Statistical Thinking

Instructor Manual

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The purpose of this module is to give students a basic understanding of statistical principles to help them interpret the results of research studies. It focuses on distributional thinking, statistical significance using the probability model, generalizability, and drawing causal conclusions using randomization. Four examples of research studies are presented in the module that highlight and apply statistical thinking.

Learning Objectives

- **Relevant APA Learning Objectives** (Version 2.0)
  - Describe applications of psychology (1.3).
  - Use scientific reasoning to interpret psychological phenomena (2.1).
  - Interpret, design and conduct basic psychological research (2.4).
  - Interact effectively with others (4.3).
  - Enhance teamwork capacity (5.4).
- **Content Specific Learning Objectives**
  - Define basic elements of a statistical investigation.
  - Describe the role of p-values and confidence intervals in statistical inference.
  - Describe the role of random sampling in generalizing conclusions from a sample to a population.
  - Describe the role of random assignment in drawing cause-and-effect conclusions.

- Critique statistical studies.

Abstract

As our society increasingly calls for evidence-based decision making, it is important to consider how and when we can draw valid inferences from data. This module will use four recent research studies to highlight key elements of a statistical investigation.

Class Design Recommendations

This module can be taught in one 90-minute class, or two shorter class periods (45 to 60 minutes). If it is taught in two class periods, we suggest stopping day one after completing the M&Ms® activity. Please also refer to the Noba PowerPoint slides that complement this instructor's manual.

Overview

- Introduction
  - Key components to a statistical investigation
- Distributional thinking
- Statistical significance
  - Control
  - Probability
  - Level of significance
- Generalizability
  - Samples and populations
  - Random sample
  - Margin of error

- Cause and effect
    - Statistical tendency
    - Random assignment

Module Outline

Introduction: This module opens by presenting statistical findings from a study investigating whether drinking coffee increases life expectancy. Conducting an experiment and interpreting the results (illustrated by the coffee example) requires an understanding of the basic principles of statistics.

- Key components to a statistical investigation include:
    - Planning the study
    - Examining the data
    - Inferring from the data
    - Drawing conclusions

Distributional Thinking: Statistical data varies and understanding how it varies is critically important.

- *Distribution*: Researchers need to first look at the pattern of the variation, called the distribution of the variable, to understand the information. You can look at the center of the distribution (not ideal) or the whole distribution using a graph (ideal).

Statistical Significance: A research study is described that investigated if infants would choose to play with a doll they witnessed behaving in a helpful or hindering manner toward another person's goals. In thinking about the results, how might researchers determine whether the patterns observed in the small set of data is convincing enough evidence to suggest that all infants might behave this way?

- *Control*: Controlling for variables that might also explain the findings are important.
- *Probability/p-value*: The probability model is also used to determine if random chance is a factor in an experiment. Probability is referred to as a *p*-value. If you assume that your results are completely due to random chance, the p-value tells you how often you should get a result at least as extreme as the findings in the actual study.
- *Level of significance*: A small *p*-value indicates strong evidence your results are not due to chance, but how small is small enough? The cut-off value of $p < .05$ is often used in research studies and is called the level of significance.

Generalizability: A survey is described that polls a sample of Americans yet makes conclusions about general societal trends in the United States.

- *Samples and Populations*: In research studies the participants are a sample of people from a larger group or population.
- *Generalizability*: Can you use findings from a sample to draw conclusions about the population from which it was drawn?
- *Random Sample*: Every member of the population is given an equal chance of being selected for the sample of a research study.
- *Margin of Error*: When you use the random sampling method, you can make claims about how much random variation you expect in a statistic (often defined as a 95% confidence interval). This means that you can infer how often the sample result should fall, within a certain range from the unknown population parameter, by chance alone. Other sources of error, such as dishonest participants or non-random samples, are not measured by the margin of error and should be taken into account.

Cause and Effect Conclusions: A research study is described that investigated whether the type of motivation that drives people—intrinsic or extrinsic—affects their creativity. In other words, are there differences between two groups of people based on their motivations?

- *Statistical Tendency*: Looking at the distribution, the variability of scores shows some overlap but also points toward an observable difference between the two groups of people. The standard deviation tells you how far away each score is from the mean on average. Comparing the mean and standard deviation of each group can tell you if there is a statistical tendency present in the data.
- *Random Assignment*: How were the two comparison groups formed? In random assignment, each individual is just as likely to be assigned to either group. This should produce groups that are as similar as possible except for the variable of interest. This eliminates other

variables as possible explanations for the study's findings.

- *Cause and Effect*: The probability model and *p*-value are again applied to account for the chance that random assignment did not equally distribute variables of interest between the two groups. If the *p*-value is small (less than .05), the observed mean scores are assumed not to be coincidental. Thus, cause-and-effect relationships can be concluded.

Conclusions: Probability models help researchers assess how much random variation they can expect in the results of a study. They are used to determine whether the results could happen by chance alone, and to estimate a margin of error. Random sampling allows for the generalization of results from a sample to a larger population, and random assignment allows for causal conclusions.

Difficult Terms

Confidence Interval
Control, Probability Model
Correlation
Distribution
Generalizability
Margin of Error
Parameter
p-value
Standard Deviation
Statistical Significance
Statistical Tendency

Lecture Frameworks

Overview: Begin the class period with a structured discussion on anxiety toward statistics, followed by a lecture on the major topics from the start of the module. To cover generalizability, an activity/demonstration is recommended. Additional instruction on content as well as an application activity is provided below.

- **Warmup:** Anxiety toward mathematics, or statistics specifically, is common among students. Before diving into the content of the module, gauge how students feel about statistics. Use the think-pair-share activity described in the Activities and Demonstrations section to informally assess students' understanding of this material.

- **Direct Instruction:**Refer to the PowerPoint slides for the following major topics: key components to a statistical investigation, distributional thinking, statistical significance, generalizability, and cause-and-effect conclusions.
- **Activity/Demonstration:**To cover generalizability, use the "Teaching about sampling using M&Ms®" activity/demonstration described in the Extra Activities section, developed by Smith (1999). This will help solidify students' understanding of samples, populations, and randomization.
- **Direct Instruction:** Refer to the PowerPoint slides to talk about cause and effect.
- **Activity:**Complete the application activity "Popular press statistics" that asks students to think critically about examples of statistical conclusions they find in popular media. A description of this activity can be found in the Activities and Demonstrations section.
- **Wrap-up:** Use the Classroom Assessment Technique (CAT) to assess students' understanding of the material covered in this lesson. Have students complete the CAT by answering this question: What was the muddiest point from today's lesson?
- **Conclusion:** Conclude by summarizing key points and take home messages. Refer to the PowerPoint slides.

Activities & Demonstrations

Think-Pair-Share—Anxiety Toward Statistics: This activity can be completed during class. For this activity, students reflect on their comfort with statistics, assess it, and then pair with a partner in class to discuss their results. The activity concludes with a large class discussion.

- Time: 15 minutes
- Materials: Pen and paper for students, optional copy of the "Survey of Attitudes Toward Statistics" (SATS) scale. You can request the scale here: https://www.evaluationandstatistics.com/register

- Directions:

1. Have students complete the SATS quietly by themselves. You can make copies of the entire scale or select a sub-scale to include, either making a copy for students or putting questions on your PowerPoint slides.
2. After students have completed the scale and self-scored it, have them pair with up with a peer to discuss their results. How do they feel about statistics? The same as, or different from, their partner? What specific components from the scale did they score high or low in? Why do they have those feelings, and what can they do (good or bad) to combat or promote them? How can they help one another?
3. Facilitate a class-wide discussion for students to share their ideas with the larger group. Address how common math anxiety is, and generate a list of ideas for combating it.

Demonstration/activity—Collect and Display Data: This activity can be completed during class. For this activity, students are asked a simple question and report their answer. The class compiles the answers (data) and creates a distribution of the data together on the white- or chalkboard. The activity concludes with a large class discussion.

- Time: 15 minutes
- Materials: Pen and paper for students, whiteboard or chalkboard
- Directions:

1. Ask students a question (to collect data). Sample questions include:
    - How many siblings to do you have?
    - What is your shoe size?
    - How many concerts did you go to this past year?

You can choose any question to collect data on; however, ideally, there should be one or two students who have extreme scores (outliers), which will give you the occasion to talk about variability, and how the mean is sensitive to outliers.

2. Collect student answers. Have one or two student volunteers sort the answers. Ask them how to best visually represent the information.
3. Draw the graph on the board and have students begin to plot the data points.
4. Facilitate a class-wide discussion. What single score best represents the data? Calculate

the mean, median, and mode. Point out any students' scores that were extreme (outliers). Discuss how these affect the mean. How much variability is in the data? Discuss the variability of the responses and the concept of skewness. Were most students' responses similar or dissimilar?

Application Activity—Popular Press Statistics: This activity can be completed during class. Have students complete the research aspect at home before class, or during class with computers or smart devices. For this activity, students look up an example of a statistical finding in the popular press (on the internet). Some great examples to show students can be found on Beth Morling's "Everyday Research Methods" blog. The link for this blog is **http://www.everydayresearchmethods.com.** Students work in teams to think critically about the statistic and generate a list of questions they want answered so they can better interpret its meaning. The activity can conclude with a large class discussion or submission of the work.

- Time: 20 minutes
- Materials: Pen and paper for students, optional use of computers or smart phones.
- Directions:

1. Have students locate a statistical outcome on the Internet. The outcome can be about any subject; however, psychology-related topics are recommended. They can search specifically for statistics or, alternatively, for the answer to a question. For example, Do women get paid less than men for the same work? After they have found their statistic they should write it down at the top of their paper.
2. Have students get into teams of three or four. Each student shares his or her statistic. The group then decides which statistic the team will work on for the remainder of the activity. Each group requires a new sheet of paper.
3. On the team's sheet of paper, students should write all of the questions they have regarding the generation of their chosen statistic. Students should come up with relevant questions concerning, for example, the type of sampling technique used, characteristics of the participants, or other variables that ought to have been measured or controlled for, etc.
4. After each team has had ample time to generate questions, facilitate a class-wide discussion for students to share their ideas with the larger group. Address one or two examples together.

Additional Activities

Smith, R.A. (1999). A tasty sample(r): Teaching about sampling using M&Ms®. In L. Benjamin, B. Nodine, R. Ernst, & C. Broecker (Eds.), *Activities handbook for the teaching of psychology*, Vol. 4 (pp. 66-68). Washington, DC: American Psychological Association.

- This activity can be completed during class. For this activity, pass out small packs of candy to students. Through questions and demonstrations, relate the candy to research participants, samples, populations, and the processes of random selection or assignment. The activity can be used with classes of any size, if the workspace permits. For step-by-step instructions and slides please see: **http://www.teachpsychscience.org/resource.asp?id=8...** (Ciarocco, 2010).

Christopher, A. N., & Marek, P. (2002). A sweet tasting demonstration of random occurrences. *Teaching of Psychology, 29*, 122-125. doi:10.1207/S15328023TOP2902_09

- This activity uses LifeSavers® candy to introduce students to the phenomenon of random occurrences. Students guess the flavor of the candy and in doing so learn about probability, *p*-values, and random occurrences.

Selden, P. M. (2001). Increasing graphing literacy and graphing ability in undergraduate psychology majors through active learning based exercises. Retrieved from **http://teachpsych.org/Resources/Documents/otrp/res...**

- Wadded Up "Paperball" Toss Activity: In this activity students will toss a paper-ball onto a target and will measure their accuracy. They will then graph the distances between each ball and the target practicing their graphic skills while developing their distributional thinking.

Holms, K. Y., & Jemes, A. (2008). Teaching statistics and research methods: A collection of hands-on activities and demonstrations. Retrieved from **http://teachpsych.org/resources/-Documents/otrp/res...**

- Are you ready for some football? In this activity, students answer questions about statistics in the National Football League. Newer statistics can replace the older ones presented in the activity. Alternatively, the activity can be adapted to better suit the local sporting context.

Angelo, T. A., & Cross, P. K. (1993). *Classroom assessment techniques: A handbook for college* *teachers.* San Francisco, CA: Jossey-Bass.

- Muddiest Point, (p.154-158). This is a common CAT that is especially great for statistics because it allows you to see what content students are still grappling with after instruction. This can help students feel less anxiety toward statistics because they have a chance to voice misunderstandings. In the CAT, students jot down the answer to this question: "What is the muddiest point in _____?" It can be used at the end of the class period and turned in or discussed in a small or large class setting.

Discussion Points

1. Develop an example of a distribution of one variable that you often encounter in your life. What is the variable and how does it vary?
    - This discussion might lead into a conversation about the many, statistics and polls that students are faced with every day in the popular press. This is a primer to prepare students for the activity at the end of the module.
2. Tables and graphs are often presented in the media. What should you look for when examining this data to interpret it correctly? How are people able to manipulate visual depictions of statistics to skew conclusions?
    - This will lead to a similar discussion as point number one but is intended to be more specific. The instructor can use some of the ToPIX news stories (linked below) to provide additional examples, or can talk about a current political race or law about which the media often misrepresents data. Another great resource that can be reviewed with students during this discussion is an online article from National Geographic that helps people spot graphs that lie (Esteban, 2015). The link for the article is: **http://news.nationalgeographic.com/2015/06/150619-...**
3. The study with infants described in the module had alternative explanations. The researchers accounted for those by controlling certain variables. Are there any other variables that should have been controlled for in this study that the researchers missed?
    - This will encourage students to think critically about research methodology. They could range in answers, and all should be discussed openly. We recommend the instructors not only talk about variables that were missed but also how those variables could be controlled for.
4. How similar does a sample need to be to its population to generalize findings? If you were

to sample a single third grade class in a school, could you draw conclusions about the entire grade, school, district, or state?

- Students are usually less-willing to generalize than instructors are. Talk about how challenging it is to get truly random samples and how psychology research often generalizes when there is not an exact match between the sample and the population.

Extra resources you might like to know about:

TeachPsychScience (2015, June). *A resource for teaching research and statistics in psychology*. Retrieved from http://www.teachpsychscience.org

Association for Psychological Sciences (2015, June). *Teaching resources.* Retrieved from http://psych.hanover.edu/APS/teaching.html#statistics

Addison, B., Bliwise, N., Green, B., Heinzen, T. E., Nolan, S., Posey, D., Wendorf, C., Wilson-Doenges, G., Bramsfeld, K., Freeman, J., Grosofsky, A., Moore, B., Scott-Johnson, P., & Wyner, E. (2014). *Statistical literacy in psychology: Resources, activities, and assessment methods.* Society for the Teaching of Psychology. Retrieved fromhttp://teachpsych.org/Resources/Documents-/otrp/resources/statistics/STP_Statistical Literacy Resources_4-2014.pdf

Outside Resources

Apps: Interactive web applets for teaching and learning statistics include the collection at
http://www.rossmanchance.com/applets/

P-Value extravaganza
https://www.youtube.com/watch?v=bVMVGHkt2cg&feature=youtube_gdata_player

Web: Inter-university Consortium for Political and Social Research
http://www.icpsr.umich.edu/index.html

Web: The Consortium for the Advancement of Undergraduate Statistics
https://www.causeweb.org/

Evidence-Based Teaching

Jackson, S. L., & Griggs, R. A. (2012). Teaching statistics and research methods: Tips from ToP. The Society of Teaching of Psychology.

- This eBook compiles many Teaching of Psychology articles that describe methods for teaching statistical thinking. Many of the articles have evidence from scholarship of teaching and learning studies to support their effectiveness.
- Link: http://teachpsych.org/ebooks/stats2012/index.php

Gorvine, B. J. (2015). Predicting student success in a psychological statistics course emphasizing collaborative learning. *Teaching of Psychology, 42*, 56-59. doi:10.1177/0098628314562679

- This article describes the use of a collaborative learning approach to teaching psychology statistics. The authors found that students have a strong preference for group work and performed better on learning outcomes when working in groups. Collaborative approaches in teaching are suggested.

Thompson, W. B., & Fisher-Thompson, D. (2013). Analyzing data from studies depicted on video: An activity for statistics and research courses. *Teaching of Psychology, 40*, 139-142. doi:10.1177/0098628312475035

- This article describes an activity using video combined with analysis and interpretation of realistic data. Learning outcomes were measured and the findings suggested the activity helped students learn to use and interpret statistical procedures.

Links to ToPIX Materials

Activities, Demonstrations, and Handouts: Statistics
http://topix.teachpsych.org/w/page/26676025/Statistics%20in%20the%20Classroom

In the News: Statistics
http://topix.teachpsych.org/w/page/49255463/Statistics%20in%20the%20News

Videos/Audio: Statistics
http://topix.teachpsych.org/w/page/19981042/Statistics%20Video

Teaching Topics

Teaching The Most Important Course
https://nobaproject.com/documents/1_Teaching_The_Most_Important_Course.pdf

Content Coverage
https://nobaproject.com/documents/2_Content_Coverage.pdf

Motivating Students
https://nobaproject.com/documents/3_Motivating_Students_Tips.pdf

Engaging Large Classes
https://nobaproject.com/documents/4_Engaging_Large_Classes.pdf

Assessment Learning
https://nobaproject.com/documents/5_Assessment_Learning.pdf

Teaching Biological Psychology
https://nobaproject.com/documents/6_Teaching_Bio_Psych.pdf

PowerPoint Presentation

This module has an associated PowerPoint presentation. Download it at https://nobaproject.com//images/shared/supplement_editions/000/000/311/Statistical%20Thinking.ppt?1572890374.

About Noba

The Diener Education Fund (DEF) is a non-profit organization founded with the mission of re-inventing higher education to serve the changing needs of students and professors. The initial focus of the DEF is on making information, especially of the type found in textbooks, widely available to people of all backgrounds. This mission is embodied in the Noba project.

Noba is an open and free online platform that provides high-quality, flexibly structured textbooks and educational materials. The goals of Noba are three-fold:

- To reduce financial burden on students by providing access to free educational content
- To provide instructors with a platform to customize educational content to better suit their curriculum
- To present material written by a collection of experts and authorities in the field

The Diener Education Fund is co-founded by Drs. Ed and Carol Diener. Ed is the Joseph Smiley Distinguished Professor of Psychology (Emeritus) at the University of Illinois. Carol Diener is the former director of the Mental Health Worker and the Juvenile Justice Programs at the University of Illinois. Both Ed and Carol are award- winning university teachers.

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