Analysis of Psychological Data

Lab 6. Think Like a Scientist: Hypothesis Testing and Z-Test

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Some announcements

Homework 4 is due on March 15 (next Tuesday)

Don't forget to submit it on CatCourses

We don't have a lab on March 16 (next Wednesday)

Spend your time studying Exam 2

Exam 2 is on March 17 (next Thursday)

You know what to prepare for... right?

Some announcements

Exam 2 is on March 17 (next Thursday)

Big and red scantron forms

Pencil and eraser to fill in scantrons

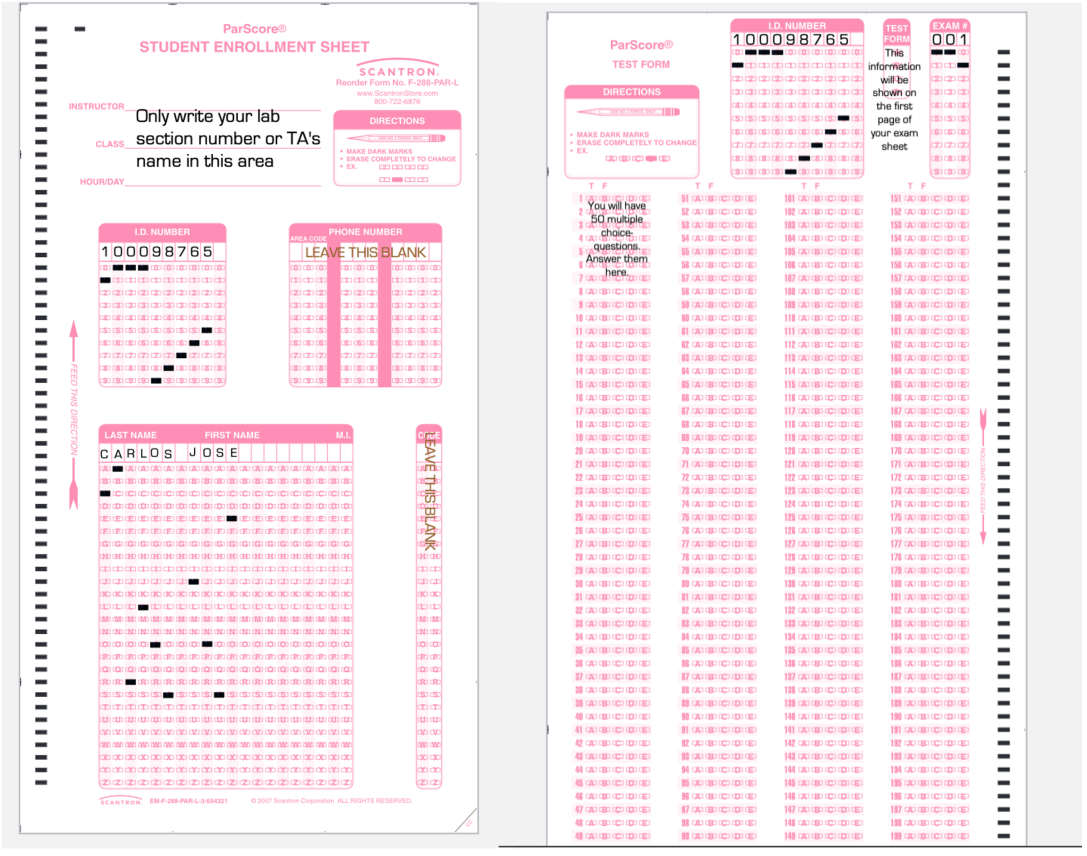
Blank scratch paper

Class-approved calculator

One 8.5 x11 crib sheet (i.e., a concise set of notes, could be double-sided)

Some announcements

Big and red scantron forms



What are we going to do?

Recap to give you a big picture

Hypothesis testing

Z-test

...and a bit more for your exam (power, effect size)

Do it together

Q&A session for homework 4

Statistical inference

Idea 1

Let's make a best guess about the population parameter and test if that guess is true
$\longrightarrow$ Estimation and hypothesis testing
$\longrightarrow$ Our best guess is a sample mean (estimation), and let's test the probability of observing this sample mean or more extreme if the null hypothesis were true (hypothesis testing)

Idea 2

Let's assume we are interested in one sample mean and have the distribution of all the possible sample means
$\longrightarrow$ Sampling distribution of the mean

Hypothesis testing

In a nutshell

A form of statistical inference to draw conclusions about population parameters using sample statistics (e.g., sample means)

How science is conducted and advanced

One of my research interests is Bayesian hypothesis testing

But... we learn frequentist hypothesis testing,
a.k.a., **Null Hypothesis Significance Testing (NHST)** :)

Hypothesis testing

From now on, let me explain a general procedure to you

Step 1. State null and alternative hypothesis (from your research question)

Step 2. Select the level of significance, i.e., α

Step 3. Compute the test statistic (e.g., z-statistic)

Step 4. Make a statistical decision $\longrightarrow$ reject or not reject the null hypothesis

Step 1. State null and alternative hypothesis

Definition of a hypothesis

Given an observation, a phenomonen, or a scientific problem,
a statement or proposed explanation about the value for a population parameter

Null Hypothesis Significance Testing

We need a null hypothesis and an alternative hypothesis

Step 1. State null and alternative hypothesis

Start from your research question
"Are UC Merced students friendlier than most other people?"

Null hypothesis $\longrightarrow$ nothing is going on; we want to reject this!

H_0: UC Merced students are equally as friendly as or less friendly than most other people
$\rightarrow \mu_{UCM} \leq \mu_{other\ people}$

Alternative hypothesis $\longrightarrow$ something is going on; we hope to retain this!

H_1: UC Merced students are more friendlier than most other people
$\rightarrow \mu_{UCM} > \mu_{other\ people}$

Step 1. State null and alternative hypothesis

Depending on research questions, alternative hypotheses can be...

Directional: expect one group might be greater or less than the other $\longrightarrow$ one-tailed

- Is the height of giraffes bigger than polar bears?
  - $H_0 : \mu_{giraffes} \leq \mu_{polar\ bears}$
  - $H_1 : \mu_{giraffes} > \mu_{polar\ bears}$

Non-directional: focus on only whether there are differences $\longrightarrow$ two-tailed

- Does playing music when studying have a different effect on concentration than without music?
  - $H_0 : \mu_{music} = \mu_{no\ music}$
  - $H_1 : \mu_{music} \neq \mu_{no\ music}$

Step 2 & 3. Select α and compute the test statistic

Go back to our example

Say we found that the mean friendliness score was much higher among UC Merced students (Mean = 130) compared to the score in other people (Mean = 100)

To compare these means...

Select the level of significance, i.e., α, which is usually .05 (5%)

Compute the test statistic and obtain the *p*-value
$\longrightarrow$ If we know the population standard deviation, we use a z-statistic

Step 4. Make a statistical decision

Say our p-value is .03

There is a 3% chance of getting our sample mean (or more extreme) if the null hypothesis were true (We can still get this sample mean if the null hypothesis is true!)

Note that we usually set α to .05

Very common in psychology

Step 4. Make a statistical decision

If our p-value is lower than α, we reject the null hypothesis!!!

H_0: UC Merced students are equally as friendly as or less friendly than most other people $\rightarrow \mu_{UCM} \leq \mu_{other\ people}$

H_1: UC Merced students are more friendlier than most other people $\rightarrow \mu_{UCM} > \mu_{population}$

Step 4. Make a statistical decision

Wait! Revisit statistical decisions...

Danniela found that UC Merced students are friendlier. However, **what if UC Merced students are actually not friendlier?**

Emerald found that UC Merced students are not friendlier. However, **what if UC Merced students are actually friendlier?**

These imply that there can be errors in statistical decision making

Type I error

Rejecting the null hypothesis when it is true

Type I error rate is the alpha (i.e., α)

False positive

We think we detected an effect, but in reality, there is not

Example?

- An allergy test says you are allergic to cats, but you are not. As a consequence, you do not adopt a cat.
- Convict an innocent person of a crime

Type II error

Failing to reject the null hypothesis when it is false

Type II error rate is the beta (i.e., β)

False negative

We did not detect an effect, but in reality, there is

Example?

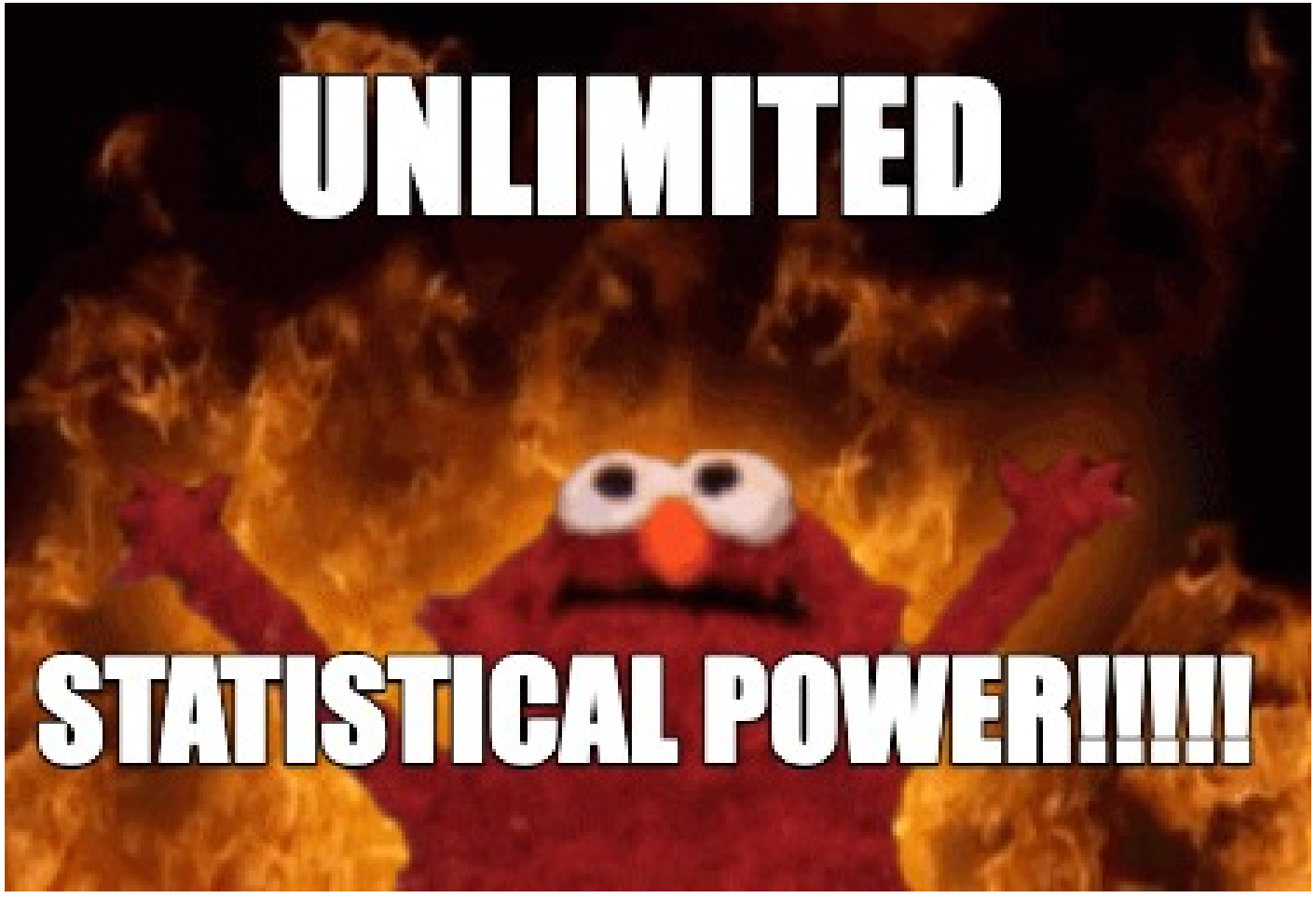
- An allergy test doesn't detect any cat allergy, but you are actually allergic to cats. So, you get sick after the adoption.
- Fail to convict a criminal of a crime

Type I and II errors

Great... now we know both types of errors

But... we want a correct decision instead of committing errors

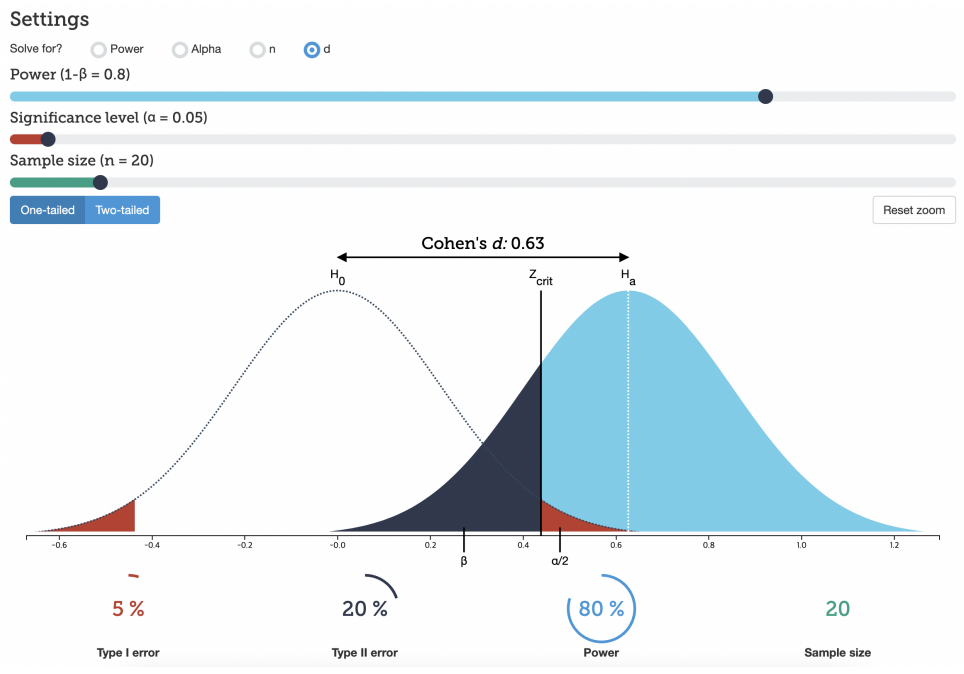
Power



Power

The probability of rejecting the null hypothesis when it is false = $1 - \beta$

R Shiny App: https://rpsychologist.com/d3/nhst/



Power

Power **increases** when...

Larger sample sizes

Larger effect sizes

Smaller spread

Larger alpha level

One-tailed test

Power **decreases** when...

Smaller sample sizes

Smaller effect sizes

Larger spread

Smaller alpha level

Two-tailed test

Effect size

Motivation

Researchers are down to reject the null hypothesis

Say, we have a p-value lower than the α level (e.g., 0.05) $\longrightarrow$ Statistical significance

Do statistically significant results tell you how much the effects are?

Effect size

Idea

Quantify the magnitude of the effect

Example: mean differences, strength of the relationships, ...

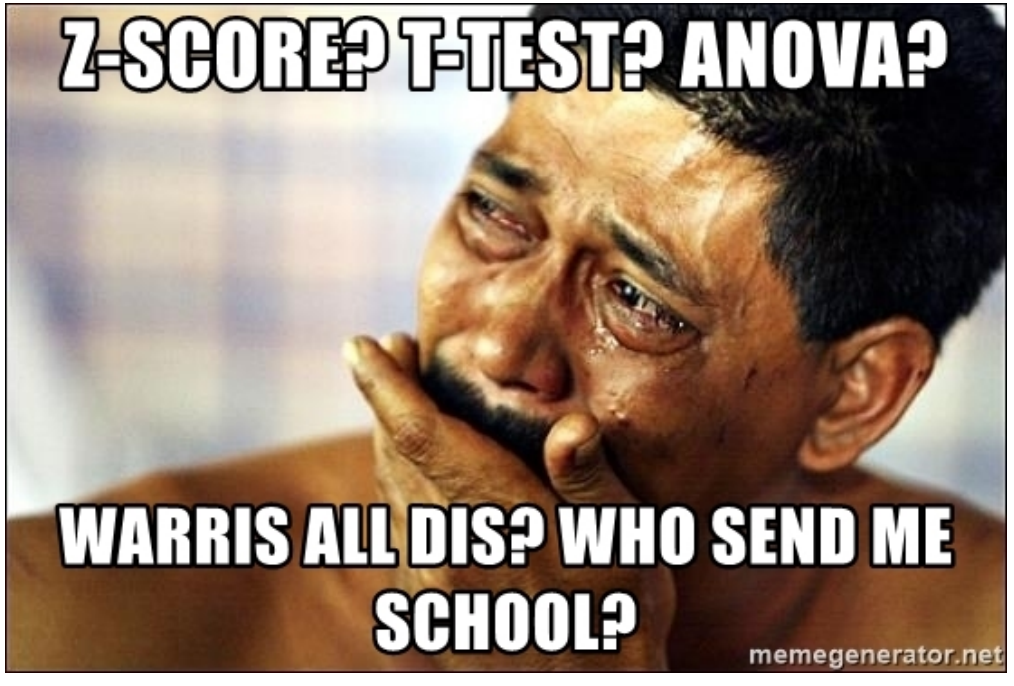
Implication

While we can reject the null hypothesis, the effect can be either small or large!

Many statistical techniques for hypothesis testing

z-test, t-test, ANOVA, ANCOVA, MANOVA, MANCOVA, RM-ANCOVA... WHAT?!

Playing the game of statistical inference about population 'means'



Z-test

What does it test?

Whether a sample mean is different from a specified population mean

Remember our Step 1: State null and alternative hypothesis

But, when?

We know the population mean and population standard deviation (VERY IDEAL!)

Z-test

Idea

We do hypothesis testing (remember Step 1 through Step 4)

In Step 3, when computing test statistic, we calculate a **z-statistic** when we know μ and σ

$$z = \frac{\overline{X} - \mu}{\frac{\sigma}{\sqrt{n}}}$$

Are you familiar with this formula?

Z-test

When doing hypothesis, our Step 4 is to make a statistical decision

See if our p-value is lower than α

This is equivalent to say...

$$|z_{obt}| > |z_{crit}|$$

In case of z-test, $|z_{crit}|$ is **1.645** for one-tailed test and **1.96** for two-tailed test

Z-test

Effect size

If we find statistical significance, we quantify the size of the effect

Means how many standard deviations (SDs) the sample mean lies from the population mean

In z-test, the effect size is calculated as

$$d = \frac{\overline{X} - \mu}{\sigma}$$

Thoughts on hypothesis testing

A black bear story from a famous Dutch statistician!

https://www.youtube.com/watch?v=Dqm1vqk8TC0

Trailer

Some critical thoughts on NHST

Say we fail to reject the null hypothesis. Does this mean the alternative hypothesis is wrong?

Say our p-value is .051 whereas α is .05. Would it be reasonable to say there is not enough evidence to reject the null hypothesis?

Note that journals love p-values lower than .05 ONLY... is it fair?

Do it together

Q17 in HW4

A professor finds that the average SAT score among all students attending his college is 1150 (sigma = 150). He polls his class of 25 students and finds that the average SAT score is 1,200. Suppose he computes a z test at a .05 level of significance. What is his decision?

- to reject the null hypothesis for a two-tailed test, but to retain the null hypothesis for an one-tailed test
- to reject the null hypothesis for an one-tailed test, but to retain the null hypothesis for a two-tailed test
- to retain the null hypothesis
- to reject the null hypothesis

Q&A session for homework 4

Before you go home...

Lab materials are available at

https://github.com/lhnwhiHeo/PSY010

Any questions or comments?

Office hours or my email

Thanks! Have a good one!