Hypothesis testing

NHST concepts

Null and alternative hypotheses

- Tell me...

Null and alternative hypotheses

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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 biology, everything is somewhat different

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

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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-

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- Probability of observing data as or more extreme than these *if every model assumption were correct*
- What assumptions?
    - Null hypothesis is true
    - No uncontrolled sources of bias (measurement or programming error, p-hacking, etc)

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- See Greenland et al 2016

For example

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- In reality, measurement error (loose cable)

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- there is no difference between groups

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Are differences *significant*?

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MENU nature Subs

EDITORIAL · 20 MARCH 2019

It’s time to talk about ditching statistical significance

https://doi.org/10.1038/d41586-019-00857-9

Are these two groups different?

```r
t.test(group.A, group.B)
```

```

    Welch Two Sample t-test

data:  group.A and group.B
t = -0.60849, df = 5.378, p-value = 0.5677
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -20.54709  12.54709
sample estimates:
mean of x mean of y 
    170.8     174.8 
```

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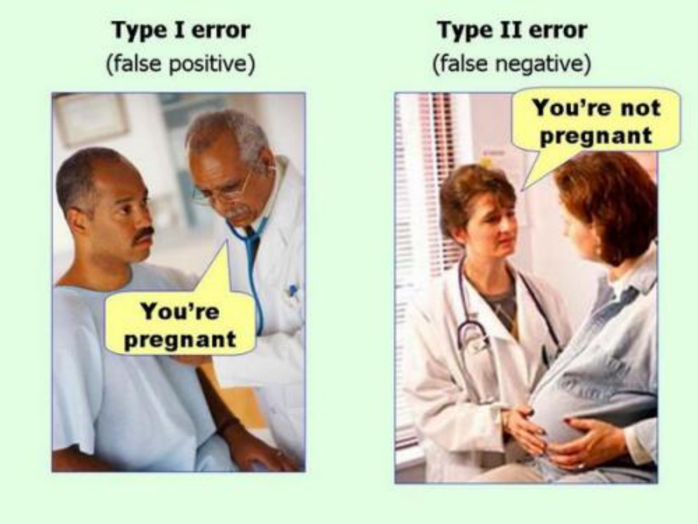
Rejecting hypotheses: two types of error



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

POWER: Probability of detecting true difference (rejecting H0 when it's false).

Is this coin biased?

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

	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
```

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Understanding NHST

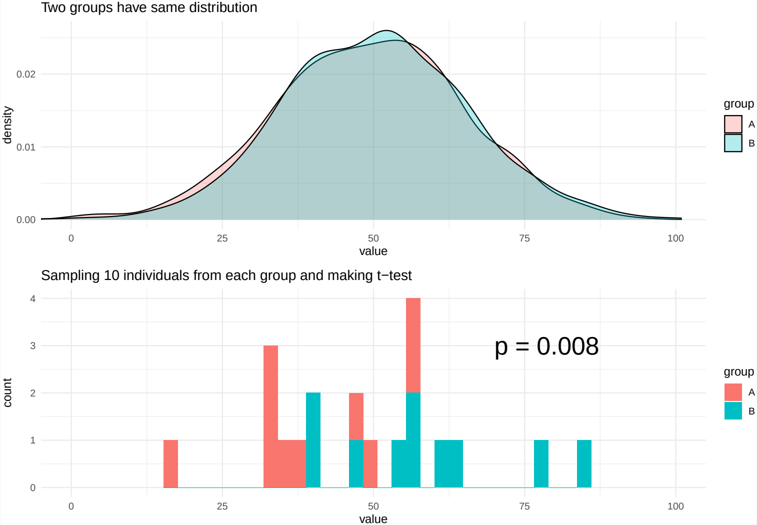
http://rpsychologist.com/d3/NHST/

http://daniellakens.blogspot.com/2017/12/understanding-common-misconceptions.html

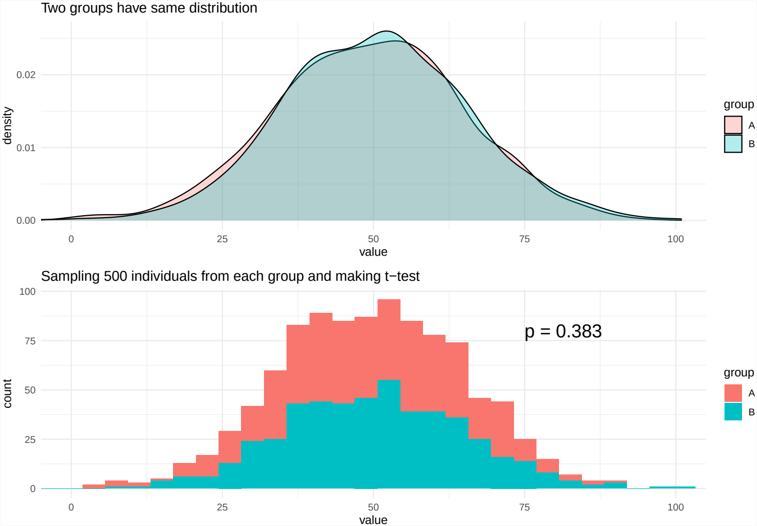
NHST and p-values: common pitfalls

A significant p-value does not mean we found a true difference

Particularly with low sample sizes



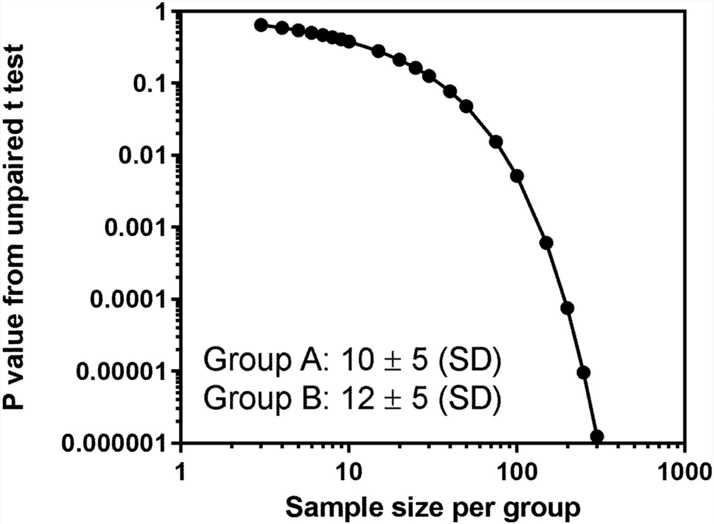
If sample size was larger...



With low sample size (power),
significant p-values
are most likely overestimates

Loken & Gelman 2014, Vasisth et al. 2018

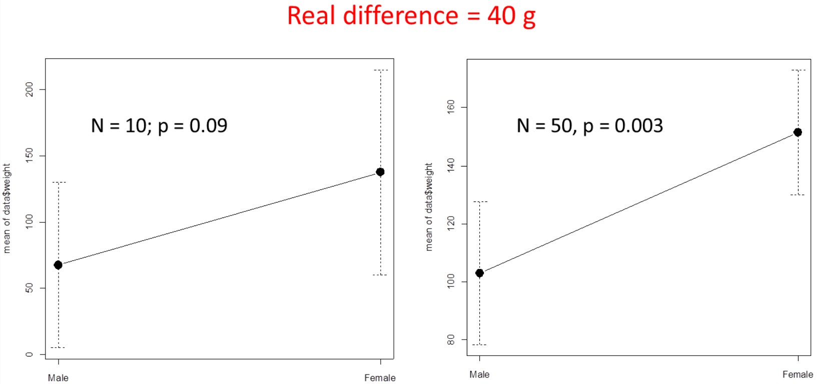
P-value depends on sample size



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

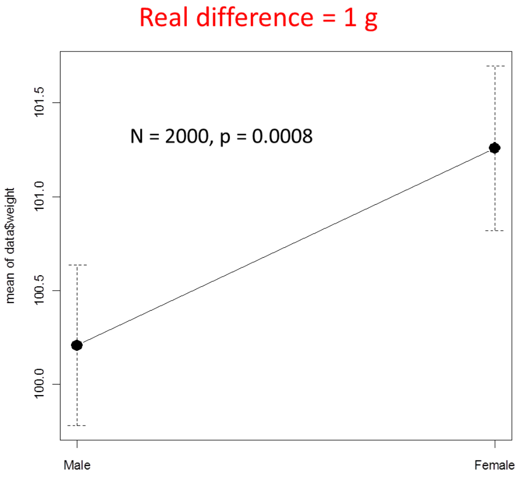
P-value depends on sample size

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



Statistically significant != biologically important

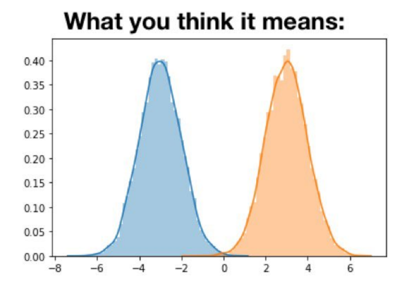
With big sample size, we can find **highly significant but biologically unimportant** differences.

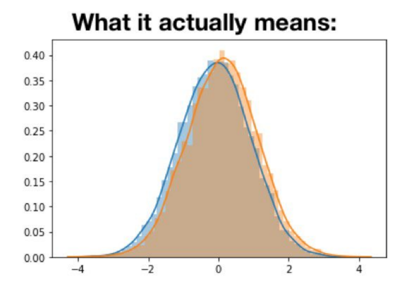


Statistically significant != biologically important

zara weinberg
@weinberz

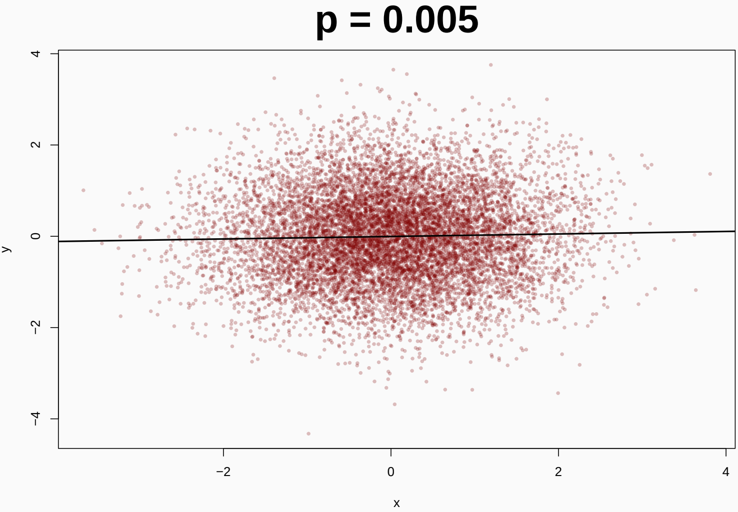
friendly reminder about $p < 0.0001$:





https://twitter.com/weinberz/status/1422405165236178947?s=20

Statistically significant != biologically important



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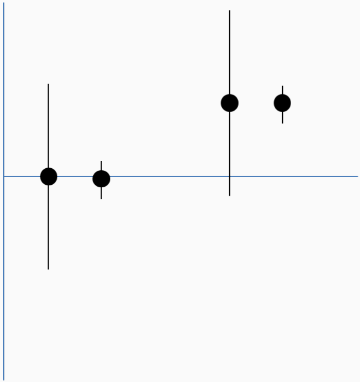
- Good read: *significantly misleading*

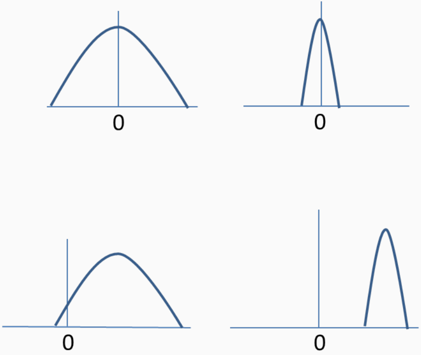
Statistically significant != biologically important

- Statistically significant = unlikely to be zero
- Good read: *significantly misleading*
- Beyond significant/not significant, look at *effect sizes* and their uncertainty.

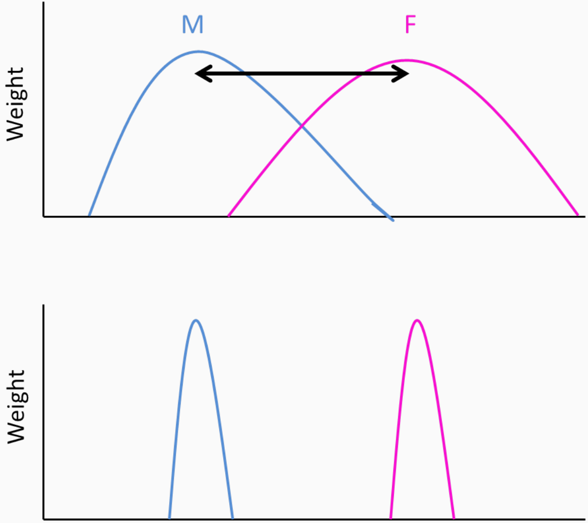
‘Not significant’ does NOT mean ‘there is no effect’

Absence of evidence != Evidence of absence





Failure to reject H0 != H0 is true



P >> 0.05

P << 0.05

p-value > 0.05?

- “We were **unable to find evidence** against the hypothesis that A = B **with the current sample size**” (Harrell)

p-value > 0.05?

- “We were **unable to find evidence** against the hypothesis that A = B **with the current sample size**” (Harrell)
- “Differences between groups were **not statistically clear**” (Dushoff et al)

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`

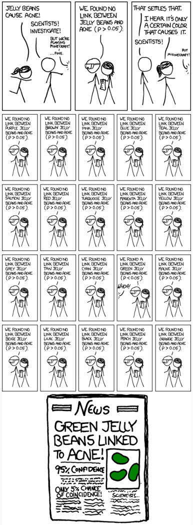
0.05 is an arbitrary threshold

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

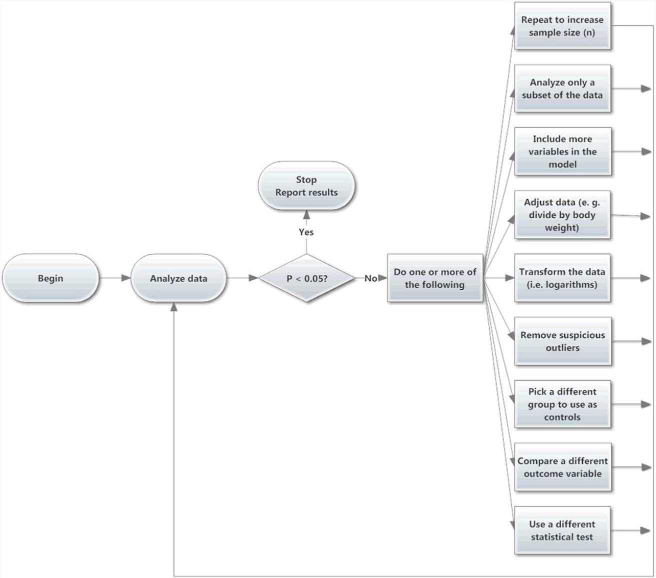
Andrew GELMAN and Hal STERN

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

Multiple hypothesis testing



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



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- To read more: Simmons et al 2011

p-hacking: try it yourself

https://www.shinyapps.org/apps/p-hacker/

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

Good practice

A must read

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

CrossMark

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

esa 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]

https://doi.org/10.1890/ES13-00160.1

Also http://www.statisticsdonewrong.com/

Good read

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

The New Statistics

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

General Article

ASSOCIATION FOR PSYCHOLOGICAL SCIENCE

The New Statistics: Why and How

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

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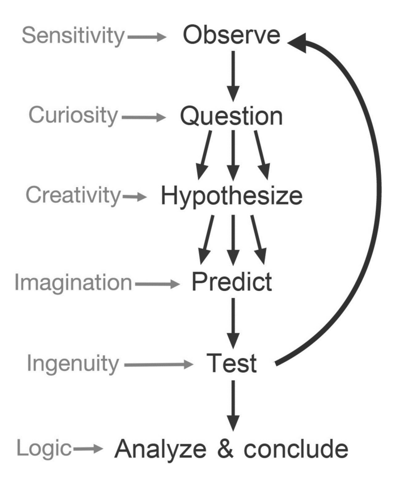
Geoff Cumming
La Trobe University

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

Instead of falsifying null model, compare meaningful models



https://doi.org/10.1242/jeb.104976

How many types of errors?

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- Beyond Power Calculations: Assessing Type S (Sign) and Type M (Magnitude) Errors