MATTHEW CRUMP

EXPERIMENTAL PSYCHOLOGY LAB MANUAL FALL 2017

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CHILDREN ARE BORN TRUE SCIENTISTS. THEY SPONTANEOUSLY EXPERIMENT AND EXPERIENCE AND RE-EXPERIENCE AGAIN. THEY SELECT, COMBINE, AND TEST, SEEKING TO FIND ORDER IN THEIR EXPERIENCES - "WHICH IS THE MOSTEST? WHICH IS THE LEASTEST?" THEY SMELL, TASTE, BITE, AND TOUCH-TEST FOR HARDNESS, SOFTNESS, SPRINGINESS, ROUGHNESS, SMOOTHNESS, COLDNESS, WARMNESS: THEY HEFT, SHAKE, PUNCH, SQUEEZE, PUSH, CRUSH, RUB, AND TRY TO PULL THINGS APART.

- BUCKMINSTER FULLER

Contents

1 Overview 9

General Overview 9

Lab structure: Major and mini projects, and presentations 9

Major projects 9

Mini projects 10

Presentations 10

Grading 10

Lab Resources 10

Website 11

Lab rooms 11

Lab manual 11

Lab Schedule 11

Lab 1: Overview 11

Lab 2: Paper project 1 11

Lab 3: Paper project 1 continued 12

Lab 4: MiniProject 1 Nairne, Pandeirada, & Thompson (2008) 12

Lab 5: Mini Project 2 Stoet et al. (2013) 13

Lab 6: Mini Project 4 Raz et al. (2006) 13

Lab 7 : Paper Project 2 Yin (1969) 13

Lab 8: Paper project 2 continued 14

Lab 9: Brainstorming for Final project 14

Lab 10: Individual Presentations 14

Lab 11-13: Group work on Final Project 14

Lab 14: Final group presentations 14

2 The QALMRI Method 15

The QALMRI Method 16

Q stands for Question 16

A stands for Alternatives 17

L stands for Logic 17

M stands for Method 18

R stands for Results 18

I stands for Inferences 18

Writing a QALMRI 19

Example QALMRI 19

What was the broad and specific question? 20

What are the alternatives? 20

What is the logic? 20

What is the Method? 20

Results 20

Inference 21

Finding the QALMRI sections in a journal article 21

Finding the Big Question 22

Finding the Specific question 22

Alternatives 22

Logic 23

Methods 23

Results 23

Inference 23

Reading between the lines 23

The Hardest Section of the QALRMI: Alternatives 24

Empirical vs. Theoretical Hypotheses 25

Labs 2 and 3: Paper Project 1 29

Overview 29

Things you will learn: 29

Background readings: 29

Grade 29

Writing the paper 30
APA formatting, Title and Abstract 30
Introduction (around 2 double-spaced pages) 30
Methods (about 1 page) 31
Results 31
Discussion 32
References and Figures or Tables 32
Data-analysis tips 32
The t-test 33
One more time 34
Writing up the results of a t-test 35

Lab 4: Memory Mini Project 37
Lab 4: MiniProject 1 Nairne, Pandeirada, & Thompson, (2008) 37
What's in store 37
Data-analysis tips 38
Simulating the data 39
Looking at the means 41
Plotting the data 41
Conducting the ANOVA 42
Comparisons between conditions 43
Writing it all up 44

Lab 5: Task-Switching Mini Project 47
What's in store 47
Critical Concepts 48
Multiple Dependent and Independent Variables 48
Main effects and interactions 48
Manipulating an Effect 48
Reducing a two-factor design to a single-factor design using difference scores 49

Data-analysis tips 50
Simulating the data 50
plotting the data 52
Running the ANOVA 53
Writing up the results 55

Lab 6: Stroop Mini Project 57
What's in store 57
Some background on the Stroop effect 57
Stroop and Selective Attention 59

Labs 7 and 8: Paper Project 2 61
Overview 61
Things you will learn: 61
Background readings: 61
Grade 61
Writing the paper 62
APA formatting, Title and Abstract 62
Introduction (around 2 double-spaced pages) 62
Methods (about 1 page) 63
Results 63
Discussion 64
References and Figures or Tables 64

Labs 9 - 14: The Final Project 65
Overview 65
2-3 minute individual presentation (5% of total grade) 65
APA style research report (15% of total grade) 66
10 minute group presentation (5% of total grade) 66

Statistical Analysis And Reporting 67

Excel Tips 67

What is Excel? 67

What is Excel used for in this course? 67

Using Excel 68

The excel window 68

Inputting data 68

Addressing cells 68

Setting one cell to equal another 69

Adding cells together, and copying commands across other cells 69

Using a formula to add two numbers together 70

Getting an average 70

Other formulas 71

Selecting a range of cells 71

Copying a formula to another cell: relative coordinates 71

Absolute coordinates 72

Sorting data 72

Making a histogram 73

Making a table 74

Paired Samples T-test 74

SPSS 76

Paired Samples T-test in SPSS 76

2 x 2 Repeated Measures ANOVA 77

From Data to Analysis 77

2x2 Repeated measures ANOVA in SPSS 79

Finding numbers in the SPSS analysis output 81

The ANOVA table 82

Main effect for IV 1 82

Main effect for IV 2 83

The interaction effect 83

Post Hoc Tests to interpret the interaction 83

Writing An APA Style Paper 85

How to write a research report 85

Introduction 85

Methods 85

Results 86

Discussion of results 86

Conclusions and recommendations 86

APA style 87

APA style formatting 87

Sample APA report 94

Bibliography 103

1 Overview

TODAY WAS GOOD. TODAY WAS FUN. TOMORROW IS ANOTHER ONE.

—DR. SEUSS

General Overview

The weekly labs are structured to give students experience with conducting experiments, analyzing data, thinking critically about theory and data, and communicating their results and analysis in writing and oral presentation.

Lab instructors facilitate this process by guiding students through the demands of each of the labs. Lab instructors are there to help you, so ask them questions when you need answers!

Lab structure: Major and mini projects, and presentations

The entire semester is divided into three major projects, and 3 mini projects. They are ordered consecutively to build upon skills. For example, the first projects focus on data analysis skills involving t-tests, then one-way ANOVAs, and finally 2x2 Factorial designs. Throughout each of the labs you will learn how to create experiments and conducts analyses on the data. Then you will employ these skills in the last half of the semester when you form groups and conduct, analyze, report and present an experiment of your own design.

Major projects

Each major project involves students completing an experiment as a class (using themselves as subjects to collect data). Students will learn about the conceptual issues behind the experiment, collect data on themselves, and analyze the class data using appropriate statistics. Each student will then be responsible for writing a short (5+ page) APA style report about the project.

The first two major projects involve predefined experiments that the class completes. These two projects are roughly finished mid-semester, and are intended to train students in the skills needed to complete the final project. The last major project is the final project, where students form groups and complete an experiment based on their own design.

Each lab instructor is responsible for grading each of their students papers. Individual lab instuctors will explain to their sections how their grading scheme will work.

Mini projects

In the first half of the semester, each of the weeks that does not introduce a new major project are reserved for mini-projects. These projects are intended to be completed within one lab session. Each of the mini-projects involve 1) reading and understanding a primary source, and 2) attempting to replicate the result in the paper. These are graded on a pass/fail basis, where a pass is given to students who show up and participate in the lab (regardless of whether their experiment turns out.)

Presentations

The final project involves two presentations. An individual presentation, and a group presentation. Prior to forming groups for the final project, each student will give a short (2-3) minute pitch for their project idea. Then, students will form groups (choose one of the members project ideas, or generate a new one) and begin working on their final project. The last lab is reserved for the group presentations where each group gives a 10 minute research presentation.

Grading

Each lab instructor will grade the work of the students in their sections. See the course syllabus for information on how each of the lab components weigh into the final grade for the course.

Lab Resources

There are many resources to help you complete the lab assignments. These are included in this lab manual, as well as online.

Website

As much as possible all of the information for this course will be posted on the course website:
`http://crumplab.github.io/courses/experimental/`

Lab rooms

There should be one computer per student in each of the lab rooms. These computers should have SPSS, Excel, Office, R, Superlab, LIVECODE, and Psychopy installed on them.

Lab manual

This lab manual contains instructions for each the lab assignments, as well as helpful tutorials for learning skills to analyze and report data.

Lab Schedule

Lab 1: Overview

1. Meet and greet your instructor and fellow classmates, and learn about what is in store for the labs this semester

   a. You will write three APA style research reports. Papers 1 and 2 will be on predefined projects, and Paper 3 will be based on a final project where students form groups to complete an experiment of their own design

   b. The final project will involve two presentations, an individual presentation and a group presentation.

   c. The first half of the semester involves completing Papers 1 and 2, and a few mini-projects that occur between papers 1 and 2. These will build the skills necessary to complete the final project which will take up most of the second half of the semester

2. Students are expected to show up and be on time for labs

3. Ask questions

4. Go over QALMRI method using provided QALMRI materials

5. Discuss/Review the components of writing an APA paper

Lab 2: Paper project 1

Students replicate the results of Song and Schwarz (2008)[1].

[1] Song, H. and Schwarz, N. (2008). If it's hard to read, it's hard to do: Processing fluency affects effort prediction and motivation. *Psychological Science*, 19(10):986–988

1. Administer the experiment using the provided materials

   a. Students will receive a piece of paper with instructions. They will read the description of an exercise routine, and then answer the questions about what they read.

2. Reading and understanding the primary source

   a. Students will be given the Song & Schwarz (2008) paper, and the to-be-filled in QALMRI worksheet. They will be given 15-20 minutes to read the paper, and in small groups attempt to fill out the QALMRI worksheet for the paper

   b. Group discussion of the paper and the QALMRI

3. Collect and analyze the data

4. Discuss the paper assignment

Lab 3: Paper project 1 continued

1. More time to work on the first paper. Use your lab instructor as a resource and ask questions if you need more info.

   E.g., Review APA style, review the structure and content of the paper, review the results, edit each others work, etc.

2. Due dates are set by the lab instructor

Lab 4: MiniProject 1 Nairne, Pandeirada, & Thompson (2008)

Students replicate the results of Nairne et al. (2008)[2].

[2] Nairne, J. S., Pandeirada, J. N., and Thompson, S. R. (2008). Adaptive memory: The comparative value of survival processing. *Psychological Science*, 19(2):176–180

1. Students read paper and write QALMRI (15-20)

2. Group discussion about paper (15-20)

3. Students attempt to replicate the major findings in the paper

   a. Break into four-five groups, each group assigned an encoding condition (Survival, Pleasantness, Imagery, Self-reference, Intentional learning)

   b. Each group picks their own 30 words. Can follow same procedure as in paper by choosing 30 words from Overschelde, Rawson, & Dunlosky (2004) [3].

   c. Groups try to run at least 10 participants in their condition, recording proportion of correctly recalled words

   d. Groups enter their collected data into the master spreadsheet, which is given back to groups upon data completion

4. Discussion of how to analyze the data

[3] Van Overschelde, J. P., Rawson, K. A., and Dunlosky, J. (2004). Category norms: An updated and expanded version of the norms. *Journal of Memory and Language*, 50(3):289–335

5. Group attempt to analyze the data using t-tests and one-way ANOVA to determine if the survival framing produced better recall than the other conditions.

Lab 5: Mini Project 2 Stoet et al. (2013)

Students replicate the results of Stoet et al. (2008) [4].

[4] Stoet, G., O'Connor, D. B., Conner, M., and Laws, K. R. (2013). Are women better than men at multi-tasking? *BMC Psychology*, 1(1):18

1. Students read paper and write QALMRI (15-20)
2. Group discussion about paper (15-20)
3. Students download the task-switching program available from the website and individually complete the task. Individual students then enter their data in the master spreadsheet
4. Discussion of how to analyze the data. Major analysis goals are:
   a. Was there a mixing cost? Compare pure lists to mixed lists
   b. Was there a switching cost? Compare switch vs. repeat trials in pure lists
   c. Was there a gender effect?
5. Students break into groups to analyze the data.

Lab 6: Mini Project 4 Raz et al. (2006)

Students replicate the results of Raz et al. (2006) [5]

[5] Raz, A., Kirsch, I., Pollard, J., and Nitkin-Kaner, Y. (2006). Suggestion reduces the Stroop effect. *Psychological Science*, 17(2):91–95

1. Students read paper and write QALMRI (15-20)
2. Group discussion about paper (15-20)
3. Students instructed their task is create their own Stroop design and employ a manipulation that increases or decreases the size of the Stroop effect
4. Students break into groups and conduct a Stroop experiment, measuring the size of the Stroop effect in a "normal" condition, and in their manipulated condition.
5. Groups analyze conduct a 2x2 ANOVA to see if their interaction was significant

Lab 7 : Paper Project 2 Yin (1969)

Students replicate the results of Yin (1969) [6]

[6] Yin, R. K. (1969). Looking at upside-down faces. *Journal of experimental psychology*, 81(1):141

1. Students read paper and write QALMRI (15-20)
2. Group discussion about paper (15-20)

3. Students complete computerized task and report their data in the master spreadsheet. Data is given back to students for analysis
4. Discussion about writing the 2nd paper

Lab 8: Paper project 2 continued

1. Extra-time for completing second paper, again use your lab instructor as a resource, they are there to help.

Lab 9: Brainstorming for Final project

1. Learn about details of the final project
2. Learn about details of the individual presentation (next lab)
3. Brainstorming session allowing students to think about possible projects that they would propose for their individual project

Lab 10: Individual Presentations

1. Students give their individual (2-3 minute) presentations
2. Students are divided into groups for their final project
3. Each group decides on the experiment for their final project. This could be from one of the individual project ideas, or a new idea. Groups need permission from the lab instructor for their final project before data collection begins

Lab 11-13: Group work on Final Project

1. Help groups finalize their final project aims
2. Groups collect data
3. Discuss requirements for final presentation and paper

Lab 14: Final group presentations

2 *The QALMRI Method*

QUESTION ALTERNATIVES LOGIC METHOD RESULTS INFERENCE

—THE QALMRI METHOD

The general goal of this course is to give you experience with the scientific process of asking and answering psychological questions. At the end of the course you should gain at least two kinds of skills. First, in the labs you will learn to ask and answer your own questions by conducting, analyzing, and reporting the results of experiments that you conduct. Second, you learn how understand the research literature, where other researchers have asked and answered questions, and communicated them publicly by publishing journal articles on their research.

There are a lot of details involved in asking and answering questions in science, and you can easily see these details on display by reading any published peer-review journal article. You will become very familiar these details as you read more papers, and as you write your own APA style research reports.

The details can be daunting, mainly because the format and structure of articles may be unfamiliar, and the language that scientists use is often very specific (or jargony). As a result, if you are not already an expert in a particular domain, it can be very difficult to read and understand research presented in journal articles. Furthermore, if you do not understand the concepts behind the questions, and the details behind the methods and results, then it is difficult to write your own research reports about experiments that you conduct. Have no fear, this lab manual is here to guide you through the process.

Ultimately, by learning the skills we teach you throughout this semester, you will be able to critically evaluate your own research, as well as the research literature at large. This will allow you form your own opinions about the process of asking and answering questions. For example, when you learn how to critically evaluate research you will be able to:

1. Evaluate whether or not you should believe particular scientific claims, or claims made by the media about new "research findings"
2. Look at the evidence to see whether it actually provides an answer to the question that was being asked
3. Look at the questions to see if they are good ones, and learn how to ask better questions
4. Understand how theories and hypotheses work and make predictions about psychological phenomena
5. Learn how to find scientific research that has been conducted on topics of your own interest, and then evaluate the claims and evidence for yourself. For example, the skills you learn here about evaluating psychological research are the same skills that you would need to evaluate medical research. So, if you are wondering whether a particular medical procedure, or drug, or diet works or doesn't work, then you can read the research for yourself to arrive at your own informed opinion.

The QALMRI Method

The first step is learning how to read journal articles. We will use the QALMRI method throughout this course as a tool to help you identify the major ideas and findings presented in journal articles. The major aspects of the QALMRI method will also help you identify whether your own research reports contain the information necessary to communicate your own research. First, we will explain the QALMRI method, then we will explain how you will be asked to use it throughout the course.

Adapted nearly verbatim from: Kosslyn, S.M. & Rosenberg, R.S. (2001). Psychology: The Brain, The Person, The World. Boston: Allyn & Bacon.

The QALMRI method provides a means for critically evaluating experiments, as well as for organizing your own experiment proposals. It helps you to find connections between theory and data by making explicit the question being asked, the approach used to answer it, and the implications of the answer. QALMRI is an acronym, and each letter identifies critical parts of research articles.

Q stands for Question

All research begins with a question, and the point of the research is to answer it. For example, we can ask whether a placebo is better than no action in alleviating depression. For most journal articles, the General Introduction should tell the reader what question the article is addressing, and why it is important enough that anyone should care about the answer. Questions fall into two categories:

broad and specific. In your QALMRI, state both the broad and the specific questions being asked. Broad questions are typically too general to answer in a single experiment, although one should view the experiment as one step on a journey to answer the broad question. An example of a broad question might be "Does language influence perception?" This sort of question provides the general topic of the paper, and can only be answered through compiling many experimental results. In contrast, the specific question can typically be addressed in a single experiment or set of experiments. A specific question might be "If one language has a specific term for one color, and another language does not have any term for that color, will speakers of the two languages perceive the color differently?"

Again, be sure to identify the broad and specific question relevant to your data collection.

A stands for Alternatives

Good experiments consider at least 2 possible alternative answers to a specific question, and explains why both answers are plausible. For example, the possibility that speakers of different languages will perceive colors differently is plausible based on evidence that top-down processes can affect perception. The alternative hypothesis, that language does not influence perception of color, is also plausible because color perception in particular might be impervious to top-down influences. That is, it might be based solely on properties of the visual system which are unaffected by language. When describing an existing article or when proposing an experiment, you should identify the alternatives the authors considered. There are always at least 2 alternatives: that factor X will show an effect, or that it won't (that a null result will be obtained). If possible, identify other alternative patterns as well.

L stands for Logic

The logic of the study identifies how the experiment's design will allow the experimenter to distinguish among the alternatives. The logic is typically explained towards the end of the study's introduction, and has the following structure: If alternative 1 (and not alternative 2) is correct, then when a particular variable is manipulated, the participants' behavior should change in a certain way. For example, the logic of the color experiment would be: If a person's native language influences their perception of color, then speakers who have a term for a given color should respond differently to that color than speakers whose language contains no term for that color. Alternatively, if language does not influence color perception, then speakers

who have a color term should respond no differently than speakers who lack the term. Note that the logic of the experiment is integrally connected to the alternatives you stated in the last section. Indeed, this section should be comprised of a series of "If, then" statements in which you restate the alternatives you offered ("If X,"), and then state what pattern of data would support that alternative ("then Y"). You should therefore have equal numbers of alternatives and IfâĂęthen statements.

M stands for Method

This section identifies the procedures that will be used to implement the logical design. It should state the independent variable (the factor being experimentally manipulated) and the dependent variable (the behavior being measured) of the experiment. It should also describe the subjects, including whether subjects were divided into groups receiving different experimental manipulations. What materials were used to conduct the experiment, and what were the experimental stimuli like?

R stands for Results

What was the outcome of the experiment? Describe the results of the primary measures of interest. For example, did different subject groups yield different group means? What were these means? Or did the entire subject population produce a distinctive pattern of responses? Describe that pattern. Did the results seem reliable, or do you feel they might have been an artifact of the way the experiment was conducted? For this section, it is often a good idea to use graphs or tables to illustrate the pattern of data you obtained.

I stands for Inferences

What can the results of the experiment tell us about the alternatives? If the study was well designed, the results should allow you to eliminate at least one of the possible alternatives. For example, if a language lacks a color word but the speakers of that language respond to the color no differently than speakers of a language lacking a term for the color, then the experiment supports the view that language does not influence color perception. At this point, take a step back and think about any potential problems with the experiment that could have led to the pattern of results you obtained. Were there confounds that could have caused the results? For example, if you did find a difference between the subject groups, are there other ways in which the groups differ that are not language-related? Might

this have caused the result? Were there problems during the data collection? In addition, this is the section in which to consider the hypothetical next step in answering the broad question. If you were to conduct a follow-up experiment, what would it be (hint: think of questions that remain unanswered by the present results, and sketch a study that could bear on one or more of those questions)? What questions do your results raise?

Writing a QALMRI

Writing a QALMRI for any research paper (one that you are writing, or one that you are reading) is simply writing short answers to each of these questions using clear and concise language. It is a condensed, short-form, version of the research. To be even more specific, your task is to answer these questions:

HOW LONG IS A QALMRI? Long-enough to answer each question with clear and brief sentences.

- Question: What was the broad question? What was the specific question?
- Alternative hypotheses: What were the hypotheses?
- Logic: If hypothesis 1 was true, what was the predicted outcome? What was the predicted outcome if hypothesis 2 was true?
- Method: What was the experimental design?
- Results: What was the pattern of data?
- Inferences: What can be concluded about the hypotheses based on the data? What can be concluded about the specific and broad question? What are the next steps?

In many of the weekly labs you will read a primary research article, and then write your own QALMRI summary. This will help you extract the big ideas and findings from the research. You will also discuss your QALMRIs as a group to make sure that everyone is on the same page about what the research was about, and what the research showed.

Example QALMRI

Even if you haven't read the article, reading a QALMRI should provide you with enough information to get a basic idea of what the article was about. The following QALMRI summarizes the article by Crump & Logan (2010). [7]

[7] Crump, M. J. C. and Logan, G. D. (2010). Warning: This keyboard will deconstruct— The role of the keyboard in skilled typewriting. *Psychonomic Bulletin & Review*, 17(3):394–399

What was the broad and specific question?

The broad questions are about spatial cognition. How do people understand and represent the spatial relationships between objects in the environment? Do people have "spatial maps" in their head?

The specific question is how do typists know where the keys are on the QWERTY keyboard?

What are the alternatives?

1. Typists have an internal cognitive spatial map of the keyboard that they use to guide their fingers during typing
2. Typists do not have a map-like representation, instead they rely on learned associations between cues such as the feel of the keyboard to guide their fingers during typing

What is the logic?

1. If typists have an internal map of the keyboard, then they should be able guide their fingers to correct locations based on the map alone, and no feedback from the environment. For example, if we could measure "air-typing" without a keyboard, then typists should still be able to put their fingers in the correct locations even when the keyboard is missing because they are relying on their internal map.
2. If typists do not use an internal map of the keyboard, then their finger movements should become slow and inaccurate when they try to type without a keyboard, or in other conditions that change the normal feel of the keyboard, and thereby remove the cues that typists use to direct their fingers.

What is the Method?

Typists copied paragraphs in four conditions that manipulated tactile (touching) feedback from the keyboard. They typed on a normal keyboard, a keyboard with the keys removed exposing the rubber buttons underneath, a flat circuit board without, and on a flat table with a laser projection keyboard.

Results

Typists were fast and accurate in the normal keyboard condition. Typists were slow and inaccurate in all of the other keyboard conditions, where normal tactile feedback was removed.

Inference

The results are *not consistent* with the internal map hypothesis. If typists had an internal map, and did not rely on tactile cues, then they should have typed normally even when the cues were removed. The results are consistent with learned association hypothesis, that typists rely on cues, like the feel of the keyboard, that are associated with particular key locations.

Finding the QALMRI sections in a journal article

Most psychology journal articles are in APA format. See the textbook, and the sections about APA style in this lab manual for more on that format. APA format makes it relatively easy to find the sections of the QALMRI. The basic parts of an APA manuscript are

1. Title - Offers clues about the big idea and finding
2. Abstract - Usually a useful summary of the whole research.
3. Introduction - Big questions are usually near the beginning, specific questions are usually in the middle. Alternatives (or Hypotheses) and Logic are usually just before the Experiment, and sometimes in the short introduction to the experiment.
4. Methods - a whole section devoted to the M part
5. Results - a whole section devoted to the R part
6. Discussion - Usually provides a summary of the main important finding right at the beginning
7. General Discussion - Should connect the main finding to the hypotheses and questions under investigation

Most articles that are not in APA style also have very similar sections, and you should find the answers to the QALMRI in the same places. Some journals like Science and Nature have the method sections at the very end. Also, some journals have short article formats, where the research is presented in one or two pages. Oftentimes short reports do not have headers; nevertheless, the answers to the QAL parts are usually near the beginning and middle, and the answers to the RMI parts are usually near the end.

To get some practice extracting QALMRI from a journal article, let's look at short report published in Science. We'll look at the Mehl et al. (2007) [8] paper, discussed in chapter 1 of the textbook. It's only one page long, so it's an easy read.

[8] Mehl, M. R., Vazire, S., Ramírez-Esparza, N., Slatcher, R. B., and Pennebaker, J. W. (2007). Are women really more talkative than men? *Science*, 317(5834):82–82

Click this link to get the paper online. Note, if you are on the Brooklyn College network, this should take you directly to the paper. If you are at home, you will need to first sign into the library.

Finding the Big Question

You might say the big question is implied by first sentence, "Sex differences in conversational behavior have long been a topic of public and scientific interest". The big question is not stated directly, but you could infer that the questions are something like, 1) Are there sex differences in talking, or other conversational behavior?, 2) Do women talk more than men?, 3) Why do women talk more than men?, and so on.

You might also read this article and conclude that the authors did not really spell out the big questions. After all, they only had a single page to communicate their research. So, it is important to realize that there are big questions that may not actually be stated. You, the reader, need to connect the dots. For example, we could say some of the really big questions are: 1) What are the main sex differences in communication, language, and cognition in general, 2) How do people use language to communicate, 3) What cognitive, biological, genetic, and environmental mechanisms cause sex differences in these behaviors? You can see that the research relates to these bigger questions, even if they are not explicitly stated.

Finding the Specific question

In this case, the specific question is hard to miss. It's in the title, "Are women really more talkative than men?". The authors motivate asking this question by pointing out that systematic research has not actually measured how many words men and women say on average per day.

Alternatives

The hypotheses in this article are pretty straightforward because they are clearly related to an empirical question. One hypothesis is alluded to in the second sentence, where the authors claim that western society has a stereotype that women are more talkative than men. In this case, the hypotheses in question are not about psychological processes or mechanisms, they are simply about the data. The authors also do not formally state two hypotheses. We have to do that for them.

- Hypothesis 1: Women are more talkative than men

- Hypothesis 2: Women are not more talkative than men

Logic

In this case, the logic of the hypotheses is nearly identical to the hypotheses themselves, but simply stated in terms of a logical if/then structure.

- If, women are more talkative than men, then women should on average produce more words per day than men
- If, women are not more talkative than men, then women should on average produce the same or less number of words per day than men.

Methods

You can see the methods described in paragraphs three and four. Basically, they recorded subjects all day long in their natural environments, and then counted how many words they said.

Results

The results are in paragraph six, and presented in the table. You already know the question: "Do women talk more than men?", and that they measured the number of words spoken by groups of men and women, so you should expect to find some average data showing the actual counts. We see this in the weighted average in the table. Women said on average 16,215 words per day, and men said 15,669 words per day. The results section says that this result was not statistically different, and could have easily been produced by chance. You can even see that some of the sub-groups showed the opposite pattern of data, with men saying more words per day than women.

Inference

The authors make inferences about their hypotheses in the last two paragraphs. Their major inference is that, contrary to popular belief, women are not more talkative than men. They also discuss some limitations of their work.

Reading between the lines

We saw that some parts of the QALMRI weren't explicitly stated the by authors in the manuscript. However, all of the major parts were implied by what they wrote. This will be a common theme in reading

the research literature. You will have to extract the implications when they are not explicitly stated. That means you have to read between the lines to understand the ideas and connections between them.

This research appeared to have no theory behind it. So, the results of the paper did not appear to test predictions of any theory. Instead, the results were testing the popular claim or stereotype that women talk more than men. The data show strong, reliable evidence that this claim simply isn't true, at least for the subjects they measured. But, do the data have implications beyond testing the stereotype? Do these data have theoretical implications? Yes, they do, but you have to read between the lines to see the connection.

The author's allude to this connection in the final paragraph, where they say "Further, to the extent that sex differences in daily word use are assumed to be biologically based, evolved adaptations [3], they should be detectable among university students as much as in more diverse samples". The clue is the reference to [3], which you can find in the article, and refers to a book called "The Female Brain". I have not read this book, but let's imagine that it contains a theory about evolved adaptations that are biologically based, which cause differences in how women and men talk. This theory would make a number of assumptions, and it would predict that women talk more than men. So, even though the authors do not describe this theory in detail to explain how it works, and why it might predict that women talk more than men, their data nevertheless has implications for that theory. Specifically, any data showing that women and men say about the same numbers of words per day, has implications for any theory that predicts otherwise. So, reading between the lines, we can see that findings suggest that theories suggesting differences between women and men must be making wrong assumptions. And, the results point us toward theories that suggest common psychological principles and processes driven male and female talking behavior. So, indeed there are many implications between the lines that we arrive at when we draw them out of the text by thinking about the ideas, and the connections between ideas and the data.

The Hardest Section of the QALRMI: Alternatives

In my opinion, the alternatives section is the hardest, and sometimes the most confusing part to extract from a journal article. Sometimes the author's make it really easy by writing very clearly and explicitly. For example, you may find that the authors explicitly define two hypotheses, which is very helpful. But, this is not always the case. So, when there is only one hypothesis, don't spend time looking in the manuscript for a second one (however, just because the authors

didn't generate a second hypothesis, doesn't mean that you can't do that for yourself. There's always an alternative way of explaining things.)

The alternatives section appears to be simple when the claim that is being tested is an empirical claim. Empirical claims are questions about whether the observations or measurements (dependent variables) are different between the conditions of the experiment (independent variables). There are always two general possibilities.

1. There is a difference between conditions.
2. There is no difference between conditions (like in the above paper, there were no differences between women and men in the number of words spoken per day)

So, you might come across articles where the paper is asking whether one thing influences another. For example, does the color of a room (red vs. blue) change how fast you can read; or does drinking coffee vs. tea change how quickly you can learn piano. There are many "does this do something to that" kind of questions. In these cases, the alternative section boils down to:

X is the manipulation (independent or manipulated variable), like a blue or red room. And, Y is the measurement (dependent variable), like how fast you read.

- Empirical Hypothesis 1: X does change something in Y (This does do something to that)
- Empirical Hypothesis 2: X does not change something in Y (This does nothing to that)

Empirical vs. Theoretical Hypotheses

Notice the new label "Empirical hypothesis". This label means that the hypothesis is directly concerned with whether the experiment will do something, that is whether the manipulation will actually change something that was measured, or will do nothing at all. In fact, we might make a new label that eliminates the word hypothesis, because these two statements aren't really hypotheses in any interesting sense, instead they just the two possible outcomes that can always occur in any experiment. So, let's use the labels "Empirical Outcome"

- Empirical Outcome 1: X does change something in Y (This does do something to that)
- Empirical Outcome 2: X does not change something in Y (This does nothing to that)

You should be able to see by now that there are always two outcomes when running an experiment. It does something (produces

some difference), or it does nothing (produces no differences). So, for every experiment, you could always write an "Alternative"section that simply says the alternatives were 1) the experiment will do something, or 2) the experiment will not do anything. But, because this is true of all experiments, it really does not tell us anything useful.

Instead, what you should be looking for is the "THEORETICAL HYPOTHESIS" or "THEORETICAL HYPOTHESES". The theoretical hypotheses are where the alternative sections get really interesting, but at the same time can be very challenging to understand. Theoretical hypotheses can be challenging to understand because you have to understand what the theory is, how it works, and why it makes particular hypotheses. Most important are the connections between the theoretical hypotheses and the research findings. In particular, when a theoretical hypothesis fails to predict the research findings, the hypothesis must be somehow wrong! So, we can use the findings from experiments to rule out bad theories or explanations, which opens the door to new and improved theories that can explain the findings.

Returning the "read between the lines" theme, not all papers will be explicit about the difference between theoretical hypotheses and empirical hypotheses. For example, look back at our QALMRI summary for the Mehl et al. (2007) paper. What kind of Alternatives did we list? It should be clear that we listed two empirical hypotheses: Either women talk more than men, or they don't. Also, reading the paper, the authors' themselves were mainly concerned with the empirical question, and only alluded to the theoretical issues in passing at the end of the article.

So, when you are writing QALMRI summaries be aware that some papers fail to state the theoretical issues. When this is the case it is totally appropriate to state the Alternatives in terms of the Empirical hypotheses, as perhaps the authors were not testing any theories, or have no theoretical explanations for their results. You could also attempt to figure out what the theoretical issues might be by reading between the lines. However, when the article discusses the theories that motivate the research, you must state the alternatives in terms of the Theoretical hypotheses, because in these cases they are the most important parts of the paper.

Finally, let's consider how we could change the Alternatives section that we wrote for the Mehl et al. (2007) paper, so that rather than listing empirical hypotheses, we instead imagine what the theoretical hypotheses might be.

The original empirical hypotheses were:

- Empirical Hypothesis 1: Women are more talkative than men

- Empirical Hypothesis 2: Women are not more talkative than men

Some possible theoretical hypotheses are:

1. Theoretical Hypothesis 1: Women and men have specific biological adaptations stemming from different evolutionary pressures that cause women to be more social than men. The implication is that women may exhibit more social behaviors, such as talking, than men.
2. Theoretical Hypothesis 2: The neuro-biological and cognitive processes involved in language production are virtually identical between the sexes. The implication is that talking behaviors are not fundamentally different between men and women.

To make the distinction and relationship between theoretical and empirical hypotheses more clear, we can put the empirical hypotheses inside the theoretical ones.

1. Theoretical Hypothesis 1: Women and men have specific biological adaptations stemming from different evolutionary pressures that cause women to be more social than men. The implication is that women may exhibit more social behaviors, such as talking, than men.
   (a) Empirical Hypothesis 1: Women are more talkative than men
2. Theoretical Hypothesis 2: The neuro-biological and cognitive processes involved in language production are virtually identical between the sexes. The implication is that talking behaviors are not fundamentally different between men and women.
   (a) Empirical Hypothesis 2: Women are not more talkative than men

Each theoretical hypothesis implies particular empirical outcomes. So, we collect the data about the empirical outcomes because they test the implications of the theoretical hypotheses.

Labs 2 and 3: Paper Project 1

THE PURPOSE OF PSYCHOLOGY IS TO GIVE US A COMPLETELY DIFFERENT IDEA OF THE THINGS WE KNOW BEST.

—PAUL VALERY

Overview

In this project you will attempt to replicate a recent short report published in Psychological Science. A replication of the experiment has already been designed. To collect data, you will first participate as a subject in the experiment. Then, as a class you will be introduced to the published paper. You will read the paper and it in class. Then, the class will analyze the collected data to determine whether or not the major effects of interest have been replicated. Data will be collected using pen and paper methods, and analyzed by computer software. Each student will write a 5+ page, APA style report on the project.

Things you will learn:

- Reading and citing primary source material
- Writing a brief APA style research report
- Conducting and reporting T-tests

Background readings:

To be provided by Lab Instructor

Grade

- 10% of final grade

- Graded by your lab instructor. Lab instructor sets due date, and determines whether revised drafts are submittable.
- If you submit completed versions of all paper assignments (1, 2, and 3), then you get to drop your lowest paper grade from paper 1 or 2. Specifically, you will receive your highest grade from paper 1 or 2 for both papers, thereby eliminating the lower grade. This allows room to learn and improve as you go.

Writing the paper

There are many resources for help on writing an APA style research report in the lab manual, on the textbook, and the website. Check them out. As well, here is a rough roadmap for writing paper 1.

APA formatting, Title and Abstract

- Use APA formatting rules.
- Create a suitable title for the paper
- Write the abstract : No more than 250 words. The aim is to briefly describe the issue at hand, the experiment, and the results.

Introduction (around 2 double-spaced pages)

The goal of the introduction is to first put the research into a broader context, and then narrow the focus to describe the specific research aims.

1. A. Opening section: (starting broad)
   - about 1 paragraph
   - Discuss a real-world example of the general phenomena under investigation by the paper
   - Tell the reader that the purpose of the current experiment is to conduct a replication of the work in question
   - Establish the domain and big questions.
2. Middle section: Prior work
   - Discuss some examples of previous research that are similar to the present research. You have an opportunity here to look this kind of research up on Google Scholar. One or two examples ought to be enough.
   - Explain the specific question that is being asked in this replication work.

3. Final section: (briefly explain the present aims, the experiment and what you expect to find)
   - Explain the hypotheses (alternatives)
   - Explain the logic of how the hypotheses will be tested
   - Briefly explain what the participants will be doing in the task
   - Briefly give predictions for performance in each condition

Methods (about 1 page)

The methods section should be a complete recipe that anyone could follow to replicate your experiment. There are lots of details that you can include, some of these are listed below. Be brief and concise

1. Participants
   - how many people?
   - where did they come from?
2. Materials
   - what were the stimuli?
   - how were they organized?
3. Design & Procedure
   - What was the design
   - What were the independent variable(s)
   - What was the dependent variable
   - Within or between subjects?
   - How were the stimuli for each trial chosen
   - Describe the steps each participant took to complete the experiment

Results

The result section is used to report the patterns in the data, and the statistical support for those patterns. You will compute the results using SPSS in the lab computers. The lab manual can be consulted for help on running statistical tests, and for reporting results.

- Describe the statistical analysis
- Tell the reader where they can see the data. E.g., the results of experiment 1 are presented in table 1, or in figure 1
- Make a table or figure to display the data in your paper
- Report the statistical test, and the pattern of the means.

Discussion

The discussion can be used to briefly restate verbally the pattern of the most important results, and then to relate the results to theory and ideas developed in the introduction

- Highlight the main findings from the experiment
- Discuss how the data can be explained by the hypothesis. What inferences do you make about the hypotheses based on the research findings?
- Broaden your discussion. Can the findings be explained by an alternative theory? What can be generalized to the real world? Are there important confounds that prevent us from interpreting our results?

References and Figures or Tables

- Include citations used in the paper using APA style format
- Include a figure or table to show the results

Data-analysis tips

In lab one you will be collecting measurements on several dependent variables, in each of two manipulated conditions (the independent variable). For each dependent variable you will want to determine whether the manipulation had an effect. That is, did the independent variable cause a change in the dependent variable. We know that differences can sometimes be observed by chance alone, so we want to conduct an inferential statistical test to determine the probability that our observed difference could have been produced by chance alone. To do this we will be conducting several t-tests. This is a short primer on the process. You can conduct t-tests in the software of your choice, or by hand using a calculator (or in excel). Here, we will use the free and open-source statistical package called R, to illustrate the process.

Let's imagine we have two groups of 10 subjects each. Group A receives condition 1 of the independent variable, and Group B recieves condition 2 of the independent variable. We then measure some behavior for all of the subject in all of the groups. To make this more concrete, let's say 10 subjects drink coffee, and the the 10 subjects drink tea. Then we present all of the subjects with a piece of art and ask them rate how beautiful they think it is on a scale from 1 to 7.

When we collect all the data we should have 20 total ratings, one for each subject in each group.

For example, if you put the data in a table it might look something like the following. Note, the grey text box shows the R code used to simulate the data. For, each group, we sample 10 numbers from a normal distribution with a mean of 4, and a standard deviation of .5. Then we put the numbers in a table.

```
coffee<-round(rnorm(10,4,.5))
tea<-round(rnorm(10,4,.5))
all_data<-data.frame(coffee,tea)
kable(all_data,format="latex")
```

coffee	tea
4	5
3	4
3	4
3	3
4	3
4	5
4	4
4	4
4	4
3	4

We can do some quick descriptive statistics, for example, we might want to know the means of the beauty ratings for the coffee and tea groups.

```
mean(coffee)
```

```
## [1] 3.6
```

```
mean(tea)
```

```
## [1] 4
```

The means aren't very different, and of course we should expect they should be similar. After all, we sampled these means from the exact same distribution. So, we should expect that on average, the means should both be close to 4. However, they won't necessarilly be exactly 4, because of variability introduced by random sampling.

The t-test

What we want to do next is conduct an independent samples t-test. We want to determine whether any possible difference between the

coffee and tea groups could have been produced by chance alone. We can conduct a t-test in R very easily using the t.test function.

```
t.test(coffee,tea,var.equal=TRUE)
```

```
##
##  Two Sample t-test
##
## data:  coffee and tea
## t = -1.5, df = 18, p-value = 0.151
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.9602459  0.1602459
## sample estimates:
## mean of x mean of y
##       3.6       4.0
```

R gives us back the t values, the degrees of freedom (df), and the associated p-value. The p-value tells us the likelihood that our difference, or a difference greater than the one we observed could have been produced by chance.

One more time

Let's try this whole process again, but this time we will simulate data with an actual difference between the groups. For example, let's say we want to simulate the idea that drinking coffee makes people think the art is less beautiful by at least 2 points, and then reconduct the t-test with the new simulated data. We will sample numbers from a normal distribution with mean 3 for the coffee group, and mean 5 for the tea group (for an average expected difference of 2).

```
coffee<-round(rnorm(10,3,.5))
tea<-round(rnorm(10,5,.5))
all_data<-data.frame(coffee,tea)
kable(all_data,format="latex")
```

coffee	tea
3	5
3	5
3	4
3	6
2	5
4	5
3	6
3	5
3	5
3	5

```r
mean(coffee)
```

```
## [1] 3
```

```r
mean(tea)
```

```
## [1] 5.1
```

```r
t.test(coffee,tea,var.equal=TRUE)
```

```
##
##  Two Sample t-test
##
## data:  coffee and tea
## t = -9, df = 18, p-value = 4.404e-08
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -2.590215 -1.609785
## sample estimates:
## mean of x mean of y
##       3.0       5.1
```

Writing up the results of a t-test

We've now conducted two different t-tests, and received different results on each them. You will likely find different results for all of the t-tests that you conduct for the lab experiment. However, you will use the basic sentence structure to report all of the results. When you report the results of your experiment along with statistical tests there are two important features to include, the pattern of the results, and the inferential statistic. In this situation, we would simply report the means and the t-test information. Here are is an with made-up numbers.

The coffee group gave a lower mean beauty rating (M = 3.4) than the tea group (M = 5.6), and the difference was significant, t (18) = 5.4, p < .001.

So, just in one sentence we tell the reader what the means were in both conditions, as whether the result was significant. APA style recommends reporting exact p-values when they are greater than .001 (for example p = .047). If the p-value is less than .001, then you just need to report p < .001.

Lab 4: Memory Mini Project

MEMORY... IS THE DIARY THAT WE ALL CARRY ABOUT WITH US.

—OSCAR WILDE

Lab 4: MiniProject 1 Nairne, Pandeirada, & Thompson, (2008)

In the first mini-project, you will read, summarize and discuss the paper by Nairne et al. (2008)[9]. Then, you will attempt to replicate their results in the lab, by conducting an experiment and analyzing the data.

[9] Nairne, J. S., Pandeirada, J. N., and Thompson, S. R. (2008). Adaptive memory: The comparative value of survival processing. *Psychological Science*, 19(2):176–180

What's in store

1. Students read paper and write QALMRI (15-20)
2. Group discussion about paper (15-20)
3. Students attempt to replicate the major findings in the paper

   a. Break into four-five groups, each group assigned an encoding condition (Survival, Pleasantness, Imagery, Self-reference, Intentional learning)

   b. Each group picks their own 30 words. Can follow same procedure as in paper by choosing 30 words from Overschelde, Rawson, & Dunlosky (2004) [10].

   c. Groups try to run at least 10 participants in their condition, recording proportion of correctly recalled words

   d. Groups enter their collected data into the master spreadsheet, which is given back to groups upon data completion
4. Discussion of how to analyze the data
5. Group attempt to analyze the data using t-tests and one-way ANOVA to determine if the survival framing produced better recall than the other conditions.

[10] Van Overschelde, J. P., Rawson, K. A., and Dunlosky, J. (2004). Category norms: An updated and expanded version of the norms. *Journal of Memory and Language*, 50(3):289–335

Data-analysis tips

In this mini-lab, you will be determining whether different kinds of manipulations improve your ability to recall lists of words. Each condition different subjects will read a list a words, and then recall as many as they can on a sheet of paper. Then, you will measure recall for each subject by counting the number of correctly recalled words. You will try to get at least 10 subjects in each condition, the more the merrier. The empirical question will be whether memory recall is differs across the conditions. If they do differ, then some of those conditions help you remember words better, and some conditions may hurt your ability to remember words. With these kinds of experiments, we can learn about the factors that influence our memory, as well as how cognitive processes allow us to encode and retrieve memories.

The new tool you be using here is a one-way ANOVA, which you may remember from your statistics classes. In particular, we will be performing an independent samples ANOVA, because we are conducting a between-subjects experiment, where different subjects contribute data in each of the conditions. More specifically, we will be conducting an omni-bus test. The omni-bus test is a catch-all test, that let's us enter the data from as many conditions as we want, and ask the general question: are any of the conditions different from one another. This is different from a t-test, which only let's us make a comparison between two conditions. In fact, the t-test and ANOVA are related, but this is a topic that we will leave for now. Except to say, that if you ran a t-test comparing two groups, or an ANOVA with only two groups, they would return the same p-values, because they are testing the same underlying question... which is the likelihood the observed occurs by chance alone.

One drawback about the ANOVA, is that it only tells us if there is some difference, any difference, among the conditions we are comparing. But, it does not tell us which specific conditions are different. Fortunately, after we conduct the ANOVA, we can run follow-up t-tests comparing any groups we want. We can also conduct more complex comparisons using linear contrasts, but that is a topic for another day as well.

We will again use to R to simulate a memory recall experiment with multiple conditions. Then, we will create fake data, plot the data, then analyze the data for differences using an ANOVA and follow-up tests.

Simulating the data

Consider an experiment with five different memorizing conditions. This will be a between-subjects experiment with 10 simulated subjects in each condition. We will have condition A, B, C, D, and E. To simulate data for each subject we need to make some assumptions. Let's that out of 30 words most people remember about 15 of them, but there is variation, so some people do better and some people do worse. We can model this by sampling numbers randomly from a distribution of our choice. For convenience, we will use the normal distribution, which looks like bell-curve (should be familiar from statistics class). Let's imagine that condition A and B help memory more than C and D, and that memory is worse in condition E. Take a look at the code and output for simulating this kind of data.

```
A<-round(rnorm(10,20,2))
B<-round(rnorm(10,20,2))
C<-round(rnorm(10,15,2))
D<-round(rnorm(10,15,2))
E<-round(rnorm(10,10,2))
all_data<-data.frame(A,B,C,D,E)
kable(all_data,format="latex")
```

A	B	C	D	E
23	19	17	18	13
18	21	17	15	11
20	24	16	11	10
22	20	15	11	12
22	21	12	13	12
17	15	15	18	10
20	19	14	13	9
19	23	17	17	12
20	23	13	17	6
21	22	19	13	12

We have produced a table with fake data for 10 subjects in each condition. The numbers all represent the number of correctly recalled words for each simulated subject. For groups A and B we sample 10 numbers, from a distribution with mean 20, and standard deviation 2. This is a higher mean than groups C and D (mean = 15). The lowest mean was for Group E (mean = 10). So, on average, groups A and B should have higher scores than C and D, which should be higher than E.

Ok, so what happened in our simulated experiment. We can see the numbers in the table, but it would be nice to summarize them so we can more easily look at differences. After all, it's hard to make

sense of a bunch of raw data in a table.

One way to summarize the data is to compute the group means for each condition. This averages over the subjects, and gives us only 5 means to look at, so it is easier to see the differences. We can "easily" do this in R in a couple different ways. However, R often likes the data in a particular format, in this case long-data format. So, we will first convert to that format, and see what it looks like.

```
long_data<-data.frame(Conditions=rep(c("A","B","C","D","E"),each=10),
                      Recall=c(A,B,C,D,E))
kable(long_data[1:25,],format="latex")
```

Conditions	Recall
A	23
A	18
A	20
A	22
A	22
A	17
A	20
A	19
A	20
A	21
B	19
B	21
B	24
B	20
B	21
B	15
B	19
B	23
B	23
B	22
C	17
C	17
C	16
C	15
C	12

I've only printed the first 25 lines, but the dataframe contains all of the data for conditions, C, D, and E as well. You can see why they call it long format. It's because each data point gets it's own row in the table.

Looking at the means

Now that the data is in long format we can easily make a table of the condition means

```
condition_means<-aggregate(Recall~Conditions,long_data,mean)
kable(condition_means,format="latex")
```

Conditions	Recall
A	20.2
B	20.7
C	15.5
D	14.6
E	10.7

We can now see the group means, but we can't see any measure of how variable the data are in each condition. We might, for example, also want to compute the standard deviation as well as the mean, and put them both in the table. We could run the same code from above and substite sd for mean, which would give us a table of standard deviations. However, we will use a more advanced function from the plyr package, called ddply. ddply let's you compute multiple statistics and put them all in a single table. The syntax is a bit different, but it doesn't take long to get used to it.

```
library(plyr)
condition_means<-ddply(long_data,.(Conditions),summarise,
                       MeanRecall=mean(Recall),
                       StdDeviation=sd(Recall))
kable(condition_means,format="latex")
```

Conditions	MeanRecall	StdDeviation
A	20.2	1.873796
B	20.7	2.626785
C	15.5	2.121320
D	14.6	2.756810
E	10.7	2.057507

Plotting the data

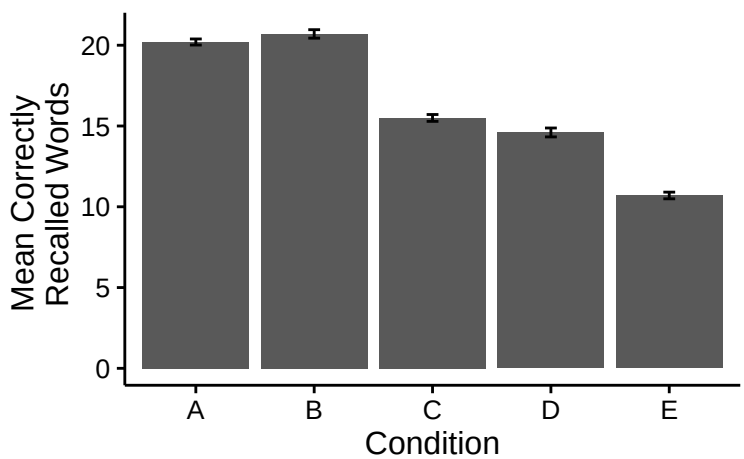
It's often very desirable to plot the data in a graph, rather than just present the means in a table. People find it easier to look at graphs, because the differences in the data just pop-out much easier than looking at numbers in a table. R has a fantastic graphing package called ggplot2. ggplot2 is a whole philosophy for visual design and data-presentation, and it can be daunting at first. But, it's complexity makes it very powerful, and when you get the hang of it you can very

quickly make all sorts of beautiful graphs to present data. Here is some code to make ggplot create a bar graph to plot the means, along with error bars. In this case the error bars with represent standard errors of the mean, rather than standard deviations. R does not have a built in function for the standard error of the mean, so we have to write it ourselves.

```
library(ggplot2)
sde<-function(x){sd(x)/length(x)}
plot_means<-ddply(long_data,.(Conditions),summarise,
                        MeanRecall=mean(Recall),
                        SE=sde(Recall))

limits <- aes(ymax = MeanRecall + SE, ymin = MeanRecall - SE)

ggplot(plot_means,aes(x=Conditions, y=MeanRecall))+
  geom_bar(position="dodge",stat="identity")+
  geom_errorbar(limits, width=.1)+
  theme_classic(base_size=12)+
  ylab("Mean Correctly \n Recalled Words")+
  xlab("Condition")
```



Now it is easy to the differences between conditions. Just as we had hoped, Groups A and B appear to have recalled more words than Groups C and D, which remembered more words than group E.

Conducting the ANOVA

Although the graph and the tabe show some clear differences in the means, we still want to find out the probability that this kind of finding occurs by chance alone. We can be confident in the differences when we know that they do not occur very often by chance alone. The first step is conduct a one-way ANOVA. This is very easy in R.

```
aov.out<-aov(Recall~Conditions,long_data)
```

We're done! It's only one line of code. However, we need a couple more to see the results.

```
aov_summary<-summary(aov.out)
kable(xtable(aov_summary),format="latex")
```

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Conditions	4	694.52	173.630000	32.46095	0
Residuals	45	240.70	5.348889	NA	NA

The ANOVA table gives us a bunch of information. We will go into much greater detail about the meaning of each number in the table, but also assume for now that you are somewhat familiar with these ideas because you have already taken statistics, right?

We are mainly interested in the p-value, which tells how often results like the ones we found can occur by chance. But, when we report the results of our ANOVA, we also provide additional information about the F-value, the degrees of freedom values, and the mean squared error term. The reason is that if you know these numbers, you can actually reconstruct all of the other numbers. The results of our ANOVA are significant. You could report this in a sentence like the following.

The main effect of condition was significant, $F(4, 45) = 32.46$, MSE $= 5.35$, $p < .001$.

Comparisons between conditions

The p-value from above is much smaller than .05, which shows the difference between conditions in the data does not occur very often by chance alone. However, because we conducted an omni-bus test, we only know that there is some difference between conditions, but we do not know which specific conditions are different from one another.

So, we have to conduct additional tests between specific conditions. There are multiple strategies for conducting these tests. For now, we will simply run t-tests between comparisons of interest.

Remember, our data simulated the pattern that memory recall would be better for groups A and B, which would be better than groups C and D, which would better than group E. In other words A=B > C=D > E.

We can confirm this pattern by conducting tests to see if it holds up. For example, how would we test the pattern A=B > C=D > E, all of the following comparisons need to be true,

- A = B

- A > C
- A > D
- B > C
- B > D
- C = D

and, all of the conditions should be greater than E

- A > E
- B > E
- C > E
- D > E

Let's conduct a few of these tests, and then report the findings.

```
library(broom)
#conduct t-tests
ab<-tidy(t.test(A,B,var.equal = TRUE))
ac<-tidy(t.test(A,C,var.equal = TRUE))
cd<-tidy(t.test(C,D,var.equal = TRUE))
de<-tidy(t.test(D,E,var.equal = TRUE))

#put the results in a table
alltests<-rbind(ab,ac,cd,de)
alltests<-cbind(alltests,Comparison=c("AB","AC","CD","DE"))
finaltable <- subset(alltests, select = c(Comparison,estimate1,estimate2,statistic,p.value,parameter))
kable(finaltable,format="latex")
```

Comparison	estimate1	estimate2	statistic	p.value	parameter
AB	20.2	20.7	-0.4900286	0.6300329	18
AC	20.2	15.5	5.2511144	0.0000541	18
CD	15.5	14.6	0.8181818	0.4239528	18
DE	14.6	10.7	3.5851808	0.0021158	18

Writing it all up

The following is an example results section for our hypothetical experiment. This could serve as a model for your own results section.

The number of correctly recalled words for each subject in each condition were submitted to a one-way ANOVA, with memorization condition (A, B, C, D, and E) as the sole between-subjects factor. Mean recall scores in each condition are displayed in Figure 1.

The main effect of memorization condition was significant, $F(4, 45) = 32.46$, $MSE = 5.35$, $p < .001$. Figure 1 shows that Groups A and B had higher recall scores than Groups C and D, which had higher recall scores than Group E. This pattern was confirmed across four independent sample t-tests. Group A ($M = 20.2$) and Group B ($M = 20.7$) were not significantly different $t(18) = -0.49$, $p = 0.63$. Group A recalled significantly more words than Group C ($M = 15.5$), $t(18) = 5.25$, $p = 0$. Group C and Group D ($M = 14.6$) were not significantly different $t(18) = 0.82$, $p = 0.424$. Finally, Group D recalled significantly more words than Group E ($M = 10.7$), $t(18) = 3.59$, $p = 0.002$.

Lab 5: Task-Switching Mini Project

THE SECRET TO MULTITASKING IS THAT IT ISN'T ACTUALLY MULTITASKING. IT'S JUST EXTREME FOCUS AND ORGANIZATION.

—JOSS WHEDON

In the second mini-project, you will read, summarize and discuss the paper by Stoet et al. (2013)[11]. Then, you will attempt to replicate their results in the lab, by conducting an experiment and analyzing the data.

[11] Stoet, G., O'Connor, D. B., Conner, M., and Laws, K. R. (2013). Are women better than men at multi-tasking? *BMC Psychology*, 1(1):18

What's in store

1. Students read paper and write QALMRI (15-20)
2. Group discussion about paper (15-20)
3. Students download the task-switching program available from the website and individually complete the task. Individual students then enter their data in the master spreadsheet
4. Discussion of how to analyze the data. Major analysis goals are:

   a. Was there a mixing cost? Compare pure lists to mixed lists

   b. Was there a switching cost? Compare switch vs. repeat trials in pure lists

   c. Did these effects depend on gender? Did the women have a smaller mixing cost than the men? Did the women have a smaller switching cost than the men?
5. Students break into groups to analyze the data.

Critical Concepts

Multiple Dependent and Independent Variables

In lab 5 we begin looking at more complex designs that involve multiple dependent or and independent variables. For example, we can look at the dependent variable of reaction time or error rate, which are our two difference measured variables. There are also three independent variables, including gender (male vs female), block (pure list vs. mixed list), and trial sequence (repeat trial vs. switch trial).

Main effects and interactions

Throughout this course we will be talking a lot about main effects and interactions. Feel free to jump ahead in the textbook and learn more about them.

Main effects refer to the influence of single independent variables. And, each independent variable always has one main effect. So, we could look at the main effect of gender, block, or trial sequence. The main effect is like conducting a one-way ANOVA on the variable of interest, collapsing over the other variables. For example, a main effect of trial sequence usually shows slower mean reaction times in the switch condition compared to the repeat condition. This is called the task-switching cost, or also the task-switching effect.

Interactions occur when the effect of one independent variable depends on the levels of another independent variable. For example, if women actually multi-task better than men, then we should expect an interaction between gender and task-switching. Specifically, women should be better at task-switching than men. This would mean that women should have smaller task-switching costs (meaning they are unaffected by switching) compared to men (who should have bigger task-switching costs if they are more affected by switching).

If women have smaller task switching costs than men, then the effect of task-switching independent variable (repeat vs. switch) will depend on the level of the gender variable (women vs. men), which is the definition of an interaction.

Manipulating an Effect

Things get complicated when we add more dependent and independent variables, and it can be easy to lose track of what is going on in an experiment.

Many experiments are conducted for the purpose of better understanding some phenomena. For example, researchers observe

phenomena like the task-switching effect, they create theories to explain the phenomena, then they test their theories by running more experiments.

A primary question is often to identify factors that manipulate, influence, or somehow change the phenomena of interest. We know that switching between tasks can hurt performance, and we measure this cost by calculating a switch cost, which is the difference in performance between switching conditions and repeating conditions. What kinds of factors would make this cost ? Perhaps extended practice, time of day, gender, personality, motivation, drug interventions, details of the task, and many other factors could make the normal cost get smaller. Many of these factors might also make the effect get larger. And, knowledge of what makes switching costs smaller or larger can be used to test theories, which need to explain how and why those factors cause switching costs to change.

The Stoet et al. (2013) took this approach to determine if switch costs are smaller for men than women. Notice we have been talking about switch costs, which is the phenonemon and effect of interest. We have not been talking too much about the dependent variable of reaction times that we use to compute the switch costs. Remember that switch costs are computed as RT switch - RT repeat.

Reducing a two-factor design to a single-factor design using difference scores

We can use the term switch cost as a convenient term to describe the effect of the switching variable on reaction times. We can also think of the switch cost as the dependent variable of interest, rather than the base reaction time scores. Thinking of the switch cost this way can change how you conceptualize the design.

For example, how many independent variables are in a design testing whether women have smaller switch costs than men? The answer could be two or one, depending on how you think of the design.

If we go with two, then the design involves the independent variables gender (women vs. men) and trial sequence (switch vs. repeat), and the dependent variable of reaction time. This design would have two main effects (effect of gender, and effect of switching), and one interaction (gender x switching). We would be mainly interested in the interaction. For example, women may have a smaller difference in mean reaction time between the switch and repeat conditions than men.

We can reduce the design to a simple single-factor design. To do so, we create a new dependent variable called switch costs. For

example, for each subject we compute the mean reaction in the switch and repeat condition. Then we calculate the switch costs (difference between switch and repeat) for each subject. Now, each subject has one switch cost, rather than two reaction times. Now, the design would have gender as the single independent variable, and switch costs as the dependent variable. To determine whether women have smaller costs than men would you could run a t-test comparing the switch-costs between conditions.

Data-analysis tips

To give you an idea about the analyses you will be performing, we will again create simulated data to mimic aspects of the experiment, and then go through the steps of performing the analysis.

We will simulate data for the switching cost. Specifically, we will imagine that women have a smaller switching cost than men. The code below generates sample data for 10 women and 10 men, who each have mean reactions in the repeat and switch conditions. For women, the mean reaction times were 580 ms for repeat and 600 ms for switch sequences, for a total expected switch cost of 20 ms. For men, the mean reaction times were 580 ms for repeat and 650 ms for switch sequences, for a total expected switch cost of 70 ms.

Simulating the data

```
women_switch <-round(rnorm(10,600,20))
women_repeat <-round(rnorm(10,580,20))
men_switch <-round(rnorm(10,650,20))
men_repeat <-round(rnorm(10,580,20))
all_data<-data.frame(Subject=c(rep(seq(1,10,1),2),
                               rep(seq(11,20,1),2)),
                     Gender=rep(c("Female","Male"),each=20),
                     Sequence=rep(rep(c("switch","repeat"),each=10),2),
                     RT=c(women_switch,women_repeat,
                          men_switch,men_repeat))

kable(all_data,format="latex")
```

Subject	Gender	Sequence	RT
1	Female	switch	572
2	Female	switch	621
3	Female	switch	569
4	Female	switch	609
5	Female	switch	574
6	Female	switch	598
7	Female	switch	590
8	Female	switch	623
9	Female	switch	586
10	Female	switch	590
1	Female	repeat	556
2	Female	repeat	566
3	Female	repeat	588
4	Female	repeat	611
5	Female	repeat	575
6	Female	repeat	582
7	Female	repeat	576
8	Female	repeat	578
9	Female	repeat	558
10	Female	repeat	581
11	Male	switch	660
12	Male	switch	657
13	Male	switch	622
14	Male	switch	651
15	Male	switch	664
16	Male	switch	623
17	Male	switch	642
18	Male	switch	676
19	Male	switch	659
20	Male	switch	618
11	Male	repeat	585
12	Male	repeat	571
13	Male	repeat	575
14	Male	repeat	594
15	Male	repeat	572
16	Male	repeat	605
17	Male	repeat	556
18	Male	repeat	650
19	Male	repeat	594
20	Male	repeat	606

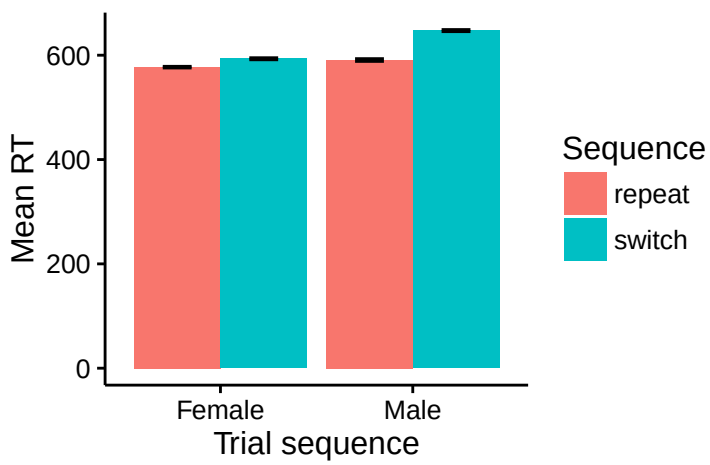
plotting the data

We can plot the data at least two ways. See the bar and line graphs below. Note that the x-axis changes between graphs.

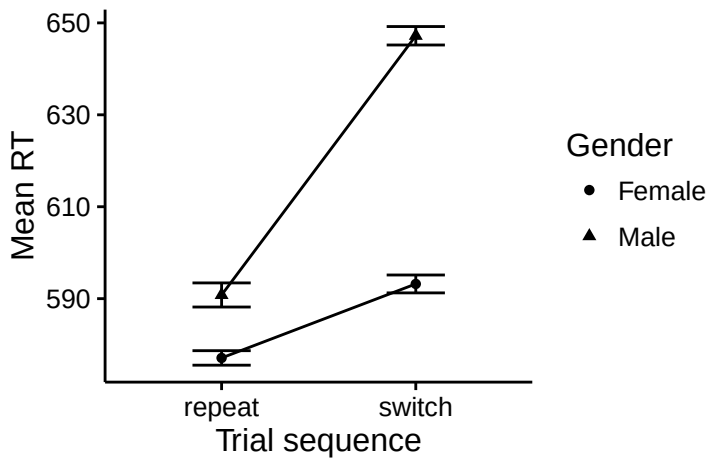
```
library(ggplot2)
library(plyr)
sde<-function(x){sd(x)/length(x)}
plot_means<-ddply(all_data,.(Gender,Sequence),summarise,
                        MeanRT=mean(RT),
                        SE=sde(RT))

limits <- aes(ymax = MeanRT + SE, ymin = MeanRT - SE)

ggplot(plot_means,aes(x=Gender, y=MeanRT, group=Sequence,fill=Sequence))+
  geom_bar(position="dodge",stat="identity")+
  geom_errorbar(limits, width=.3,position=position_dodge(.9))+
  theme_classic(base_size=12)+
  ylab("Mean RT")+
  xlab("Trial sequence")
```




```
ggplot(plot_means,aes(x=Sequence, y=MeanRT, group=Gender,shape=Gender))+
  geom_line()+
  geom_point()+
  geom_errorbar(limits, width=.3)+
  theme_classic(base_size=12)+
  ylab("Mean RT")+
  xlab("Trial sequence")
```



The graphs show that the switch costs (difference between repeat and switch trials) is smaller for women and men. Which is good, because we are simulating the data with this outcome in mind.

Running the ANOVA

The next step is to conduct an ANOVA. This design has two factors or independent variables, gender and trial sequence. The gender variable is between-subjects, and the trial sequence variable is within subjects. So, we will run a 2 (Gender: Female vs. Male) x 2 (trial sequence: Repeat vs. Switch) mixed design ANOVA with Gender as the betwen-subjects factor, and trial sequence as the within-subjects factor.

```
library(broom)
all_data$Subject<-as.factor(all_data$Subject)
aov.out<-aov(RT~Gender*Sequence+Error(Subject/Sequence),all_data)
aov_summary<-summary(aov.out)
kable(xtable(aov_summary),format="latex")
```

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Gender	1	11458.225	11458.2250	22.10104	1.78e-04
Residuals	18	9332.050	518.4472	NA	NA
Sequence	1	13140.625	13140.6250	38.47507	7.50e-06
Gender:Sequence	1	4060.225	4060.2250	11.88813	2.87e-03
Residuals	18	6147.650	341.5361	NA	NA

```
mt<-model.tables(aov.out,"means")
mt
```

```
## Tables of means
## Grand mean
##
```

```
## 602.075
##
##  Gender
## Gender
## Female   Male
##  585.1  619.0
##
##  Sequence
## Sequence
## repeat switch
##  583.9  620.2
##
##  Gender:Sequence
##         Sequence
## Gender   repeat switch
##   Female 577.1  593.2
##   Male   590.8  647.2
```

The above shows the ANOVA table and the means for the main effects and interaction. We also conduct t.test comparisons to look at the switch costs separately for men and women.

```
FemaleT<-t.test(RT~Sequence,all_data[all_data$Gender=="Female",],paired=TRUE,var.equal=TRUE)
MaleT<-t.test(RT~Sequence,all_data[all_data$Gender=="Male",],paired=TRUE,var.equal=TRUE)
FemaleT
```

```
##
##  Paired t-test
##
## data:  RT by Sequence
## t = -2.3034, df = 9, p-value = 0.04674
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -31.9115634  -0.2884366
## sample estimates:
## mean of the differences
##                   -16.1
```

```
MaleT
```

```
##
##  Paired t-test
##
## data:  RT by Sequence
## t = -6.0205, df = 9, p-value =
```

```
## 0.0001975
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -77.59196 -35.20804
## sample estimates:
## mean of the differences
##                   -56.4
```

Writing up the results

The next step is to interpret the results and write them up. Here is an example write-up.

The mean reaction times for each subject in trial sequence condition were submitted to a 2 (Gender: Female vs. Male) x 2 (trial sequence: Repeat vs. Switch) mixed design ANOVA with Gender as the betwen-subjects factor, and trial sequence as the within-subjects factor. Mean reaction times in each condition collapsed across subjects are displayed in Figure 1.

The main effect of gender was significant, $F(1, 18) = 22.1$, $MSE = 518.45$, $p < 0$. Women (585 ms) had faster mean reaction times than men (619 ms).

The main effect of trials sequence was significant, $F(1, 18) = 38.48$, $MSE = 341.54$, $p < 0$. Repeat trials (584) had faster mean reaction times than switch trials (620).

Most important was the significant two-way interaction between gender and trial sequence, $F(1, 18) = 11.89$, $MSE = 341.54$, $p < 0.003$. We interpreted the interaction further by conducting the following comparisons. Women showed a significant switch cost, $t(9) = -2.3$, $p = 0.047$, with faster mean reaction times for repeat (577) than switch (593) trials. Men also showed a significant switch cost, $t(9) = -6.02$, $p = 0$, with faster mean reaction times for repeat (591) than switch trials (647). The presence of an interaction indicates that the size of the switch cost for women was significantly smaller than the size of the switch cost for men.

Lab 6: Stroop Mini Project

THE SIMPLE ACT OF PAYING ATTENTION CAN TAKE YOU A LONG WAY.

—KEANU REEVES

In the second mini-project, you will read, summarize and discuss the paper by Raz et al. (2013)[12]. This paper provides some background about the Stroop effect, which is a classic measure of selective attention, and then shows one manipulation that effectively helps people overcome Stroop interference. Your task in this lab will be to replicate the Stroop effect in one condition, and then attempt to change the size of the effect (make larger or smaller) in another condition.

[12] Raz, A., Kirsch, I., Pollard, J., and Nitkin-Kaner, Y. (2006). Suggestion reduces the Stroop effect. *Psychological Science*, 17(2):91–95

What's in store

1. Students read paper and write QALMRI (15-20)
2. Group discussion about paper (15-20)
3. Students instructed their task is create their own Stroop design and employ a manipulation that increases or decreases the size of the Stroop effect
4. Students break into groups and conduct a Stroop experiment, measuring the size of the Stroop effect in a "normal" condition, and in their manipulated condition.
5. Groups analyze conduct a 2x2 ANOVA to see if their interaction was significant

Some background on the Stroop effect

The Stroop effect is a well-known and classic phenomena in experimental psychology. The effect was first reported by J. R. Stroop (1935).

Several hundreds of Stroop experiments have been conducted since 1935 and these experiments are summarized in Macleod's (1992) review.[13]

[13] Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18(6):643–662; and MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological bulletin*, 109(2):163

The original Stroop task involved color naming of word stimuli that are printed in different ink colors. There are two important conditions involving congruent and incongruent item types. *Congruent* items occur when the ink-color of the word matches the name of the word (e.g., the word red printed in red ink: RED). Incongruent items occur when the ink-color of the word does not match the name of the word (e.g., the word blue printed in red ink: BLUE). For each of these stimuli the task is to identify the ink-color of the word and ignore the written meaning of the word. Here are a few more examples of congruent and incongruent Stroop items:

Congruent: BLUE, GREEN, YELLOW, RED

Incongruent: BLUE, GREEN, YELLOW, RED

In the original set of experiments participants were presented with long lists of items and asked to read through the lists naming only the ink-colors and ignoring the word information. The important finding was that people were faster to finish reading lists that were composed of congruent items than incongruent items. This difference in reading time is termed the Stroop effect. For example, letâĂŹs say you were given a list of 60 congruent words and you read all of the ink-color names in 71 seconds. Next, you receive a list of 60 incongruent words and it takes you 94 seconds to read all of the ink-color names. You would compute your Stroop effect by taking the difference between the Congruent and Incongruent reading times. Congruent reading times are subtracted from incongruent reading times to give a positive Stroop effect value:

Stroop effect = Incongruent âĂŞ Congruent = 94 seconds âĂŞ 71 seconds = 23 seconds

The Stroop test can be administered in many different ways. A common modern variant of the task is to present a single Stroop item on a computer screen per trial and have participants identify the ink-color by pressing a key or typing out the response. Several trials could be presented over the course of an experimental session, and the experimenter could vary whether upcoming trials are congruent or incongruent. The trial-based version of the Stroop procedure provides more experimental control and more precise measurement of reaction times. This provides a more fine-grained measure of the time taken to respond congruent and incongruent items. Stroop effects using this procedure are usually measured in the milliseconds (ms). For example, reaction times for congruent items are usually around 500 ms, and reaction times for incongruent items are usually around 600 ms. So, the overall Stroop effect might be around 100 ms.

Stroop and Selective Attention

The Stroop effect has been used as a tool to study various aspects of learning and attention. For example the Stroop effect has been used as a tool to study cognitive control. Cognitive control refers broadly to the psychological processes that allow people to plan, coordinate, and execute actions necessary to accomplish goals. A central aspect of cognitive control involves the attention processes that are responsible for selecting task-relevant information and ignoring task-irrelevant information when performing a task.

The Stroop procedure provides a simple, yet effective, method for presenting people with two sources of information, one that is task-relevant (color) and one that is task-irrelevant (word). For this reason, Stroop items are sometimes referred to as bi-valent stimuli, in that they present two sources of information. Congruent Stroop items (blue in blue) do not present much of a selective attention challenge, both the word and the color information point to the same response. Incongruent items (blue in red) do present a selective attention challenge, the color points to the correct response and the word points to an incorrect response. When faced with incongruent items people must pay attention to the relevant color information and ignore or somehow filter out the irrelevant word information. The fact that people get Strooped, or that the Stroop effect exists at all, tells us something important about selective attention in this task. Specifically, people can not completely ignore the irrelevant word information. If people could completely ignore the irrelevant word information then the Stroop effect would cease to appear. People would be just as fast identifying congruent and incongruent items because they would be able to successfully ignore word information.

Using the logic above the Stroop effect is often taken as a measure of selective attention ability. This means that changes in the size of the Stroop effect may represent differences in selective attention ability. People who have very large Stroop effects have poor attentional control over their ability to ignore the word stimulus. People who have very small Stroop effects have excellent attentional control over their ability to ignore the word stimulus.

Labs 7 and 8: Paper Project 2

THE PURPOSE OF PSYCHOLOGY IS TO GIVE US A COMPLETELY DIFFERENT IDEA OF THE THINGS WE KNOW BEST.

—PAUL VALERY

Overview

In this project you will attempt to replicate a classic study on face perception (Yin, 1969)[14]. A replication of the experiment has already been designed. To collect data, you will first participate as a subject in the experiment. Then, as a class you will be introduced to the published paper. You will read the paper and it in class. Then, the class will analyze the collected data to determine whether or not the major effects of interest have been replicated. Data will be collected using pen and paper methods, and analyzed by computer software. Each student will write a 5+ page, APA style report on the project.

[14] Yin, R. K. (1969). Looking at upside-down faces. *Journal of experimental psychology*, 81(1):141

Things you will learn:

- Reading and citing primary source material
- Writing a brief APA style research report
- Conducting and reporting Factorial designs

Background readings:

Available on the lab website, or download from Brooklyn College library

Grade

- 10% of final grade

- Graded by your lab instructor. Lab instructor sets due date, and determines whether revised drafts are submittable.
- If you submit completed versions of all paper assignments (1, 2, and 3), then you get to drop your lowest paper grade from paper 1 or 2. Specifically, you will receive your highest grade from paper 1 or 2 for both papers, thereby eliminating the lower grade. This allows room to learn and improve as you go.

Writing the paper

There are many resources for help on writing an APA style research report in the lab manual, on the textbook, and the website. Check them out. As well, here is a rough roadmap for writing paper 2.

APA formatting, Title and Abstract

- Use APA formatting rules.
- Create a suitable title for the paper
- Write the abstract : No more than 250 words. The aim is to briefly describe the issue at hand, the experiment, and the results.

Introduction (around 2 double-spaced pages)

The goal of the introduction is to first put the research into a broader context, and then narrow the focus to describe the specific research aims.

1. A. Opening section: (starting broad)
   - about 1 paragraph
   - Discuss a real-world example of the general phenomena under investigation by the paper
   - Tell the reader that the purpose of the current experiment is to conduct a replication of the work in question
   - Establish the domain and big questions.
2. Middle section: Prior work
   - Discuss some examples of previous research that are similar to the present research. You have an opportunity here to look this kind of research up on Google Scholar. One or two examples ought to be enough.
   - Explain the specific question that is being asked in this replication work.

3. Final section: (briefly explain the present aims, the experiment and what you expect to find)
   - Explain the hypotheses (alternatives)
   - Explain the logic of how the hypotheses will be tested
   - Briefly explain what the participants will be doing in the task
   - Briefly give predictions for performance in each condition

Methods (about 1 page)

The methods section should be a complete recipe that anyone could follow to replicate your experiment. There are lots of details that you can include, some of these are listed below. Be brief and concise

1. Participants
   - how many people?
   - where did they come from?
2. Materials
   - what were the stimuli?
   - how were they organized?
3. Design & Procedure
   - What was the design
   - What were the independent variable(s)
   - What was the dependent variable
   - Within or between subjects?
   - How were the stimuli for each trial chosen
   - Describe the steps each participant took to complete the experiment

Results

The result section is used to report the patterns in the data, and the statistical support for those patterns. You will compute the results using SPSS in the lab computers. The lab manual can be consulted for help on running statistical tests, and for reporting results.

- Describe the statistical analysis
- Tell the reader where they can see the data. E.g., the results of experiment 1 are presented in table 1, or in figure 1
- Make a table or figure to display the data in your paper
- Report the statistical test, and the pattern of the means.

Discussion

The discussion can be used to briefly restate verbally the pattern of the most important results, and then to relate the results to theory and ideas developed in the introduction

- Highlight the main findings from the experiment
- Discuss how the data can be explained by the hypothesis. What inferences do you make about the hypotheses based on the research findings?
- Broaden your discussion. Can the findings be explained by an alternative theory? What can be generalized to the real world? Are there important confounds that prevent us from interpreting our results?

References and Figures or Tables

- Include citations used in the paper using APA style format
- Include a figure or table to show the results

Labs 9 - 14: The Final Project

THE PURPOSE OF PSYCHOLOGY IS TO GIVE US A COMPLETELY DIFFERENT IDEA OF THE THINGS WE KNOW BEST.

—PAUL VALERY

Overview

Your task for the final project is to design and run your own experiment. There are 3 major components.

- 2-3 minute individual presentation
- Individual APA research report
- 10 minute group presentation

For your individual presentation you will have the opportunity to develop your own experimental idea. Following the individual presentations you will be divided into smaller groups, and will decide on a final experiment idea. Each group will be required to have their experimental design approved by the lab instructor. Once the experiment is approved data collection can begin. Your lab instructors will help you with your experimental design to ensure that your project is feasible given the constraints that you are working with. Every student in the group will be responsible for writing their own APA research report on the findings of the experiment conducted by the group. As well as the paper, each group will be responsible for a 10 minute presentation that explains the findings of the research.

Requirements

The following applies for all aspects of the following assignments.

1. The final project (or proposal for individual presentation) must be a factorial design with two manipulated independent variables.
2. The project must identify an effect from the literature that can be measured by one of the independent variables. For example, the choice of effect could be the Stroop effect, in which case the first independent variable would be congruency (congruent vs. incongruent).
3. The second independent variable will involve a manipulation intended to influence the size of the effect under investigation. The manipulation could be intended to increase the size of the effect relative to an established condition, or to decrease or eliminate the the effect. For example, in a Stroop experiment, the second independent variable could be word-size, and the empirical question could be whether the Stroop effect is larger when the words are printed in a large font, compared to when the words are printed in a smaller font.
4. In other words, the design of the final project will attempt to produce an interaction effect.

2-3 minute individual presentation (5% of total grade)

Every student is responsible for one 2-3 minute presentation that outlines their proposal for the final project. After the presentation, students will form groups, and the groups will decide on a particular proposal for the final project (from the presentations, or a new proposal)

Each individual presentation at a minimum should accomplish the following:

- Describe the effect that will be studied
- Describe the proposed manipulation that will influence the effect
- Show the predicted results in a graph
- Explain the hypothesis or theory that would lead you to predict those results

Presentations should be made in powerpoint. You are allowed to develop any kind of experiment that interests you. However, your experiment must involve a factorial design.

APA style research report (15% of total grade)

Every student will be responsible for reporting the findings of their group experiment in an APA style research report. The paper should

have a minimum of 5 pages, and should include an introduction, methods section, results section, discussion, and reference section. The paper should contain at least 3 citations to relevant papers from the psychological literature. The format of the paper will be identical to all of the previous labs. The paper is not a group assignment. Each student will write their own paper.

10 minute group presentation (5% of total grade)

After data collection and data analysis has taken place, each group will be responsible for presenting their findings. The group presentation should last approximately 10 minutes. The group presentation should be shared amongst the members of the group, with each member responsible for presenting a section of the material. The following material should be covered in the presentation:

- Explain relevant background knowledge
- Explain the hypothesis under investigation
- Explain the proposed design of the experiment
- Explain the predicted findings of the experiment
- Explain the actual findings
- Discuss the meaning of the findings as they relate to the hypotheses under investigation.

Statistical Analysis And Reporting

MEMORY... IS THE DIARY THAT WE ALL CARRY ABOUT WITH US.

—OSCAR WILDE

Excel Tips

This document gives a brief introduction to using excel for data analysis. The guide covers basic excel operation, formula use, and pivot tables. Many first time users will find aspects of excel confusing, this guide is intended to give you enough basic knowledge to get you started. There are extensive help guides published on the internet, and if you find yourself confronted with a problem that is not discussed here you will often find valuable help by searching Google for the answer. If you have suggestions for excel tips that should be included in this document please let your lab instructor know.

What is Excel?

Excel is a spreadsheet tool. It allows you to organize and analyze data that are stored in column and row format. Excel is extremely powerful. With enough know-how almost all of the data analysis that statistics programs like SPSS are built for, can be accomplished directly in Excel.

What is Excel used for in this course?

You can use excel (or another spreadsheet program) to:

- Store your data,
- to perform basic analysis of your data (e.g., getting averages and standard deviations, computing correlations etc.), and
- to create figures, graphs, and tables to present your data.

Using Excel

The excel window

Excel is a spreadsheet that contains different rows (the numbers), and different columns (the letters). The individual cells can be used to hold data in the form of numbers or letters, to analyze data, and to report data using tables and figures.

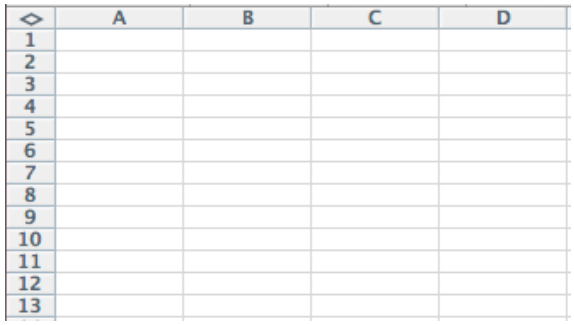


Figure 1: The excel window

Inputting data

Type or paste individual numbers or letters into individual cells, and then press return.

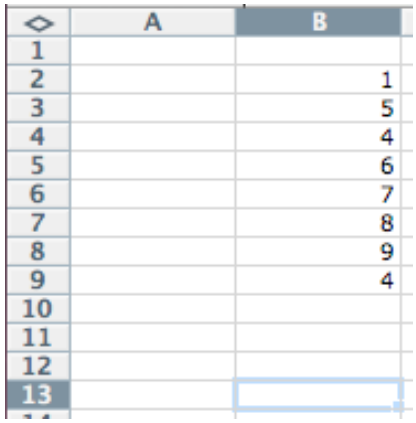


Figure 2: Inputting data

Addressing cells

Excel uses a Letter-Number system to address or point to specific cells. As you can see, all of the numbers in this example have been added to rows 2-9 in Column B. Using the Letter- Number system, the B2=1, B3=5, B4=4, B6=7, and so on.

Setting one cell to equal another

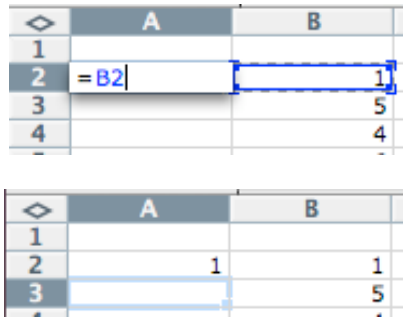


Figure 3: Making one cell equal another

If you click on an empty cell, you can make this cell have the same contents as another cell by typing the (=) sign, then clicking on the cell you want to duplicate. E.g., click on A2, type (=), then click on B2. B2 initially had a 1 in it, now when you press enter, cell A2 will also have a 1 in it. Now if you change the contents of B2 to another number (say 5), the contents of A2 will also change to 5. Note: this trick becomes handy later on to help you quickly manipulate data in excel

Adding cells together, and copying commands across other cells

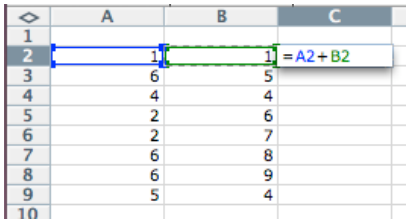


Figure 4: Adding

Let's say you had two columns of numbers. For each row you want to compute the sum of the first and second number (e.g., the first two numbers are 1 and 1, you want to add them together to get 2. Click on a new column (C2) and type the equal sign = Now click on A2 (which contains 1) once with the mouse, and then click on B2 (which also contains 1). Now the formula in C2 will automatically contain =A2+B2 When you press enter the two numbers will be summed, and the answer in C2 with be 2.

If you want to do the same operation for all of the rows, all you have to do is click on C2. Notice there is a little blue square at the bottom right hand corner of the cell.

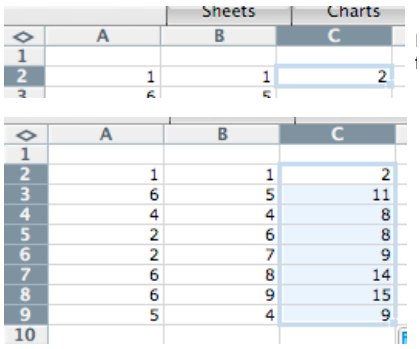


Figure 5: Applying across cells

Using a formula to add two numbers together

You can do the same addition operation from above by using the sum formula. In this example you would click on C2, then type =sum(Then you need to tell excel the range of columns and rows that you want to sum over. In this case you can just click on A2, and drag across to B2. This will make a temporary blue rectangle, which represents the cells that will be summed together Complete the formula by using the) Then press enter, and you will get the answer.

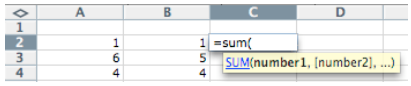


Figure 6: Adding using the sum formula

You can also copy this formula down across the other cells in the same way as above If you click on the little square, then drag down, the formula will be applied to each of the rows. And, then you have all the answers without having to enter the formula separately for each row.

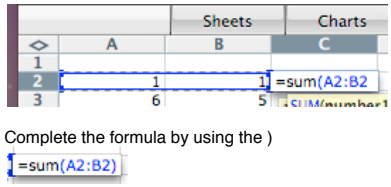


Figure 7: Completing the formula

Getting an average

Using the same method as the sum formula, you can also compute the mean of a set of numbers by using the average function instead of the sum function. The process is the same. Select a cell, type =average(then select the cells you want (in the example B2:B9) and press enter.

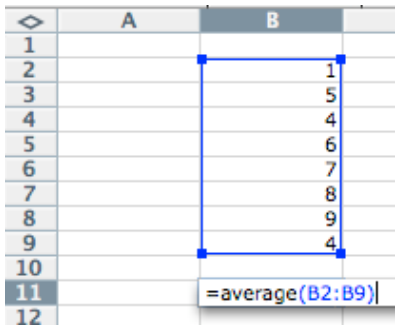


Figure 8: The average formal

Other formulas

- Max âĂŞ finds the biggest number
- Min- finds the smallest number
- Stdev- computes the standard deviation
- Countif âĂŞ counts the number of times a specific value occurs

Excel has a dictionary of other functions that may be useful, you can look them using help, or using insert: function, from the menu.

Selecting a range of cells

Formulas usually require you to enter a range of cells to compute. The format is put the upperleftmost cell first (e.g., A2), and then the bottomrightmost cell last (e.g., C9). So, A2:C9 would signify the following rectangle.

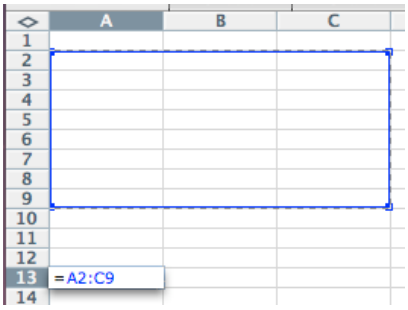


Figure 9: selecting a range

Copying a formula to another cell: relative coordinates

If you were to now select cell A13 it would have the formula =A2:C9 inside. If you copied this cell, and then pasted it into the cell beside it A14, Excel would automatically move the rectangle over one. This

is because without further specification, excel always treats cells in relative coordinates.

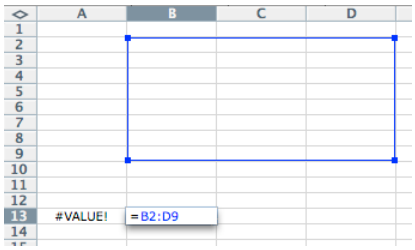


Figure 10: Relative coordinates

Absolute coordinates

You can control whether or not excel uses relative coordinates. When you set the range you can insert the $ sign to make sure that excel holds the rectangle in place. For example: A13 =A2:C9 -this formula has no $s, as in the above example, if you copy this formula to another cell say B13, then B13=B2:D9, and not the original A2:C9 A13=$A$2:$C$9 -This formula has $s infront of both letter and number for each cell in the rectangle. Now, when the formula is copied to another cell, the original rectangle will be used. E.g., B13=A2:C9 You can set the only columns or the row or both to absolute coordinates using the $ sign.

Sorting data

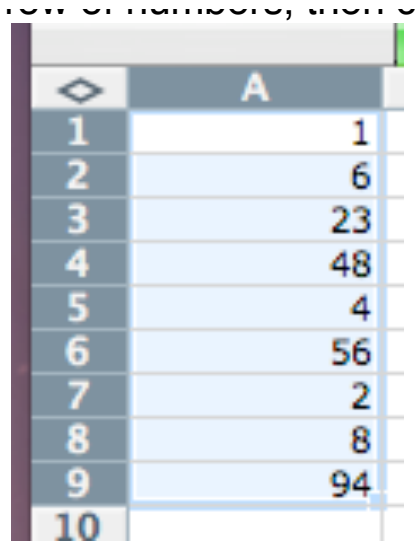


Figure 11: Some numbers to sort

If you had a bunch of numbers in random order, you could easily

sort them by selecting the column or row of numbers, then click on Data from the menu, and choose sort:

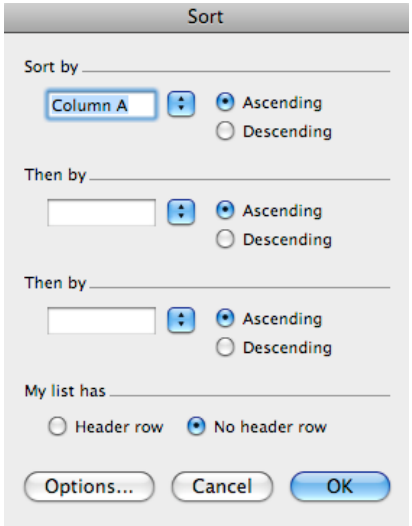


Figure 12: Sorting

You will see a menu something like this. You can choose to sort the current column ascending (smallest to largest) or descending (largest to smallest). Click OK and the data will be rearranged in order.

Making a histogram

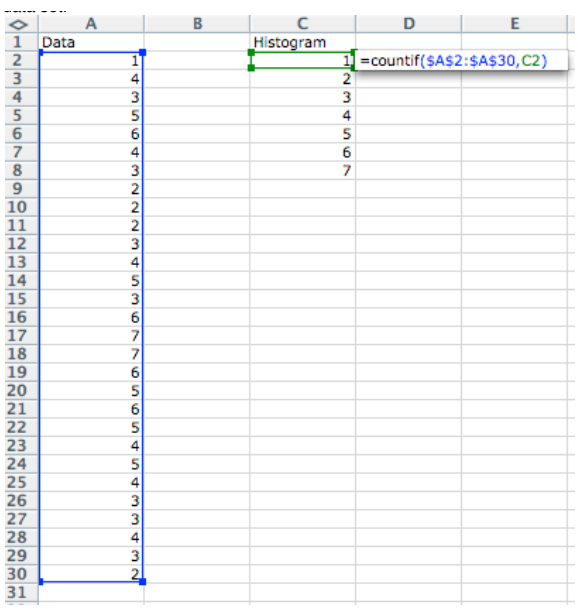


Figure 13: Making a histogram

If you want to know how many responses occurred for a particular

range of values you can create a histogram. The following example is a very simple way to count individual categories of values in a data set. Column A has the example data. In column C, I created cells with values ranging from 1 to 7 (Cells C2 : C8). In cell D2, I typed in the countif(range,value) formula. The range refers to the selected data ($A$2:$A$30).

Note, there are $ signs used before the letter and numbers so that the selected data will be the same when the formula is copied. In this case, it is the value 1, which is in Cell C2. The value refers to the entity that is being counted. When you press enter, excel will compute the number of times that 1 appears in the data. You can now drag cell (D2) with the formula down, and it will be used to count the rest of the numbers.

Making a table

C	D
Histogram	Frequency
1	1
2	4
3	7
4	6
5	5
6	4
7	2

Figure 14: Making a table

Now that you have the frequency of each of the values from 1-7. You can make a graph by selecting the column with the frequencies in it, and then click on INSERT, from the menu, and choose chart. Select a column chart, and then you will see: You can then edit this chart. You should insert a title for the figure, an x-axis label (e.g., the numbers on the bottom represent different categories from the data), and a y-axis label (the numbers on the left side represent the frequency count).

Paired Samples T-test

Suppose you ran an experiment with one independent variable that has 2 levels. You used a within- subject design so each participant contributed data to each of the 2 levels. You want to find out if there

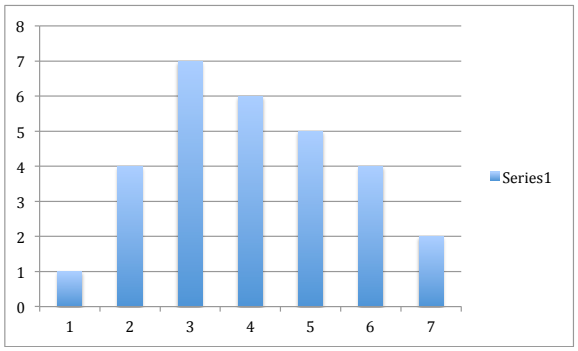


Figure 15: A figure for the histogram

was significant effect. That is, is the mean performance in Level 1 different from mean performance in Level 2. An appropriate test is the paired-samples t-test. Here is some sample data in Excel. and the number 1 tells excel to use a paired samples t-test. The resulting p-value is <.05 so we now know that there was a significant effect. The means for level 1 were significantly smaller than the means for level 2.

	A	B	C	D	E
1					
2		Independent Variable 1			Difference
3	Subject	Level 1	Level 2		Level 1- Level 2
4	1	190	209		19
5	2	181	218		37
6	3	166	214		48
7	4	162	164		2
8	5	164	191		27
9	6	161	164		3
10	7	194	198		4
11	8	179	183		4
12	10	194	214		20
13	11	157	173		16
14	12	166	169		3
15	13	197	171		-26
16	14	171	171		0
17	15	194	190		-4
18	16	177	186		9
19					
20	Means	176.866667	187.666667		10.8
21					
22	T-test	0.03501425			

Figure 16: t test in excel

Tip: Even before you run a paired samples t-test you should have a good idea whether the test will be significant. You can get a ballpark estimate by computing the differences between means for each subject. This has been done in the example under the column labeled Difference. Here, the mean for level 1 has been subtracted from the mean for level 2 for each subject. This gives us a difference score. Look at all of the difference scores. You will see that almost all of them (except for 2) are positive. So, most of the subjects showed the effect. As a ballpark rule, when most of the subjects show the effect

you should expect that a t-test will likely show a significant result.

SPSS

Paired Samples T-test in SPSS

	Lev1	Lev2
1	187.00	173.00
2	174.00	218.00
3	182.00	207.00
4	197.00	209.00
5	163.00	190.00
6	196.00	168.00
7	160.00	196.00
8	150.00	214.00
9	198.00	190.00
10	165.00	202.00
11	193.00	160.00
12	156.00	171.00
13	178.00	198.00
14	153.00	173.00
15	176.00	188.00
16	154.00	189.00

Figure 17: Copy the data into SPSS

1. Copy the data for each level of the independent variable into separate columns in the data editor. In the example I've given new names (lev1, lev2) to each of the conditions.

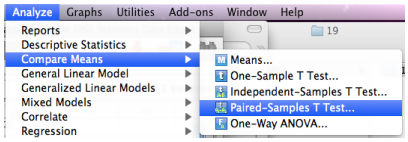


Figure 18: Choose t-test

2. Next,choose analyze from the menu, select Compare Means, then select Paired-Samples T Test
3. You will see the following menu. Select both of your variables (Lev1, Lev2) then press the arrow button to move them into the paired variables list
4. It should look like this... now click the button for the analysis
5. The first box shows basic descriptive statistics, means, number per cell, standard deviation and standard error of the mean.

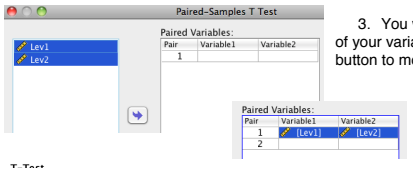


Figure 19: Select levels

T-Test

[DataSet0]

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Lev1	173.8750	16	17.01323	4.25331
	Lev2	190.3750	16	17.47331	4.36833

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Lev1 & Lev2	16	-.162	.549

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	Lev1 - Lev2	-16.50000	26.28815	6.57204	-30.50796	-2.49204	-2.511	15	.024

Figure 20: ttest output

6. The third box shows the t-value, the associated degrees of freedom (df), and the p- value (Sig. (2-tailed)

7. Here's how you write up your results in one sentence.

8. Means were significantly smaller for level 1 (174) than level 2 (190), $t(15) = 2.51$, $p<.05$.

2 x 2 Repeated Measures ANOVA

From Data to Analysis

Suppose you ran an experiment with 2 independent variables, each with 2 levels. If this is a within- subject design, each participant will contribute data to each of the 4 levels in the design. The appropriate test is a 2x2 repeated measures ANOVA. We begin by looking at the data in excel.

1. All of the four conditions are placed into 4 separate columns. The second IV is nested underneath the first IV.

2. The means and standard deviations can be computed directly in excel for each of the conditions

3. The means are then organized in a table, and a figure can be created so that we can see the pattern of results.

4. Main effects: It looks like there are two main effects. One for IV1: level 1 is smaller than level 2. One for IV2: level 1 is smaller than level 2

5. Interaction:It looks like there is an interaction. The difference

	A	B	C	D	E
1					
2		IV1 Level 1		IV1 Level 2	
3	Subjects	IV2 Level 1	IV2 Level 2	IV2 Level 1	IV2 Level 2
4	1	491	488	660	747
5	2	462	471	617	761
6	3	480	479	696	772
7	4	494	479	666	778
8	5	458	512	687	752
9	6	486	515	696	743
10	7	486	512	615	744
11	8	478	506	630	706
12	9	489	498	670	778
13	10	479	517	688	719
14	11	469	475	637	704
15	12	456	496	664	706
16	13	475	513	659	798
17	14	458	510	656	780
18	15	497	500	697	753
19	16	482	513	609	703
20					
21	Means	477.5	499	659.1875	746.5
22	Standard Deviation	13.3716117	15.8577005	30.0404588	31.0333154
23					
24					
25			IV1 Level 1	IV1 Level 2	
26		IV2 Level 1	477.5	659.1875	
27		IV2 Level 2	499	746.5	

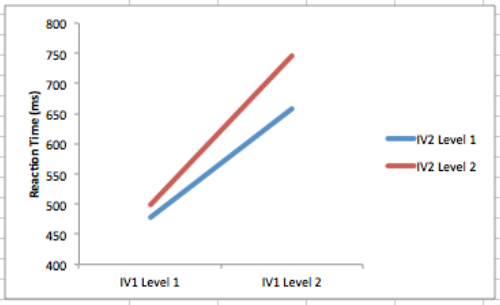


Figure 21: Sample data for a 2 x 2 factorial design

between L1 and L2 of IV1 is larger for level 1 of IV2 (in red) than level 2 of IV2 (in blue).

6. We need to run a 2x2 repeated measures ANOVA to determine whether the main effects are significant, and to determine if the interaction is significant.

2x2 Repeated measures ANOVA in SPSS

	Iv1L1_Iv2L1	Iv1L1_Iv2L2	Iv1L2_Iv2L1	Iv1L2_Iv2L2
1	491.00	488.00	660.00	747.00
2	462.00	471.00	617.00	761.00
3	480.00	479.00	696.00	772.00
4	494.00	479.00	666.00	778.00
5	458.00	512.00	687.00	752.00
6	486.00	515.00	696.00	743.00
7	486.00	512.00	615.00	744.00
8	478.00	506.00	630.00	706.00
9	489.00	498.00	670.00	778.00
10	479.00	517.00	688.00	719.00
11	469.00	475.00	637.00	704.00
12	456.00	496.00	664.00	706.00
13	475.00	513.00	659.00	798.00
14	458.00	510.00	656.00	780.00
15	497.00	500.00	697.00	753.00
16	482.00	513.00	609.00	703.00

Figure 22: Copy data into SPSS

1. Copy the data into SPSS. Make sure each column represents a different condition in the design.

2. Give names to each of the variables. The first column represents IV1 Level1 & IV2 Level 1. The second column represents IV1 Level 1 & IV2 Level 2. The third column represents IV1 Level 2 & IV2 Level 1. The fourth column represents IV1 Level 2 & IV2 Level 2.

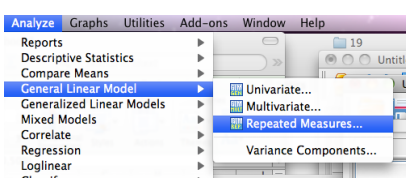


Figure 23: Choose the model

3. Choose Analyze, General Linear Model, Repeated Measures from the menu.

4. Name IV1, specify 2 levels

5. Name IV1, specify 2 levels

6. Name dependent variable, click define

7. Select all four conditions, press the first right arrow, if you want more options see below, otherwise press ok.

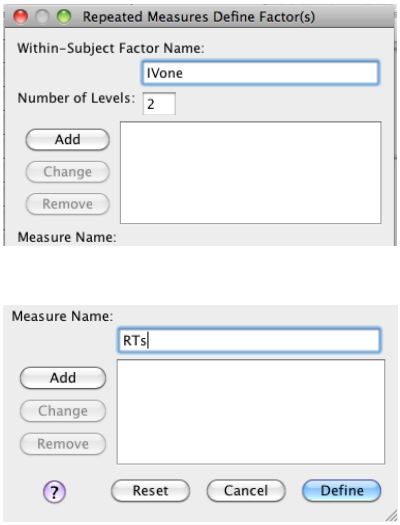


Figure 24: Name variables

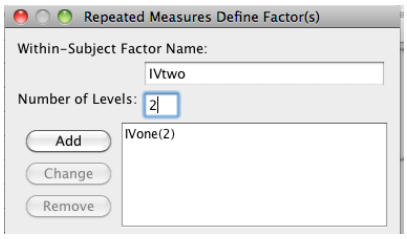


Figure 25: thing a

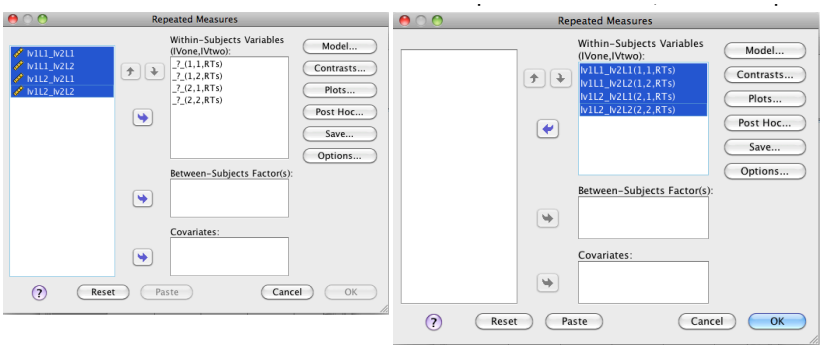


Figure 26: Select conditions

8. If you pressed options, then you can ask SPSS to report descriptive statistics for each condition. Choose the factors that you want, then press the arrow button to move them into the display means field. Make sure you click descriptive statistics. Then click continue.

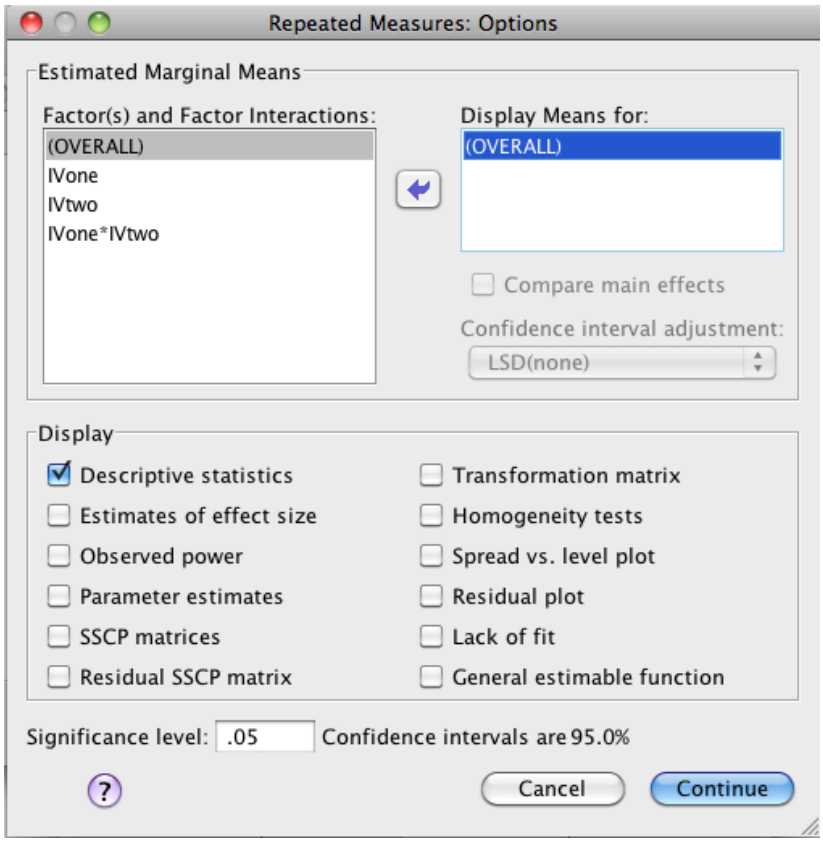


Figure 27: Option to report descriptive statistics

Finding numbers in the SPSS analysis output

SPSS gives you lots of information, you need to know what you are looking for. When you report the results from a 2x2 ANOVA, you will have 2 main effects, and 1 interaction. This means you will be looking for 3 F-values, 3 MSEs (Mean squared error terms), and 3 associated p-values. You will also need to know the means for the main effects and the means for the interaction.

If you chose the option for descriptive stats, then you will see a small table with Means and standard deviations for each condition in the design. You will use these means to compute averages for the main effects. You will use these means to report the pattern for the interaction.

Figure 28: Descriptive Statistics

Descriptive Statistics

	Mean	Std. Deviation	N
Iv1L1_Iv2L1	477.5000	13.37161	16
Iv1L1_Iv2L2	499.0000	15.85770	16
Iv1L2_Iv2L1	659.1875	30.04046	16
Iv1L2_Iv2L2	746.5000	31.03332	16

The ANOVA table

All of the information that you need to report main effects and interactions is available in the "tests of within-subjects effects" table.

Figure 29: ANOVA table

Tests of Within-Subjects Contrasts

Measure:RTs

Source		IVtwo	Type III Sum of Squares	df	Mean Square	F	Sig.
IVone	Linear		736807.641	1	736807.641	1122.371	.000
Error(IVone)	Linear		9847.109	15	656.474		
IVtwo		Linear	47360.641	1	47360.641	124.916	.000
Error(IVtwo)		Linear	5687.109	15	379.141		
IVone * IVtwo	Linear	Linear	17325.141	1	17325.141	36.890	.000
Error(IVone*IVtwo)	Linear	Linear	7044.609	15	469.641		

Main effect for IV 1

Each main effect is listed under source. Each main effect has a corresponding error term listed below. The source for the main effect of independent variable 1 is labeled IV one. You will see it has a corresponding df of 1, an F-value of 112.371, and a p-value <.05. This main effect is significant. You would report this in the following way.

The main effect for independent variable 1 was significant, $F(1,15) = 112.371$, $MSE = 656.47$, $p<.05$.

The 15 comes from the df from the error term for IVone. As well, the MSE (656.47) comes from the Mean Square from the error term. When you report the main effect, you will also need to report the pattern. The above sentence simply tells the reader that there was a significant difference between the levels of IVone, however it does not explain whether level 1 was larger or smaller than level 2. To report the main effect you will need to compute the averages for each level of IVone. You can do this directly in excel, or you can have SPSS

compute these numbers for you by checking the appropriate options before running the analysis. You will need all of the numbers from the above descriptive statistics table.

First, we find the average for level 1 of IVone (477.5 + 499)/2 = 488

Second, we find the average for level 2 of IVone (659.1875 + 746.5)/2 = 703

Now we can write a complete description of the main effect for IVone.

The main effect for independent variable 1 was significant, F(1,15) = 112.371, MSE = 656.47, p<.05. Mean performance was lower for level 1 (488) than level 2 (703).

Main effect for IV 2

Following the same steps as above we look for IV two in the source table and find the dfs, the F-value, the MSE for the error term, and the p-value.

The main effect for independent variable 2 was significant, F(1,15) = 124.92, MSE = 379.14, p<.05. Mean performance was lower for level 1 (568) than level 2 (623).

The interaction effect

Reporting the interaction uses the same information that you would use to report the main effect. The interaction is listed in the source table as IVone*IVtwo. It has corresponding dfs, F-value, MSE for the error term, and a p-value.

The interaction between independent variable one and two was significant, F(1,15) = 36.89, MSE = 469.64, p<.05. The difference between level one and level two for independent variable two was smaller for level one (499 - 478 = 21) than level two (747 - 659 = 88) of independent variable 1.

Post Hoc Tests to interpret the interaction

Post hoc tests are used to clarify the nature of the interaction. In the above example we found a significant interaction. The difference between level 1 and level 2 for IV two was 21 and 88 for level 1 and level 2 of the first independent variable. The significant interaction tells us that 21 and 88 are significantly different from each other. However, we still do not know whether each comparison is significant in an of itself. For example it may be the case that the difference between level 1 and level 2 for IV 2 was only significant for the 2nd level of IV1 (88), and not significant for the 1st level of IV1 (21). In this example you can run a paired t-test, or a one-way repeated mea-

sures ANOVA on the specific comparison that you are interested in. For example, you would compare the means from IV1L1/IV2L1 and IV1L1/IV2L2. This comparison would test whether the difference of 21 that was found was actually significant from 0. You will report the statistics for the post-hoc tests in the same manner as you would report t-tests, or F-statistics from the above examples.

Writing An APA Style Paper

MEMORY... IS THE DIARY THAT WE ALL CARRY ABOUT WITH US.

—OSCAR WILDE

How to write a research report

Bean, J. C. (2001). Engaging ideas: The professorâĂŹs guide to integrating writing, critical thinking, and active learning in the classroom. San Francisco: Jossey-Bass Publishers

A formal scientific research report is a piece of professional writing addressed to other professionals who are interested in the investigation you conducted. They will want to know why you did the investigation, how you did it, what you found out, and whether your findings were significant and useful. Research reports usually follow a standard five-part format: (1) introduction, (2) methods, (3) results (4) discussion of results, and (5) conclusions and recommendations.

Introduction

Here you explain briefly the purpose of your investigation. What problem did you address? Why did you address it? You will need to provide enough background to enable the reader to understand the problem being investigated. Sometimes the introduction also includes a âĂIJliterature reviewâĂİ summarizing previous research addressing the same or a related problem. In many scientific disciplines, it is also conventional to present a hypothesisâĂŤa tentative âĂIJanswerâĂİ to the question that your investigation will confirm or disconfirm.

Methods

This is a âĂIJcookbookâĂİ section detailing how you did your investigation. It provides enough details so that other researchers could

replicate your investigation. Usually, this section includes the following subsections: (a) research design, (b) apparatus and materials, and (c) procedures followed.

Results

This section sometimes headed âĂIJFindings,âĂİ presents the empirical results of your investigation. Often, your findings are displayed in figures, tables, graphs, or charts that are referenced in the text. Even though the data are displayed in visuals, the text itself should also describe the most significant data. (Imagine that the figures are displayed on a view graph and that you are explaining them orally, using a pointer. Your written text should transcribe what you would say orally.) Your figures and tables must have sufficient information to stand along, including accurate titles and clear labels for all meaning-carrying features.

Discussion of results

This is the main part of the report, the part that will be read with the most care by other professionals. Here you explain the significance of your findings by relating what you discovered to the problem you set out to investigate in your introduction. Did your investigation accomplish your purpose? Did it answer your questions? Did it confirm or disconfirm your hypothesis? Are you results useful? Why or why not? Did you discover information that you hadnâĂŹt anticipated? Was your research design appropriate? Did your investigation raise new questions? Are there implications from your results that need to be explored? The key to success in this section is to link your findings to the questions and problems raised in the introduction.

Conclusions and recommendations

In this last section, you focus on the main things you learned from the investigation and, in some cases, on the practical applications of your investigation. If your investigation was a pure research project, this section can be a summary of your most important findings along with recommendations for further research. If your investigation was aimed at making a practical decision (for example, an engineering design decisions), here you recommend appropriate actions. What you say in this section depends on the context of your investigation and the expectations of your readers.

APA style

The next sections provide information about APA style, and an example research report written in APA style.

APA style formatting

Centered Title of Paper Every First Letter Capitalized

Your Name

College Affiliation

Abstract

No indentation and 120 words maximum for this section. See Pages 12-14 APA guide. Describe problem in one sentence. Participants and characteristics. Method and procedures. Findings. Conclusions, implications, application. Double spaced. Words here will be used as index for subject searches. Replication of another study? Define all abbreviations. Concise yet maximally informative overview of manuscript.

Centered Title of Paper Every First Letter Capitalized

Indent first line of each paragraph. Introduce the problem in first paragraph. Why problem important? Implications? Arguments?

Discuss previous research bearing on this subject. Devote one or two paragraphs to each article. Relationship of previous research to present work. Assume reader is knowledgeable about the field but relate important info from previous study.

Last paragraph or two explaining current study's approach to the problem. Define variables and formal statement of hypothesis. Why expect outcome?

The introduction can often have subsections that are given headings. As well, all remaining sections of the manuscript include major sections such as Method, Results, Discussion, etc. Some of these sections can have subsections, for example the Methods section might have the subsections, Participants, Materials, and Procedure. In the sixth edition of APA, unlike earlier editions, these sections should be bolded (but not the title above, or anything on the title page). For example:

Heading Level 1

Heading Level 2

Heading Level 3 (note the Indent, Bold and Period).

Heading Level 4.

Heading Level 5 (Hopefully you don't need this many headings).

These Heading styles are used for the rest of the sections

Method

Participants or Subjects

Describe important characteristics of sample. Include demographic information important for replication or if it is a variable in the study. Age, gender, education, disability, paid or not, SES, animals, etc.

Materials or Apparatus

Describe materials and equipment used such that study can be replicated with same materials and equipment.

Procedure

Summarize each step in the execution of the research. Instructions given, randomization, design, etc.

Entire Method section should focus on relevant information needed to adequately replicate study. If there are any, identify subsections with italicized script as demonstrated above. See pages 17-20 APA guide. The method, results, and discussion sections do not start on a new page unless section heading would appear alone at the bottom of a page.

Results

Summarize data collected and statistical results. Do not mention raw data unless maximally informative. If tables and figures will be used they will be referenced from this section. Explain tables and figures and results but do not discuss implications. Report relevant descriptive statistics (means, standard deviations, sample size, correlations), inferential statistics (within or between subjects, ANOVA, *t* or *F* test, etc.), and alpha levels (.05, .01) and significance if any. See pages 20-26 APA guide and details of reporting statistical text.

Discussion

Open section with clear statement of support or nonsupport of research hypothesis. How relate to previous research without restating info from introduction. If appropriate, mention importance of findings, implications, and applications.

References

Last name. Initials. (Date of pub). All lowercase title of article except first word.

Italicized Journal and volume, non italicized page numbers. All studies cited in paper appear here. Left justified first line, indented thereafter. See Refs section of APA guide for details.

Remaining Sections

On separate pages you may need to add these remaining sections, in this order: Appendix, Footnotes, Tables, Figures.

Appendix

Use the appendix to add bulky groups of information, like questionnaire questions, or stimulus lists. If you have more than one then use Appendix A, Appendix B, and so on.

Footnotes

[1]Each footnote must correspond to the same number in the body of text. Generally, footnotes should be avoided, and their content incorporated into the main body of text

Table 1

Table name goes here

The actual Table goes here

Notes. Any notes about the Table goes here.

Figure 1.

Sample APA report

Symbolic Cuing of Visual Attention

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Abstract

Selective attention processes allow people to process relevant information and ignore irrelevant information in a task environment. Selective attention is controlled by top-down and bottom-up factors. The current experiment investigates how meaningful symbolic information guides attention to a visual target. Participants performed a simple detection task. Visual targets appeared on the left or right of fixation. Targets were cued by an arrow stimulus that pointed left or right. Reaction time to detect the target was faster for validly than invalidly cued targets. These findings replicate the symbolic cuing effect, and demonstrate that symbolic information can guide selective attention.

Symbolic Cuing of Visual Attention

Real-world task environments are full of information that can be relevant or irrelevant to current task-demands. To successfully accomplish task goals people must select relevant from irrelevant information and use relevant information to guide their actions. For example, when navigating a busy subway terminal people must correctly follow the path to their desired train while avoiding fellow travelers and alternative subway routes. In the subway example, signage is an important cue that travelers follow to reach their intended train. The purpose of the current experiment is to investigate how symbolic information, like signage in a subway station, guides attention to detect visual targets.

Attention refers broadly to the ability to focus on specific information. There are several factors that influence how attention is deployed in a task-environment. A common distinction is between exogenous and endogenous control over attention (for a review see, Ruz & Lupianez, 2002). Exogenous control refers to external factors that automatically attract attention. For example, highly salient perceptual information, like bright lights or loud sounds are known to orient attention toward the signal. Endogenous control refers to internal factors that control how attention is deployed. For example, people are capable of intentionally deciding to attend to particular stimuli in a display.

The Posner cuing task (or visual cuing task) is commonly used to measure exogenous and endogenous control over visual attention (Posner, 1980). In the task participants are asked to detect the onset of a visual target (e.g., a dot) that can appear on the left or right side of a computer screen. At the beginning of each trial participants view a fixation cross at the center of the screen. Following fixation a cue is presented on the left or right side of screen. Usually the cue is a small box that

flashes and then disappears. Following the presentation of the cue the target appears in one of two locations. On validly cued trials the target appears in the cued location. On invalidly cued trials the target appears in the location opposite to the cue. In many experiments the cue does not predict the location of the target. That is, 50% of the trials are valid and 50% of the trials are invalid. Nevertheless, reaction times to detect the target are influenced by the cuing manipulations. Reaction times are faster to detect validly cued targets than invalidly cued targets. This difference in reaction time is termed the cuing effect.

The above example demonstrates exogenous control over attention. The cues were small boxes that flashed abruptly on the computer screen, thereby producing a highly salient perceptual event. These visual flashes automatically attracted attention to their location. As a result, targets that appeared in validly cued locations were detected faster than targets that appeared in invalidly cued locations.

The purpose of the current experiment is to investigate whether meaningful symbolic cues can automatically control deployment of attentional resources. Rather than using abrupt visual onsets to cue target location, the current experiment employs arrow stimuli (> or <) that will be placed in the center of the screen following fixation. Arrow stimuli are interesting because they are partly exogenous and partly endogenous in nature. They are exogenous in the sense that they appear as external perceptual events. However, the arrows in this study are not highly salient. A leftward and rightward pointing arrow are fairly similar, and each arrow-type will be presented centrally. In this way when the arrow flashes on screen attention will be directed to the center of the screen and not to a potential target location. Arrows are endogenous in the sense that they convey semantic information

about direction. Arrows are symbols and people understand their meaning based on pre-experimental knowledge.

The current experiment tests the hypothesis that attention can be automatically controlled by symbolic information, like arrows, that point to a potential target location. The procedure is identical to the Posner Cuing task, with the exception that central arrows will be employed as cues rather than peripheral boxes. If arrows can automatically guide attention then validly cued targets ought to be detected faster than invalidly targets.

Method

Participants

20 Brooklyn College undergraduates participated for course credit. All participants had normal or corrected to normal vision.

Materials

The experiment was conducted on PCs (18” LCD monitor) controlled by LIVECODE. The arrow cues (> or <) were 1 cm in height and width. The target was an “x” (1cm x 1cm) that appeared 3 cm to the left or right of fixation.

Procedure

There 50 valid and 50 invalidly cued trials. On valid trials the direction of the arrow was consistent with the target location. On invalid trials the direction of the arrow was opposite to the target location. Valid and invalid trials were intermixed randomly from trial to trial.

Each trial began with a fixation cross “+” presented in the center of the computer monitor. After 500 ms the fixation cross was removed and immediately replaced by an arrow cue. The arrow cue remained on screen for 150 ms. Following removal of the arrow cue a target “x” appeared to the left

or right of fixation. The target remained onscreen until the participant detected the target by pressing the space-bar. Participants were instructed to perform the task as quickly and accurately as possible.

Results

Mean reaction time (RT) was computed for each subject in each of the valid and invalidly cued conditions. The results are presented in Figure 1. As predicted, RTs were faster for validly (150 ms) than invalidly (170 ms) cued trials, $t(19) = 5.32$, $p<.05$.

Discussion

The results of Experiment 1 show that symbolic information signaling direction can automatically orient attention toward a potential target location. This finding is interesting because it shows that salient perceptual information is not the only kind of cue that can automatically direct attention.

The current experiment restricted its investigation of symbolic cuing to arrow stimuli but there are many other kinds of cues that may also automatically orient attention. For example, the words “left” or “right” are symbols that convey directional information, and it would be interesting to investigate whether word cues also orient attention. Another kind of cue that is socially important is eye gaze. Perhaps replacing the arrow stimuli with pictures of eyes gazing to the right or to the left would produce a similar pattern of results as seen here.

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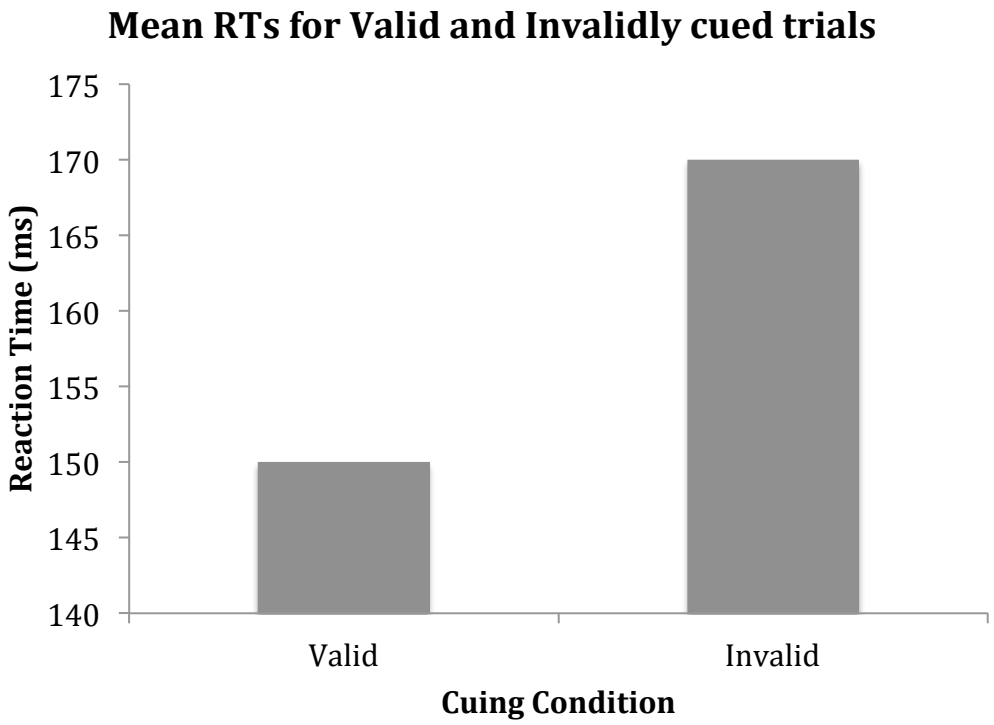
Figure 1.


Mean RTs for Valid and Invalidly cued trials
175
170
165
160
155
150
145
140
Reaction Time (ms)
Valid
Invalid
Cuing Condition

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