Hypothesis testing

NHST concepts

Null and alternative hypotheses

- Tell me. . .

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- **Null hypothesis**: there is no difference between groups.

Null and alternative hypotheses

- Tell me. . .
- **Null hypothesis**: there is no difference between groups.
- **Alternative hypothesis**: groups are different.

In ecology, everything is somewhat different

Are there any differences? A non-sensical question in ecology

Alejandro Martínez-Abraín

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Received 19 December 2006
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ABSTRACT

One of the main questions that ecologists pose in their investigations includes the analysis of differences in some trait between two or more populations. I argue here that asking whether there are differences or not between populations is biologically irrelevant, since no two livings things are ever equal. On the contrary the appropriate question to pose is how large differences are between populations. That is, we urge a shift in interest from statistical significance to biological relevance for proper knowledge accumulation. I empha-

What is the p-value?

https://pollev.com/franciscorod726

P value

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- Probability of observing data as or more extreme than these *if H0 was true*.
- Low P-value: data unlikely if H0 was true.
- Large P-value: data not unusual if H0 was true.

Are differences *significant*?

- If p < 0.05, we **reject** H0.

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- If p $>$ 0.05, we **fail to reject** H0

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- This is **very widespread, but incorrect** practice.

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- P-value is continuous. We must **avoid binary decisions** based on **arbitrary thresholds**.

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- This is **very widespread, but incorrect** practice.
- P-value is continuous. We must **avoid binary decisions** based on **arbitrary thresholds**.
- More on this later.

Let's do the test

```
t.test(h.sevi, h.out)
```

```
    Welch Two Sample t-test

data:  h.sevi and h.out
t = -1.3308, df = 5.1625, p-value = 0.239
alternative hypothesis: true difference in means is not equal to
95 percent confidence interval:
 -22.433933   7.033933
sample estimates:
mean of x mean of y
    169.8     177.5
```

Are heights different then?

Rejecting hypotheses: two types of error

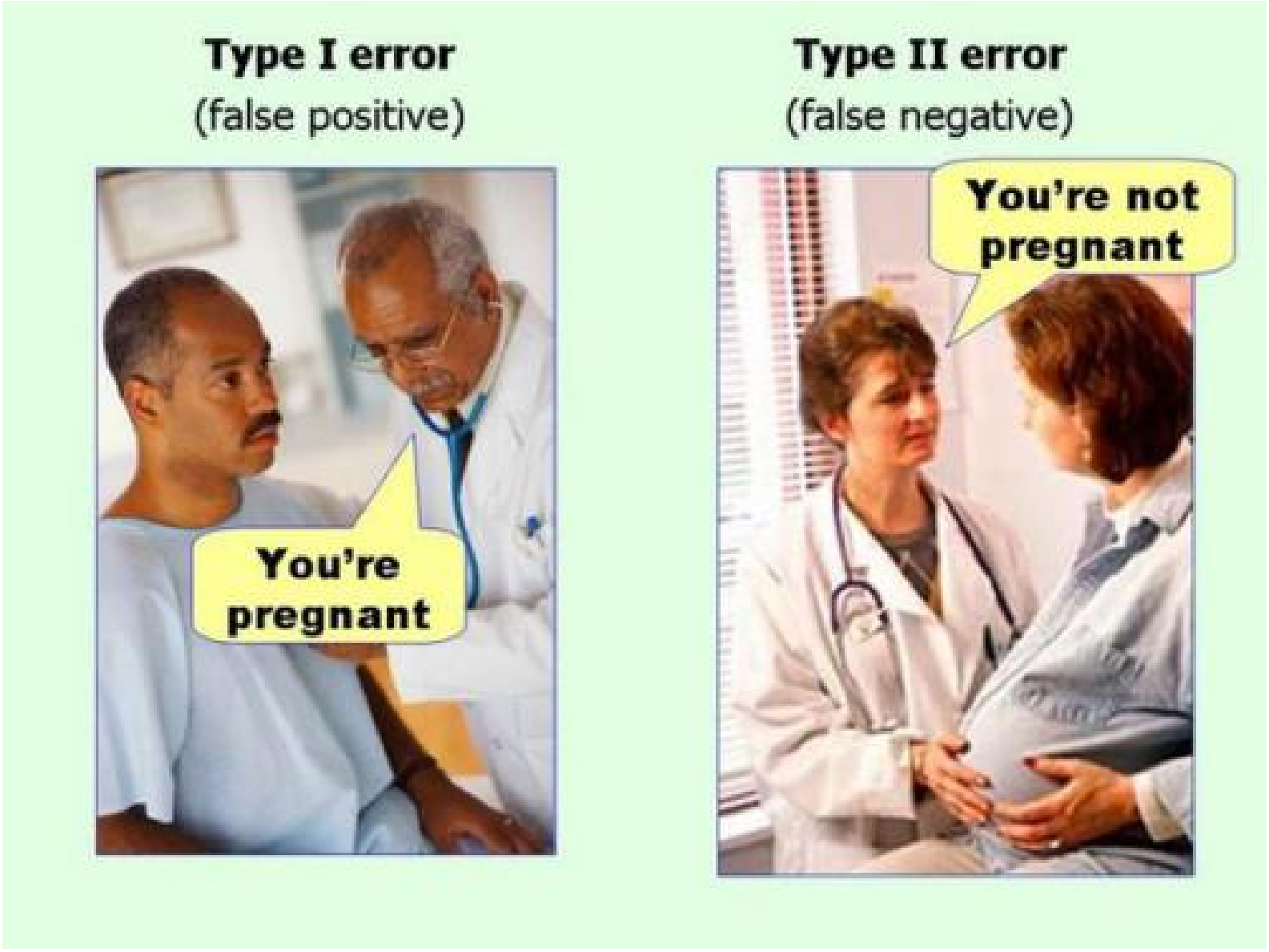

Figure 1:

Rejecting hypotheses: two types of error

Statistics: Hypothesis Test	Null Hypothesis is True	Null Hypothesis is False
Reject Null Hypothesis	Type I Error	Correct
Fail to Reject Null Hypothesis	Correct	Type II Error

Figure 2:

Understanding NHST

http://rpsychologist.com/d3/NHST/

Example: biased coin

```
 [1] 0 0 1 0 1 0 1 0 1 1
```

```
    1-sample proportions test without continuity correction

data:  sum(coin) out of ntrials, null probability 0.5
X-squared = 0, df = 1, p-value = 1
alternative hypothesis: true p is not equal to 0.5
95 percent confidence interval:
 0.2365931 0.7634069
sample estimates:
  p
0.5
```

Correlation between variables

http://rpsychologist.com/d3/correlation/

Common pitfalls and good practice

A must read

Eur J Epidemiol (2016) 31:337–350
DOI 10.1007/s10654-016-0149-3

ESSAY

Statistical tests, *P* values, confidence intervals, and power: a guide to misinterpretations

Sander Greenland[1] · Stephen J. Senn[2] · Kenneth J. Rothman[3] · John B. Carlin[4] · Charles Poole[5] · Steven N. Goodman[6] · Douglas G. Altman[7]

https://doi.org/10.1007/s10654-016-0149-3

Good read

ECOSPHERE

Applied statistics in ecology:
common pitfalls and simple solutions

E. Ashley Steel,[1,†] Maureen C. Kennedy,[2] Patrick G. Cunningham,[3] and John S. Stanovick[4]

Figure 3:

https://doi.org/10.1890/ES13-00160.1
Also http://www.statisticsdonewrong.com/

Good read

Twenty tips for interpreting scientific claims

https://doi.org/10.1038/503335a

Visualisation of data and models is key

First things first

- Always

First things first

- Always
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Plot data and models

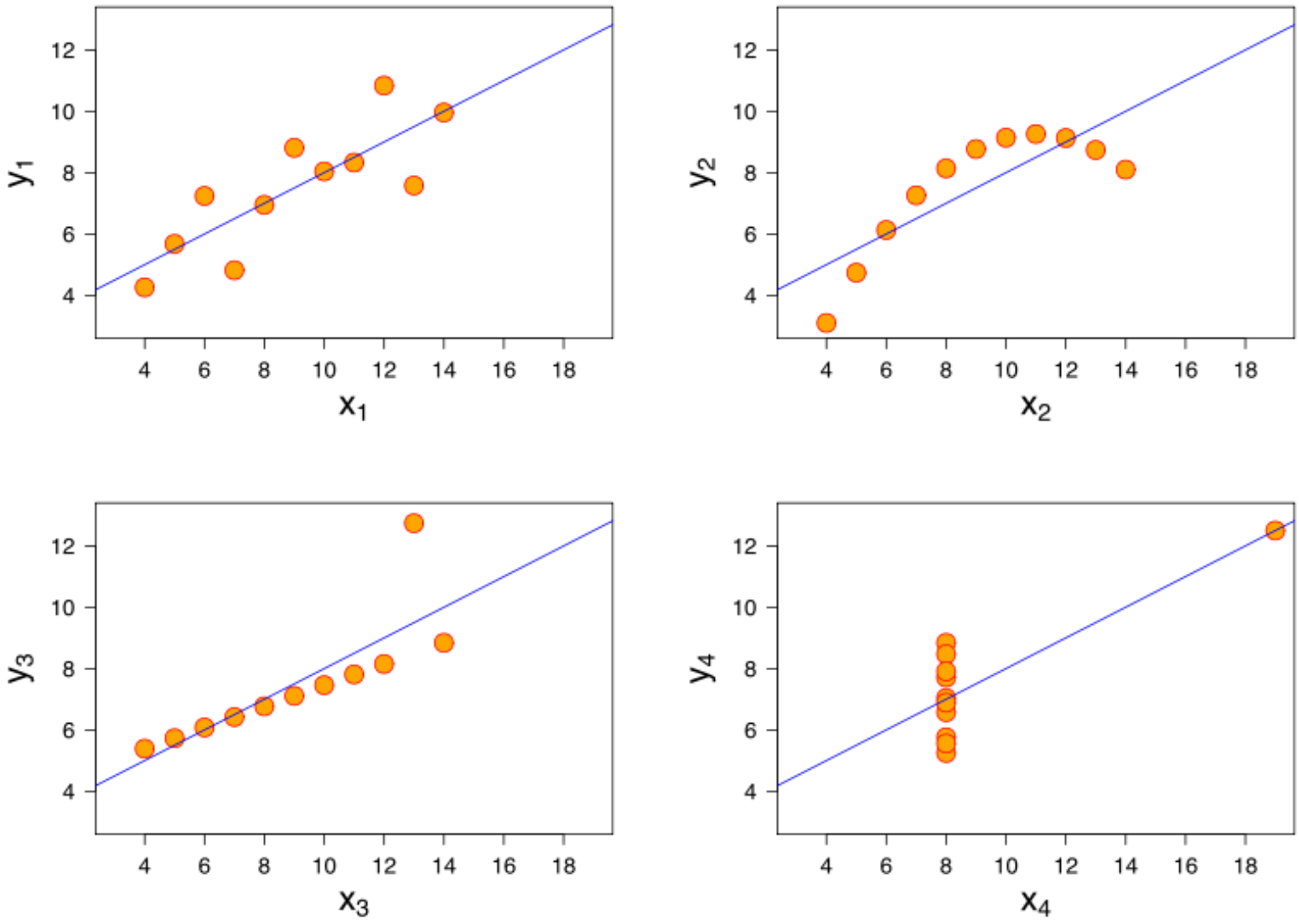
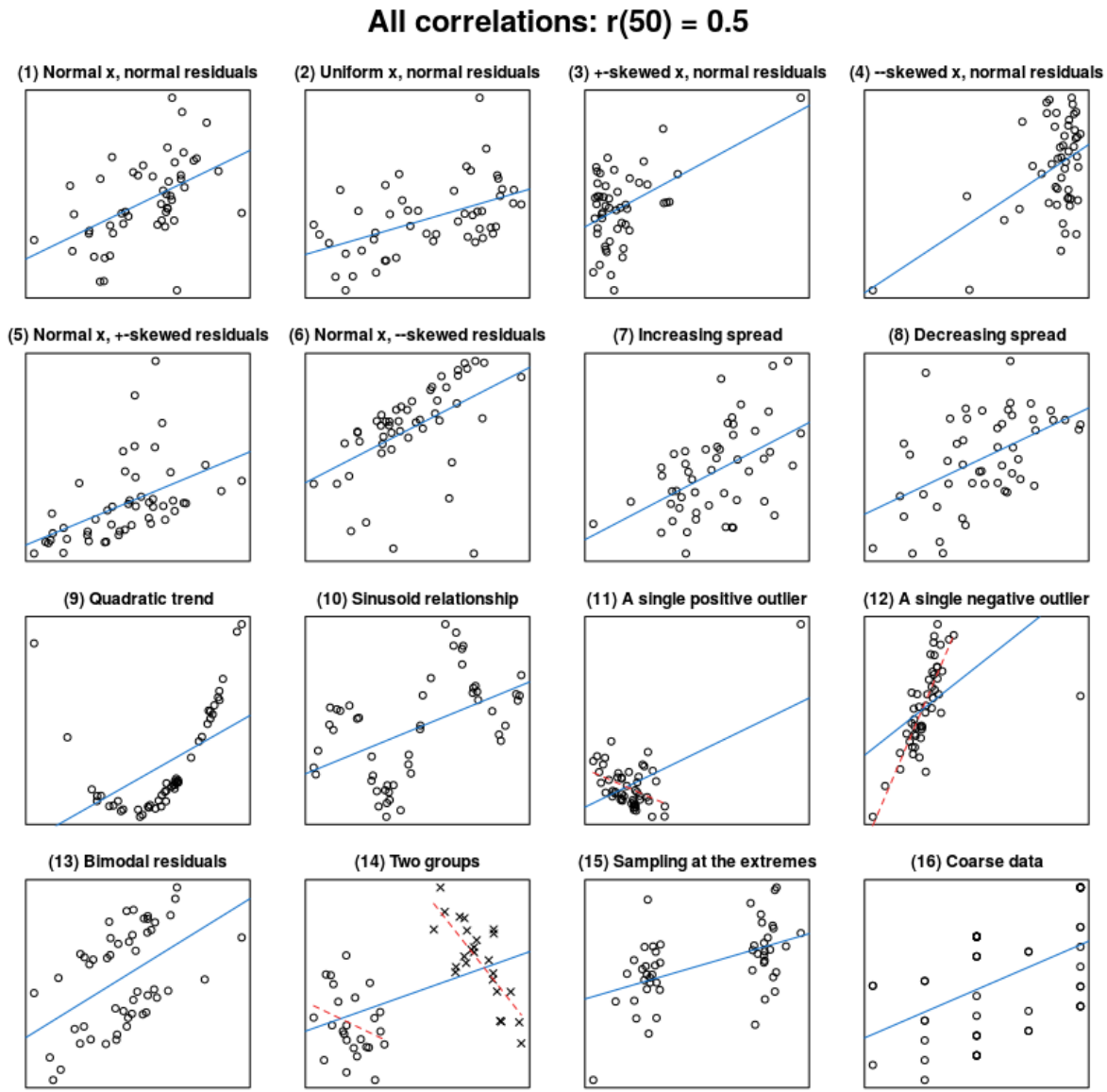


Figure 4:

Don't use statistics blindly: *Visualise*



https://janhove.github.io/teaching/2016/11/21/what-correlations-look-like

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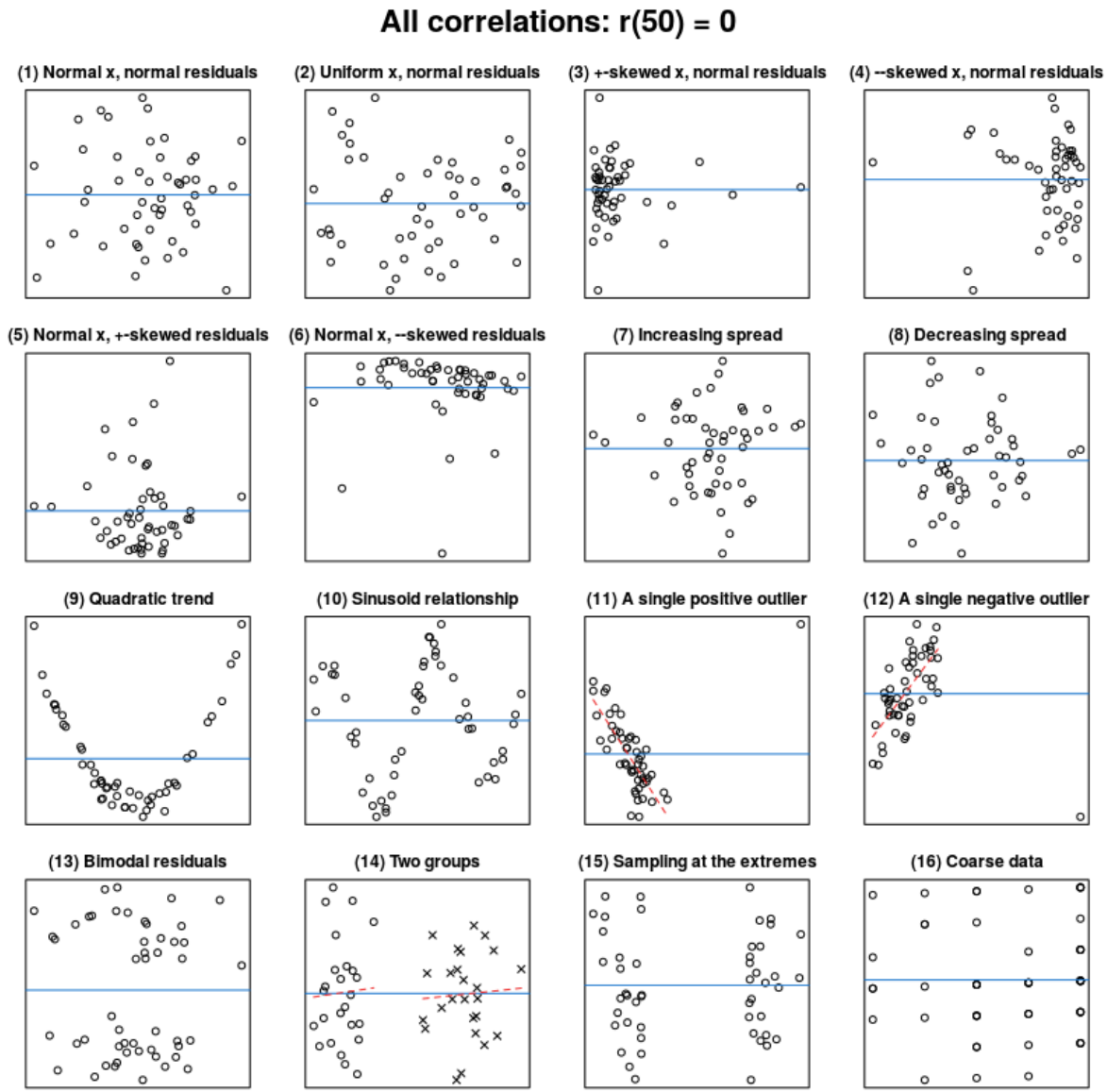

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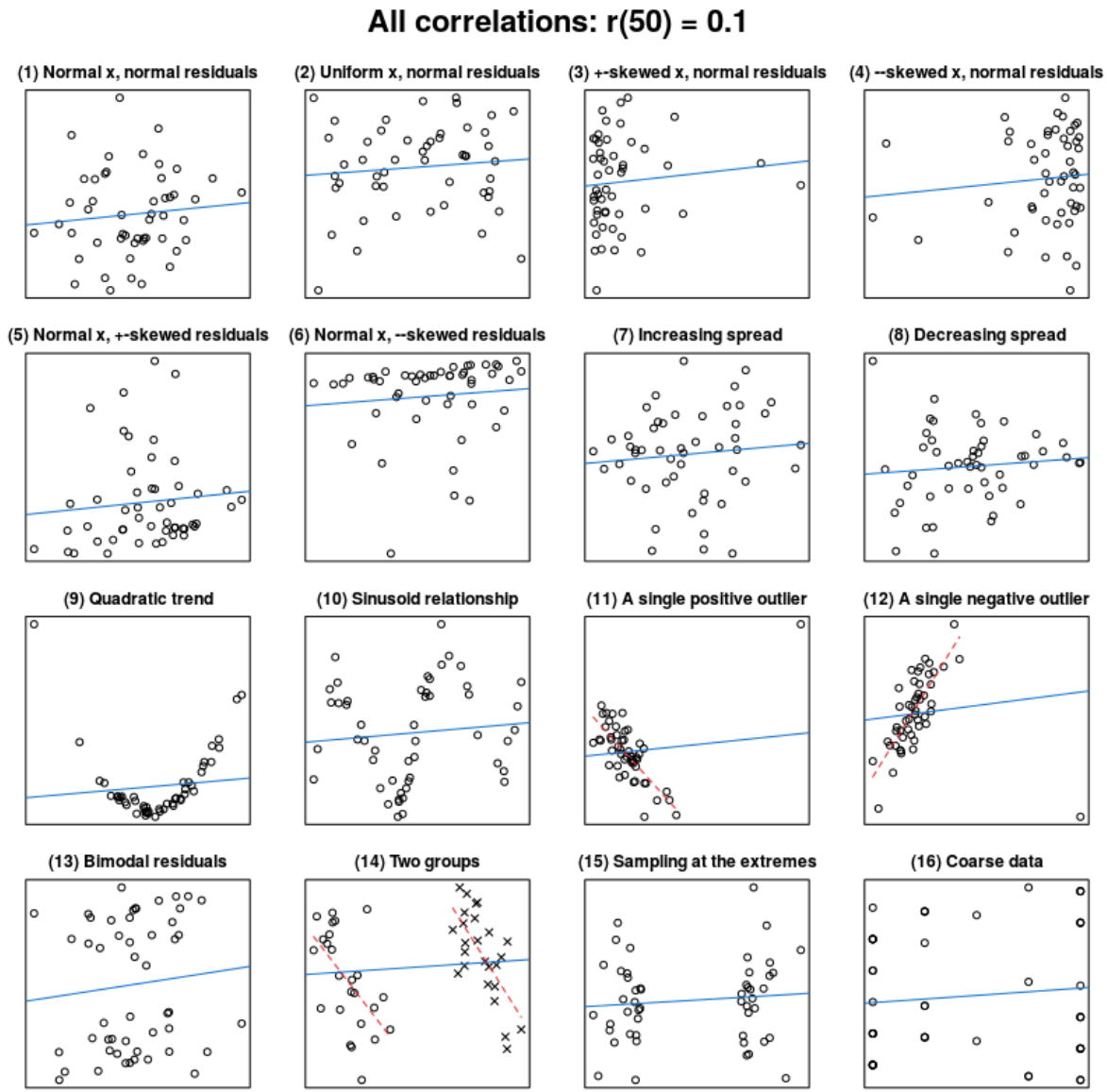

https://janhove.github.io/teaching/2016/11/21/what-correlations-look-like

Plot. Check models. Plot. Check assumptions. Plot.

Lavine 2014 *Ecology*

Inference from observational studies

News: Hamburgers increase risk of heart attack

- In a sample of 10,000 people, it was found that people eating >2 hamburgers a week had 20% higher probability of heart attack.

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- **Do hamburgers increase heart attacks?**

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Bigger flowers increase reproductive success

- We found that plants with big flowers produced 30% more seeds...

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Correlation vs Causation

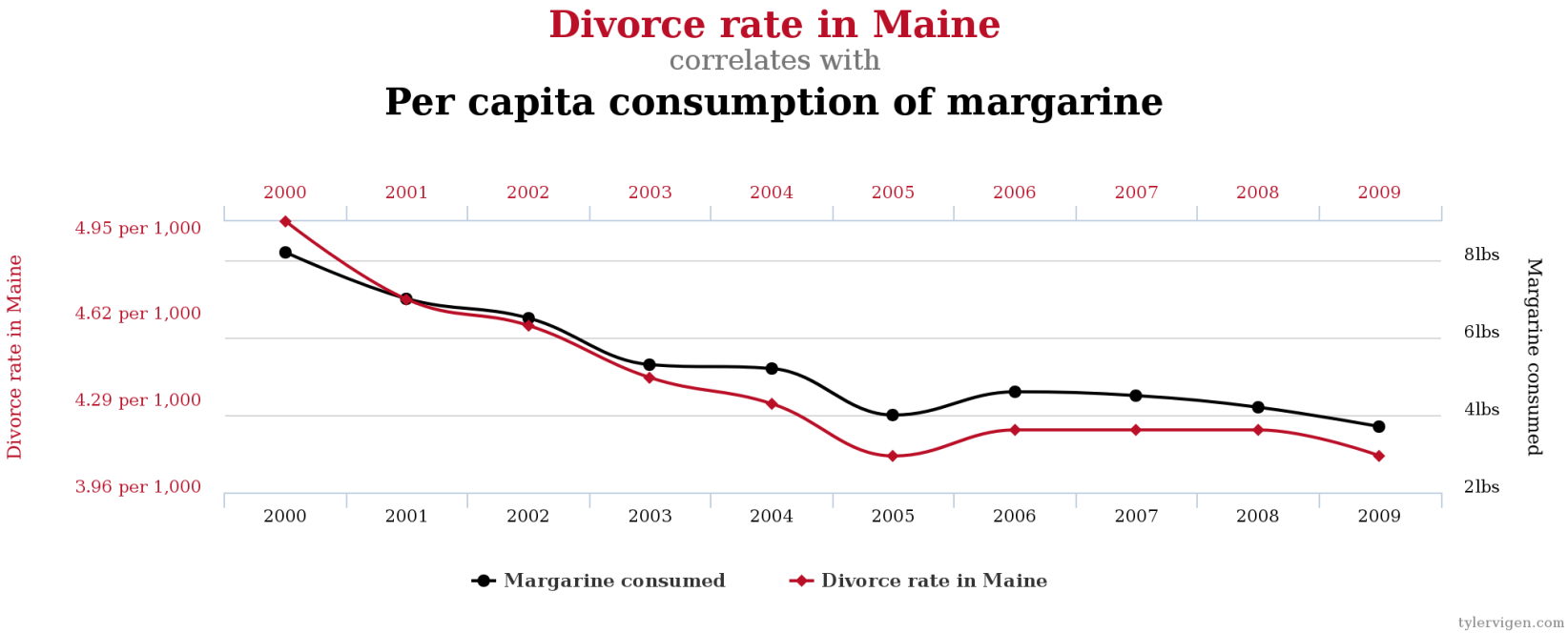
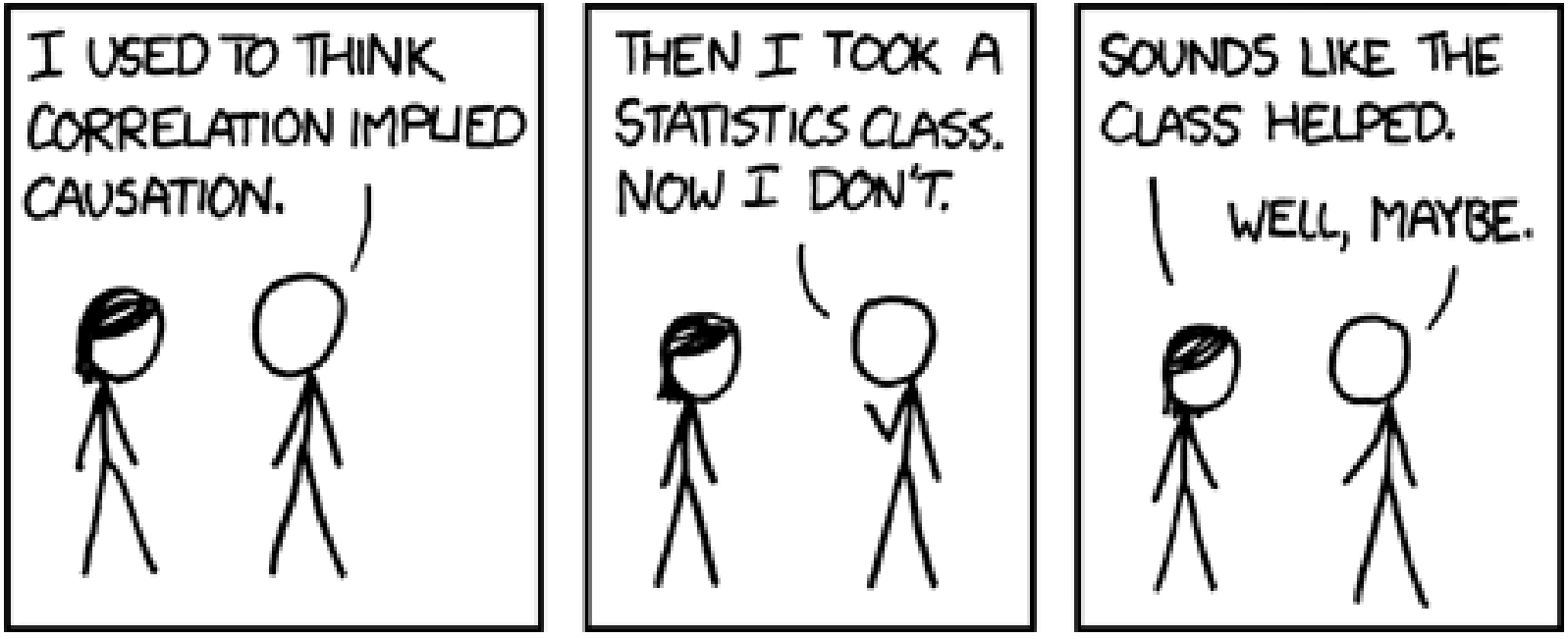


Figure 5:

http://tylervigen.com/spurious-correlations

Learning statistics through xkcd



NHST and p-values

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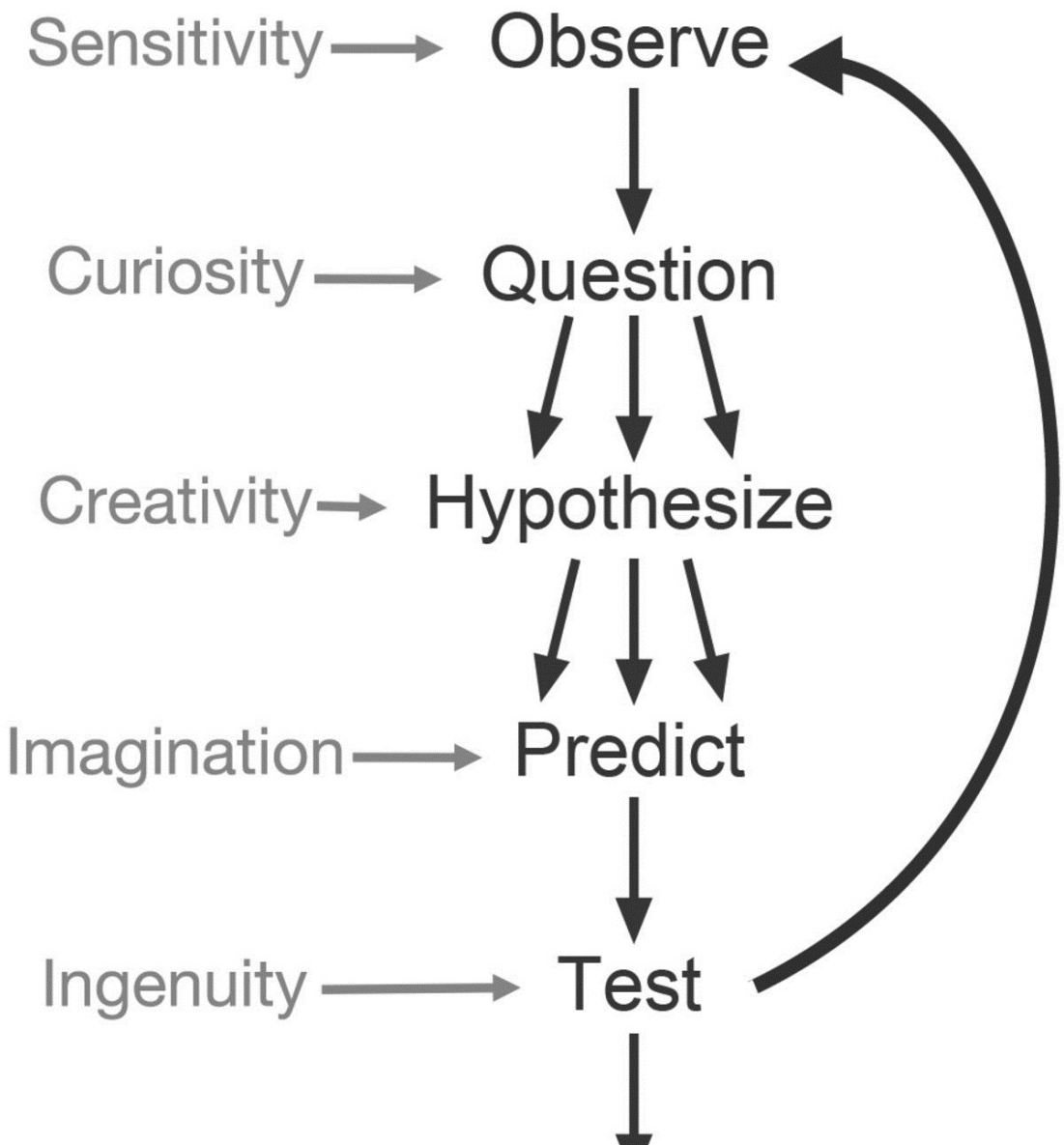
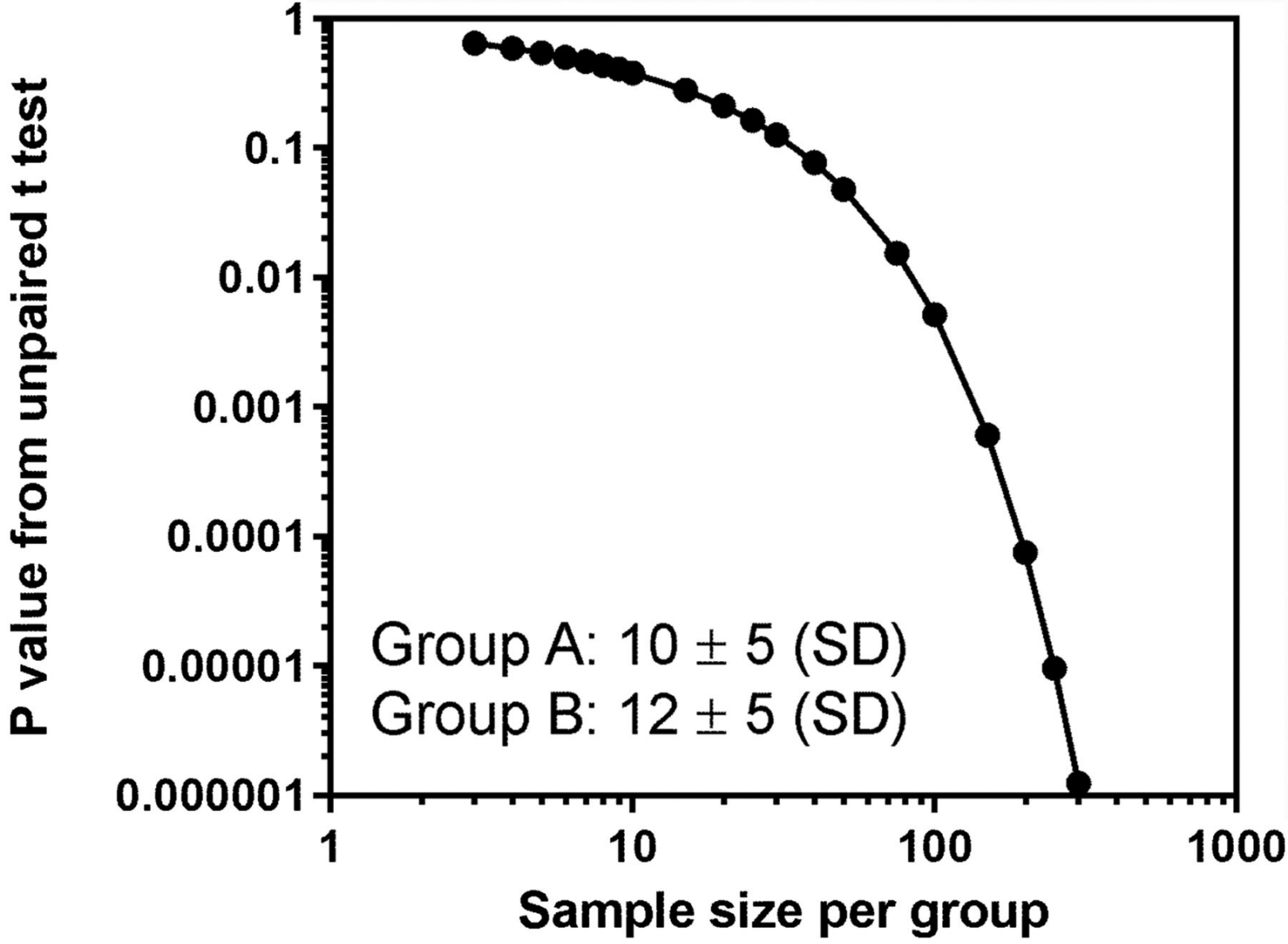
Instead of falsifying a null model, estimate effects and compare meaningful models



P-value depends on sample size



https://doi.org/10.1002/prp2.93

P-value depends on sample size

- Same real difference is detected as significant or not depending on sample size:

Real difference = 40 g

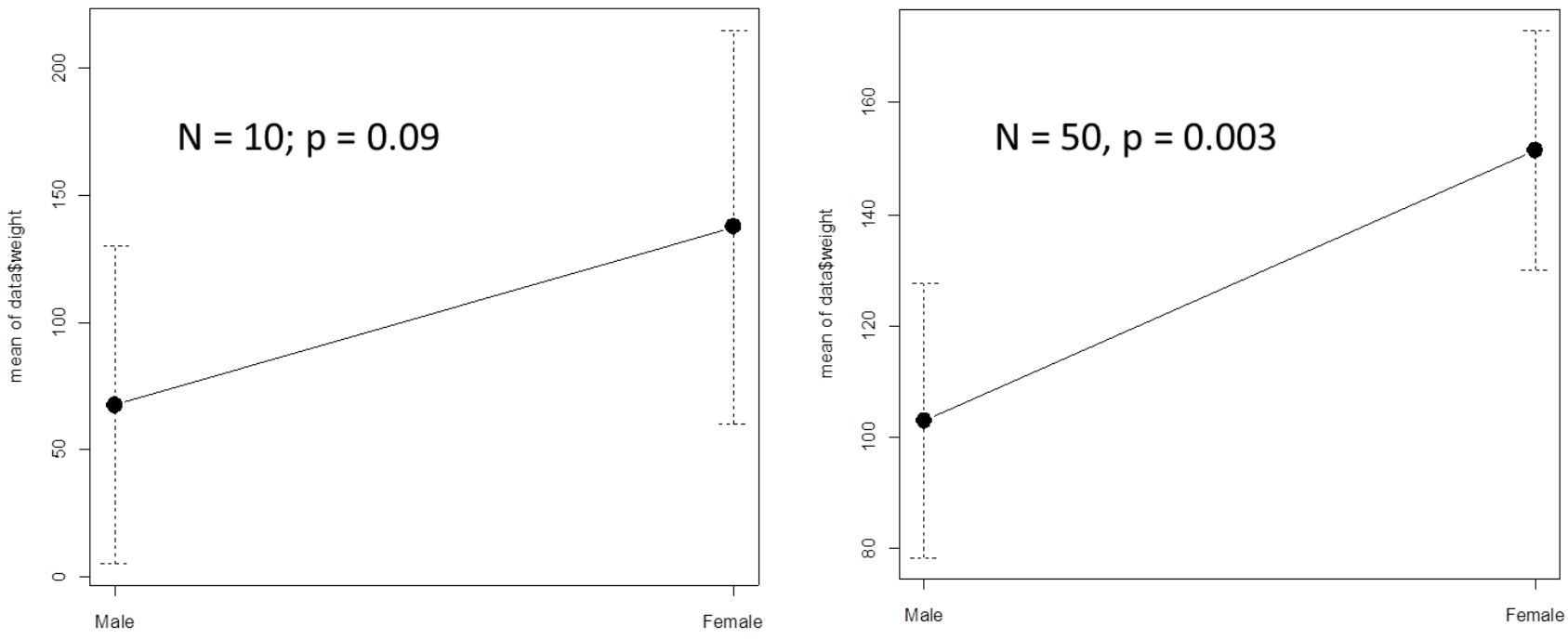
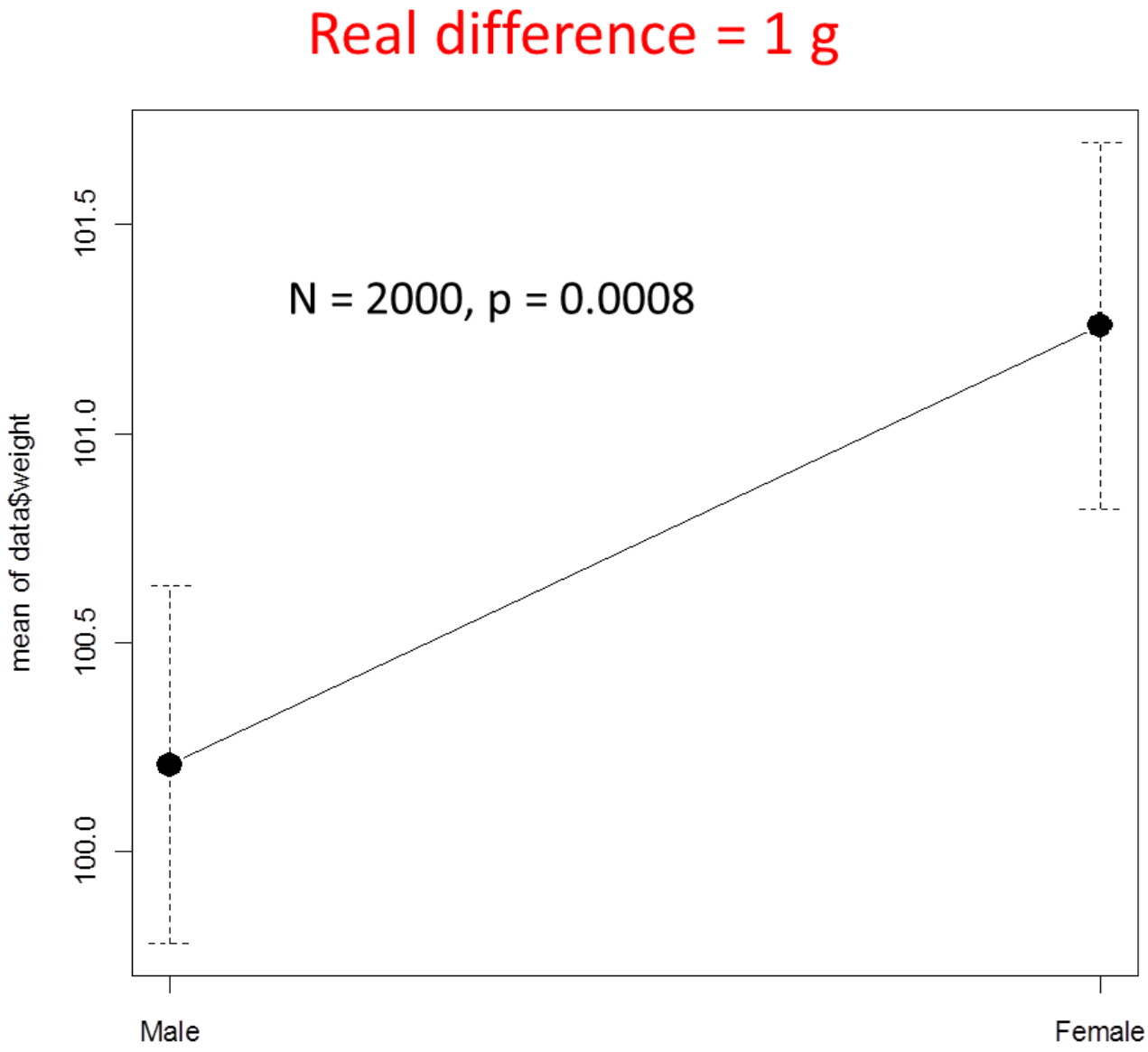


Figure 6:

Statistically significant != biologically important

- With big sample size, we can find **highly significant but biologically unimportant** differences.



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Statistically significant != biologically important

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- Good read: *significantly misleading*
- My suggestion: avoid significant/not significant (and maybe p-values too)
- Beyond significance, look at *effect sizes*.

‘Not significant’ does NOT mean ‘there is no effect’

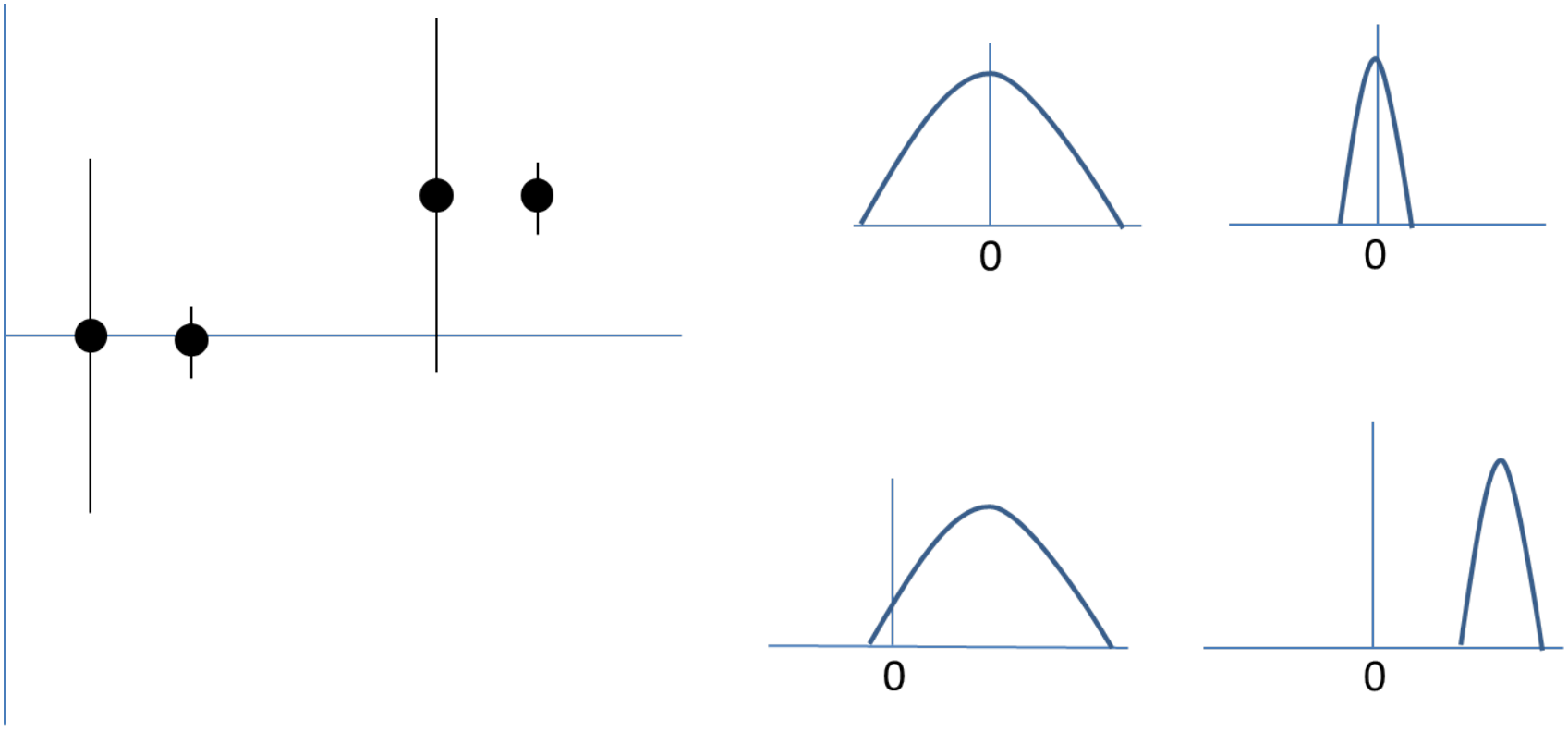
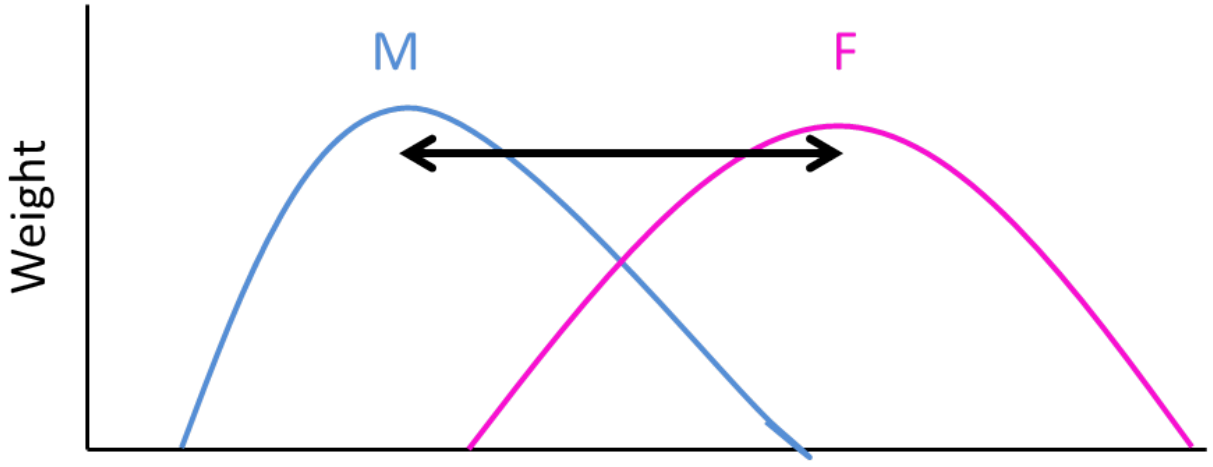


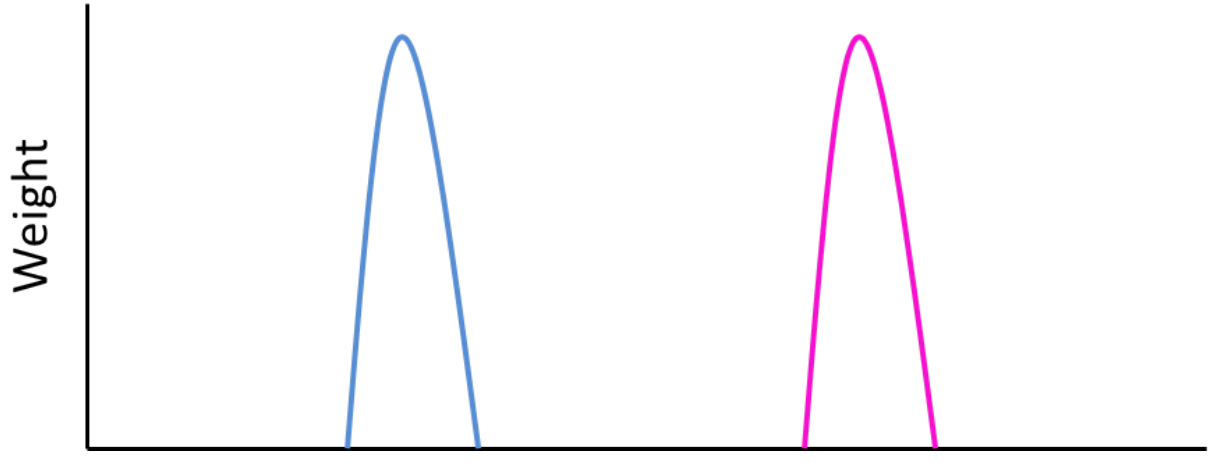
Figure 8:

- **Absence of evidence != Evidence of absence**

Failure to reject H0 != H0 is true



P >> 0.05



P << 0.05

Figure 9:

p-value > 0.05?

"We were unable to find evidence against the hypothesis that A $=$ B with the current sample size"

Is it safe to allow right turn with red lights?

- Right turn not allowed: 308 accidents

https://www.statisticsdonewrong.com/power.html#the-wrong-turn-on-red

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- Right turn allowed: 337 accidents
- No *significant* difference, hence safe
- Misinterpretation of underpowered study cost lives

https://www.statisticsdonewrong.com/power.html#the-wrong-turn-on-red

0.05 is an arbitrary threshold

The Difference Between "Significant" and "Not Significant" is not Itself Statistically Significant

Andrew GELMAN and Hal STERN

Figure 10:

http://dx.doi.org/10.1198/000313006X152649

Multiple hypothesis testing

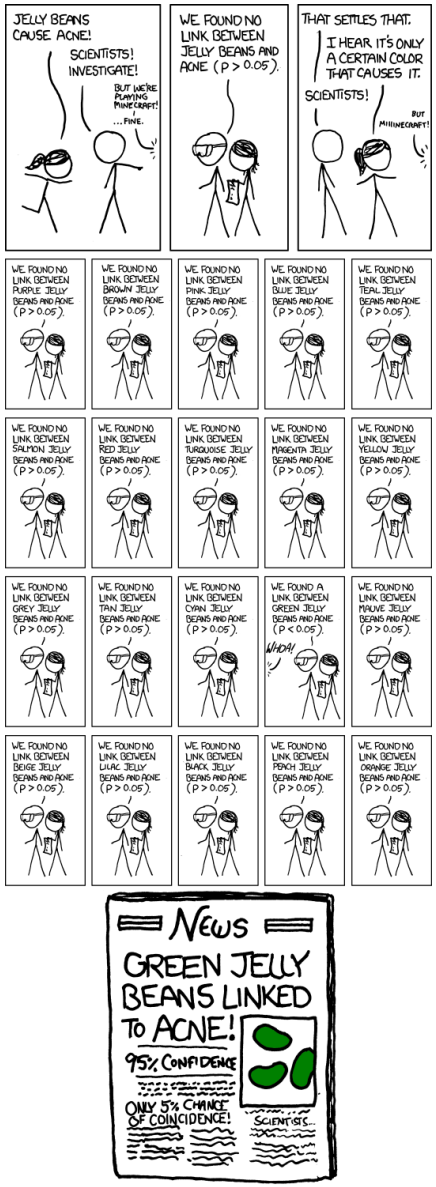
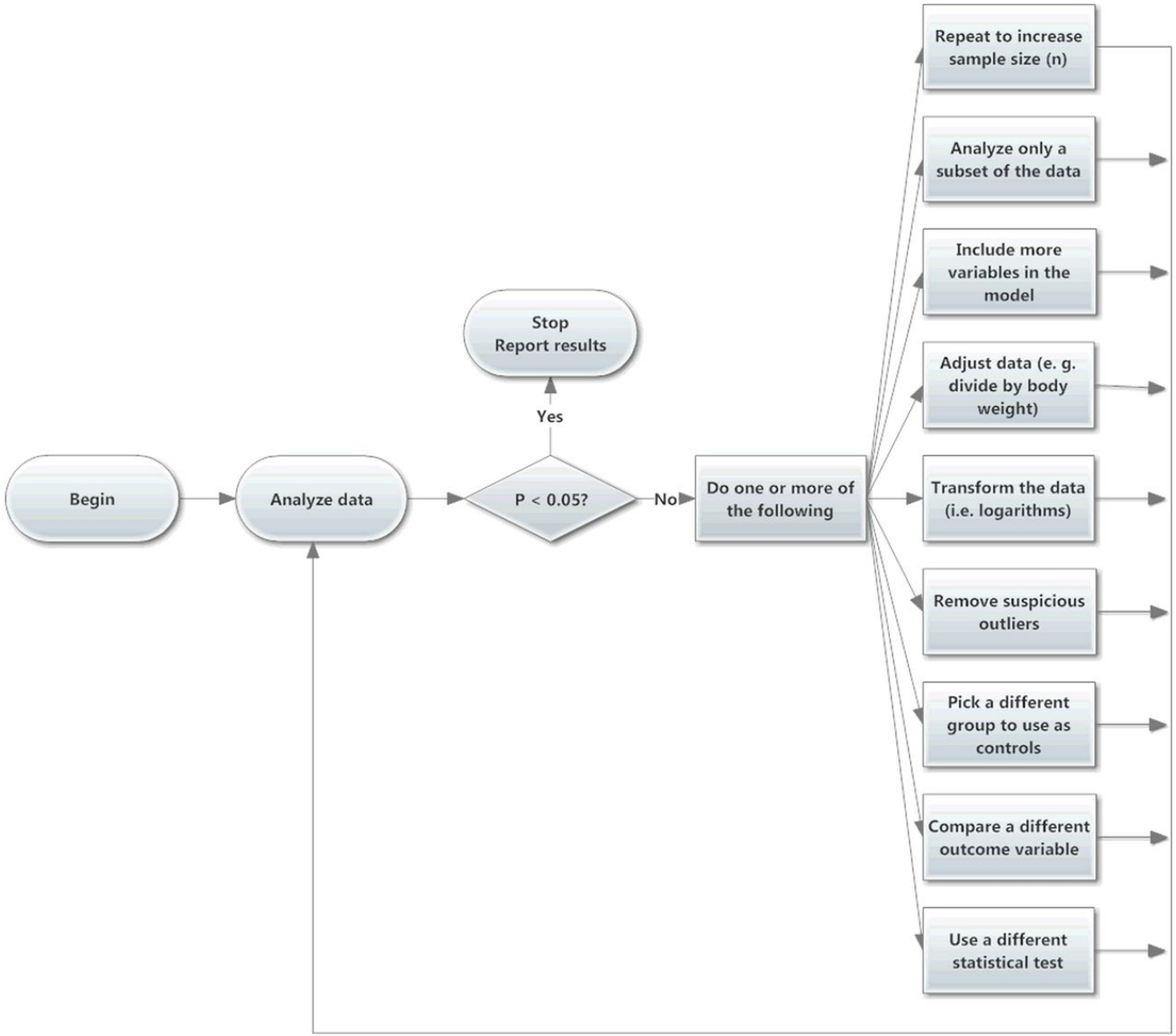


Figure 11:

How to make your results significant: *p-hacking*



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- To read more: Simmons et al 2011

How to make your results significant: *p-hacking*

https://www.youtube.com/watch?v=ZaNtz76dNSI

ASA statement on p-values

- P-values do not measure the **probability of hypothesis** being true, or the probability that the data were produced by **random chance** alone.

https://doi.org/10.1080/00031305.2016.1154108

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- By itself, a p-value does NOT provide a good **measure of evidence** regarding a model or hypothesis.

https://doi.org/10.1080/00031305.2016.1154108

The New Statistics

Aim for estimation of effects and their uncertainty (SE, CI. . .)

General Article

The New Statistics: Why and How

Geoff Cumming
La Trobe University

Psychological Science
2014, Vol. 25(1) 7–29

DOI: 10.1177/0956797613504966
pss.sagepub.com

Figure 12:

http://dx.doi.org/10.1177/0956797613504966

How many types of errors?

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