

Statistical philosophy

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- Download pdf notes (should be this version)
- Download pdf slides (from some recent version)

How do we use statistics

- We use statistics to confirm effects, estimate parameters, and predict outcomes
- It usually rains when I'm in Cape Town, but mostly on Sunday
 - *Confirmation*: In Cape Town, it rains more on Sundays than other days
 - *Estimation*: In Cape Town, the *odds* of rain on Sunday are 1.6–2.2 times higher than on other days
 - *Prediction*: I am confident that it will rain at least one Sunday the next time I go

Raining in Cape Town

- How we interpret data like this necessarily depends on assumptions:
 - Is it likely our observations occurred by chance?
 - Is it likely they *didn't*?

Vitamin A

- We measure the average heights of children raised with and without vitamin A supplements
 - *Estimate*: how much taller (or shorter) are the treated children on average?
 - *Confirmation*: are we sure that the supplements are helping (or hurting)?
 - *Range of estimates*: how much do we think the supplement is helping?

1 Estimation

- We use *P values* to say how sure we are that we have seen some effect
- We use *confidence intervals* to say what we think is going on (with a certain level of confidence)
- P values are *over-rated*
- *Never* use a high P value as evidence for anything, e.g.:
 - that an effect is small
 - that two quantities are similar

Vitamin A example

- We want to know if vitamin A supplements improve the health of village children
 - Is height is a good measure of general health?
 - How will we know height differences are due to our treatment?
 - * We want the two groups to start from the same point – independent randomization of each individual
 - * We may measure *changes* in height
 - * Or *control for* other factors

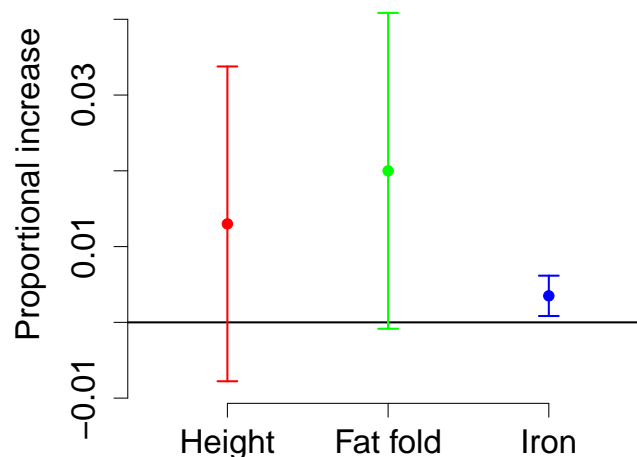
What do we hope to learn?

- Is vitamin A good for these children?
- How sure are we?
- How good do we think it is?
- How sure are we about that?

P values

- What does it mean if I find a "significant P value" for some effect in this experiment?
- The difference is unlikely to be due to chance
 - So what! I already know vitamin A has strong effects on metabolism
- If I'm certain that the true answer isn't exactly zero, why do I want the P value anyway?

Confidence intervals



- What do these results mean?
- Which are significant?

Confidence intervals and P values

- A high P value means we can't see the sign of the effect clearly
- A low P value means we can

The meaning of P values

- More broadly, a P value measures whether we are seeing *something* clearly
 - It's usually the sign (\pm) of some quantity, but doesn't need to be

Types of Error

- Type I (*False positive:*) concluding there is an effect when there isn't one
 - This doesn't happen in biology. There is always an effect.
- Type II (*False negative:*) concluding there is no effect when there really is
 - This *should* never happen, because we should never conclude there is no effect

Experimental design

- Type I (*False positive:*) in the hypothetical case that the effect is exactly zero, what is the probability of falsely finding an effect
 - Should be less than or equal to my significance value
- Type II (*False negative:*) what is the probability of failing to find an effect that is there?
 - Useful, but can only be asked for a specific hypothetical effect *size*
- These are useful to analyze **power** and **validity** of a statistical design
 - You should do these analyses *before* you collect data, not after

A new view of error

- *Sign error:* if I think an effect is positive, when it's really negative (or vice versa)
- *Magnitude error:* if I think an effect is small, when it's really large (or vice versa)
- Confidence intervals clarify all of this

Low P values

- If I have a low P value I can see something clearly
- But it's usually better to focus on what I see than the P value

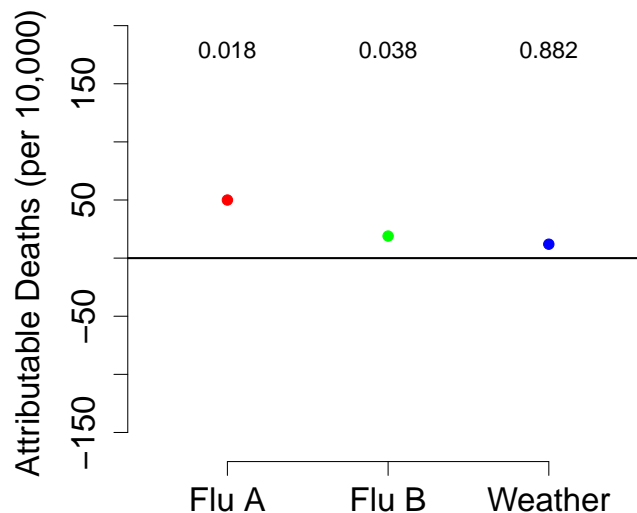
High P values

- If I have a high P value, there is something I *don't* see clearly
- It *may be* because this effect is small
- High P values should *not* be used to advance your conclusion

What causes high P values?

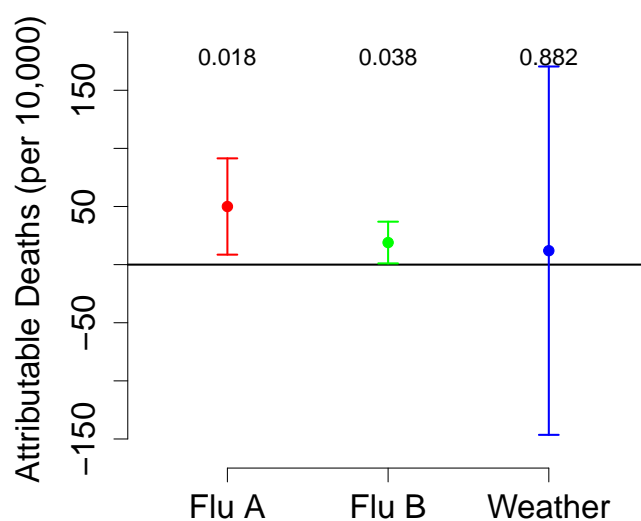
- Small differences
- Less data
- More noise
- An inappropriate model
- Less model resolution
- A lower P value means that your evidence for difference is better
- A higher P value means that your evidence for similarity is better – or worse!

Annualized flu deaths



- Why is weather not causing deaths at this time scale?

... with confidence intervals



- **Never** say: A is significant and B isn't, so $A > B$
- **Instead:** Construct a statistic for the hypothesis $A > B$
 - May be difficult

Syllogisms

- All men are mortal
- Jacob Zuma is mortal
- Therefore, Jacob Zuma is a man

Syllogisms

- All men are mortal
- Fanny the elephant is mortal
- Therefore, Fanny is a man

Bad logic

- A lot of statistical practice works this way:
 - bad logic in service of conclusions that are (usually) correct
- This sort of statistical practice leads in the aggregate to bad science
- The logic can be fixed:
 - Estimate a difference, or an interaction

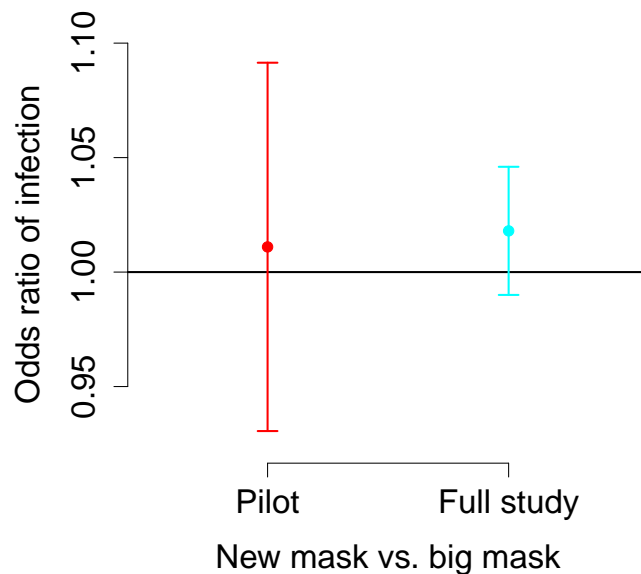
Small effects

- We can't build statistical confidence that something is small by failing to see it clearly
- We must instead see clearly that it is small
- This means we need a standard for what we mean by small

Flu mask example

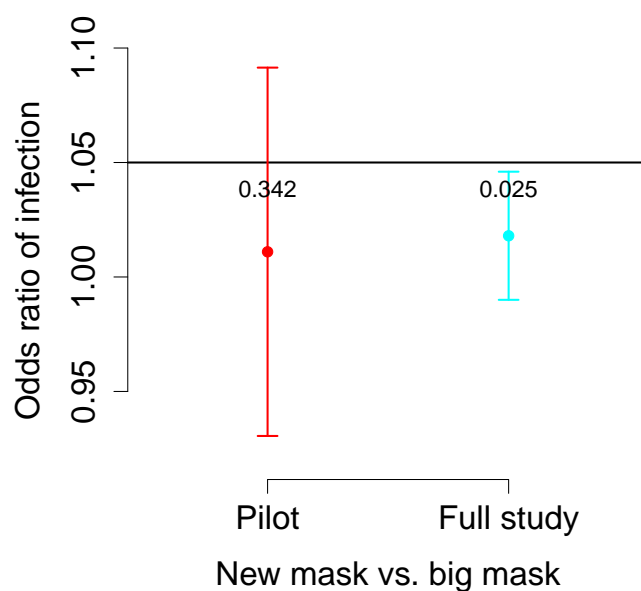
- People who work in respiratory clinics sometimes have to wear bulky, uncomfortable, expensive masks
- They would like to switch to simpler masks, if those will do the job
- How can this be tested statistically? We don't want the masks to be "different".
 - Use a confidence interval
 - Decide how big a level is acceptable, and construct a P value for the hypothesis that this level is excluded!

Study results



- Is the new mask "good enough"?
- What's our standard for that?

Non-inferiority trial



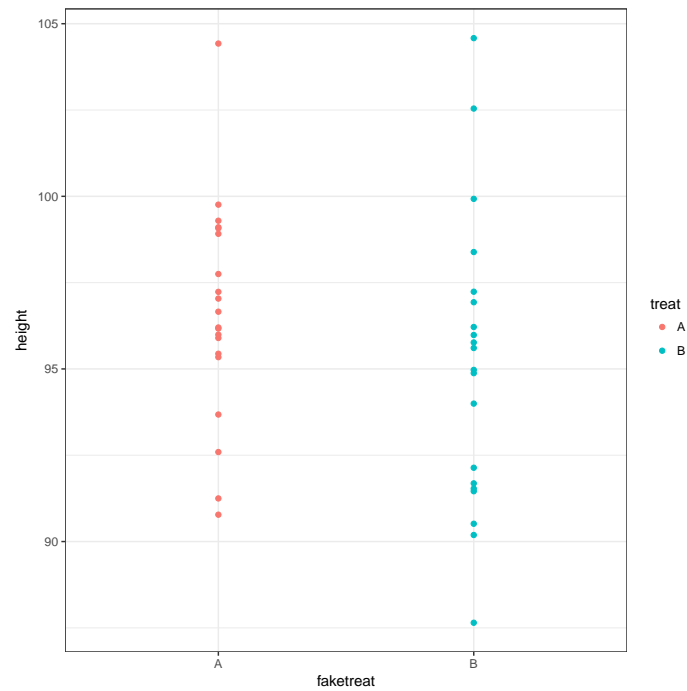
- We can even attach a P value by basing it on the “right” statistic.
- The right statistic is the thing whose sign we want to know:
 - The difference between the observed effect and the standard we chose

2 Paradigms for inference

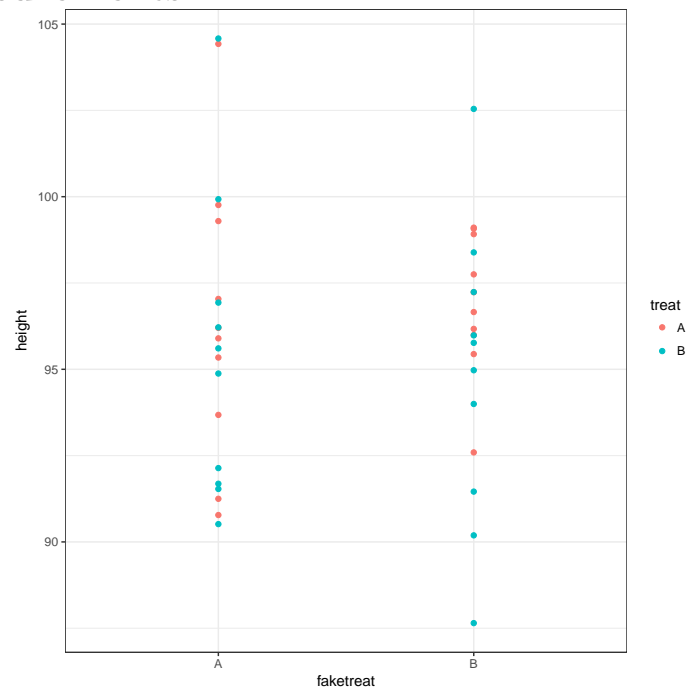
2.1 Frequentist paradigm

- Make a null model
- Test whether the effect you see could be due to chance
 - What is the probability of seeing exactly a 1.52 cm difference in average heights?
- Test whether the effect you see *or a larger effect* could be due to chance
 - This probability is the P value

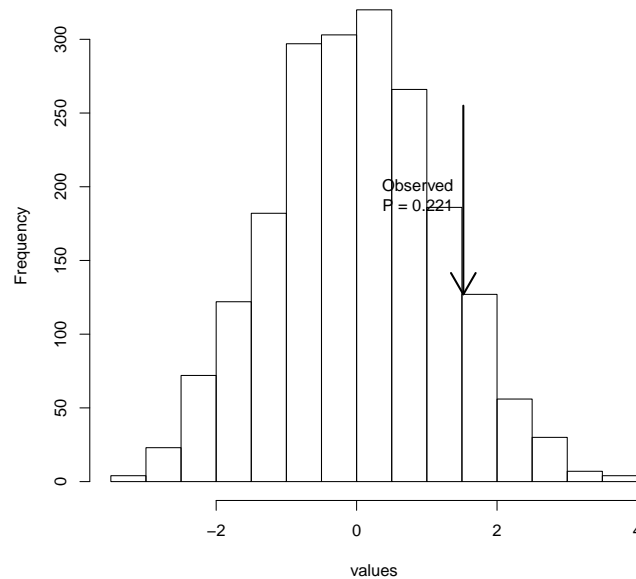
Height measurements



Scrambled measurements



The null distribution



2.2 Bayesian paradigm

- Make a complete model world
- Use conditional probability to calculate the probability you want

A powerful framework

- More assumptions \implies more power
- With great power comes great responsibility

Bayesian inference

- We want to go from a *statistical model* of how our data are generated, to a probability model of parameter values
 - Requires *prior* distributions describing the assumed likelihood of parameters before these observations are made
 - Use Bayes theorem to calculate posterior distribution – likelihood after taking data into account

Vitamin A study

- A frequentist can do a clear analysis right away
- A Bayesian needs a ton of assumptions – will try to make “uninformative” assumptions

Cape Town weather

- Frequentist: how unlikely is the observation, from a random perspective?
- Bayesian: what's my model world? What is my prior belief about weather-weekday interactions.

3 Conclusion

Your philosophy

- Statistics are not a magic machine that gives you the right answer
- If you are to be a serious scientist in a noisy world, you should have your own philosophy of statistics
 - Be pragmatic: your goal is to do science, not get caught by theoretical considerations
 - Be honest: it's harder than it sounds.

Honesty

- You can always keep analyzing until you find a “significant” result
 - If you do this you will make a lot of mistakes
- You may also keep analyzing until you find a result that you already “know” is true.
 - This is confirmation bias; you're probably right, but your project is not advancing science
- Good practice
 - Keep a data-analysis journal
 - Start *before* you look at the data