = 11.40$ ) .

# Module 3 Summary

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- ▶ Measures of Central Tendency
- ▶ Measures of Variability
- ▶ Frequency Distributions
- ▶ Running Descriptive Statistics



# Review Activity and Quiz

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- ▶ Please complete the Module 3 Review Activity: Descriptive Statistics Terminology located in Module 3.
- ▶ Upon completion of the Review Activity, please complete the Module 3 Quiz.
- ▶ Please note that all modules in this course build on one another; as a result, completion of the Module 3 Review Activity and Module 3 Quiz are required before moving on to Module 4.
- ▶ You can complete the review activities and quizzes as many times as you like.

# Upcoming Modules

---

- ▶ Module 1: Introduction to Statistics
- ▶ Module 2: Introduction to SPSS
- ▶ Module 3: Descriptive Statistics
- ▶ **Module 4: Inferential Statistics**
- ▶ **Module 5: Correlation**
- ▶ **Module 6: *t*-Tests**
- ▶ **Module 7: ANOVAs**
- ▶ **Module 8: Linear Regression**
- ▶ **Module 9: Nonparametric Procedures**





# Module 4: Inferential Statistics

The Applied Research Center

# Module 4 Overview

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- ▶ Inferential Statistics
- ▶ Brief Introduction to Probabilities
- ▶ Hypothesis Testing





# Parameter vs. Statistic

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- ▶ A population is the **entire** set of individuals that we are interested in studying
- ▶ A sample is simply a subset of individuals selected from the population
- ▶ In most studies, we wish to quantify some characteristic of the population → parameter
- ▶ Parameters are generally unknown, and must be estimated from a sample
- ▶ The sample estimate is called a statistic



# Inferential Statistics

- ▶ Techniques that allow us to make inferences about a population based on data that we gather from a sample
- ▶ Study results will vary from sample to sample strictly due to random chance (i.e., sampling error)
- ▶ Inferential statistics allow us to determine how likely it is to obtain a set of results from a single sample
- ▶ This is also known as testing for “statistical significance”

# Statistical Significance

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- ▶ Consider a small weight loss study of 40 patients.
- ▶ After such a study is over, we want to make generalizations about a larger group (e.g. all similar patients in the nation), but, since it is a small study, the results will be inexact.
- ▶ Statistical significance helps us by giving us a "ballpark range" (i.e., confidence interval) around the number (for example the amount of weight lost), encompassing the true number.

## Statistical Significance (cont'd)

---

- ▶ If the range is small enough ( $p < .05$ ), we say we are confident that the true amount of weight lost is "more than zero" and "statistically significant."
- ▶ Naturally, it says nothing about the practical significance, since the patients might have lost just a gram of weight!



# Statistical Significance Testing

Hypothesis Testing

# A Brief Introduction to Probability

- ▶ A basic understanding of probability is needed
- ▶ The probability of an outcome (A), can be thought of as a fraction, proportion, or percentage

$$\text{probability of A} = \frac{\text{number of A outcomes}}{\text{total number of outcomes}}$$



# Probability Examples

---

- ▶ What is the probability of rolling a single die and coming up with a six?
  - ▶ There is only 1 outcome A (a six)
  - ▶ There are 6 possible outcomes (1 to 6)
  - ▶ The probability is  $1/6 = .1667 = 16.7\%$
- ▶ What is the probability of obtaining a red number in the game of roulette?
  - ▶ There are 18 red numbers (A)
  - ▶ There are 38 numbers total
  - ▶ The probability is  $18/38 = .4737 = 47.4\%$



# The Null Hypothesis

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- ▶ The null hypothesis **always states** that nothing is going on
  - ▶ There is no difference, no relationship, no treatment effect, etc.
  - ▶  $H_0: X = Y$
- ▶ The alternate hypothesis states that there is a difference
  - ▶  $H_a: X \neq Y$  (non directional)
  - ▶  $H_a: X > Y$  or  $H_a: X < Y$  (directional)



# The (Somewhat Twisted) Logic of Significance Testing

---

- ▶ Compute a probability value that tells how likely our data (or results) would occur just by chance
- ▶ If the probability is “low” (e.g.,  $p = .02$ ), this means our data is inconsistent with the null
  - ▶ There is evidence that there is a difference
- ▶ If the probability value is “high” (e.g.,  $p = .30$ ), this means our data is consistent with the null
  - ▶ There does not seem to be evidence that there is a difference

## More on the Logic

---

- ▶ The confusing thing is that we are not directly testing whether or not there is a treatment effect, or relationship
- ▶ We are testing how consistent the data is with the hypothesis that there is **no** treatment effect, relationship, etc.
- ▶ Thus, a treatment effect is demonstrated indirectly if the data is inconsistent with the null hypothesis



## Rule of Thumb ( $p < .05$ )

---

- ▶ How inconsistent with the null does the data have to be to demonstrate an effect?
- ▶ Conventional rules use a  $p < .05$  cutoff
- ▶ If the data yields a probability value less than .05 ( $p < .05$ ), that means the data is inconsistent with the null, which states no treatment effect or relationship exists ( $H_0: X = Y$ )
- ▶ Therefore, we reject the null



# Two Outcomes

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- ▶ If  $p < .05$ , our data is inconsistent with the null
  - ▶ We “reject the null” and declare our results “statistically significant”
- ▶ If  $p > .05$ , our data is consistent with the null
  - ▶ We “fail to reject the null” and declare our results “statistically non-significant”



# Example 1

---

- ▶ Suppose we were comparing how males and females differed with respect to their satisfaction with an online course
- ▶ The null hypothesis states that men ( $X$ ) and women ( $Y$ ) do not differ in their levels of satisfaction
  - ▶  $H_0: X = Y$

## Example 1 (cont'd)

---

- ▶ On a 25-point satisfaction scale, men and women differed by about 5 points (means were 18.75 and 23.5, respectively)
- ▶ They were not identical, but how likely is a 5 point difference to occur just by chance?



## Example 1 (cont'd)

---

- ▶ An analysis was conducted, and the p-value for the gender comparison was  $p = .11$
- ▶ Thus, there was about a 11% chance that this data (the 5 point difference) would occur by chance
- ▶ The p-value is greater than .05, so we would fail to reject the null (results are not significant)
- ▶ Thus, there is no evidence that males and females differ in their satisfaction

## Example 2

---

- ▶ Suppose we were comparing how males and females differed with respect to how likely they would be to recommend an online course (measured on a 5 point scale)
- ▶ The null hypothesis states that there is no difference between men and women in their recommendation of an online course.
  - ▶ ( $H_0: X = Y$ )



## Example 2 (cont'd)

---

- ▶ On a 5-point satisfaction scale, men and women differed by about 1 point (means were 4.3 and 3.1, respectively)
- ▶ They were not identical, but how likely is a 1 point difference to occur by chance?



## Example 2 (cont'd)

---

- ▶ An analysis was conducted, and the p-value for the gender comparison was  $p = .03$
- ▶ Thus, there was only a 3% probability that this data would occur by chance
- ▶ The p-value is less than .05, so we would reject the null (results are significant)
- ▶ Thus, there is evidence that males and females differ in their recommendations

# The Meaning of Statistical Significance

- ▶ p-values tell how likely it was that our sample was drawn from a hypothetical population where “nothing was going on”
- ▶ Thus, the term “statistical significance” simply means that the obtained results are unlikely to represent a situation where there was no relationship between variables
- ▶ The difference is big enough to be unlikely to have happened simply due to chance



# Cautionary Note

---

- ▶ Just because results are statistically significant, does not mean that the results are of practical importance
- ▶ It ends up that large samples are more likely to yield “significant results”, even if the differences are rather trivial
- ▶ Don't equate “statistical significance” with a “large” or “important” effect

# Module 4 Summary

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- ▶ Inferential Statistics
- ▶ Brief Introduction to Probabilities
- ▶ Hypothesis Testing



# Review Activity and Quiz

---

- ▶ Please complete the Module 4 Review Activity: Hypothesis Testing located in Module 4.
- ▶ Upon completion of the Review Activity, please complete the Module 4 Quiz.
- ▶ Please note that all modules in this course build on one another; as a result, completion of the Module 4 Review Activity and Module 4 Quiz are required before moving on to Module 4.
- ▶ You can complete the review activities and quizzes as many times as you like.



# Upcoming Modules

---

- ▶ Module 1: Introduction to Statistics
- ▶ Module 2: Introduction to SPSS
- ▶ Module 3: Descriptive Statistics
- ▶ Module 4: Inferential Statistics
- ▶ **Module 5: Correlation**
- ▶ **Module 6: *t*-Tests**
- ▶ **Module 7: ANOVAs**
- ▶ **Module 8: Linear Regression**
- ▶ **Module 9: Nonparametric Procedures**





# Module 5: Correlation

The Applied Research Center



# Module 5 Overview

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- ▶ Definition of Correlation
- ▶ Relationship Questions
- ▶ Scatterplots
- ▶ Strength and Direction of Correlations
- ▶ Running a Pearson Product Moment Correlation
- ▶ Factors Affecting the Correlation
- ▶ Other Types of Correlations

# Correlation

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- ▶ The term correlation is used to describe the relationship between two variables
- ▶ Pearson's  $r$  is used to quantify the relationship between two continuous variables

# Relationship Questions

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- ▶ Relationship questions ask the following:
- ▶ As scores on one variable go up (or down), what happens to scores on the second variable?
- ▶ We are trying to identify a **trend**

# Characteristics of Relationship Questions

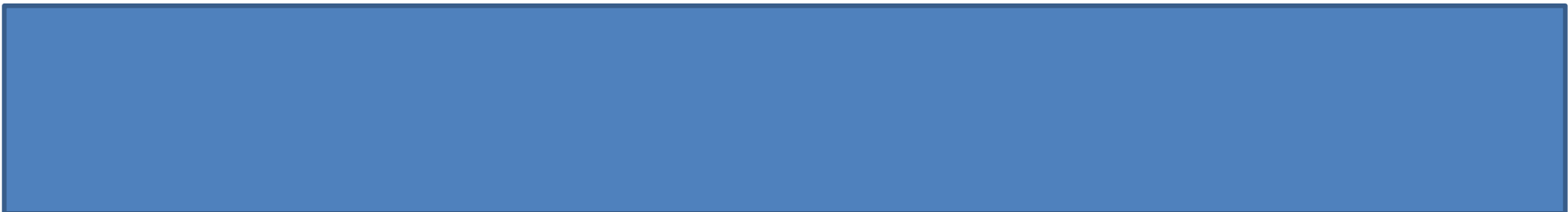
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- ▶ Note that the previous questions could all be phrased in terms of the following question:
- ▶ As scores on  $X$  go up (or down), what happens to scores on  $Y$  ?
- ▶ Such a statement was not possible with comparative questions (e.g., scores on gender can't go up or down!)

# Scatterplots

---

- ▶ Data for a correlation can be visually displayed using a scatterplot
- ▶ The scales of the two variables are plotted on the X and Y axes
- ▶ For each observation, a dot is placed at the point at which the X and Y scores intersect



# Characteristics of a Correlation

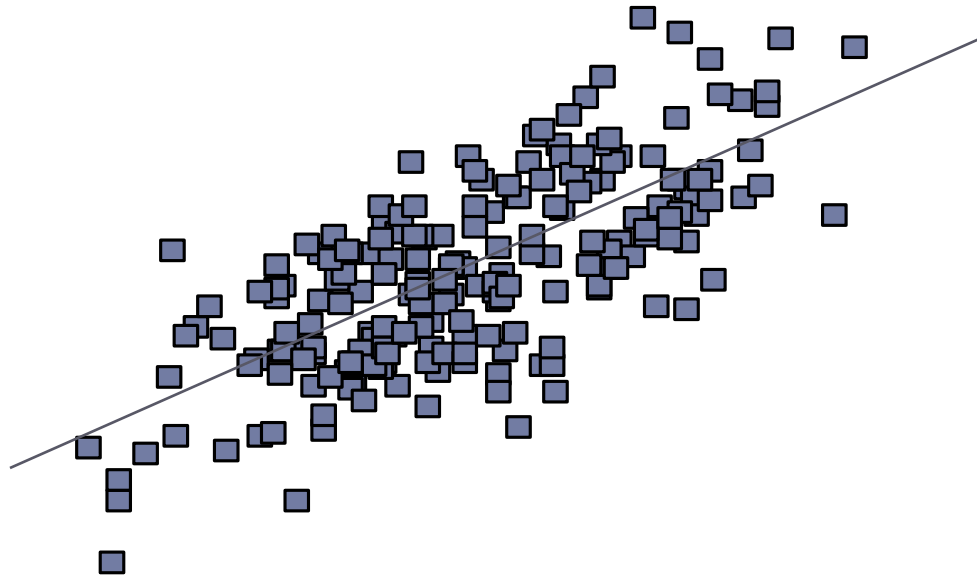
- ▶ Scatterplots can help us describe both the direction and the strength of the correlation
- ▶ The direction of a correlation can either be positive or negative
- ▶ The strength of a correlation can range from weak (or none = 0) to strong (perfect = 111)

# Positive Correlations

---

- ▶ Scores on the two variables tend to move in the same direction
- ▶ Those who score high on one variable tend to score high on the other (and vice versa)
- ▶ **Examples:**
  - ▶ SAT scores and college GPA
  - ▶ Age and reading ability
  - ▶ Years of education and salary

# Scatterplot of a Positive Correlation



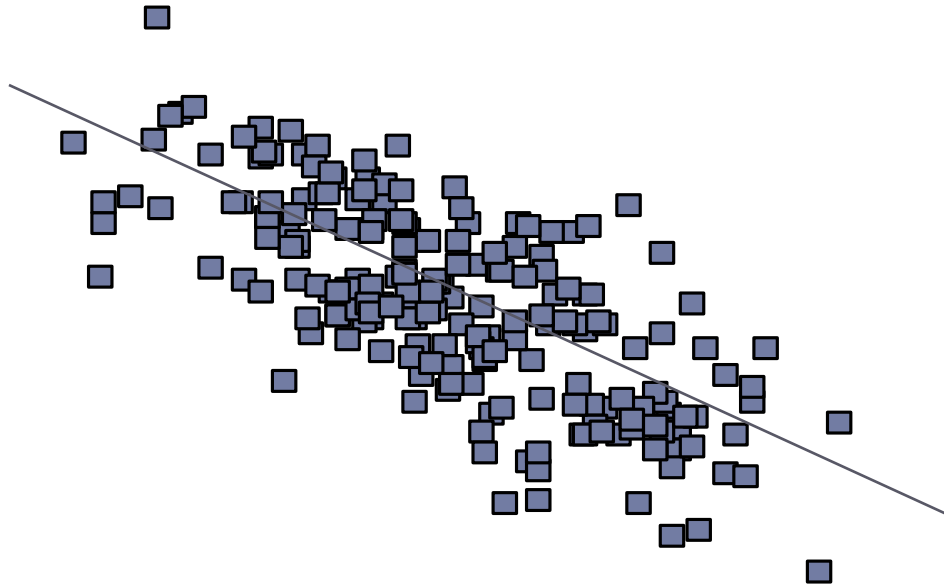


# Negative Correlations

---

- ▶ The two variables are inversely related
- ▶ Those who score high on one variable tend to score low on the other (and vice versa)
- ▶ **Examples:**
  - ▶ Percentage free/reduced lunch and FCAT scores
  - ▶ Anxiety and test performance
  - ▶ Stress and job satisfaction

# Scatterplot of a Negative Correlation

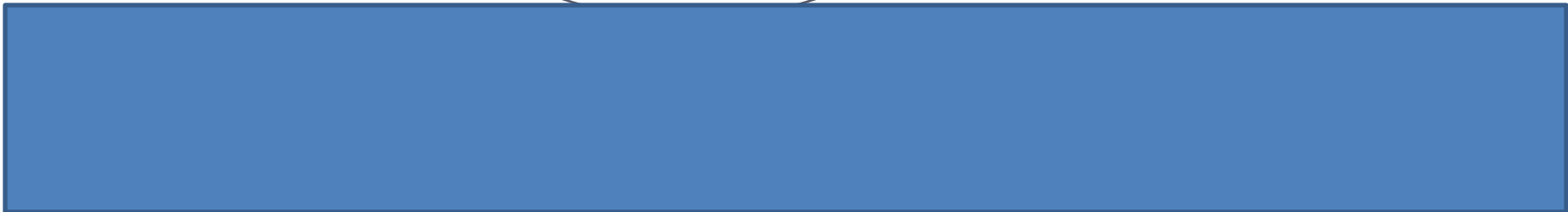
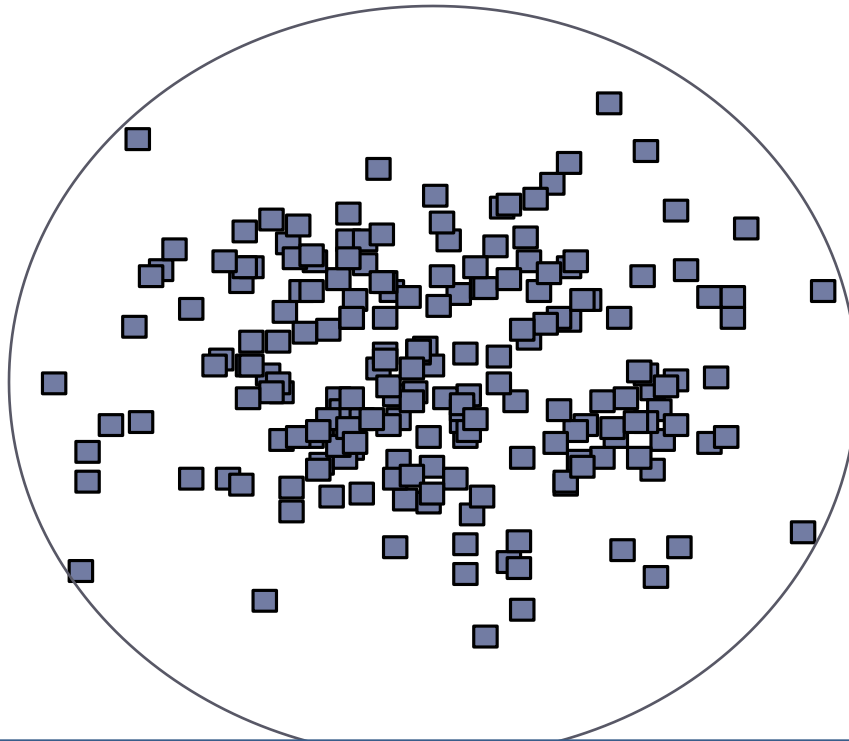


# Strength of the Relationship

- ▶ The strength of the relationship can be visually estimated by degree to which the data fall on a straight line (i.e., the degree of **linear** trend)
- ▶ The correlation gets stronger as the plot approaches a straight line, and reaches a maximum when all data points fall directly on a line

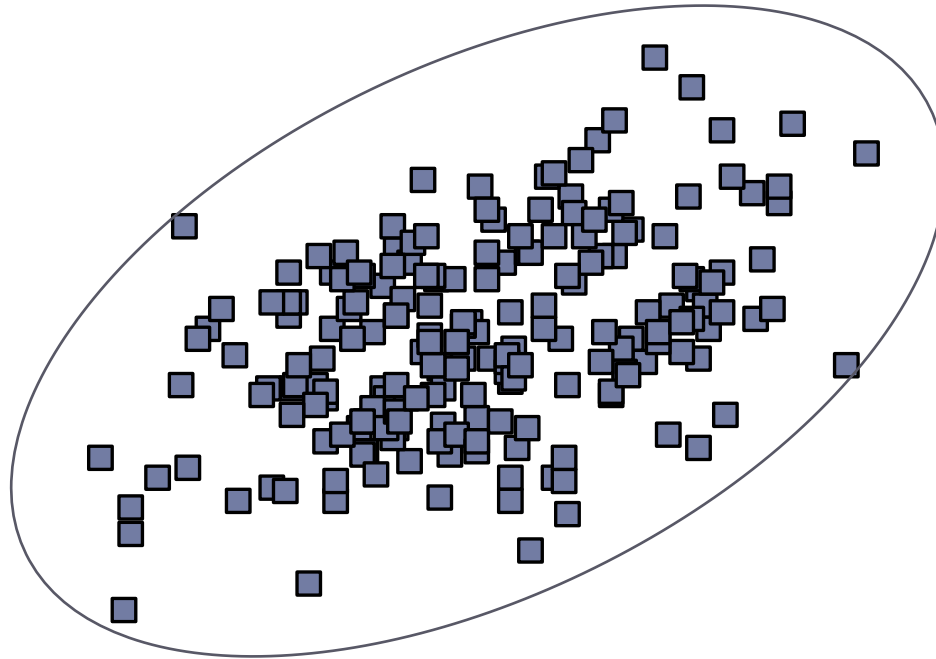
# No Correlation

---



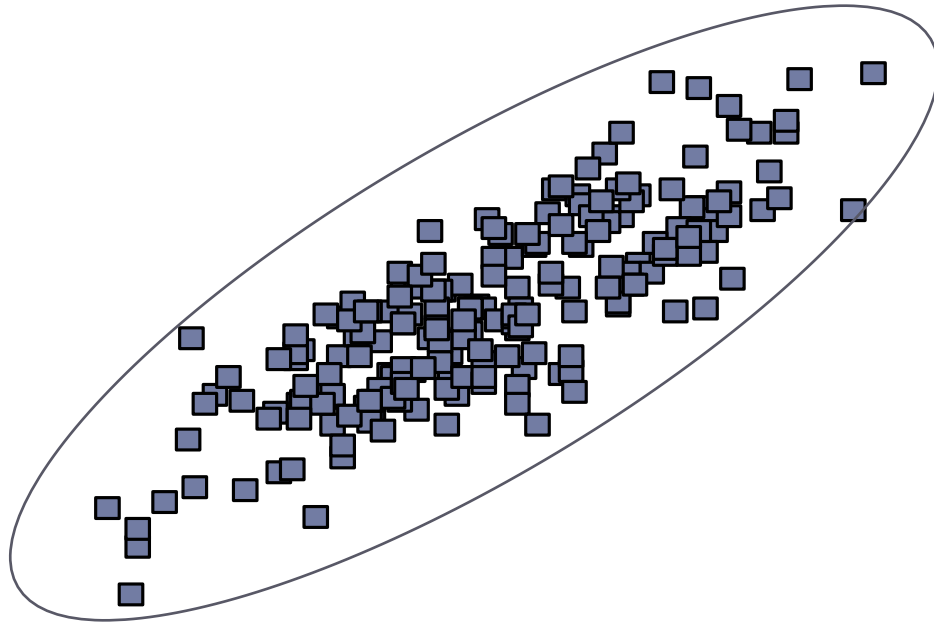
# Weak Correlation

---



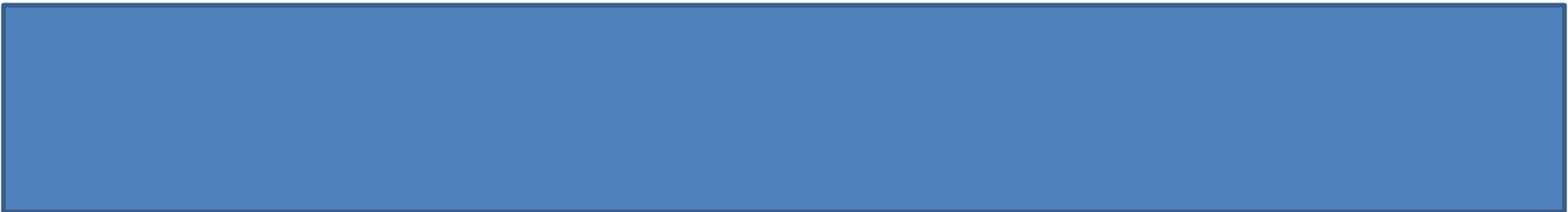
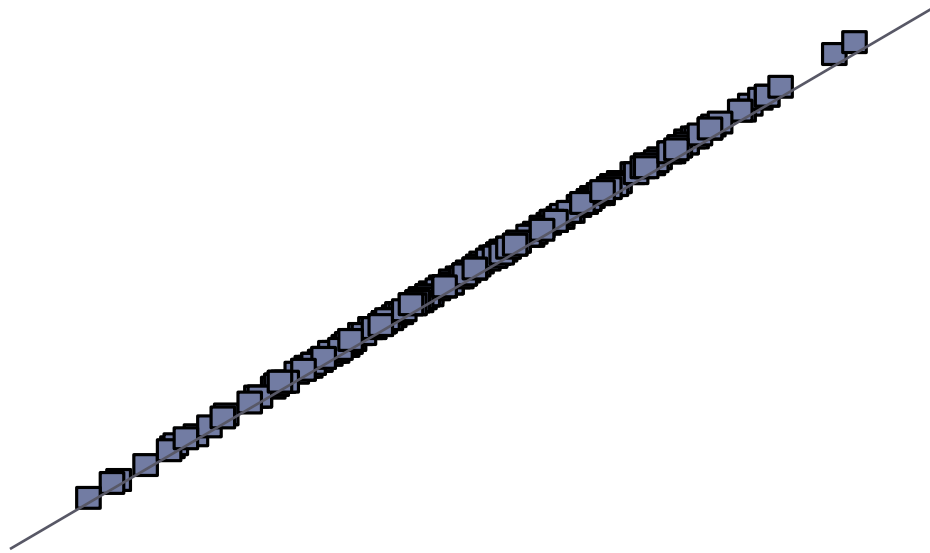
# Strong Correlation

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# Perfect Correlation

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## Pearson's $r$

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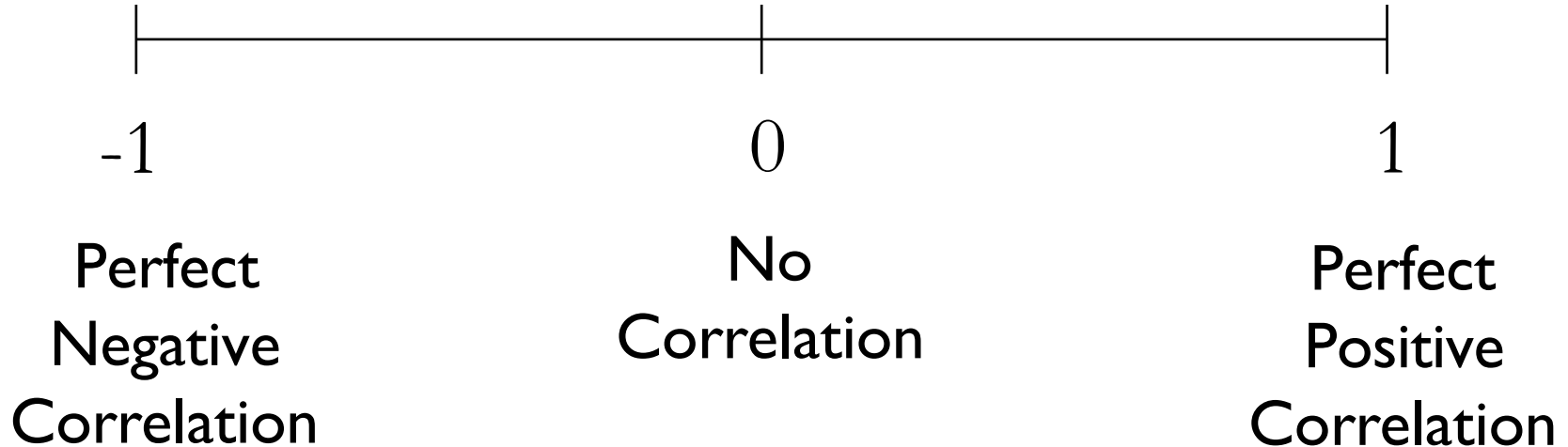
- ▶ When describing the correlation between two continuous variables, Pearson's  $r$  is used
- ▶ This index quantifies the degree (and direction) of the linear trend in the data
- ▶ The sign of  $r$  (+ or -) gives the direction of the correlation
- ▶ The magnitude of  $r$  gives the strength of the relationship



# Pearson's $r$ Scale

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- ▶ Pearson's  $r$  ranges in value from -1 to 1



# Example 1

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- ▶ Using the online course survey, it is of interest to determine if there is a relationship between age and satisfaction
- ▶ As age increases, what happens to satisfaction?
- ▶ What type of trend exists?

## Example 1 (cont'd)

---

- ▶ Step 1: Write your null and alternate hypotheses:
- ▶ What is the null hypothesis?
  - ▶  $H_0: X = Y$
  - ▶ Written out?
- ▶ What is the alternate hypothesis?
  - ▶  $H_a: X \neq Y$ ,  $H_a: X > Y$ , or  $H_a: X < Y$  ?
  - ▶ Written out?
  
- ▶ Is this a one-tailed or two-tailed test? Why?

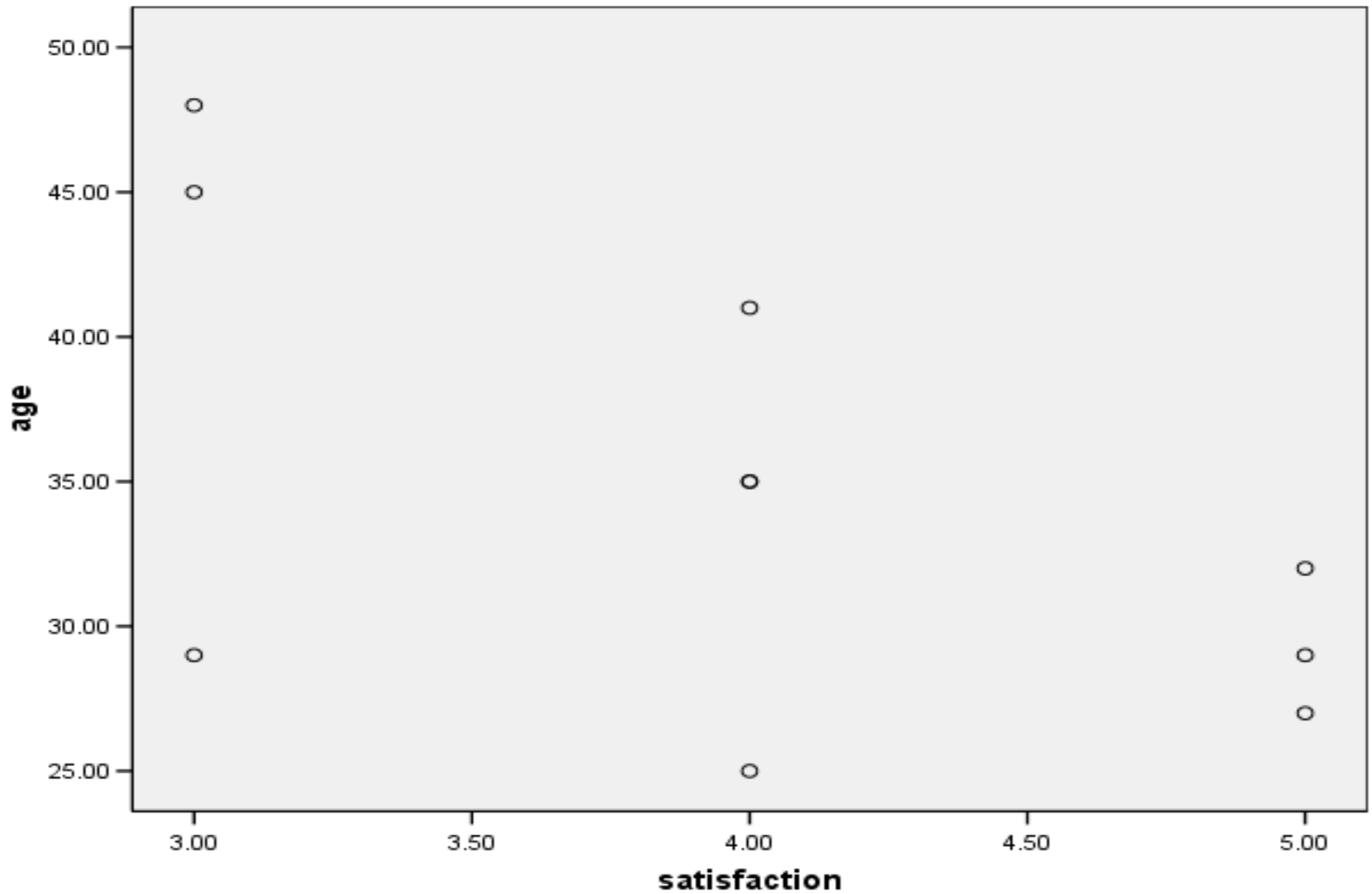
## Example 1 (cont'd)

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- ▶ Step 2: Create a simple scatterplot with age on the Y axis and satisfaction on the X axis.
  - ▶ Graph → Legacy Dialogue → Scatter/Dot → Simple Scatter → Define
  - ▶ Age → Y-axis
  - ▶ Satisfaction → the X-axis.
  - ▶ Click OK

# Example 1 (cont'd)

---



## Example 1 (cont'd)

---

- ▶ **Step 3: Run the Bivariate Correlation**
  - ▶ Analyze → Correlate → Bivariate
  - ▶ Select the variables, select Pearson, and select two-tailed → OK

## Example 1 (cont'd)

---

- ▶ From SPSS, the correlation between satisfaction and age was  $-.593$  ( $r = -.593$ )
- ▶ The correlation is negative
- ▶ Thus, as age increases satisfaction with the course tends to decrease

**Correlations**

		age	satisfaction
age	Pearson Correlation	1	-.593
	Sig. (2-tailed)		.071
	N	10	10
satisfaction	Pearson Correlation	-.593	1
	Sig. (2-tailed)	.071	
	N	10	10

# Incorrect Interpretations

---

- ▶ Pearson's  $r$  is not a percentage (i.e., there is not a 59% relationship)
- ▶ A correlation of .59 is not twice as strong as a correlation of .29
- ▶ A correlation of .59 does not mean that satisfaction scores can be predicted with 59% accuracy



# Correlation and Causation

- ▶ The correlation coefficient simply describes the degree of relationship between two variables
- ▶ A correlation does not tell us why two variables are related, nor does it allow for causal statements
- ▶ As always, causality is **NOT** a statistical issue, and can only be inferred when using true experiments with random assignment.

# Testing $r$ for Statistical Significance

- ▶ When taking samples out of a population, correlation values will differ somewhat simply due to random chance (i.e., sampling error)
- ▶ The question is, could an  $r$  value of  $-.593$  have occurred simply due to chance, or does this represent a “true” relationship between these variables in the population



# Probability Value

---

**Correlations**

		age	satisfaction
age	Pearson Correlation	1	-.593
	Sig. (2-tailed)		.071
	N	10	10
satisfaction	Pearson Correlation	<del>.593</del>	1
	Sig. (2-tailed)	<del>.071</del>	
	N	10	10

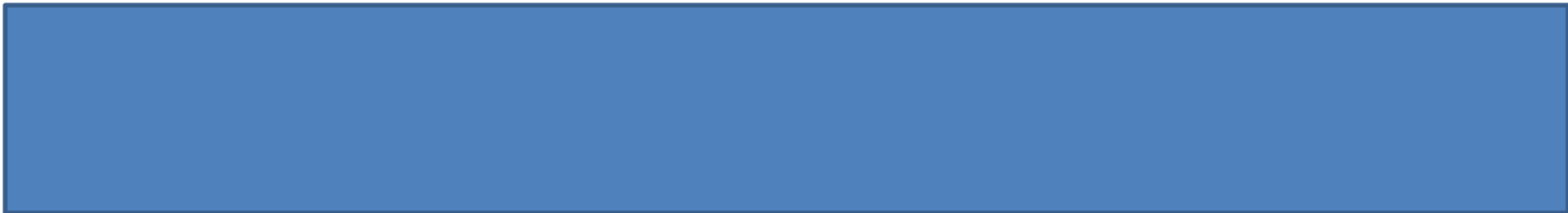
- ▶ The p-value for the correlation is .07  
( $p = .07$ )
- ▶ Do we reject or fail to reject the null?



## Example 1 (cont'd)

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- ▶ Step 4: Write up your results
- ▶ The hypothesis was tested through the computation of a Pearson Product Moment Correlation between age and satisfaction in an online course. The correlation was not significant ( $r = -.593, p = .07$ ).



# Factors Influencing $r$

---

## ▶ Outliers

- ▶ Observations that do not fit the overall trend of the relationship
  - ▶ Can increase or decrease the value of  $r$

## ▶ Non-linear trends

- ▶ Relationships described by a curved line (a polynomial, not linear trend)
  - ▶ Will decrease the value of  $r$

## ▶ Restriction of range

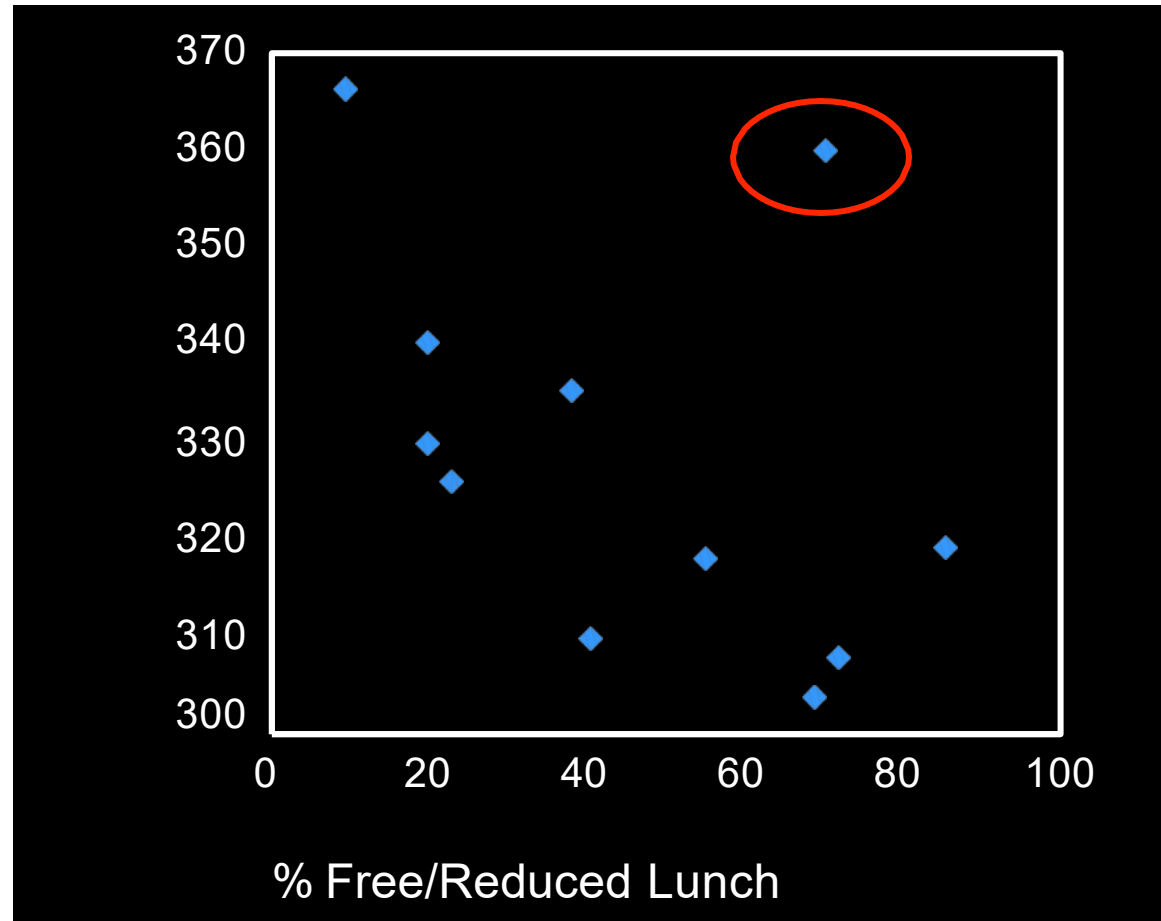
- ▶ Scores are not obtained along the entire range of the scale for  $X$  and/or  $Y$



# Outlier Example

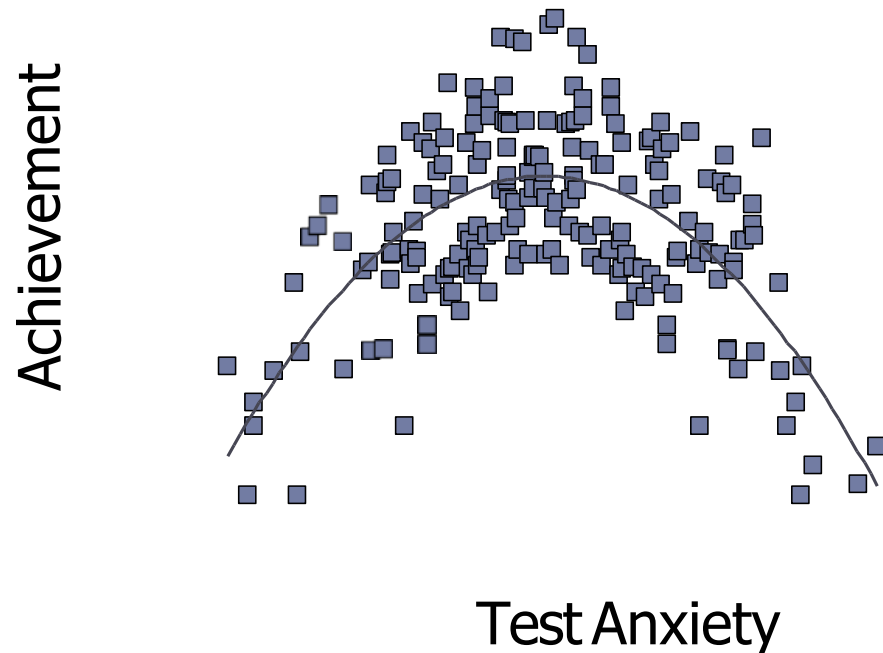
---

- ▶ The presence of a single outlier that was inconsistent with the trend reduced the  $r$  value from  $-.689$  to  $-.452$



# Non-Linear Trend Example

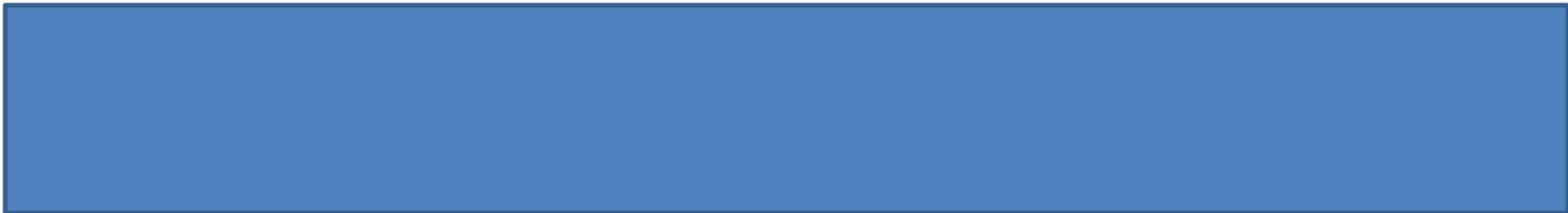
- ▶ Some anxiety is good (i.e., in order to reach an “optimal level of arousal”)
- ▶ Beyond a certain point, an increase in anxiety results in detrimental performance
- ▶  $r$  will be near 0 in this case



# Restriction of Range Example

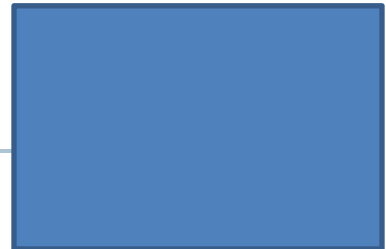
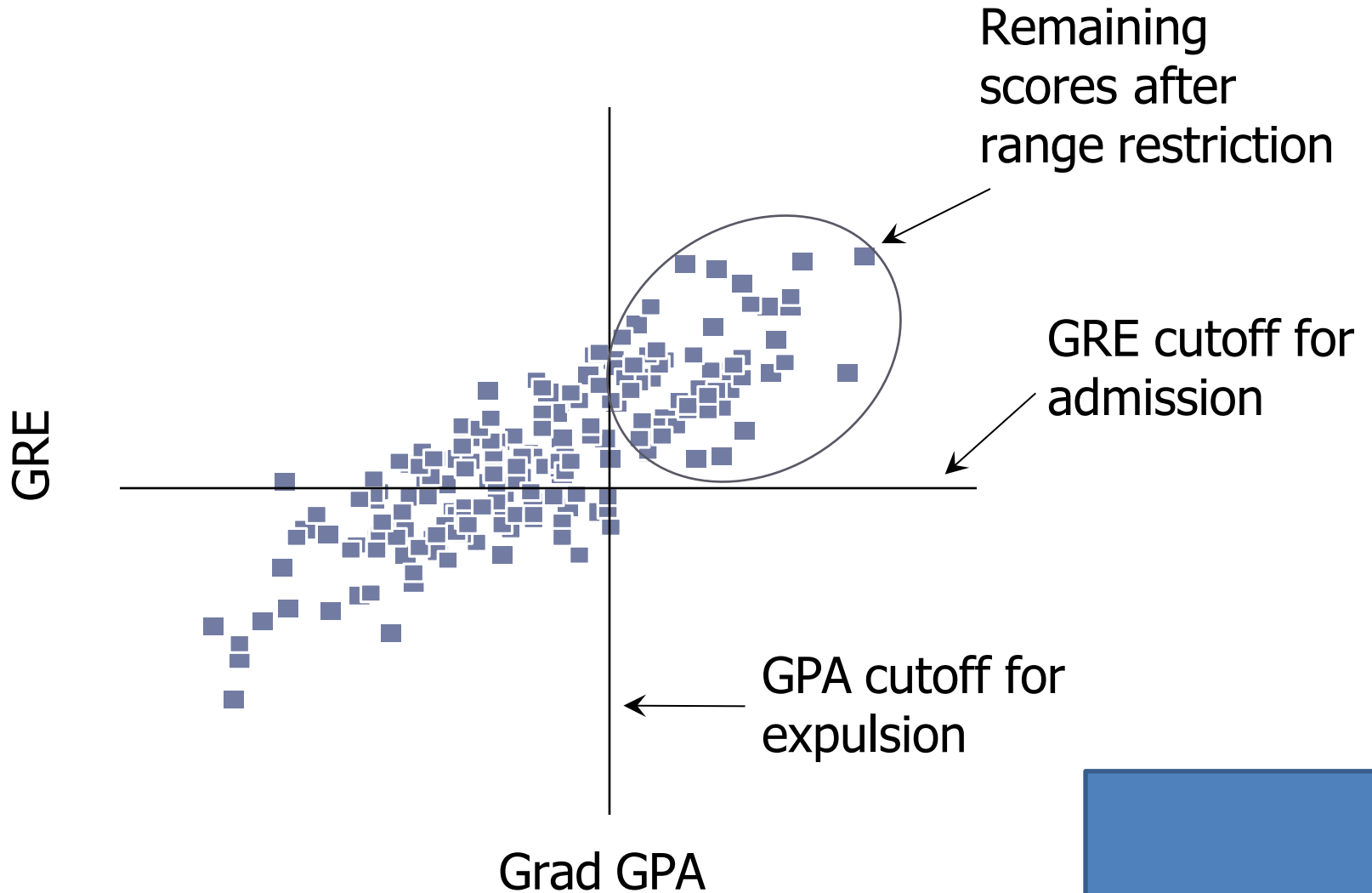
---

- ▶ It is known that there is only moderate correlation between the GRE and graduate school GPA, in part, due to range restriction
- ▶ In this example, both variables likely have restricted ranges
- ▶ Only the highest GRE scores and GPA values are used in the computation of  $r$





# Graphic Representation



# Coefficient of Determination

---

- ▶ =  $r^2$
- ▶ Proportion of variability in one variable explained by variability in the other variable.
- ▶ Multiply by 100 to discuss the percentage of explained variability b/n two variables.
- ▶ Implication is that  $r$  tends to exaggerate how strong the relationship is.



# Other Correlation Coefficients

- ▶ **Point-biserial correlation**
  - ▶ One continuous and one categorical variable with only two groups
- ▶ **Spearman's rho**
  - ▶ At least one variable is ordinal (the other is ordinal or continuous)
- ▶ **Phi**
  - ▶ Twodichotomous categorical variables
- ▶ **Cramer's C (or V)**
  - ▶ Twocategorical variables with any number of categories

# Module 5 Summary

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- ▶ Definition of Correlation
- ▶ Relationship Questions
- ▶ Scatterplots
- ▶ Strength and Direction of Correlations
- ▶ Running a Pearson Product Moment Correlation
- ▶ Factors Affecting the Correlation
- ▶ Other Types of Correlations



# Review Activity


---

- ▶ Please complete the review activity at the end of the module.
- ▶ All modules build on one another. Therefore, in order to move onto the next module you must successfully complete the review activity before moving on to next module.
- ▶ You can complete the review activity and module as many times as you like.



# Upcoming Modules

---

- ▶ Module 1: Introduction to Statistics
  - ▶ Module 2: Introduction to SPSS
  - ▶ Module 3: Descriptive Statistics
  - ▶ Module 4: Inferential Statistics
  - ▶ Module 5: Correlation
  - ▶ **Module 6: *t*-Tests**
  - ▶ **Module 7: ANOVAs**
  - ▶ **Module 8: Linear Regression**
  - ▶ **Module 9: Nonparametric Procedures**
- 



## Module 6: $t$ Tests

The Applied Research Center

# Module 6 Overview

---

- ▶ **Types of  $t$  Tests**
  - ▶ One Sample  $t$  Test
  - ▶ Independent Samples  $t$  Test
  - ▶ Paired Samples  $t$  Test
- ▶ **Examples**





# *t*-Tests

---

- ▶ Used for inferences concerning one or two means
- ▶ 3 main types:
  - ▶ One-sample t-test
  - ▶ Independent samples t-test
  - ▶ Paired samples t-test

# One Sample t-Test

---

- ▶ Used to test whether the mean of single variable differs from a specified constant.
- ▶ Example
  - ▶ A researcher wants to test whether the average IQ score of a group of students differs from 100.
  - ▶ A stats professor wants to determine whether the average grade on Assignment 1 differs significantly from 23 (an A average).



# One Sample t-Test

---

- ▶ Step 1: State the Null and Alternate Hypotheses
- ▶  $H_0$  = The average grade on Assignment 1 is equal to 23.
- ▶  $H_a$  = The average grade on Assignment 1 is not equal to 23.
- ▶ Is this a directional or nondirectional  $H_a$ ?



# One Sample t-Test (cont'd)

---

- ▶ Step 2: Input each student's grade into SPSS
- ▶ Step 3: Run the Analysis.
  - ▶ Analyze → Compare Means → One Sample T-test
  - ▶ Testvariable = assign I
  - ▶ Testvalue = 23
  - ▶ Click OK



# One Sample t-Test (cont'd)

---

## One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
assign1	15	21.0333	1.54072	.39781

## One-Sample Test

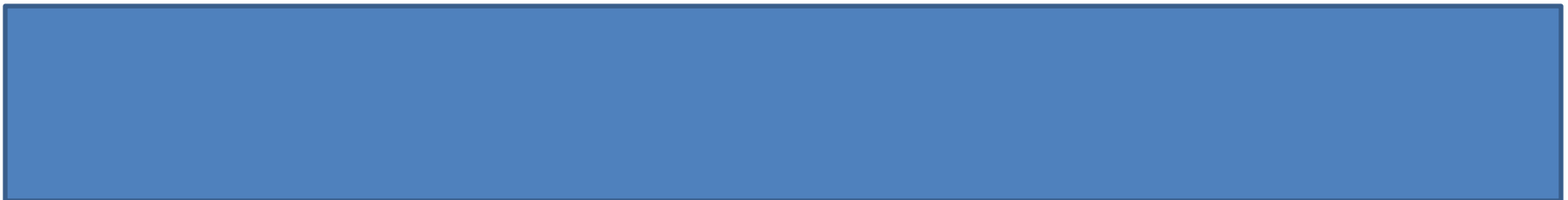
	Test Value = 23					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
assign1	-4.944	14	.000	-1.96667	-2.8199	-1.1134



## One Sample t-Test (cont'd)

---

- ▶ Step 4: Make a decision regarding the null
  - ▶  $M = 21.03, SD = 1.54$
  - ▶  $t(14^*) = -4.944$
  - ▶  $p < .001$
  
- ▶ What is the decision regarding the null?
  
- ▶  $*14 = df = n - 1 = 15 - 1 = 14$



## One Sample t-Test (cont'd)

---

- ▶ Using the level of significance = .05, do we reject or fail to reject the null?
  - ▶ If  $p < .05$ , we reject the null
  - ▶ if  $p > .05$ , we fail to reject the null
- ▶ According to SPSS,  $p < .001$
- ▶  $.001 < .05$ , therefore, we reject the null!



## One Sample t-Test (cont'd)

---

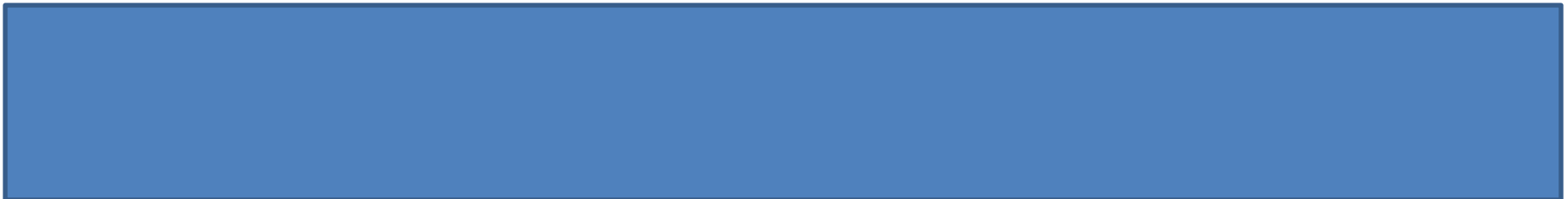
- ▶ Step 5: Write up your results.
- ▶ The null hypothesis stated that the average grade on Assignment 1 is equal to 23. A one sample t-test revealed that the average grade on Assignment 1 ( $M = 21.03$ ,  $SD = 1.54$ ) differed significantly from 23,  $t(14) = -4.944$ ,  $p < .01$ . Consequently, the null hypothesis was rejected.



# Independent t-Test

---

- ▶ The independent samples t-test is used to test comparative research questions
- ▶ That is, it tests for differences in two group means or compares means for two groups of cases.



## Independent t-Test (cont'd)

---

- ▶ Example:
- ▶ Suppose the stats professor wanted to determine whether the average score on Assignment I in one stats class differed significantly from the average score on Assignment I in her second stats class.



# Independent t-Test

---

- ▶ Step 1: State the Null and Alternate Hypotheses
- ▶  $H_0$  = There is no difference between class 1 and class 2 on Assignment 1.
- ▶  $H_a$  = There is a difference between class 1 and class 2 on Assignment 1.
- ▶ Is this a directional or nondirectional  $H_a$ ?



# Independent t-Test (cont'd)

---

- ▶ Step 2: Input each student's grade into SPSS, along with which class they are in

<b>Grade</b>	<b>Class</b>
20.00	1.00
20.50	1.00
21.00	1.00
20.50	1.00
20.00	1.00
24.50	2.00
23.50	2.00
20.00	2.00
20.00	2.00



# Independent t-Test (cont'd)

---

- ▶ **Step 3: Run the Analysis.**
  - ▶ Analyze → Compare Means → Independent Samples T-test
  - ▶ Testvariable = assign I
  - ▶ Grouping variable = class
  - ▶ Define Groups:
    - ▶ Type “1” next to Group 1
    - ▶ Type “2” next to Group 2
    - ▶ Click Continue
  - ▶ Click OK



# Independent t-Test (cont'd)

## Group Statistics

	class	N	Mean	Std. Deviation	Std. Error Mean
assign1	1.00	14	21.1786	1.48851	.39782
	2.00	13	21.9038	1.93525	.53674

## Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
assign1	Equal variances assumed	4.519	.044	-1.096	25	.283	-.72527	.66152	-2.08771	.637
	Equal variances not assumed			-1.086	22.530	.289	-.72527	.66810	-2.10894	.658



## Independent t-Test (cont'd)

---

- ▶ Step 4: Make a decision regarding the null
  - ▶ Class 1 (M = 21.18, SD = 1.49)
  - ▶ Class 2 (M = 21.90, SD = 1.94)
  
- ▶ Which row do we look at on the output?



# Independent t-Test (cont'd)

- ▶ Step 5: Levene's Test for equal variances
  - ▶  $H_0$  = The variances of the two variables are equal.
  - ▶  $H_a$  = The variances of the two variables are not equal.

		Levene's Test for Equality of Variances	
		F	Sig.
assign1	Equal variances assumed	4.519	.044
	Equal variances not assumed		

$p = .044$ ,  
which is  $< .05$ ;  
Therefore, we reject  
the null and do not  
assume equal  
variances!





# Independent t-Test (cont'd)

- ▶ Looking at the Equal variances not assumed row (the bottom row)

**Independent Samples Test**

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
assign1	Equal variances assumed	4.519	.044	-1.096	25	.283
	Equal variances not assumed			-1.086	22.530	.289

## Independent t-Test (cont'd)

---

- ▶ Make a decision regarding the null
  - ▶  $t(22.5) = -1.086$
  - ▶  $p = .289$
- ▶ Using the level of significance = .05, do we reject or fail to reject the null?



# Independent t-Test (cont'd)

---

- ▶ Remember

- ▶ If  $p < .05$ , we reject the null
- ▶ if  $p > .05$ , we fail to reject the null

- ▶ According to SPSS,  $p = .289$

- ▶  $.289 > .05$ , therefore, we fail to reject the null!!



## Independent t-Test (cont'd)

---

- ▶ Step 5: Write up your results.
- ▶ The null hypothesis stated that there is no difference between class 1 and class 2 on Assignment 1. An independent samples t-test revealed that the average grades on Assignment 1 did not differ significantly from Class 1 (M = 21.18, SD = 1.49) to Class 2 (M = 21.90, SD = 1.94),  $t(22.5) = -1.086, p = .289$ . Consequently, the researcher failed to reject the null hypothesis.

# Paired Samples t-Test

---

- ▶ Used to compare the means of two variables for a single group.
- ▶ The procedure computes the differences between values of the two variables for each case and tests whether the average differs from 0.

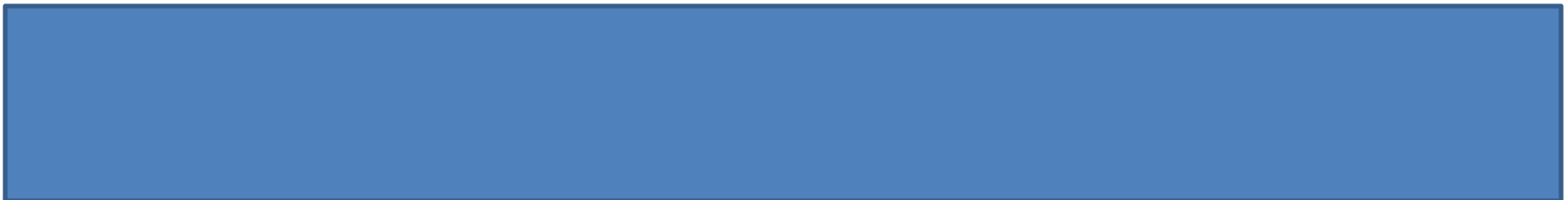


# Paired Samples t-Test

---

## ▶ Example

- ▶ A researcher wanted to know the effects of a reading program. The researcher gave the students a pretest, implemented the reading program, then gave the students a post test.



# Paired Samples t-Test

---

- ▶ Step 1: State the Null and Alternate Hypotheses
- ▶  $H_0$  = There is no difference in students' performance between the pretest and the posttest.
- ▶  $H_a$  = Students will perform better on the posttest than on the pretest.
- ▶ Is this a directional or nondirectional  $H_a$ ?



## NOTE for One-tailed Tests!!

---

- ▶ Remember when we have a directional hypothesis, we conduct a one-tailed test.
- ▶ When we have a non-directional hypothesis, we conduct a two-tailed test.
- ▶ SPSS (unless given the choice) automatically runs a 2-tailed test, IF you have a directional alternate hypothesis (and a 2-tailed test was run), you **MUST** divide the p-value by 2 to obtain the correct p-value!





# Paired Samples t-Test

---

▶ Step 2: Set up data

<b>Pre</b>	<b>Post</b>
20.00	25.00
21.00	24.00
19.00	23.00
18.00	22.00
20.00	24.00
21.00	25.00



# Paired Samples $t$ -Test

---

- ▶ Step 3: Analyze the Results
- ▶ Analyze → Compare Means → Paired Samples  $t$ -Test
- ▶ Paired variables: pre--post



# Paired Samples *t*-Test (cont'd)

**Paired Samples Statistics**

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	pre	19.8333	6	1.16905	.47726
	post	23.8333	6	1.16905	.47726

**Paired Samples Test**

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	pre - post	-4.00000	.63246	.25820	-4.66372	-3.33628	-15.492	5	.000



## Paired Samples $t$ -Test (cont'd)

---

- ▶ **Step 4:** Make a decision regarding the null
  - Pretest ( $M = 19.83, SD = 1.17$ )
  - Posttest ( $M = 23.83, SD = 1.17$ )
  - $t(5) = -15.49$
  - $p < .001$  (two-tailed)
  
- ▶ What is the decision regarding the null?



# Paired Samples *t*-Test (cont'd)

- ▶ We have a directional alternate, therefore we have to divide the  $p$ -value by 2.

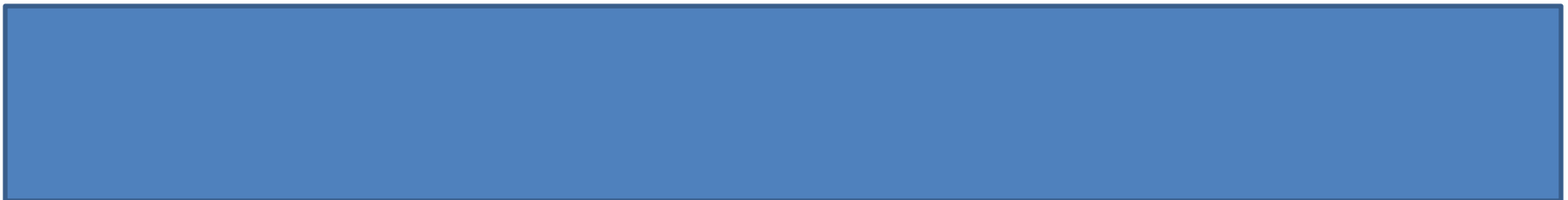
**Paired Samples Test**

Paired Differences			t	df	Sig. (2-tailed)
Std. Error	95% Confidence Interval of the Difference				
Mean	Lower	Upper			
.25820	-4.66372	-3.33628	-15.492	5	.000

## Paired Samples $t$ -Test (cont'd)

---

- ▶  $.000/2 = 0$
- ▶  $p < .001$
- ▶ What is the decision regarding the null?



## Paired Samples *t*-Test (cont'd)

- ▶ Using the level of significance = .05, do we reject or fail to reject the null?
  - If  $p < .05$ , we reject the null
  - if  $p > .05$ , we fail to reject the null
- ▶ According to SPSS,  $p < .001$
- ▶  $.001 < .05$ , therefore, we reject the null!



## Paired Samples $t$ -Test (cont'd)

---

- ▶ **Step 5:** Write up your results.
- ▶ The null hypothesis stated that there is no difference in students' performance between the pretest and the posttest. A paired samples  $t$ -test revealed that students scored significantly higher on the posttest ( $M = 23.83, SD = 1.17$ ) than they did on the pretest ( $M = 19.83, SD = 1.17$ ),  $t(5) = -15.49, p < .001$ . Consequently, the null hypothesis was rejected.





# Directional Hypothesis Example

- ▶ Suppose:
  - $H_a$  = Class 1 will score higher on Assignment 3 than Class 2.
  - → Must be based on literature (or prior data/test scores).
- ▶ Run everything the same, only difference is final p-value!
- ▶ According to SPSS,  $p = .289/2 = .145$
- ▶ → still fail to reject the null!

## Another Example

---

- ▶ If  $H_a$  = Class 1 will score higher on Assignment 3 than Class 2.
- ▶ And SPSS reported a p-value of .08. When  $.08/2 = .04$ , which IS significant; in this case, we would reject the null!

# Module 6 Summary

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- ▶ **Types of  $t$  Tests**
  - ▶ One Sample  $t$  Test
  - ▶ Independent Samples  $t$  Test
  - ▶ Paired Samples  $t$  Test
- ▶ **Examples**



# Review Activity

---

- ▶ Please complete the review activity at the end of the module.
- ▶ All modules build on one another. Therefore, in order to move onto the next module you must successfully complete the review activity before moving on to next module.
- ▶ You can complete the review activity and module as many times as you like.



# Upcoming Modules

---

- ▶ Module 1: Introduction to Statistics
- ▶ Module 2: Introduction to SPSS
- ▶ Module 3: Descriptive Statistics
- ▶ Module 4: Inferential Statistics
- ▶ Module 5: Correlation
- ▶ Module 6: *t*-Tests
- ▶ **Module 7: ANOVAs**
- ▶ **Module 8: Linear Regression**
- ▶ **Module 9: Nonparametric Procedures**





# Module 7: ANOVA

The Applied Research Center

# Module 7 Overview

---

- ▶ Analysis of Variance
  - ▶ Types of ANOVAs
    - ▶ One-way ANOVA
    - ▶ Two-way ANOVA
  - ▶ MANOVA
  - ▶ ANCOVA



# One-way ANOVA



Jennifer Reeves, Ph.D.



# ANOVA

---

- ▶ Analysis of variance
- ▶ Used to test 3 or more means
- ▶ Used to test the null hypothesis that several means are equal
- ▶ For example:
  - ▶  $H_0: \mu_1 = \mu_2 = \mu_3$
  - ▶  $H_a: \mu_1 \neq \mu_2 \neq \mu_3$  or  $H_a: \mu_1 > \mu_2 > \mu_3$

# Different types of ANOVAs

---

- ▶ **One-way ANOVA**

- ▶ one IV (more than two levels)

- ▶ **Two-way ANOVA**

- ▶ two IVs

- ▶ **RM ANOVA**

- ▶ repeated measures on one or more factors

- ▶ **MANOVA**

- ▶ multiple DVs



# One-way ANOVA

---

## ▶ Example:

- ▶ A stats teacher wants to know if there is a significant difference in grades for assignments 1, 2, and 3 in her stats class.
- ▶ **NOTE:** the assignments could not be matched, therefore, a RM ANOVA was not appropriate.

# One-way ANOVA (cont'd)

---

## ▶ Step 1: Write the $H_0$ and $H_a$ hypotheses

▶  $H_0$ : The means for Assignment 1, Assignment 2, and Assignment 3 are equal.

▶  $H_0: \mu_1 = \mu_2 = \mu_3$

▶  $H_a$ : The means for Assignment 1, Assignment 2, and Assignment 3 are not equal.

▶  $H_a: \mu_1 \neq \mu_2 \neq \mu_3$

# One-way ANOVA (cont'd)

---

- ▶ **Step 2: Input each student's grade into SPSS**
- ▶ **Run the Analysis:**
  - ▶ Analyze → Compare Means → One-way ANOVA
  - ▶ Dependent List = Grade
  - ▶ Factor = Assign#
  - ▶ Click Options and select Descriptive, click continue
  - ▶ Click OK

# One-way ANOVA (cont'd)

---

## Descriptives

Grade

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
					Assignment 1	15		
Assignment 2	13	22.5385	1.19829	.33235	21.8143	23.2626	20.50	24.50
Assignment 3	13	23.4615	1.68895	.46843	22.4409	24.4822	20.00	25.00
Total	41	22.2805	1.78202	.27831	21.7180	22.8430	18.50	25.00

## ANOVA

Grade

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	42.330	2	21.165	9.496	.000
Within Groups	84.695	38	2.229		
Total	127.024	40			

# One-way ANOVA (cont'd)

---

- ▶ **Step 4: Make a decision regarding the null**
  - ▶ Assignment 1:  $M = 21.03$ ,  $SD = 1.54$
  - ▶ Assignment 2:  $M = 22.54$ ,  $SD = 1.20$
  - ▶ Assignment 3:  $M = 23.46$ ,  $SD = 1.54$
  - ▶  $F(2, 38) = 9.50$
  - ▶  $p < .001$
  
- ▶ **df = (df between, df within)**
  - ▶  $df\ b/n = k - 1 = 3 - 1 = 2$
  - ▶  $df\ within = [(n_1 - 1) + [(n_2 - 1) + [(n_3 - 1)]] = 14 + 12 + 12 = 38$
- ▶ **What is the decision regarding the null?**

## One-way ANOVA (cont'd)

---

- ▶ Using the level of significance = .05, do we reject or fail to reject the null?
  - ▶ If  $p < .05$ , we reject the null
  - ▶ if  $p > .05$ , we fail to reject the null
  
- ▶ According to SPSS,  $p < .001$
  
- ▶  $.001 < .05$ , therefore, we reject the null!



## One-way ANOVA (cont'd)

---

- ▶ We reject the null that said the means for Assignment 1, Assignment 2, and Assignment 3 are equal.
- ▶ Therefore, the means are not equal.
- ▶ How do we know which means are different?

# Post hoc comparisons

---

- ▶ In addition to determining that differences exist among the means, you can also look at which means differ after the fact.
- ▶ Most common post hoc comparisons:
  - ▶ Fisher's LSD (Least sig diff)
  - ▶ Tukey's HSD (Honestly sig diff)

# One-way ANOVA (cont'd)

---

- ▶ Step 5: Post hoc analyses
- ▶ Using Fisher's LSD post hoc comparison:
  - ▶ Analyze → Compare Means → One-way ANOVA
  - ▶ Dependent List = Grade
  - ▶ Factor = Assign#
  - ▶ Click Options, select Descriptive, click continue
  - ▶ Click Post Hoc, select LSD, click continue
  - ▶ Click OK

# One-way ANOVA (cont'd)

---

## Multiple Comparisons

Dependent Variable: Grade

LSD

(I) Assign#	(J) Assign#	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Assignment 1	Assignment 2	-1.50513*	.56572	.011	-2.6504	-.3599
	Assignment 3	-2.42821*	.56572	.000	-3.5734	-1.2830
Assignment 2	Assignment 1	1.50513*	.56572	.011	.3599	2.6504
	Assignment 3	-.92308	.58557	.123	-2.1085	.2624
Assignment 3	Assignment 1	2.42821*	.56572	.000	1.2830	3.5734
	Assignment 2	.92308	.58557	.123	-.2624	2.1085

\*. The mean difference is significant at the .05 level.



## One-way ANOVA (cont'd)

---

- ▶ Which effects are significant?
- ▶ Remember, the nulls here say the 2 means are equal, therefore there are 3 nulls
  - ▶  $H_0: \mu_1 = \mu_2; H_a: \mu_1 \neq \mu_2$
  - ▶  $H_0: \mu_1 = \mu_3; H_a: \mu_1 \neq \mu_3$
  - ▶  $H_0: \mu_2 = \mu_3; H_a: \mu_2 \neq \mu_3$
- ▶  $\mu_1 - \mu_2, p = .01$
- ▶  $\mu_1 - \mu_3, p < .001$
- ▶  $\mu_2 - \mu_3, p = .123$

## One-way ANOVA (cont'd)

---

- ▶ Using the level of significance = .05, do we reject or fail to reject the null?
  - ▶ If  $p < .05$ , we reject the null
  - ▶ if  $p > .05$ , we fail to reject the null
  
- ▶  $A1 - A2$ ,  $p = .01 < .05$ ; reject null
- ▶  $A1 - A3$ ,  $p < .001 < .05$ , reject null
- ▶  $A2 - A3$ ,  $p = .123 > .05$ , fail to reject null

## One-way ANOVA (cont'd)

---

- ▶ **Step 6:** Write up your results.
- ▶ The null hypothesis stated that the means for Assignment 1, Assignment 2, and Assignment 3 are equal. A One-way ANOVA revealed a significant difference among the means for the 3 assignments,  $F(2, 38) = 9.50, p < .001, \eta^2 = .33$ . Students' grades on A1 ( $M = 21.03, SD = 1.54$ ) were significantly lower than A2 ( $M = 22.54, SD = 1.20; p = .01$ ), and A3 ( $M = 23.46, SD = 1.54; p < .001$ ). There was no significant difference in students' grades between A2 and A3 ( $p = .12$ ).

# Partial eta squared ( $\eta^2$ )

---

- ▶ Measure of effect size
- ▶ Interpretation: The percentage of variance in each of the effects (or interaction) and its associated error that is accounted for by that effect.
- ▶ Used as a comparison to other studies (rather than typical cut-off values as in Cohen's *d*).



# Partial eta squared ( $\eta^2$ )

---

## ▶ To obtain:

- ▶ Analyze → General Linear Model → Univariate
- ▶ Dependent Variable = Grade
- ▶ Fixed Factor = Assign#
- ▶ Click Options, select
  - ▶ Descriptive statistics
  - ▶ Estimates of effect size
  - ▶ Click Continue
- ▶ Click OK

---

# Univariate Analysis of Variance

## Between-Subjects Factors

	Value Label	N
Assign# 1.00	Assignment 1	15
2.00	Assignment 2	13
3.00	Assignment 3	13

## Descriptive Statistics

Dependent Variable: Grade

Assign#	Mean	Std. Deviation	N
Assignment 1	21.0333	1.54072	15
Assignment 2	22.5385	1.19829	13
Assignment 3	23.4615	1.68895	13
Total	22.2805	1.78202	41

---

# Univariate Analysis of Variance

---

## Tests of Between-Subjects Effects

Dependent Variable: Grade

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	42.330 <sup>a</sup>	2	21.165	9.496	.000	.333
Intercept	20377.354	1	20377.354	9142.696	.000	.996
Assign#	42.330	2	21.165	9.496	.000	.333
Error	84.695	38	2.229			
Total	20480.250	41				
Corrected Total	127.024	40				

a. R Squared = .333 (Adjusted R Squared = .298)



# Two-way ANOVA

---

- ▶ 2 IVs
- ▶ Example:
  - ▶ A stats teacher wants to determine whether students in Class A differ from students in Class B with regards to their grades on Assignments 1 and 2.
  - ▶ If can match student grades on A1 and A2, then should be ran as a RM ANOVA.

# Two-way ANOVA

---

- ▶ Step I: Write the  $H_0$  and  $H_a$  hypotheses
- ▶  $H_0$ : There is no difference between class and assignment number on students' grades.
- ▶  $H_a$ : There is a difference between class and assignment number on students' grades.

## Two-way ANOVA (cont'd)

---

- ▶ **Step 2:** Input each student's grade into SPSS and
- ▶ **Run the Analysis:**
  - ▶ Analyze → GLM → Univariate
    - ▶ Dependent Variable = grade
    - ▶ Fixed Factors = class, assignment # (these are your IVs)
  - ▶ Click Options and select
    - ▶ Descriptives
    - ▶ Estimates of effect size
    - ▶ Homogeneity Tests
  - ▶ Click Continue

# Two-way ANOVA (cont'd)

---

- ▶ Click Plots
  - ▶ Move Class to Horizontal Axis
  - ▶ Move Assign # to Separate Lines
  - ▶ Then select “Model” or “ADD” Button
  - ▶ Click Continue
- ▶ Click Continue; Click OK
  
- ▶ Do we need to run post hoc tests??

# Two-way ANOVA (cont'd)

---

## Between-Subjects Factors

		N
class	1.00	28
	2.00	25
assign#	1.00	25
	2.00	28

## Descriptive Statistics

Dependent Variable: grade

class	assign#	Mean	Std. Deviation	N
1.00	1.00	22.5385	1.19829	13
	2.00	21.0333	1.54072	15
	Total	21.7321	1.56632	28
2.00	1.00	23.3333	.86164	12
	2.00	21.9038	1.93525	13
	Total	22.5900	1.65655	25
Total	1.00	22.9200	1.10567	25
	2.00	21.4375	1.75808	28
	Total	22.1368	1.65146	53



# Two-way ANOVA (cont'd)

---

## Levene's Test of Equality of Error Variances<sup>a</sup>

Dependent Variable: grade

F	df1	df2	Sig.
6.768	3	49	.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + class + assign# + class \* assign#



# Two-way ANOVA (cont'd)

## Tests of Between-Subjects Effects

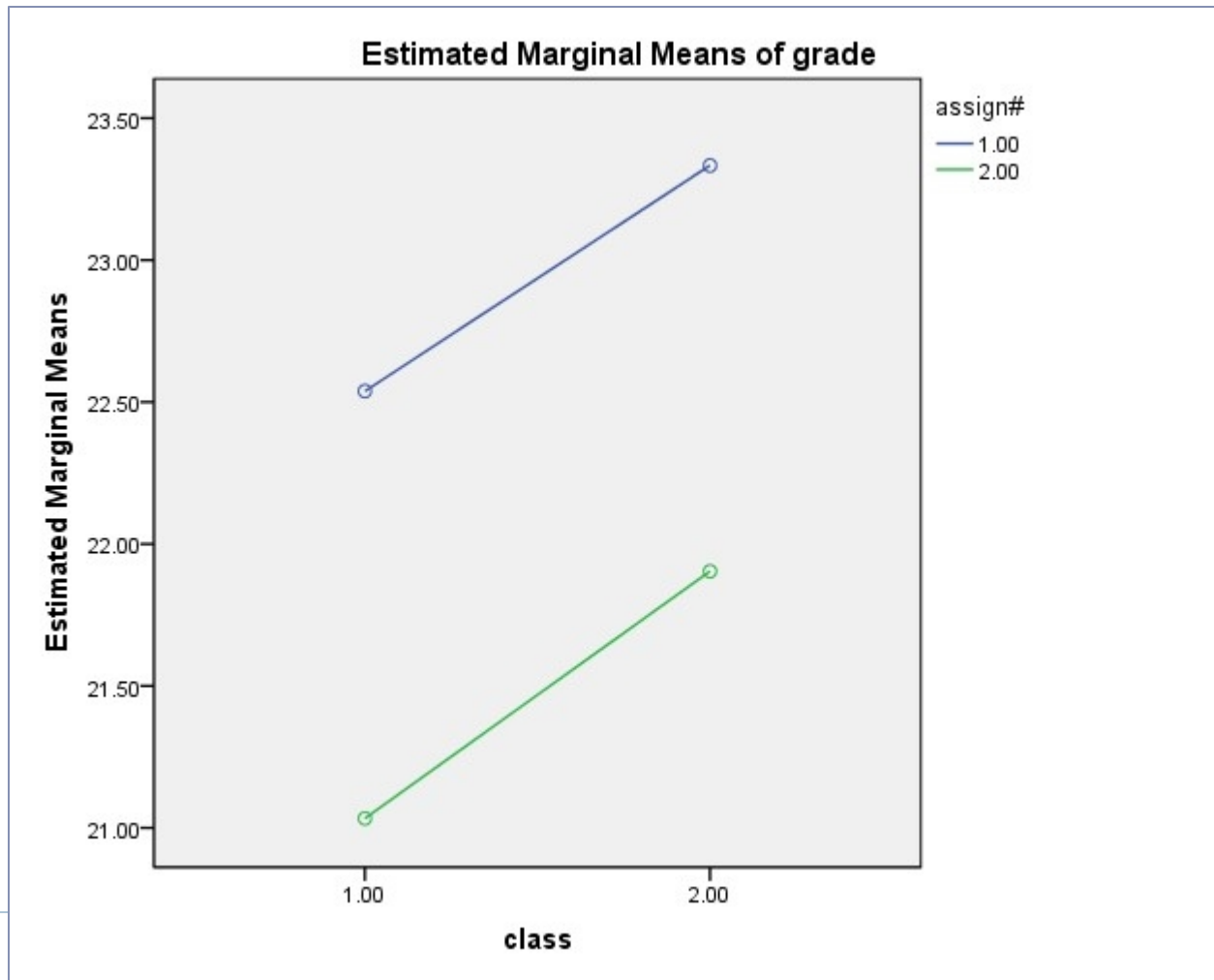
Dependent Variable: grade

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	38.248 <sup>a</sup>	3	12.749	6.032	.001	.270
Intercept	25957.327	1	25957.327	12280.305	.000	.996
class	9.128	1	9.128	4.318	.043	.081
assign#	28.343	1	28.343	13.409	.001	.215
class * assign#	.019	1	.019	.009	.925	.000
Error	103.573	49	2.114			
Total	26113.813	53				
Corrected Total	141.821	52				

a. R Squared = .270 (Adjusted R Squared = .225)

# Two-way ANOVA (cont'd)

---



## Two-way ANOVA (cont'd)

---

- ▶ Step 3: Make a decision regarding the null.
- ▶ Do we reject or fail to reject the null?

## Two-way ANOVA (cont'd)

► **Step 4:** Write up your results.

► The null hypothesis stated that there is no difference between class and assignment number on students' grades. A Two-way ANOVA revealed a significant difference between classes ( $M = 21.73$ ,  $SD = 1.57$ ;  $M = 22.59$ ,  $SD = 1.66$ ; for Class 1 and 2, respectively) on students' grades,  $F(1, 49) = 4.32$ ,  $p = .04$ ,  $\eta^2 = .08$ , and between assignment number ( $M = 22.92$ ,  $SD = 1.11$ ;  $M = 21.44$ ,  $SD = 1.76$ ; for Assignment 1 and 2, respectively) and students' grades,  $F(1, 49) = 13.41$ ,  $p = .001$ ,  $\eta^2 = .22$ ; however, the grades by class interaction effect was not significant,  $F(1, 49) = .01$ ,  $p = .93$ ,  $\eta^2 = .00$ .

# MANOVA

---

- ▶ 2 or more DVs
- ▶ Example:
  - ▶ A stats teacher wants to determine whether students in Class A differ from students in Class B on Assignment I and their anxiety towards statistics (based on a survey given at the beginning of the semester).

# MANOVA

---

- ▶ To run, Analyze → GLM → Multivariate
  - ▶ Dependent Variables = grade, anxiety score (2 DVs)
  - ▶ Fixed Factors = class, assignment # (these are your IVs)

# ANCOVA

---

- ▶ In quasi-experimental designs random assignment of subjects is not possible (e.g., using a non-equivalent control group)
- ▶ What's the biggest problem with these types of designs?
- ▶ We can control this through our data analysis by including a covariate



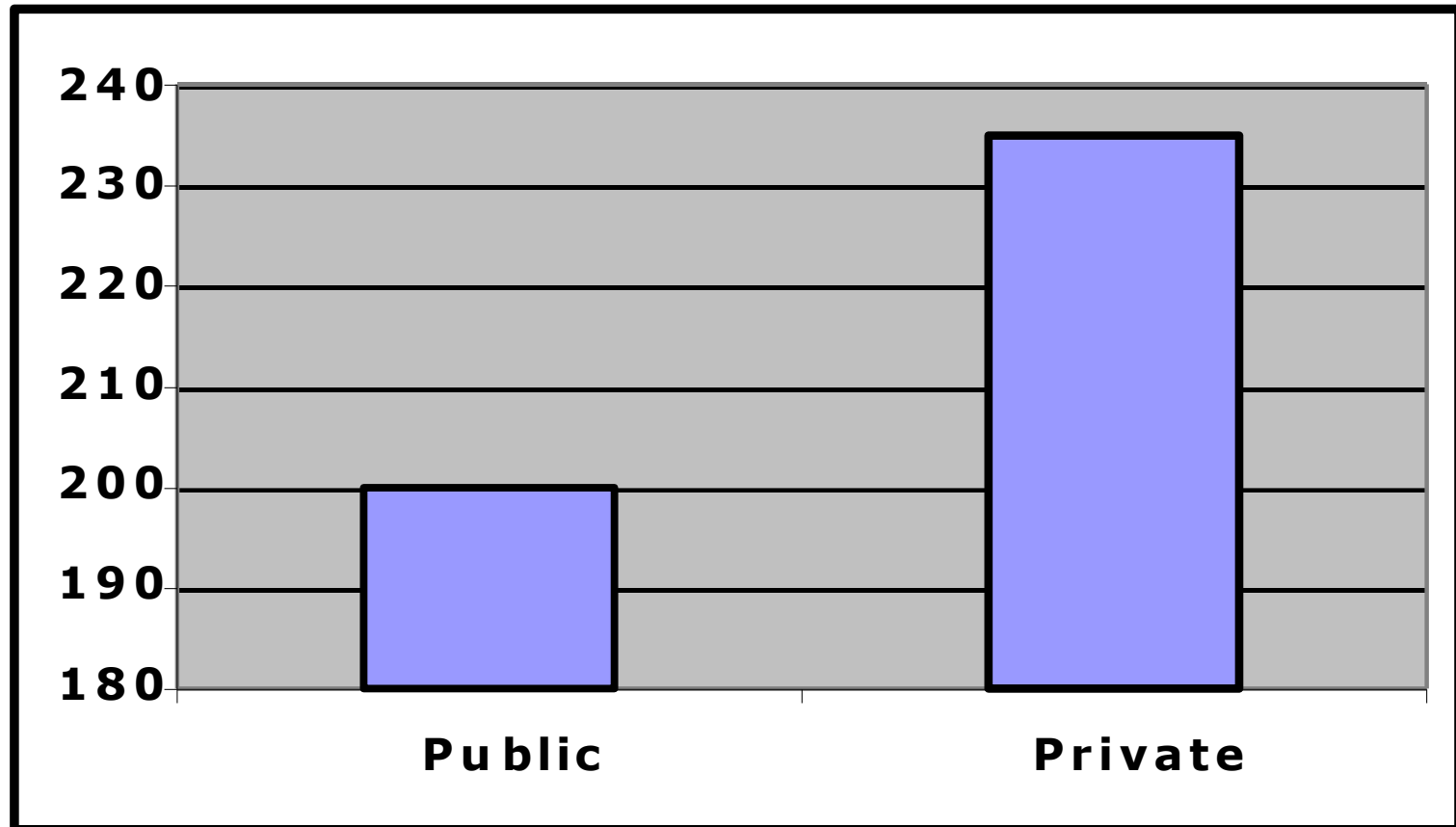
# ANCOVA Example

---

- ▶ Often times we want to evaluate the effectiveness of a program that is already in place, and we are not able to construct a treatment and a control group.
- ▶ For example, suppose we wanted to evaluate the effectiveness of public schools vs. private schools on academic achievement. We looked at the average NAEP math scores for 4th grade students in public and private schools and found the following:

# ANCOVA Example (cont'd)

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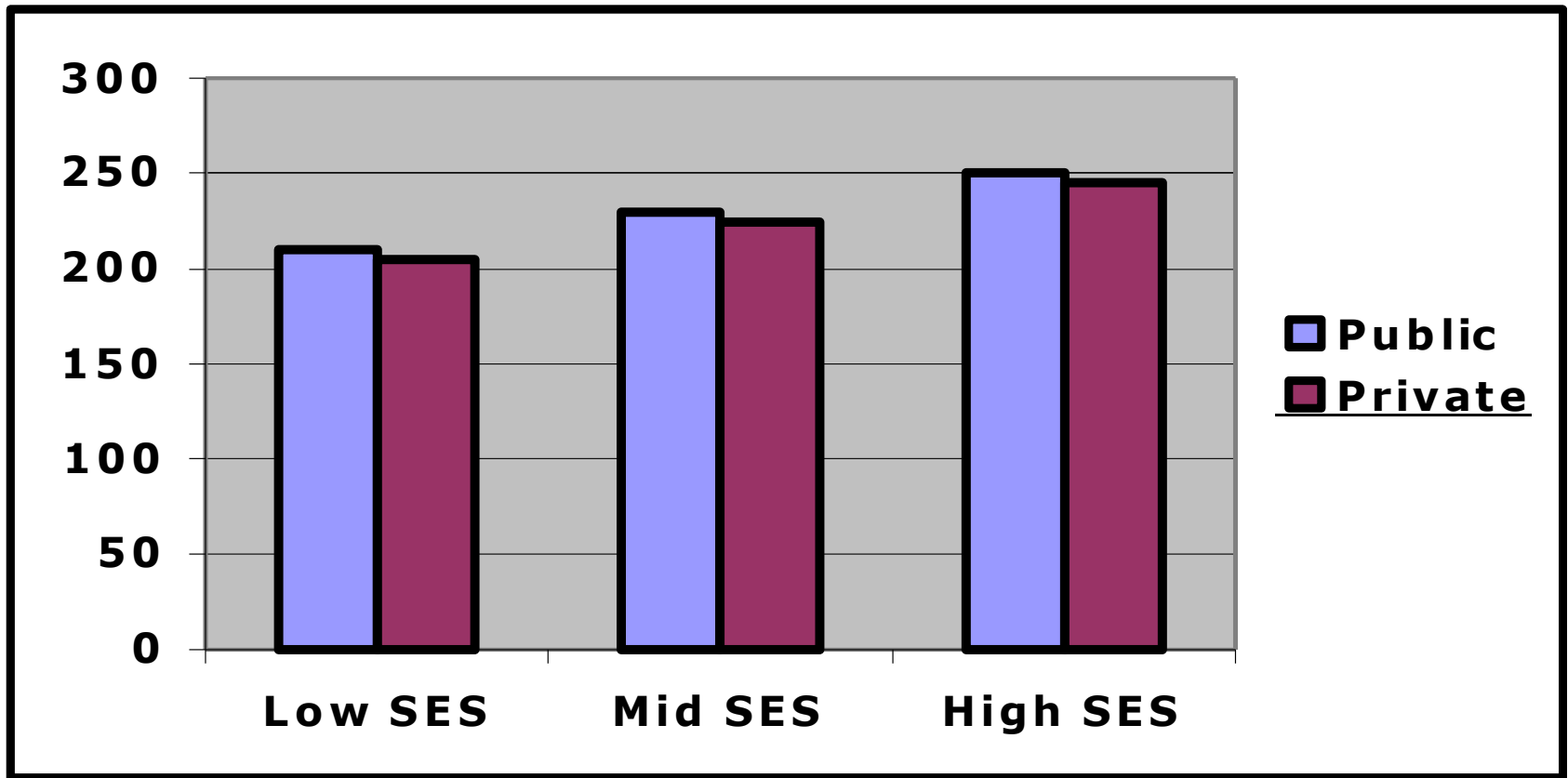
## ANCOVA Example (cont'd)

---

- ▶ What happens when we control for an extraneous variable such as SES (i.e., use SES as a covariate).

# ANCOVA Example (cont'd)

---



## ANCOVA Example (cont'd)

---

- ▶ When we compare public and private students of the same SES, we find there is little difference in their achievement. But because there are more high SES students in private schools, the overall comparison is misleading.

## ANCOVA Example (cont'd)

---

- ▶ ANCOVAs are run similarly to ANOVAs, you simply add the variable as a covariate.
- To run, Analyze → GLM → Univariate
  - ▶ Covariate = SES
- ▶ Interpreted the same way as the ANOVA output

# Module 7 Summary

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- ▶ Analysis of Variance
  - ▶ Types of ANOVAs
    - ▶ One-way ANOVA
    - ▶ Two-way ANOVA
  - ▶ MANOVA
  - ▶ ANCOVA

# Review Activity

---

- ▶ Please complete the review activity at the end of the module.
- ▶ All modules build on one another. Therefore, in order to move onto the next module you must successfully complete the review activity before moving on to next module.
- ▶ You can complete the review activity and module as many times as you like.



# Upcoming Modules

---

- ▶ Module 1: Introduction to Statistics
- ▶ Module 2: Introduction to SPSS
- ▶ Module 3: Descriptive Statistics
- ▶ Module 4: Inferential Statistics
- ▶ Module 5: Correlation
- ▶ Module 6: *t*-Tests
- ▶ Module 7: ANOVAs
- ▶ **Module 8: Linear Regression**
- ▶ **Module 9: Nonparametric Procedures**



# Module 8: Linear Regression

The Applied Research Center

# Module 8 Overview

---

- ▶ Purpose of Linear Regression
- ▶ Scatter Diagrams
- ▶ Regression Equation
- ▶ Regression Results
- ▶ Example

# Purpose

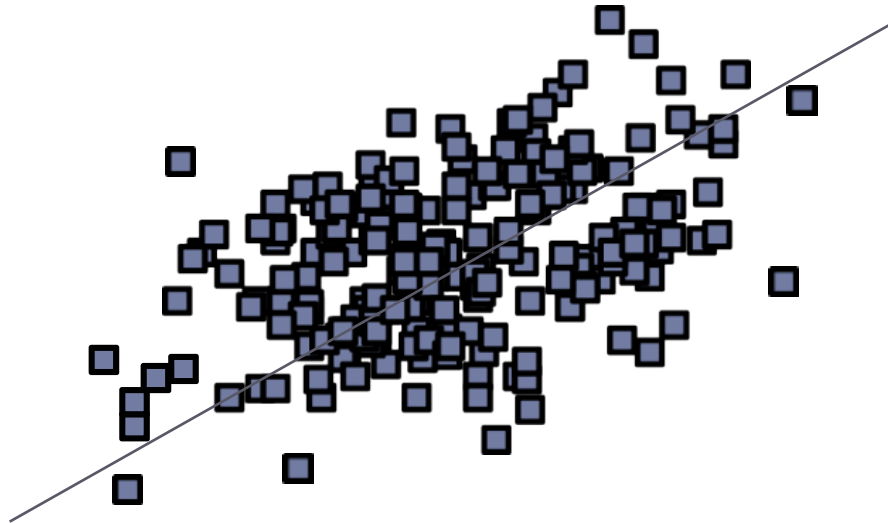
---

- ▶ To **predict** scores on one variable based on information regarding the other variables.
- ▶ OR
- ▶ To **explain** why the participants scored differently on a particular variable of interest.

# Scatter Diagrams

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- ▶ Regression can best be understood by examining a scatter diagram, which includes the data points and a line of best fit.



# Regression Equation

---

- ▶ The slanted line passing through the data points of a scatter diagram is the **regression line or line of best fit**, which is used to make predictions.
- ▶ The **regression equation** is the technical way of describing the regression line.
  - ▶  $Y' = a + bX$ 
    - ▶  $Y'$  is the predicted score for the dependent variable
    - ▶  $a$  is the constant
    - ▶  $b$  is the **regression coefficient**
    - ▶  $X$  is the known score on the independent variable

$$Y' = a + bX$$

---

- ▶  $a$  is the constant, or **intercept**
  - ▶ Indicates where the regression line would intersect the y axis (or the vertical axis, also known as the ordinate).
  - ▶ It is the value for  $Y'$  when  $X = 0$
- ▶  $b$  is the **regression coefficient**, or the slope of the regression line
  - ▶ It signifies how many predicted units of change (either positive or negative) in the DV there are for any one unit increase in the IV.

# Regression Results

---

- ▶  $r$

- ▶ the degree to which the predicted scores match up to the actual scores.

- ▶  $r^2$

- ▶ Coefficient of determination
- ▶ The proportion of variability in the dependent variable that is explained by the independent variable
- ▶ Reported as a percent



# Example

---

- ▶ A stats professor wanted to predict student grades on Assignment 2 based on student grades on Assignment 1.
- ▶ Step 1: Write your null and alternate hypotheses:
  - ▶  $H_0$  = There is no relationship between Assignment 1 and Assignment 2.
  - ▶  $H_a$  = There is a relationship between Assignment 1 and Assignment 2.

## Example (cont'd)

---

- ▶ **Step 2: Input the data into SPSS**
  - ▶ Create a variable for Assignment 1 and a second variable for Assignment 2
  - ▶ Input the student grades on Assignment 1 in the Assignment 1 column and enter student grades on Assignment 2 in the Assignment 2 column

## Example (cont'd)

---

- ▶ Step 3: Create a scatter diagram
  - ▶ **Graphs** → **Legacy Dialogues** → **Scatter/Dot**
  - ▶ Click on **Simple Scatter**, then **Define**
  - ▶ Assignment 2 → Y-axis box
  - ▶ Assignment 1 → X-axis box
  - ▶ Click **Ok**

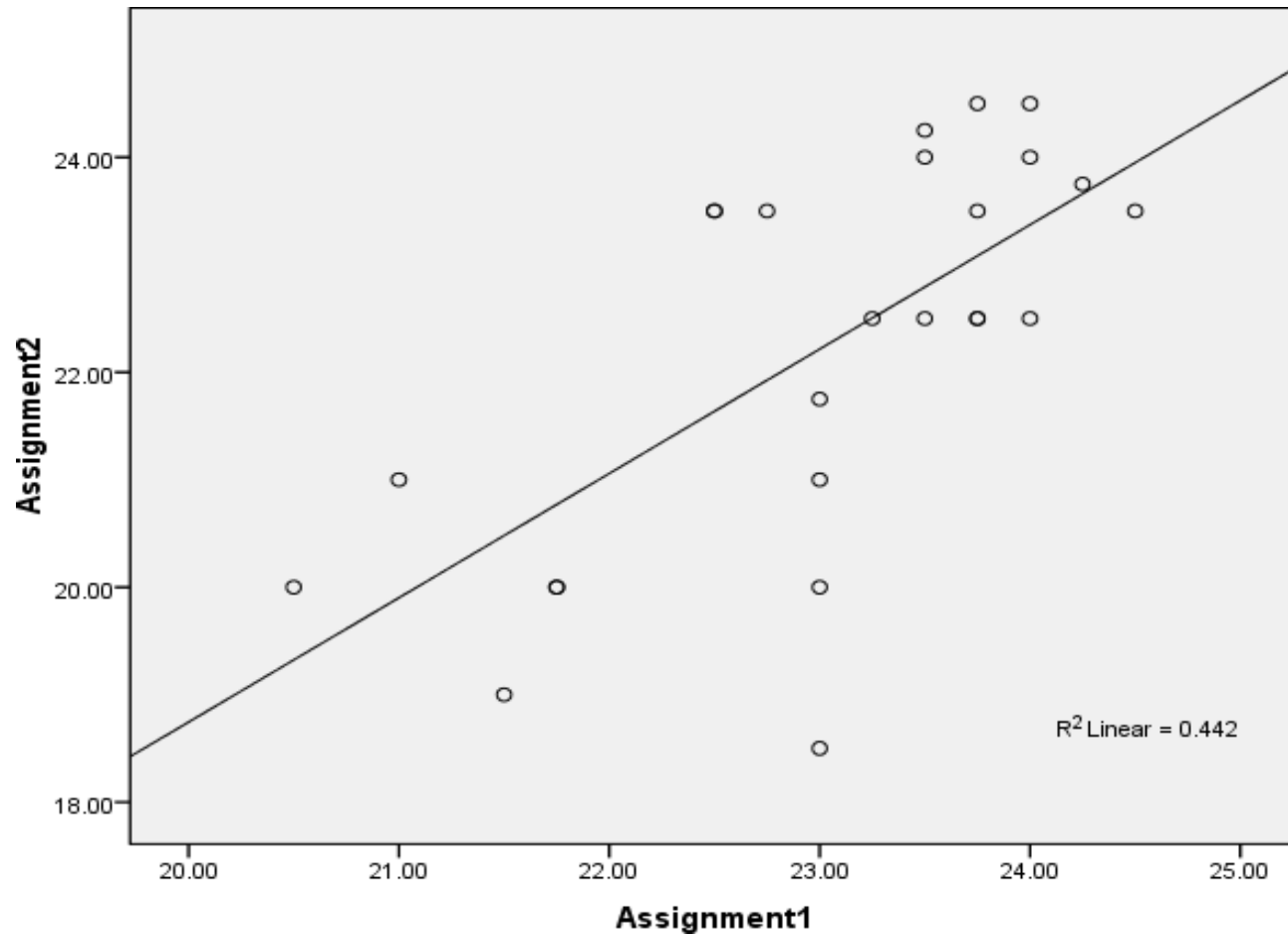
## Example (cont'd)

---

- ▶ To add a regression line to the scatter plot
  - ▶ Double click on the chart (in the SPSS Output) to select it for editing and maximize the chart editor
  - ▶ Click on any of the data points in the scatter plot to highlight the data points
  - ▶ Click **Elements** from the main menu bar and click on **Fit Line at Total**
  - ▶ Click **Close**

# Example (cont'd)

---



## Example (cont'd)

---

- ▶ **Step 4: Run the Bivariate Linear Regression**
  - ▶ Analyze → Regression → Linear
  - ▶ Assignment 2 → **Dependent** box
  - ▶ Assignment 1 → **Independent** box
  - ▶ Click **Statistics**
  - ▶ Click **Confidence Intervals** and **Descriptives** (make sure **Estimates** and **Model fit** are also selected)
  - ▶ Click **Continue**
  - ▶ Click **OK**

# Example (cont'd)

---

## Descriptive Statistics

	Mean	Std. Deviation	N
Assignment2	22.2500	1.81286	25
Assignment1	23.0300	1.04163	25

## Correlations

		Assignment2	Assignment1
Pearson Correlation	Assignment2	1.000	.665
	Assignment1	.665	1.000
Sig. (1-tailed)	Assignment2	.	.000
	Assignment1	.000	.
N	Assignment2	25	25
	Assignment1	25	25

# Example (cont'd)

---

**Model Summary**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.665 <sup>a</sup>	.442	.418	1.38351

**ANOVA<sup>b</sup>**

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	34.851	1	34.851	18.207	.000 <sup>a</sup>
	Residual	44.024	23	1.914		
	Total	78.875	24			





### Coefficients<sup>a</sup>

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
1 (Constant)	-4.393	6.250		-.703	.489	-17.322	8.536
Assignment	1.157	.271	.665	4.267	.000	.596	1.718



## Example (cont'd)

---

- ▶ Step 5: Write the prediction equation
  - ▶  $Y' = -4.39 + 1.16X$
- ▶ Step 6: Write up your results
- ▶ The hypothesis was tested using a bivariate linear regression to determine whether student grades on Assignment 2 could be predicted based on student grades from Assignment 1. Regression analysis revealed that the model significantly predicted Assignment 2 grades based on Assignment 1 grades,  $F(1, 23) = 18.207, p < .001$ .  $R^2$  for the model was .44, and adjusted  $R^2$  was .42

# Module 8 Summary

---

- ▶ Purpose of Linear Regression
- ▶ Scatter Diagrams
- ▶ Regression Equation
- ▶ Regression Results
- ▶ Example

# Review Activity

---

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- ▶ Module 8: Linear Regression
- ▶ **Module 9: Nonparametric Procedures**



# Module 9: Nonparametric Tests

The Applied Research Center

# Module 9 Overview

---

- ▶ Nonparametric Tests
- ▶ Parametric vs. Nonparametric Tests
- ▶ Restrictions of Nonparametric Tests
- ▶ One-Sample Chi-Square Test
- ▶ Chi-Square Test of Independence
- ▶ Other Nonparametric Tests

# What Are Nonparametric Tests?

- ▶ Nonparametric tests require few, if any assumptions about the shapes of the underlying population distributions
- ▶ For this reason, they are often used in place of parametric tests if or when one feels that the assumptions of the parametric test have been too grossly violated (e.g., if the distributions are too severely skewed).



# Parametric or Nonparametric tests?

- ▶ If all assumptions are met, use Parametric techniques
- ▶ Use Nonparametric techniques
  - ▶ When the dependent variable is either nominal or ordinal
  - ▶ If the distribution of the dependent variable is skewed
  - ▶ When the assumptions are not met, specifically:
    - ▶ Normality
    - ▶ Homogeneity of variance

# Restrictions

---

- ▶ Nonparametric tests do have at least two major disadvantages in comparison to parametric tests:
- ▶ First, nonparametric tests are less powerful. Why? Because parametric tests use more of the information available in a set of numbers.
- ▶ Parametric tests make use of information consistent with interval or ratio scale (or continuous) measurement, whereas nonparametric tests typically make use of nominal or ordinal (or categorical) information only.

## Restrictions (cont'd)

---

- ▶ Second, parametric tests are much more flexible, and allow you to test a greater range of hypotheses. For example, ANOVA designs allow you to test for interactions between variables in a way that is not possible with nonparametric alternatives.
- ▶ There are nonparametric techniques to test for certain kinds of interactions under certain circumstances, but these are much more limited than the corresponding parametric techniques.

# Chi-Square Test

---

- ▶ Used to test variables that have nominal data
- ▶ Examples of nominal data
  - ▶ Gender
  - ▶ Political affiliation
  - ▶ Course delivery method
- ▶ Three main types:
  - ▶ Goodness-of-fit (or one-sample) test
  - ▶ Test of independence (or association)
  - ▶ Independent-samples test

# Chi-Square Goodness-of-Fit Test

- Evaluates whether the proportions of individuals who fall into categories are equal to hypothesized values
- The variable can have two or more categories
- The categories can have quantitative (one category reflects a higher value than another; e.g., Likert scale responses of Agree and Disagree) or qualitative grouping (e.g., course delivery method)
- Note: The chi-square test does not recognize any quantitative distinction among categories; it simply assesses whether the proportions associated with the categories are significantly different from the hypothesized values

# Chi-Square Goodness-of-Fit Test (cont'd)

---

- ▶ When conducting a chi-square test in SPSS, you must first specify the values for the hypothesized proportions
- ▶ The proportions can be
  - ▶ Equal (proportion =  $1 / \text{number of categories}$ )
  - ▶ Not equal (determined based on previous research)

# Chi-Square Goodness-of-Fit Test (cont'd)

---

- Next, you must formulate a null hypothesis (the expected frequencies = hypothesized proportions)
- Then, specify the expected frequencies associated with the categories.
  - ▣ The expected frequency =  
hypothesized proportion  $\times$  total sample size.
  - ▣ If hypothesized proportions are equal, the expected frequencies will be equal
  - ▣ If hypothesized proportions are unequal, the expected frequencies will be unequal

# Contingency Tables

---

- ▶ Helps arrange the data in a study for the purpose of showing how each group split itself up on the variable
- ▶ Make it easier to understand the null hypothesis and why the data led to the rejection or not of the null.



# Goodness-of-Fit Example

- A professor was interested in whether students prefer to take classes face to face or online. A poll was taken with 100 students to determine their preference for learning.
- Step 1: State the null and alternate hypotheses
  - $H_0$ : The number of students who prefer to take classes face to face is equal to the number of students who prefer to take classes online
  - $H_a$ : The number of students who prefer to take classes face to face is not equal to the number of students who prefer to take classes online

# Goodness-of-Fit Example (cont'd)

## ▶ Step 2: Create the contingency table

	Observed Frequencies	Hypothesized Proportions	Expected Frequencies
Face to Face	39	.50	50
Online	61	.50	50

## ▶ Step 3: Input the data into SPSS

- ▶ Create a variable labeled DeliveryMethod
- ▶ Assign values: 1 = Face to Face, 2 = Online
- ▶ Enter the data (in one column): 39, 1's and 61, 2's

# Goodness-of-Fit Example (cont'd)

## ▶ Step 4: Run the Analysis

- ▶ Analyze → Nonparametric → Legacy Dialogs → Chi-square
- ▶ Move the variable (DeliveryMethod) to the “Testvariable list” box
- ▶ Under “Expected Values,” select “All categories equal”
- ▶ Click “Ok”

# Goodness-of-Fit Example (cont'd)

**DeliveryModel**

	Observed N	Expected N	Residual
Facetoface	39	50.0	-11.0
Online	61	50.0	11.0
Total	100		

**Test Statistics**

	DeliveryModel
Chi-Square	4.840 <sup>a</sup>
df	1
Asymp. Sig.	.028



## Goodness-of-Fit Example (cont'd)

- ▶ Step 4: Make a decision regarding the null
  - ▶  $\chi^2 = 4.84$
  - ▶  $df = 1$  (Number of categories – 1)
  - ▶  $p = .028$
- ▶ What is our decision regarding the null?

## Goodness-of-Fit Example (cont'd)

- ▶ Using the level of significance = .05, do we reject or fail to reject the null?
  - ▶ If  $p < .05$ , we reject the null
  - ▶ if  $p > .05$ , we fail to reject the null
- ▶ According to SPSS,  $p = .028$
- ▶  $.028 < .05$ , therefore, we reject the null!

## Goodness-of-Fit Example (cont'd)

- ▶ **Step 5: Write up your results.**
  - ▶ The null hypothesis stated that the number of students who prefer to take classes face to face is equal to the number of students who prefer to take classes online. A chi-square goodness-of-fit test revealed that significantly more students prefer to take courses online (61%) compared to face to face (39%,  $X^2 = 4.84$ ,  $df = 1$ ,  $p = .028$ ). Consequently, the null hypothesis was rejected.

# Chi-Square Test of Independence

- ▶ A test to see whether a relationship (or association) exists between two nominal variables
- ▶ Similar to a bivariate correlation



# Test of Independence Example

- ▶ A professor is interested in whether there is a relationship between gender and preference for learning statistics face to face or online. A poll was taken with 100 students (50 males and 50 females) to determine their preference for learning.
- ▶ Step 1: State the null and alternate hypotheses
  - ▶  $H_0$  : There is no relationship between gender and preference for learning statistics face to face or online
  - ▶  $H_a$  : There is a relationship between gender and preference for learning statistics face to face or online

# Test of Independence Example (cont'd)

## ▶ Step 2: Create the contingency table

	Face to face	Online
Males	20	30
Females	30	20

## ▶ Step 3: Input the data into SPSS

- ▶ Create 2 variables: Gender and DeliveryMethod
- ▶ Assign values
- ▶ Enter the data:
  - ▶ For Gender: 50, 1' and 50, 2'
  - ▶ For DeliveryMethod: 20 males and 30 females (face to face), 30 males and 20 females (online)

# Test of Independence Example (cont'd)

## ▶ Step 4: Run the Analysis

- ▶ Analyze → Descriptives → Crosstabs
- ▶ Move Gender to the “Row” box and DeliveryMethod to the “Column” box
- ▶ Select “Statistics” then select “Chi square” and “Phi and Cramer’s V” boxes, Click “Continue”
- ▶ Select “Cells” then under “Counts” select “Observed” and “Expected,” Click “Continue”
- ▶ Select “Display clustered bar charts” at the bottom left.
- ▶ Click “Ok”

# Test of Independence Example (cont'd)

## Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Gender * DeliveryMethod	100	100.0%	0	.0%	100	100.0%

## Gender \* DeliveryMethod Crosstabulation

			DeliveryMethod		Total
			Face to face	Online	
Gender	Male	Count	20	30	50
		Expected Count	25.0	25.0	50.0
	Female	Count	30	20	50
		Expected Count	25.0	25.0	50.0
Total		Count	50	50	100
		Expected Count	50.0	50.0	100.0



# Test of Independence Example (cont'd)

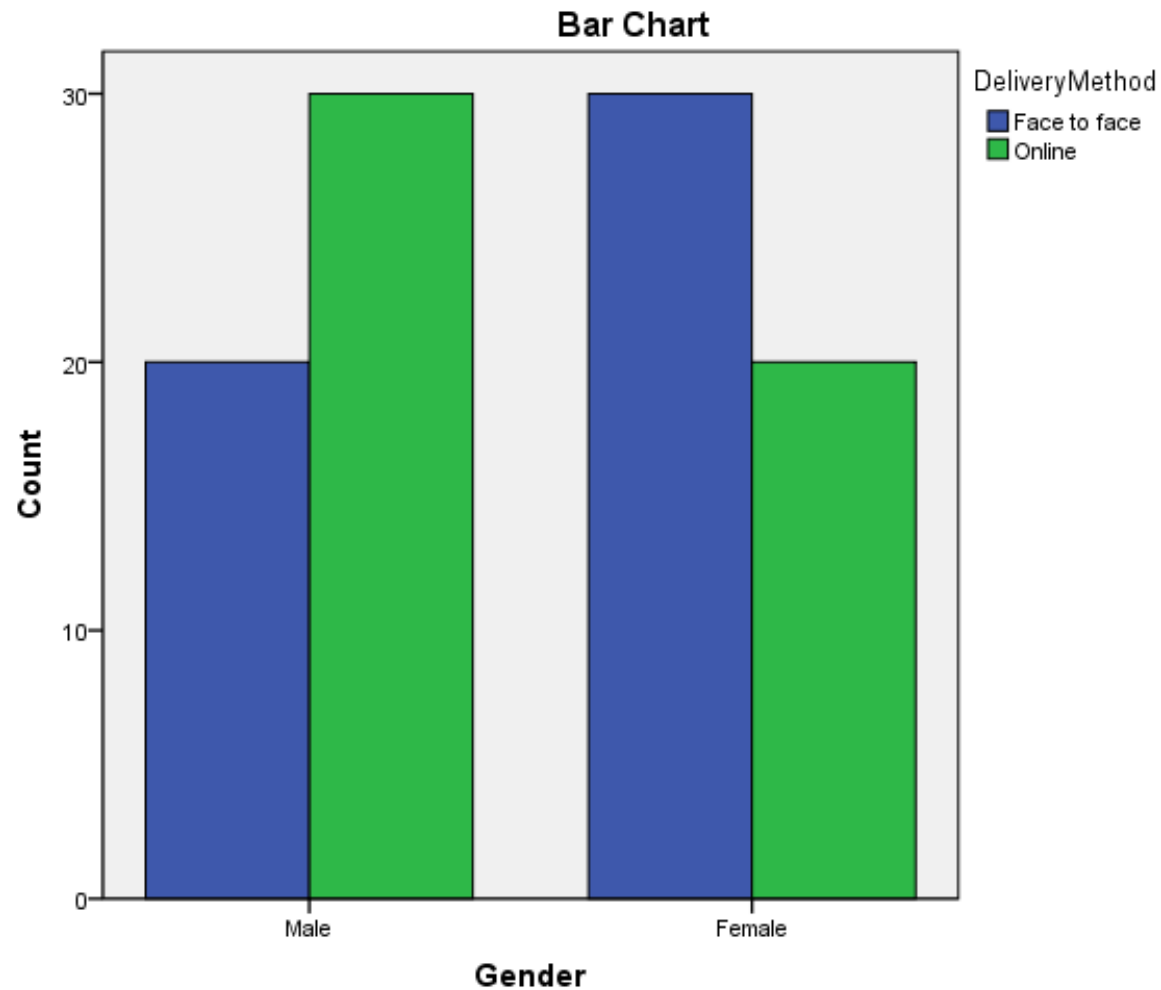
## Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.000 <sup>a</sup>	1	.046		
Continuity Correction <sup>b</sup>	3.240	1	.072		
Likelihood Ratio	4.027	1	.045		
Fisher's Exact Test				.071	.036
Linear-by-Linear Association	3.960	1	.047		
N of Valid Cases	100				

## Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.200	.046
	Cramer's V	.200	.046
N of Valid Cases		100	

# Test of Independence Example (cont'd)



## Test of Independence Example (cont'd)

- ▶ Step 4: Make a decision regarding the null
  - ▶  $\chi^2 = 4.00$
  - ▶  $df = 1$ 
    - ▶ (Number of categories in 1<sup>st</sup> variable – 1)(Number of categories in 2<sup>nd</sup> variable – 1)
  - ▶  $p = .046$
- ▶ What is our decision regarding the null?

## Test of Independence Example (cont'd)

- ▶ Using the level of significance = .05, do we reject or fail to reject the null?
  - ▶ If  $p < .05$ , we reject the null
  - ▶ if  $p > .05$ , we fail to reject the null
- ▶ According to SPSS,  $p = .046$
- ▶  $.046 < .05$ , therefore, we reject the null!



## Test of Independence Example (cont'd)

- ▶ **Step 5: Write up your results.**
  - ▶ The null hypothesis stated that there is no relationship between gender and preference for learning statistics face to face or online. A chi-square test of independence revealed a significant relationship between gender and preference for learning statistics,  $\chi^2 (1, N = 100) = 4.00; p = .046$ . Consequently, the null hypothesis was rejected.

# Nonparametric Tests for Nominal Data

- ▶ The sign test
- ▶ The binomial test
- ▶ Fischer's Exact Test
- ▶ The chi-square test
- ▶ McNemar's test
- ▶ Cochran's test

# Nonparametric Tests for Ordinal Data

- ▶ **The Mann-Whitney  $U$  test**
  - ▶ Analogous to independent samples  $t$  test
- ▶ **Wilcoxon signed-ranks test**
  - ▶ Analogous to paired samples  $t$  test
- ▶ **The Kruskal-Wallis one-way analysis of ranks**
  - ▶ Analogous to a one-way ANOVA
  - ▶ **The Friedman's ANOVA**
    - ▶ Analogous to RM ANOVA
- ▶ **Spearman's rho**
  - ▶ Analogous to Pearson correlation

# Module 9 Summary

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- ▶ Nonparametric Tests
- ▶ Parametric vs. Nonparametric Tests
- ▶ Restrictions of Nonparametric Tests
- ▶ One-Sample Chi-Square Test
- ▶ Chi-Square Test of Independence
- ▶ Other Nonparametric Tests

# Review Activity

---

- ▶ Please complete the review activities at the end of the module.
- ▶ You can complete the review activities and module as many times as you like.
- ▶ Upon completion of the review activities you will have an opportunity to print your Certificate of Completion, along with instructions for submitting your certificate to the ARC.

# Statistics PD Course Modules

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- ▶ Module 1: Introduction to Statistics
  - ▶ Module 2: Introduction to SPSS
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- 