Statistical Ideas You Can Never Unsee

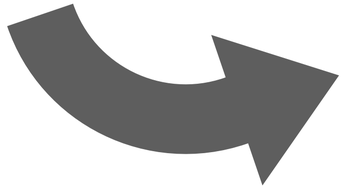
Cornell University - PSYCH1130

Ashley Mullan - March 11, 2025

Follow along with me!

https://bit.ly/ash-talks

(load the slides!)



Coming Soon to Theaters

1. **Guest Lecture**: Statistical Ideas You Can Never Unsee
   PSYCH1130, Cornell University - March 2025
   Slides - App

2. **Contributed Poster**: Visualizing Cost Effectiveness Analysis with Second-Generation Acceptability Curves
   ENAR Spring Meeting - March 2025
   Poster

The Quick Rundown

1. How’d I end up on your screen today?
2. Here are some of my hot takes about statistics.
3. Don’t believe me? Try it yourself!
4. Ask me things!

How’d I end up on your screen today?

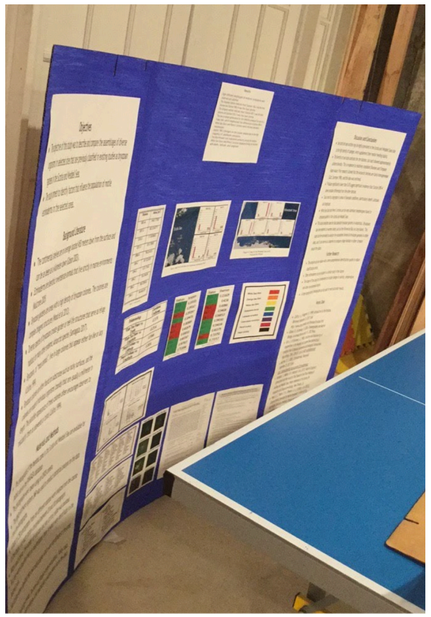
Try new things, you'll meet people!

(the origin story)

(not even close to scale)

Try new things, you'll meet people!

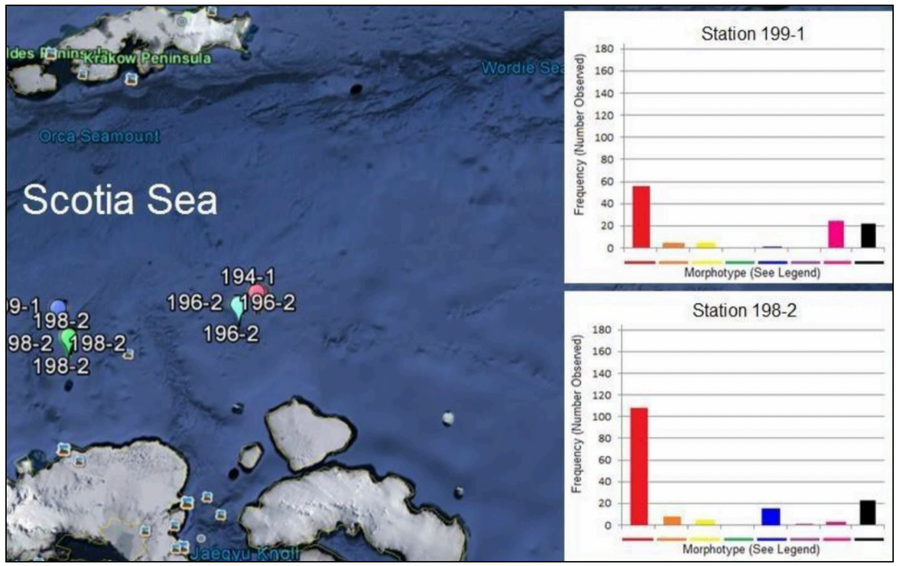
(the origin story)



(not even close to scale)

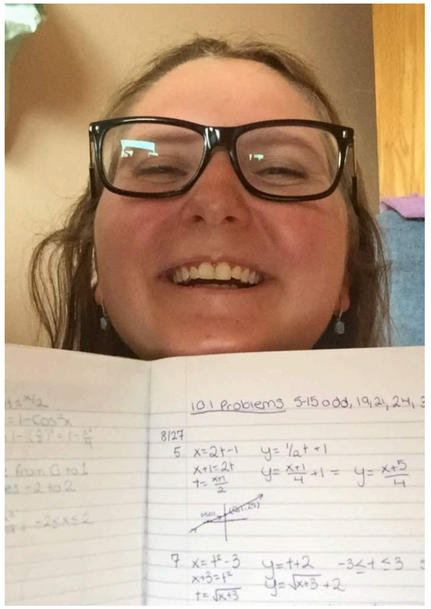
2017
LIU bio lab

biology era



Try new things, you'll meet people!

(the origin story)

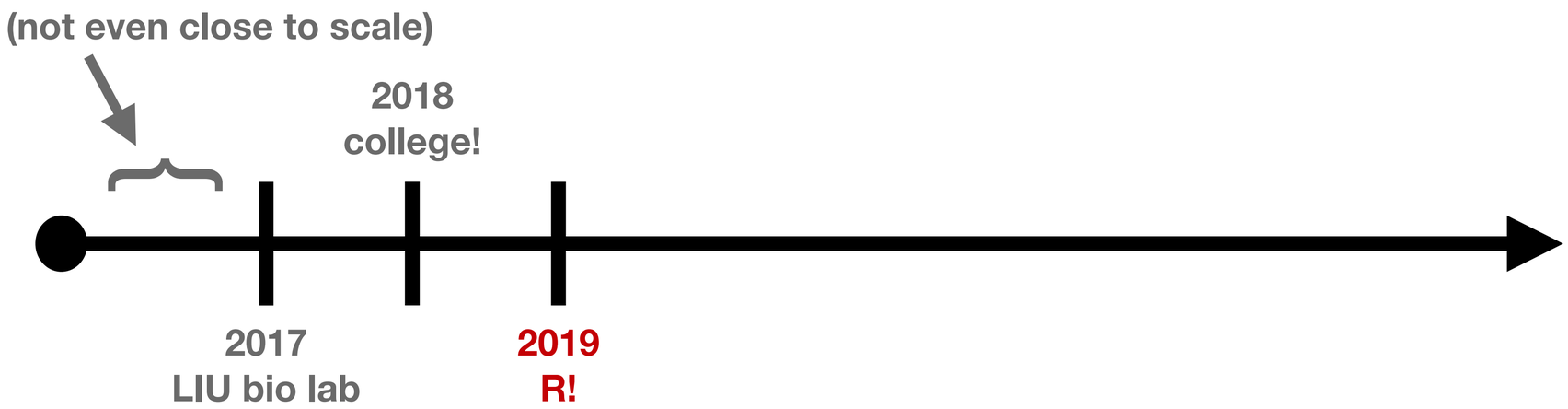


THE UNIVERSITY OF SCRANTON
A JESUIT UNIVERSITY

math era

Try new things, you'll meet people!

(the origin story)



panic era

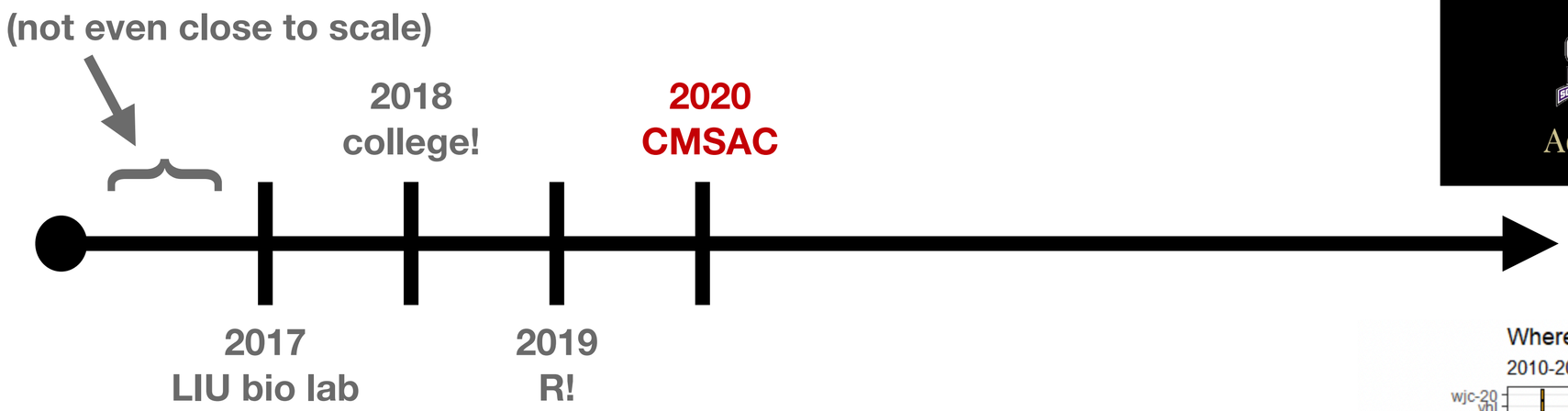
Try new things, you'll meet people!

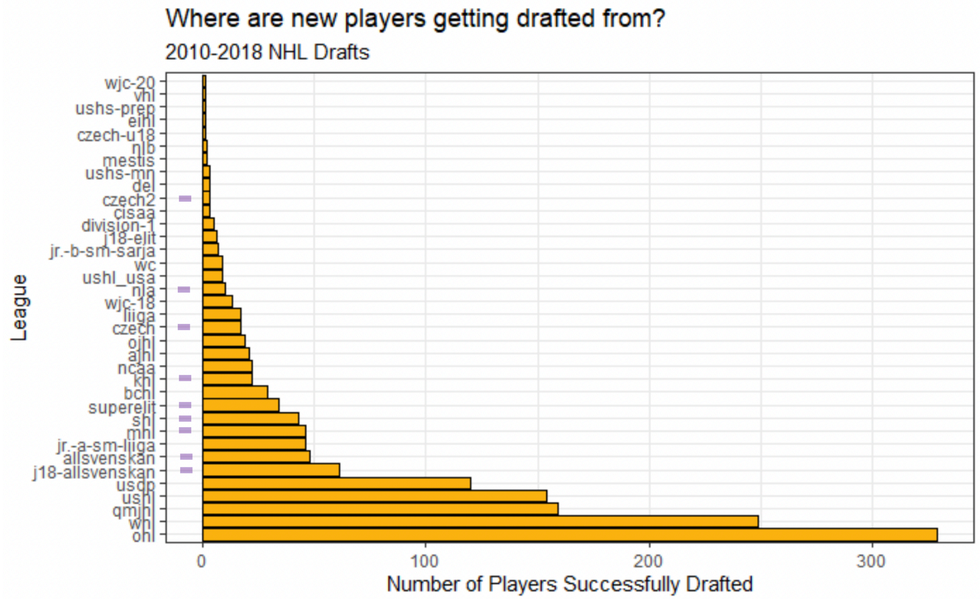
(the origin story)

sports era

A Puck Above the Rest:
Exploring the Effects of New Data on 2020 NHL Draft Decisions

Ashley Mullan and Lucy Ward
October 25, 2020
Advisors: S. Ventura, N. Citrone, R. Yurko





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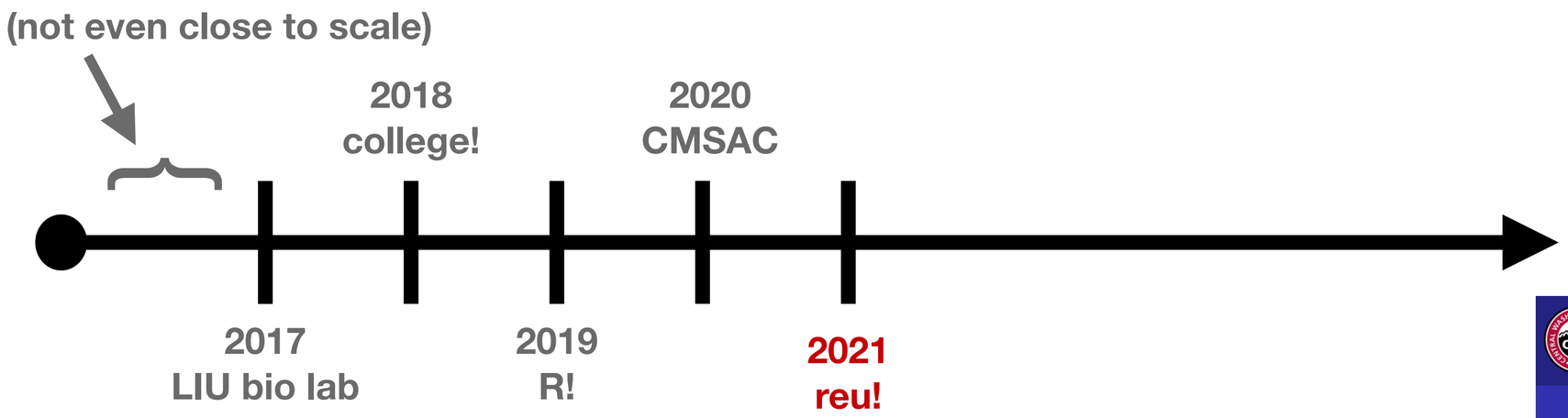
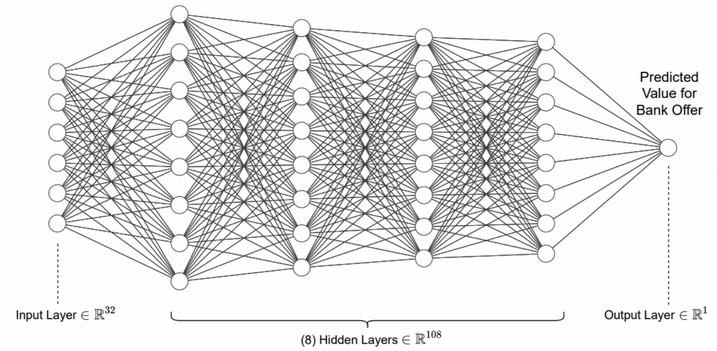
(the origin story)





game show era

Try new things, you'll meet people!

(the origin story)

(not even close to scale)

2017
LIU bio lab

2018
college!

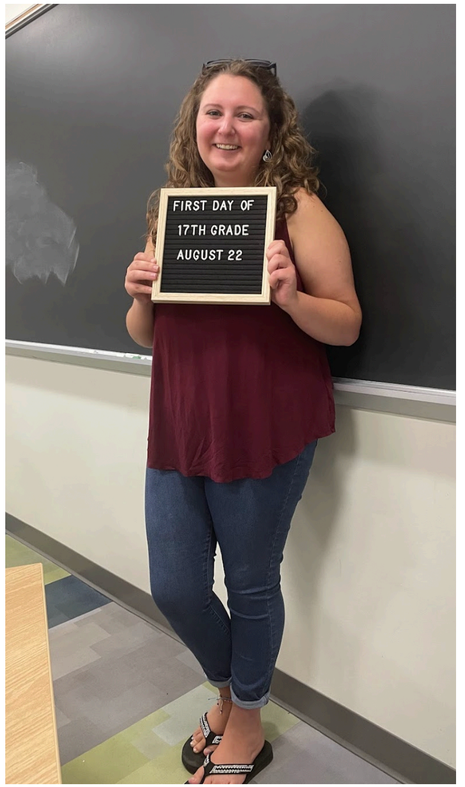
2019
R!

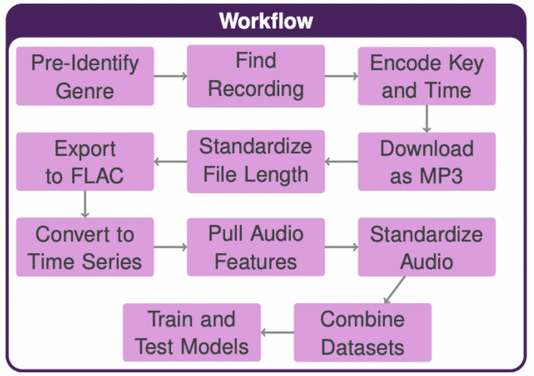
2020
CMSAC

2021
reu!

2022
thesis &
master's

first grad school era

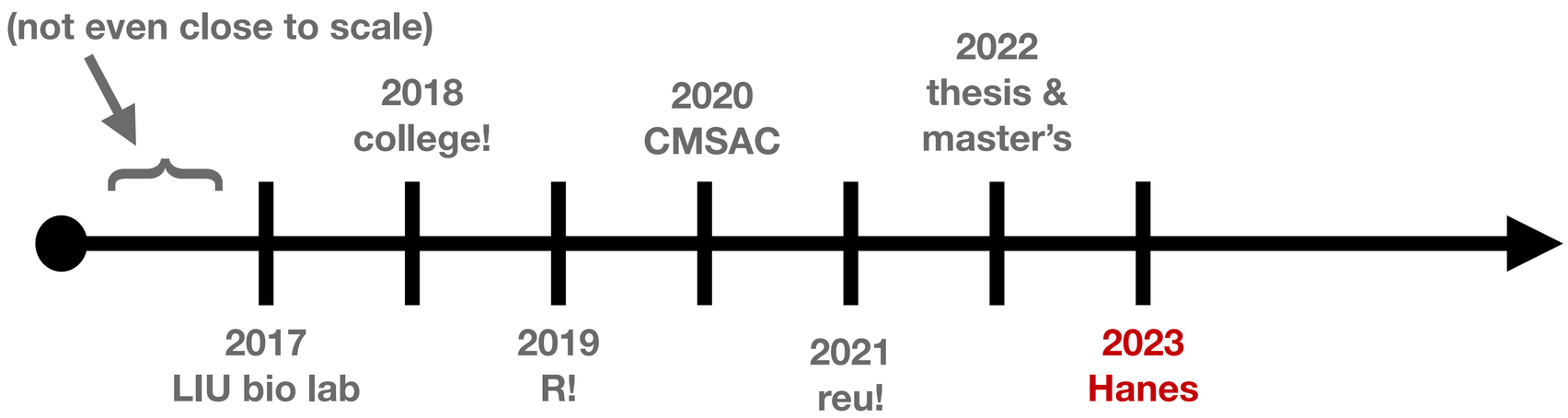




spotify era

Try new things, you'll meet people!

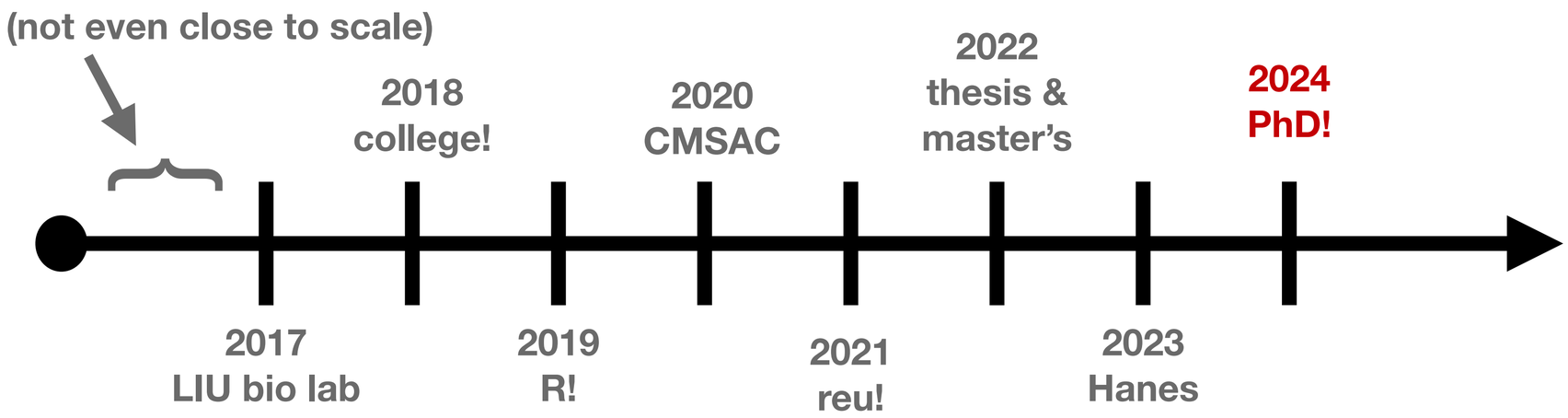
(the origin story)



corporate era

Try new things, you'll meet people!

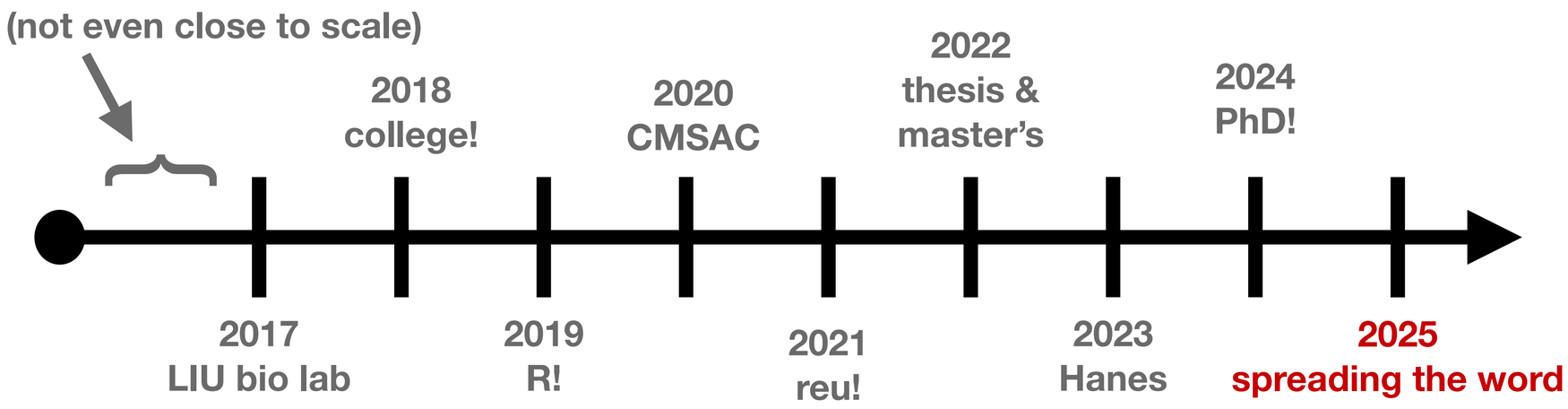
(the origin story)



grad school era
(round two)

Try new things, you'll meet people!

(the origin story)



publication era

SIGNIFICANCE

Here are some of my hot takes about statistics.

“There’s a couple of secret steps hidden in the scientific method that can blow up your entire experiment if you miss them!”

-Me, to a class of tenth graders last month

Steps of the Scientific Method

https://www.amnh.org/explore/videos/the-scientific-process

Steps of the Scientific Method

Ask a q

nclusion.

But where do statistics kick in?

https://www.amnh.org/explore/videos/the-scientific-process

the correct answer?

EVERYWHERE!

Step 1: Ask a question.

- The research question should be **specific** and **measurable**. Consider **who** we want to study, **what** we want to measure about them, and **how** we want to measure it.
- Collaborators can help you **refine** your question.

Are interesting lecture notes better for learning?

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what's wrong with this question?

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Do college students do better if there are memes in their lecture notes?

is this any better?

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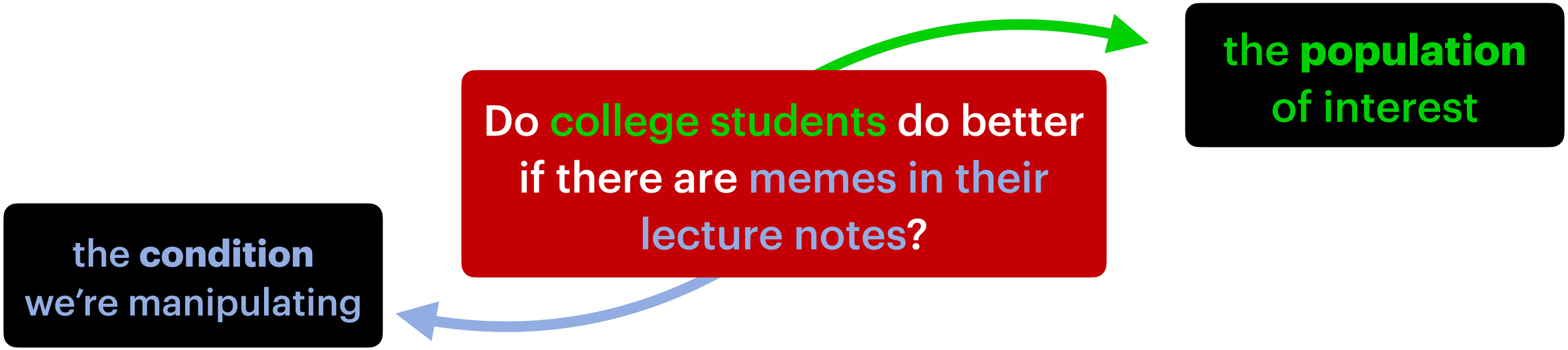

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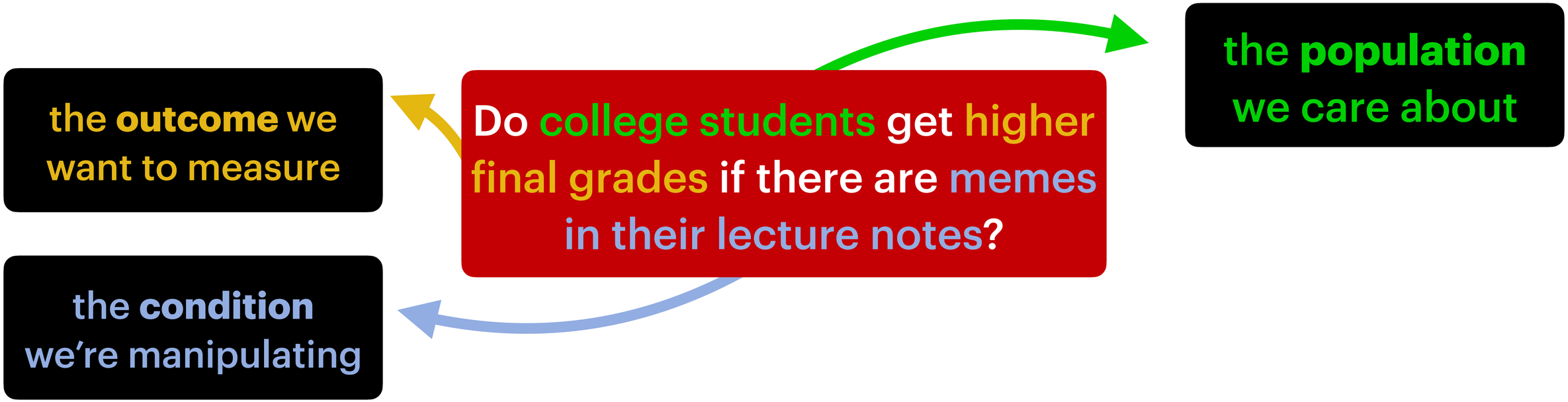

Step 2: Make a hypothesis.

- We usually make two hypotheses, the **null hypothesis** and the **alternative hypothesis**.
- The **null hypothesis (H_0)** is the skeptical answer to your question.
- You hope to find evidence for the **alternative hypothesis (H_a)**.

Do college students get higher final grades if there are memes in their lecture notes?

H_0 → **No, adding memes does not change their final grades on average.**

H_a → **Yes, adding memes increases their final grades on average.**

Step 3: Gather your data.

- There are **many statistical considerations** to think about when you gather data.
- Some questions you might want to ask are:
  - **Who** am I sampling? Do I have any **criteria** for my subjects?
  - **How** am I sampling? Do I pick randomly? Am I trying to balance any factors?
  - **What measurements** am I recording for each subject? What's my **unit**?
  - **When** am I sampling? Do I have to make observations more than once per subject?
  - How do I set up my comparison? Is there a **control** group?

Step 4: Analyze the data.

- The way you analyze your data depends on your **audience**.
- Sometimes, you might want to make a **graph** or a **table** summarizing your variables.
- You can run a **hypothesis test** or a **statistical model** to generate **quantitative evidence** that can help you decide which hypothesis makes more sense.
- You can make the jump from information about your **sample** to the larger **population** by using a **confidence interval**.

Don’t worry if these are new, more on these later!

Step 5: Draw a conclusion.

- Once you've made your case, go back and use the **evidence** you've gathered to answer your **original question**!
- Ask yourself if what you've measured is a **useful** comparison.
- Suppose we noticed that the average final grade in the memes section was an **A-**, but the students without memes only averaged a **B+**. Which hypothesis makes more sense?

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Do college students get higher final grades if there are memes in their lecture notes?

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H_a → Yes, adding memes **increases** their final grades **on average**.

Note: This might be a little overdramatic, but bear with me.

“Anyone who says ~on average~ might be trying to sneak something past you.”

-Me, literally any time I read something resembling statistics in a Buzzfeed article.

What do I mean by that?

(but first, a few definitions)

A **measure of central tendency** is a way to describe your data. Here are some examples!

- The **mean** is the average value in your data. Add up all of your observations and divide by your sample size to find it.
- The **median** is the 50th percentile of your data. Exactly half of the points are less than it, and half are greater than it.
- The **mode** is the value that appears the **most** in your data.

Let’s practice. Grab your pencils! ✏️

Suppose we ask five students how many pencils they have in their backpacks. We get the following data, and we want to compute the mean, median, and mode.

3, 0, 1, 3, 8

That’s me, I’m a walking Staples!

That’s lame, come to class prepared!

Let’s practice. Grab your pencils! ✏️

Suppose we ask five students how many pencils they have in their backpacks. We get the following data, and we want to compute the mean, median, and mode.

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Let’s practice. Grab your pencils! ✏️

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Step 2: The Mean
Sum up your data!
Then, divide by 5
for the 5 students.

$$\frac{0 + 1 + 3 + 3 + 8}{5} = \frac{15}{5} = 3$$

Let’s practice. Grab your pencils! ✏️

Suppose we ask five students how many pencils they have in their backpacks. We get the following data, and we want to compute the mean, median, and mode.

Step 3: The Median
Work from the edges
(this is why we sorted!)
to find your median.

0, 1, 3, 3, 8

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Step 3: The Median
Work from the edges
(this is why we sorted!)
to find your median.

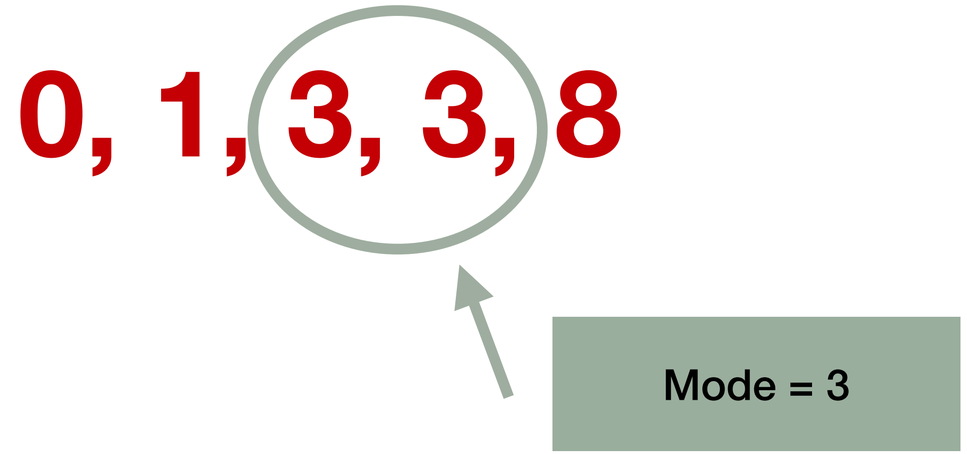
~~0~~, ~~1~~, 3, ~~3~~, ~~8~~

Found it!

Let’s practice. Grab your pencils! ✏️

Suppose we ask five students how many pencils they have in their backpacks. We get the following data, and we want to compute the mean, median, and **mode**.

Step 4: The Mode
Look for any duplicates
to find your mode!

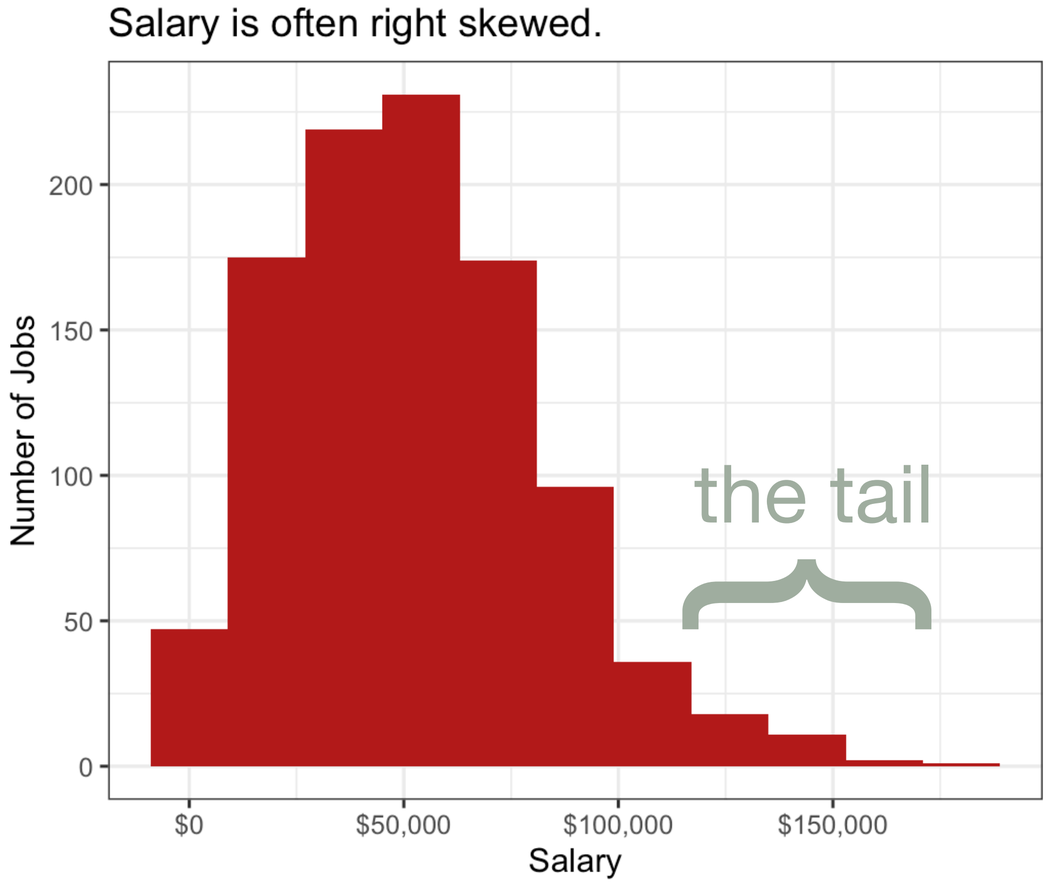


Huh, was that a coincidence? 🤔

- Did you notice that the mean, median, and mode all matched?
- We just showed that different measures of central tendency **can match**, but there are some cases where they don't. That's where the hot take comes in!
- If the mean and median are **similar**, you're looking at **symmetric** data. That means that you don't have way too many "big" data points or way too many "small" data points.
- If the mean and median are **drastically different**, you may want to take a closer look at your data. You could be dealing with **skew** or an **outlier**!

But Ashley, what are those?

- A **skewed** dataset has a tail. There are more extreme values in one direction than you'd expect!
- An **outlier** is a point that doesn't look like the others. It may be much bigger or much smaller!
- We'll see an example of an outlier later and explore how it affects the reporting decisions you make.



How am I supposed to know which measure to use? 🤯

Don’t worry!

We’ll play around with this in Part 3.

(Being a good statistician is all about asking these kinds of questions, great work!)

“Although our intellect always longs for clarity and certainty, our nature often finds uncertainty fascinating.”

-Carl von Clausewitz

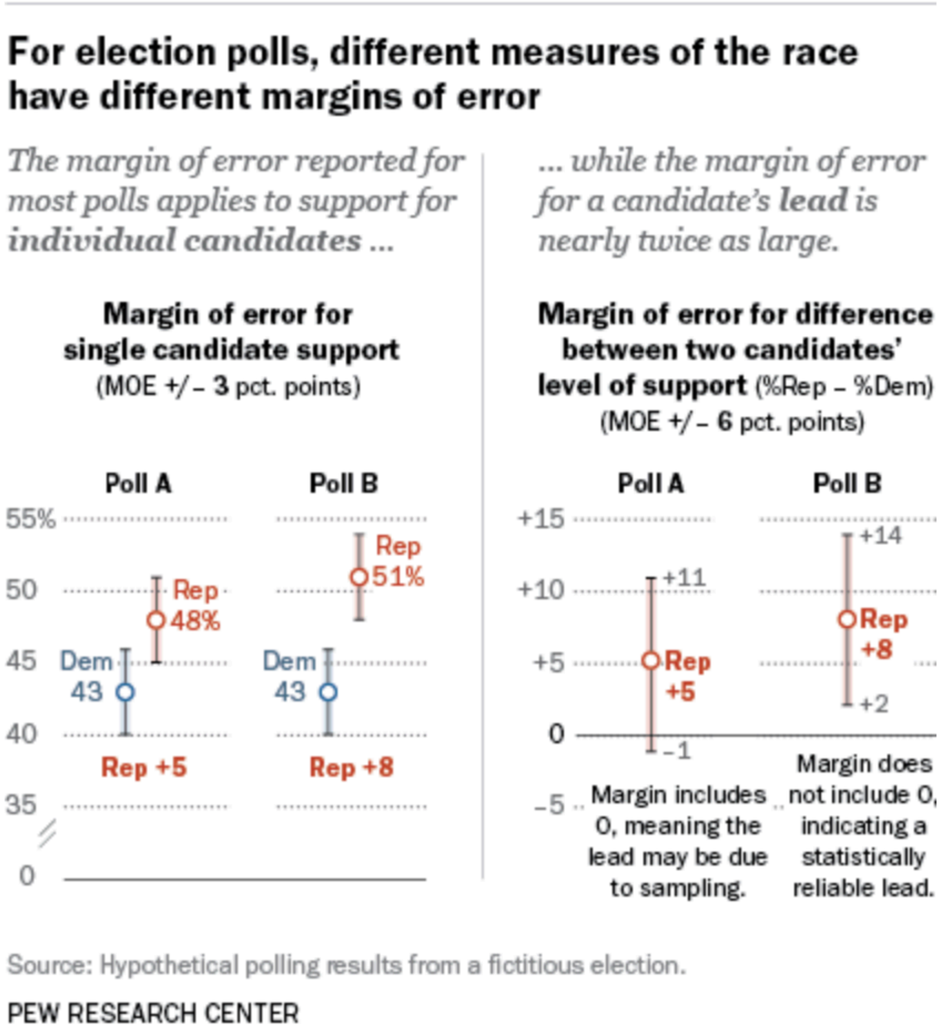
Carl von Clausewitz, painted by Wilhelm Wach.
Thanks, Wikipedia!

Prussian generals do statistics? 💣

- Obviously, we want our statistical models to be correct!
- When we try to **predict** unknown quantities or make **inferences** about a larger group (a **population**) from a smaller group (a **sample**), we will never be 100% right all the time. 😢
- Statisticians have many tools to quantify their **uncertainty**. In other words, we often give both an **estimate** for a value and **error bounds** to state how far away from our estimate we think might be a reasonable guess.

This can be pretty helpful IRL…

Political polls often report a margin of error, since it's really hard to either poll every single American or get a fair sample!



https://www.pewresearch.org/short-reads/2316/09/08/understanding-the-margin-of-error-in-election-polls/

It might even help with some of your upcoming work*!

This is how statistical results often appear in a journal article.

*You might see this article sometime soon; I won't tell James if you won't! (but who do you think sent me the article lol)

Excerpt from Zhdanova et. al (1998)

Endogenous Melatonin Levels and the Fate of Exogenous Melatonin: Age Effects

dose of melatonin significantly increased circulating melatonin levels after 30 min ($p < .001$). Serum and salivary melatonin measurements showed that mean group AUC (± *SD*) for the younger group was 441.9 ± 121.07 pg/ml h (serum) and 136.4 ± 28.11 pg/ml h (saliva) (Figure 4).

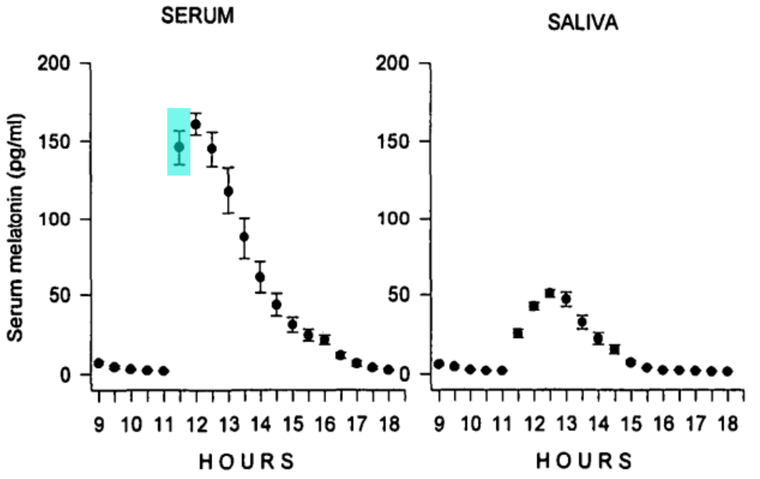


Figure 4. Profiles of serum and saliva melatonin concentrations in the group of younger volunteers (mean ± *SEM; n* = 10). Samples collected prior to and after the ingestion of a 0.3 mg dose of melatonin at 11.00 h.

How can I quantify uncertainty?

- Uncertainty can often come from **variation** either **across** samples or **within** your sample!
- One way to measure variation is with a **standard deviation**. This measures how far (on average) you expect to be from the sample mean!
- Let's go back to the ✏️ example. We had a mean of 3 ✏️ in a student's 🎒.
- I'll skip over the math, but the **standard deviation** ends up being about **3.08**.
- This means that we **expect** to be within about 0 and 6 pencils for most students! Checks out, only the walking Staples exceeded those bounds.

Don’t believe me? Try it yourself!

Hot takes deserve case studies.

1. *How would you describe my reading speed?*

   I provide a list of books I've read this year and how long it took me to finish them. Something in that dataset is a little funny, can you find it?

2. *Which section of statistics would you rather take?*

   Professor A's students have the higher average, but the test scores are all over the place. Professor B's students have a slightly lower average grade, but you know pretty well where the scores fall and think it might be less risky.

3. *What can go wrong if we don't think our question all the way through?*

   We measure how satisfied students are when they walk into a TJ Maxx, but we're unsure what variables to consider when we want to frame our research question.

https://bit.ly/ash-talks

(except this time, load the app)

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Let’s think about those case studies!

(books first)

- Before removing the outliers, where does the mean lie in relation to the median?
- Do the outliers affect the scale of the plot at all?
- How extreme do you think the outliers are?
- Does the median or the mean better represent the center of the data?
- After removing the outliers, where does the mean lie in relation to the median?
- Does this difference really matter? Why or why not?
- What does this tell you about reporting measures of center?

Let’s think about those case studies!

(now the grades)

- Do you have a section preference if you only consider the mean and median? Why?
- Do you have a section preference if you only consider the standard deviation? Why?
- Do these preferences change when you consider everything together?
- BONUS: Are there any other factors that you might want to consider?

Let’s think about those case studies!

(now the satisfaction)

- Can you spot a general trend for male students, female students, and overall?
- Does it make sense to consider male and female students in the same way if we’re trying to figure out if older students like TJ Maxx more?
- Is this a practically significant difference?
- What are some ways we might handle this situation?

Ask me things!

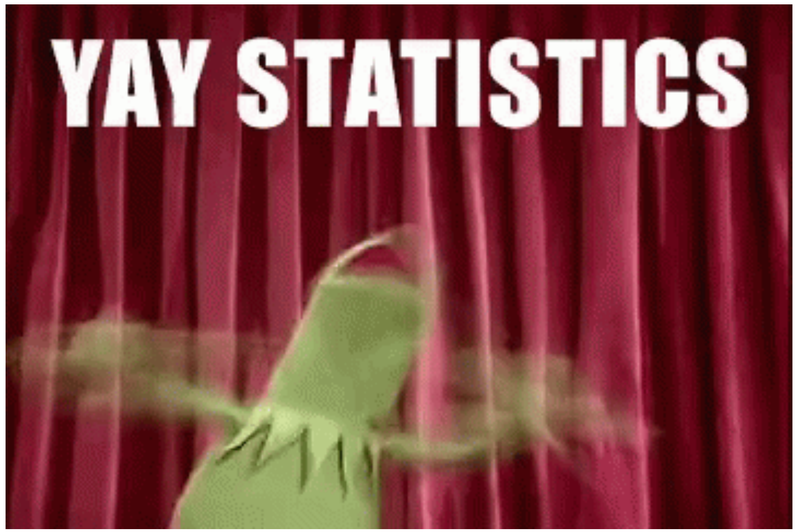
Takeaways

1. Think carefully through your experimental design, and considering the statistical end of things on the early side can only help you.

2. Always check for outliers! The mean and the median work together to give you the most reliable information about your data.

3. Always report some kind of error margin or measure of data variation!

4. Document the data decisions (like how you treat your outliers) when you write up your homework assignments, scientific articles, and business reports so future users can understand and reproduce your work!



Thank you! 😊

If you’re interested in more fun stats takes, check out my website!

ashleymullan.github.io