INTRODUCTION TO STATISTICAL INVESTIGATIONS – Tintle et al.

ANNOTATED TABLE OF CONTENTS (Winter 2014)

Preliminaries: Introduction to Statistical Investigations

Main goals:
- Understand the six steps of statistical investigations
- Understand that data has variability and that distributions are used to summarize variables and that data can be used to make more informed decisions
- Understand probability as a long-run proportion and simulation as a way to estimate probabilities
  - Example P.1: Recruiting Organ Donors
  - Key terms: Anecdotal Evidence, Data, 6 Steps of Statistical Investigations, Observational units, Variables, Quantitative/Categorical
  - Example P.2: Predicting Old Faithful Eruptions
  - Key terms: Dotplot, Distribution, Shape, Center, Variability, Mean, Standard Deviation (SD), Explainable sources of variability
  - Exploration P.3: Monty Hall Problem
  - Key terms: Random process, Simulation, Probability

UNIT 1: FOUR PILLARS OF INFERENCE: STRENGTH, SIZE, BREADTH, AND CAUSE

Chapter 1: Significance: How Strong is the Evidence?

Main goals:
- Utilize 3S strategy for the logic of statistical significance
- Analyze results of studies involving random outcomes using simulation: tactile and applet
- Understand p-values and standardized statistics to measure strength of evidence
- Understand factors that affect strength of evidence (sample size, alternative hypothesis, effect size)
- Conduct tests of significance for a single proportion using simulation and theory-based approaches

Section 1.1: Introduction to Chance Models
  - Example 1.1: Can Dolphins Communicate?
  - Exploration 1.1: Can Dogs Understand Human Cues?
  - Key terms: Bar graph, Model, Chance model, Statistic, 3S Strategy, Plausible, Statistical significance, Sample
  - Applet: One Proportion

Section 1.2: Measuring the Strength of Evidence
  - Example 1.2: Rock Paper Scissors
  - Exploration 1.2: Tasting Water
  - Key terms: Binary variable, p-hat (\( \hat{p} \)), Parameter, \( \pi \), Sample size (\( n \)), Null hypothesis (\( H_0 \)), Alternative hypothesis (\( H_a \)), Null distribution, p-value
  - Applet: One Proportion

Section 1.3: Alternative Measure of Strength of Evidence
Chapter 2: Generalization: How Broadly Do the Results Apply?

Main goals:
- Recognize biased sampling methods
- Appreciate properties of simple random samples (unbiasedness, sampling variability)
- Apply tests of significance to random samples from populations (proportion)
- Conduct tests of significance for a single quantitative variable
- Understand type I and type II errors

Section 2.1: Sampling from a Finite Population
- Example 3.1: Sampling Students
- Exploration 3.1: Sampling Words
- Example 3.1B: Soda or smoking in cars
- Exploration 3.1B: American Exceptionalism
- Key terms: Population, Process, Census, Sampling without replacement, Representative, Biased, Simple random sample, Sampling frame, Sampling variability, Unbiased, Convenience sample, Generalize, Data table (spreadsheet), Histogram
- Applet: Sampling Words; One Proportion

Section 2.2: Inference for a Single Quantitative Variable
- Example 3.2: Estimating Elapsed Time
- Exploration 3.2: Sleepless Nights?
- Key terms: Median, Skewness, Resistance, $t$-distribution, $t$-test, $t$-interval
- Applet: One Mean; Theory-Based Inference

Section 2.3: Errors and Significance
- Example 2.3: Heart Transplant Operations (continued)
- Exploration 2.3: Parapsychology Studies
- Key terms: Type I error; Type II error

Chapter 3: Estimation: How Large is the Effect?
Main goals:
- Understand a confidence interval as an interval of plausible values for the parameter
- Approximate a 95% confidence interval using 2SD Method and a theory-based z-interval
- Understand factors that affect confidence intervals (confidence level, sample size, statistic)
- Understand type I and type II errors

Section 3.1: Statistical Inference – Confidence Intervals
- Example 3.1: Can Dogs Sniff Out Cancer?
- Exploration 3.1: Kissing Right?
- Key terms: Confidence interval, Significance level, Plausible value, Interval of plausible values, Confidence level, Standard error
- Applet: One Proportion

Section 3.2: 2SD and Theory-Based Methods for a single proportion
- Example 3.2: Halloween Treats (continued)
- Exploration 3.2: Predicting Elections from Faces (continued)
- Key terms: 2SD method, Margin-of-error
- Applet: One Proportion; Theory-Based Inference

Section 3.3: 2SD and Theory-Based Methods for a single mean
- Example 3.3: Estimating elapsed time (continued)
- Exploration 3.3: Sleepness nights (continued)
- Key terms: 2SD method, Margin-of-error
- Applet: One Mean; Theory-Based Inference

Section 3.4: Factors that affect the width of a confidence interval
- Example 3.4: Heart Transplant Operations (continued)
- Exploration 3.4: Competitive Advantage to Uniform Colors? (continued)
- Exploration 3.4B: Estimating elapsed time (continued)
- Exploration 3.4C: Reese’s Pieces
- Applet: One Proportion
- Applet: Simulating confidence intervals

Section 3.5: Cautions when conducting inference
- Example 3.5A: The Controversial “Bradley Effect”
- Exploration 3.5A: Voting for President
- Example 3.5B: Parapsychology studies (continued)
- Exploration 3.5B: Cat Households
- Key terms: Random digit dialing, Response rate, Non-sampling errors

Chapter 4: Causation: Can We Say What Caused the Effect?

Main goals:
- Explore the concept of association between variables
- Understand that confounding precludes drawing cause-and-effect conclusions from observational studies
- Recognize the design and purpose of randomized experiments
- Appreciate the benefits of matched pairs designs

Section 4.1: Association between Variables
- Example 4.1: Night Lights and Near-Sightedness
Exploration 4.1: Home Court Disadvantage?
- Key terms: Explanatory variable, Response variable, Confounding variable, Association

Section 4.2: Observational Studies versus Experiments
- Example 4.2: Lying on the Internet
- Exploration 4.2: Have a Nice Trip
- Key terms: Observational study, Randomized experiment, Experimental units; Cause-and-effect
- Applet: Randomization of Subjects

Section 4.3: Paired Designs
- Example 4.3: Can You Study With Music Blaring?
- Exploration 4.3: Rounding First Base
- Key term: Paired design, independent groups design

UNIT 2: COMPARING TWO GROUPS

Chapter 5: Comparing Two Proportions

Main goals:
- Perform descriptive analyses of 2×2 tables
- Understand the reasoning process of a randomization test
- Implement a randomization test for comparing proportions in a 2×2 table
- Interpret results for simulation-based and theory-based approaches to compare two proportions
- Produce and interpret confidence intervals for comparing two proportions

Section 5.1: Comparing Two Groups: Categorical Response
- Example 5.1: Good and Bad Perceptions
- Exploration 5.1: Murderous Nurse?
- Key terms: Two-way table, Segmented bar graphs, 2×2 table, Conditional proportion, Relative risk

Section 5.2: Comparing Two Proportions: Simulation-Based Approach
- Example 5.2: Swimming with Dolphins
- Exploration 5.2: Is Yawning Contagious?
- Key terms: Randomization test, Shuffling
- Applet: Dolphins, Yawning, Two proportions applet

Section 5.3: Comparing Two Proportions: Theory-Based Approach
- Example 5.3: Smoking and Birth Gender
- Exploration 5.3: Donating Blood
- Key terms: Two-proportion z-test, z-interval, Standard error
- Applet: Theory-Based Inference applet, Multiple proportions applet

Chapter 6: Comparing Two Means

Main goals:
- Apply descriptive methods for comparing groups with a quantitative response
• Extend randomization test idea to comparing two groups with quantitative response
• Apply, interpret results of theory-based approach (two-sample t-test and t-interval)

Section 6.1: Exploring Quantitative Data
  o Example 6.1: Geyser Eruptions
  o Exploration 6.1A: Haircut Prices
  o Exploration 6.1B: Cancer Pamphlets
  o Key terms: Quartiles, Inter-quartile range, Five number summary, Parallel dotplots
  o Applet: Dotplot Summaries

Section 6.2: Comparing Two Means: Simulation-Based Approach
  o Example 6.2: Bicycling to Work
  o Exploration 6.2: Lingering Effects of Sleep Deprivation
  o Key terms: Double-blind
  o Applet: Two Means

Section 6.3: Comparing Two Means: Theory-Based Approach
  o Example 6.3: Breastfeeding and Intelligence
  o Exploration 6.3: Close Friends
  o Key term: Two-sample t-test, t-interval
  o Applet: Multiple Means

Chapter 7: Paired Data: One Quantitative Variable

Main goals:
• Distinguish between two independent groups and matched pairs
• Extend randomization test idea to compare quantitative response for matched pairs
• Apply, interpret results of theory-based approach (paired t-test and t-confidence interval for mean difference)

Section 7.1: Simulation-Based Approach for Analyzing Paired Data
  o Example 7.1: Rounding First Base
  o Exploration 7.1: Exercise and Heart Rate
  o Key terms: Independent samples, Paired samples, Matched-Pairs design
  o Applet: Matched-Pairs Randomization

Section 7.2: Theory-Based Approach to Analyzing Data from Paired Samples
  o Example 7.2: How Many M&Ms Would You Like?
  o Exploration 7.2: Comparing Auction Formats
  o Key terms: paired t-test, t-interval
  o Applet: Theory-Based Inference

UNIT 3: ANALYZING MORE GENERAL SITUATIONS

Chapter 8: Comparing More Than Two Groups Using Proportions

Main goals:
• Develop statistics for comparing proportions across multiple groups
• Utilize simulated-based approach to compare several proportions
• Apply and interpret results of theory-based approach (chi-square test)
• Consider follow-up multiple comparison analyses

Section 8.1: Simulation-Based Approach to Compare Multi-Category Categorical Variables
  o Example 8.1: Coming to a Stop
  o Exploration 8.1: Recruiting Organ Donors
  o Key terms: Mean absolute difference (MAD)
  o Applet: Multiple proportions

Section 8.2: Theory-Based Approach to Compare Multi-Category Categorical Variables
  o Example 8.2: Sham Acupuncture
  o Exploration 8.2: Conserving Hotel Towels
  o Key terms: Chi-square statistic, Chi-square distribution, Cell contribution
  o Applet: Multiple proportions

Chapter 9: Comparing More Than Two Means
Main goals:
• Develop statistics for comparing means across multiple groups
• Utilize simulated-based approach to compare several means
• Understand roles of within-group and between-group variability in assessing significance
• Apply and interpret results of theory-based approach (ANOVA F test)
• Consider follow-up multiple comparison analyses

Section 9.1: Simulation-Based For Comparing More Than Two Groups with a Quantitative Response
  o Example 9.1: Comprehending Ambiguous Prose
  o Exploration 9.1: Exercise and Brain Volume
  o Key terms: Boxplot, Mean absolute difference (MAD)
  o Applet: Multiple means

Section 9.2: Theory-Based Approach to Comparing More Than Two Groups with a Quantitative Response
  o Example 9.2: Recalling Ambiguous Prose
  o Exploration 9.2: Comparing Popular Diets
  o Key terms: F statistic, F-distribution, ANOVA test, Mean squared error
  o Applet: Multiple means

Chapter 10: Two Quantitative Variables
Main goals:
• Explore association between quantitative variables through scatterplots and correlation coefficient
• Utilize randomization test to assess statistical significance of correlation coefficient
• Interpret least squares regression model
• Utilize randomization test to assess statistical significance of regression slope
• Apply theory-based approach (t-procedures) for testing association of two quantitative variables
• Understand impact of influential observations and study design on scope of conclusion
Section 10.1: Summarizing the relationship between two quantitative variables using the correlation coefficient
  o Example 10.1: Exam Times and Exam Scores
  o Exploration 10.1: Are Dinner Plates Getting Larger?
  o Key terms: Predictor, Scatterplot, Direction, Form, Strength, Unusual observations, Influential observations, Correlation coefficient (r)
  o Applet: Corr/Regression

Section 10.2: Inference for correlation coefficient
  o Example 10.2: Exercise Intensity and Mood Changes
  o Exploration 10.2: Draft Lottery
  o Key terms: 
  o Applet: Corr/Regression

Section 10.3: Least Squares Regression
  o Example 10.3: Are Dinner Plates Getting Larger?
  o Exploration 10.3: Predicting Height from Footprints
  o Key terms: Residuals, Least squares regression, Least squares regression line, y-intercept (a), Slope (b, ), SSE, Outlier, Coefficient of determination \( R^2 \)
  o Applet: Corr/Regression

Section 10.4: Inference for Regression: Simulation-Based Approach
  o Example 10.4: Do Students Who Spend More Time in Non-academic Activities Tend to Have Lower GPAs?
  o Exploration 10.4: Perceptions of Heaviness
  o Applet: Corr/Regression

Section 10.5: Inference for Regression Slope: Theory-based Approach
  o Example 10.5A: Predicting Heart Rate from Body Temperature
  o Example 10.5B: Smoking and Drinking
  o Exploration 10.5: Predicting Brain Density from Number of Facebook Friends
  o Applet: Corr/Regression

APPENDIX: Calculation Details