Week 3: Data analysis application

Commentary on this assignment

This document is available for comments and questions. Everyone in the class can comment on it, point out errors, ask clarifying questions, and add helpful resources. I will try to update things, fix mistakes, and clarify throughout the week.

You are welcome to approach this assignment however works best for you. I will offer one possible path:

1) Read through this whole document.
    a) If it is mostly things that you're familiar with, jump right in and do it, consulting resources as needed.
    b) If this feels a little overwhelming, you're not alone! This assignment throws you in feet first by asking you about the key concepts and a full application. You will probably need to do some reading/watching to develop a background understanding.

Readings and resources

- Guidelines for hypothesis testing data analysis: this document outlines a general process to follow when approaching (inferential) statistical analysis.
- Choosing an appropriate statistical test
    - This flowchart is probably the most useful for us, but this, this and this might be helpful depending on the question you're trying to answer (or you might have to search for another type of test in less common cases).
    - Detailed explanation of common test types.
    - Another explanation of types of t-tests. (Dependent and paired t-tests are the same thing. This example shows how to do this in excel, but you can easily look up how to do this in Matlab
- Hypothesis testing
    - Overview of hypothesis testing in Matlab by Mathworks
    - Khan Academy explanation of hypothesis testing (and t-tests)
    - Statistics in Matlab textbook - see Chapter 5 on hypothesis testing (starts on pdf page 138)
    - Great explanation of hypothesis testing and tradeoff between Type I and Type II errors
- Central limit theorem
    - Simulation that allows you to draw your own starting distribution and simulate taking a sample, calculating the mean, and finding the distribution of sample means

    - Khan academy video
    - Mathematical proof from U Toronto or Wolfram
- Effect sizes
    - Sections 1, 2, 3, 4, and 7 of this paper offer some effect size insights
    - https://www.youtube.com/watch?v=6uYNVCy-8NA (this is a 3 min video explaining a large effect size, with a reference to the paper above)
- Bayes and p-values
    - More on Bayesian updating - You don't need it for this assignment, but this seemed like a reasonable place to put the link
    - If you want to go pretty deep into a math/application paper about p-values and P(H|D), this paper dives in with some simulation. Not for the faint of heart (probably skip this unless you're really into the math part of things)

Skills/Knowledge we're using

- Hypothesis testing
- Choosing an appropriate statistical test
- Central limit theorem
- Analysis of data

Conceptual questions (remember to answer these)

1. Explain the central limit theorem in your own words, code, and/or illustration.
2. Describe Type I and Type II errors in your own words and in terms of conditional probabilities.
3. Describe the meaning of a p-value in your own words and as a conditional probability.
4. Explain the difference between a large effect size and a statistically significant effect. Under what conditions might you end up with one but not the other?

Data analysis

Analyze each of the following prompts with datasets using hypothesis testing. I strongly suggest that you use these guidelines to structure your analysis process. This assignment requires careful consideration of each situation. It may be helpful to sketch out the framing of the experiment and questions on paper.

For your self-assessment of constructive engagement with this assignment, please consider each step of the analysis process as its own exercise (each data set analysis has 7 exercises).

Dataset 1: Argus II retinal prosthesis

This dataset is based on a real study (Ahuja et al., https://bjo.bmj.com/content/95/4/539.full). Here are some information about the study (quoted directly or paraphrased from the original paper):

Second Sight Medical Products has developed an epiretinal prosthesis aimed at partially restoring vision to people blinded by outer retinal degenerative diseases such as retinitis pigmentosa (RP). In these diseases, while the photoreceptors are compromised and there is anatomical remodelling of the remnant retina, post mortem anatomical studies have found that some bipolar and ganglion cells survive. Multiple acute and chronic studies in normal and degenerate animal models, and in human subjects, have shown that electrical stimulation of the retina can elicit percepts (phosphenes). More recently it has been demonstrated that stimulation with multiple electrodes can yield some level of spatial vision as measured by high-contrast square-wave grating tests.

The Argus II retinal prosthesis system (Second Sight Medical Products) consists of a surgically implanted 60-electrode stimulating microelectrode array consisting of 200 μm diameter disc electrodes, an inductive coil link used to transmit power and data to the internal portion of the implant, an external belt-worn video processing unit (VPU) and a miniature camera mounted on a pair of glasses (figure 1). The video camera captures a portion of the visual field and relays the information to the VPU. The VPU digitises the signal in real-time, applies a series of image processing filters, down-samples the image to a 6×10 pixelised grid, and creates a series of stimulus pulses based on pixel brightness values and look-up tables customised for each subject. The stimulus pulses are delivered to the microelectrode array via application-specific circuitry and a superior-temporally placed inductive radio frequency coil link allowing for wireless forward and reverse telemetry between intra and extra-ocular portions of the system.

An experiment was used to evaluate the effectiveness of the system. In the experiment, white square stimuli (5.85 cm2, 200 pixels2, 221 cd/m2) were displayed in random locations on a 19″ (48.3 cm) LCD touch screen monitor located 12″ (30.5 cm) in front of the subject (subtending a visual angle of 10.9°). After the onset of the square and an auditory prompt, the subjects were instructed to locate and touch the square centre. The program provided verbal feedback after subject's responses indicating ‘correct’ for a touch anywhere on the square and ‘close’ for a touch within 100 pixels (2.9 cm) of the edge of the square. Corrective feedback was given after ‘close’ and incorrect responses. For example, a response 6 cm to the left of and 4 cm below the stimulus square prompted the response ‘It was higher and right.’

Before the test was administered, 10 trials were presented in ‘training mode’ to familiarise the subject with the position and vertical and horizontal extent of the monitor. In this mode subjects

defined the location of the square centre by pressing the blank touch screen monitor; a 5.85 cm square appeared at that location until subjects touched another part of the monitor. The subjects' cameras were aligned with respect to the monitor centre. Experiments consisting of 40 trials were run with both the system on and off (80 trials total per subject). The subjects' eyes were not patched in either condition; in system off testing the subjects did not wear the Argus II system glasses.

The data in this study contain the mean (over 40 trials) of the difference between the target (white square stimulus) and the location that the subject touched the screen. These means are reported for each subject, separately for the “system on” and “system off” condition.

Data are here:
https://drive.google.com/file/d/1LKfocBj7tU0py-jUP5dC_5o-SSum_TwW/view?usp=sharing

As an outside evaluator, please evaluate the effectiveness of this system, including at least: one measure of effect size, one figure, one measure of statistical significance, and a written description of your results (APA formatting not required, but please think carefully about your words). Is any potential improvement observed here due to random chance?

Dataset 2: MagStimVis

A new alternative method called Localized Magnetic Stimulation for Visual Representation (MagStimVis). This theoretical method uses highly targeted transcranial magnetic stimulation to excite the occipital cortex and create visual phosphenes. This is a hypothetical, as currently, transcranial magnetic stimulation cannot incite activity in the brain with this level of precision, however people are doing interesting work in this space. The MagStimVis method is far less invasive, as it does not require any surgery. The user wears a camera and a stimulation cap. The data here () are generated from the following hypothetical experiment:

Blind participants are divided into **2 groups, those that receive the device and those that do not.** The participant did a similar test to the white square touch test described above. The screen was bigger and farther away, so the numbers of pixels are different (you can’t directly compare pixel numbers between the two experiments). The numbers reported in the data represent the improvement in the average distance between the first trials and the last trials in the experiment for each person. Positive values mean that the person got better at the task by the end of the experiment.

Data are here:
https://drive.google.com/file/d/1lzRoehkwg2dTq1m8CGZUgfG95z7aXNmu/view?usp=sharing

As an outside evaluator, please evaluate the effectiveness of this system, including at least: one measure of effect size, one figure, one measure of statistical significance, and a written description of your results (APA formatting not required, but please think carefully about your words). Is any potential improvement observed here due to random chance?

Comparison and recommendation

Please compare these two options: Argus II and MagStimVis. Assuming someone was fine with surgery, which of these systems would you recommend based on the results of your analysis. Use specific measurements to justify your recommendation.