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

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

P value

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- Very complicated concept: even statisticians fail to describe it well.

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- Low P-value: data unlikely if H0 was true.

P value

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- Very complicated concept: even statisticians fail to describe it well.
- 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.

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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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- **CAUTION:**
- 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

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

```

    Welch Two Sample t-test

data:  h.sevi and h.out
t = -0.35784, df = 4.7983, p-value = 0.7357
alternative hypothesis: true difference in means is not equal to
95 percent confidence interval:
 -19.03344  14.43344
sample estimates:
mean of x mean of y 
    174.2     176.5 
```

Are heights different then?

Rejecting hypotheses: two types of error

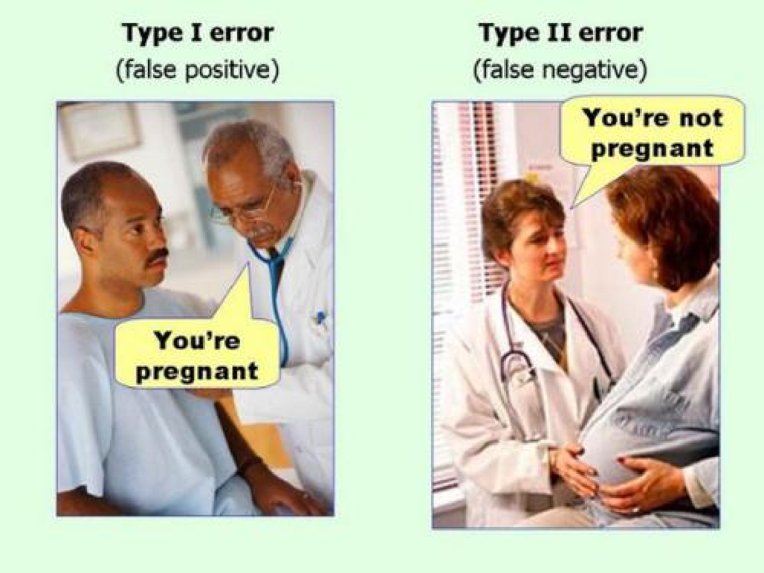
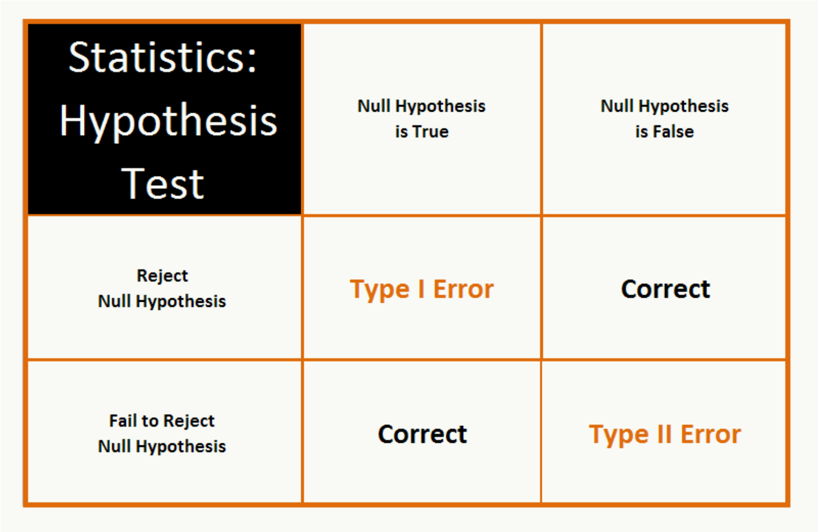


Figure 1:

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 1 0 0 1 0 0 1 1 0
```

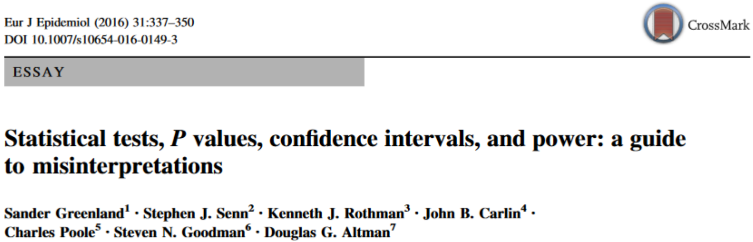
```
	1-sample proportions test with continuity correction

data:  sum(coin) out of ntrials, null probability 0.5
X-squared = 0.1, df = 1, p-value = 0.7518
alternative hypothesis: true p is not equal to 0.5
95 percent confidence interval:
 0.1369306 0.7263303
sample estimates:
  p 
0.4 
```

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

CrossMark

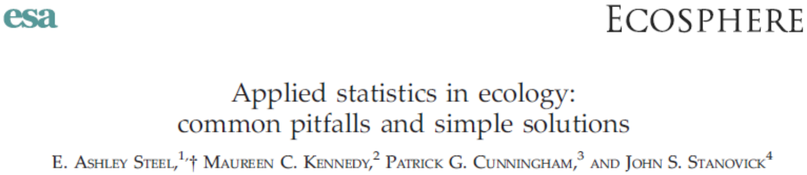
ESSAY

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 reading



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]

Figure 3:

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

First things first

- Always

First things first

- Always
- Always

First things first

- Always
- Always
- Always

Plot data and models

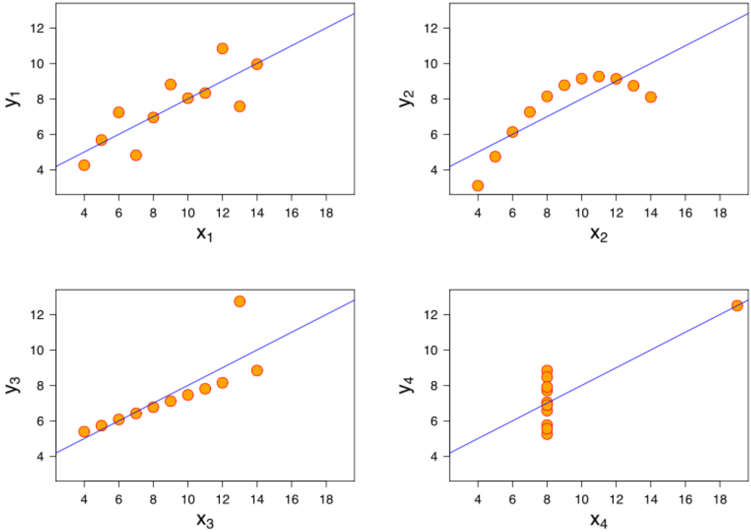
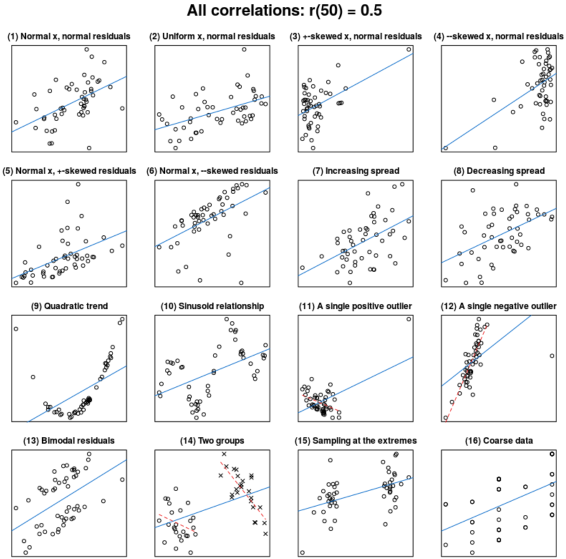


Figure 4:

Don't use statistics blindly: *Visualise*



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

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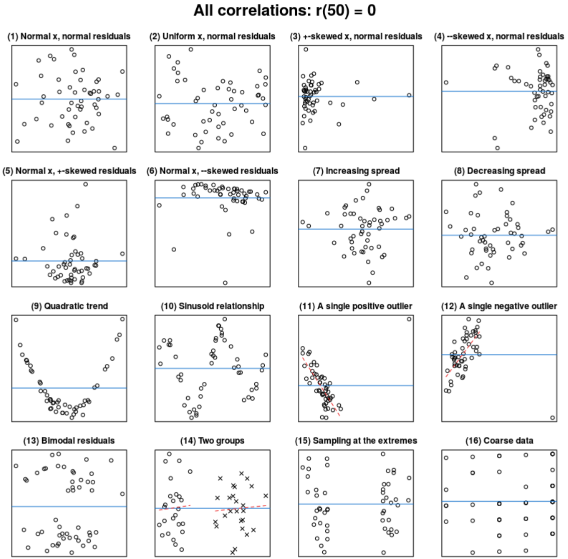

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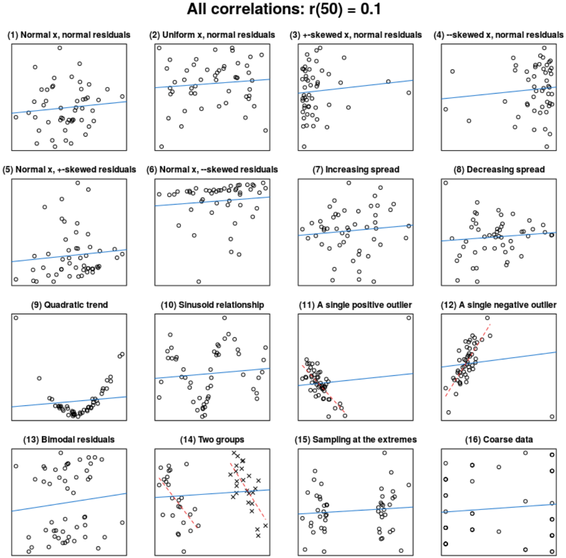

https:
//janhove.github.io/teaching/2016/11/21/what-correlations-look-like

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

Lavine 2014 *Ecology*

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.

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.
- **Do hamburgers increase heart attacks?**

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- In a sample of 10,000 people, it was found that people eating >2 hamburgers a week had 20% higher probability of heart attack.
- **Do hamburgers increase heart attacks?**
- https://pollev.com/franciscorod726

Bigger flowers increase reproductive success

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

Bigger flowers increase reproductive success

- We found that plants with big flowers produced 30% more seeds...
- **Do big flowers increase reproductive success?**

Bigger flowers increase reproductive success

- We found that plants with big flowers produced 30% more seeds. . .
- **Do big flowers increase reproductive success?**
- https://pollev.com/franciscorod726

Correlation vs Causation

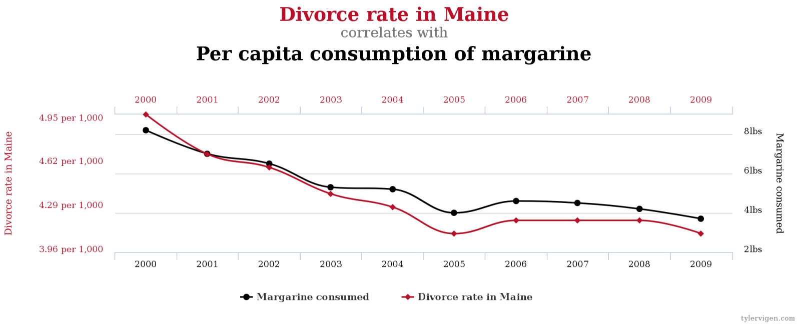
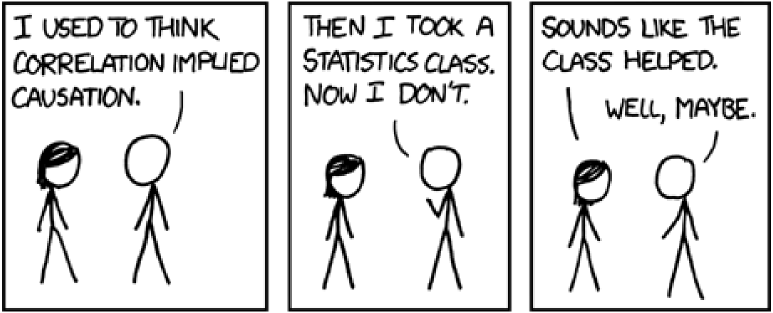


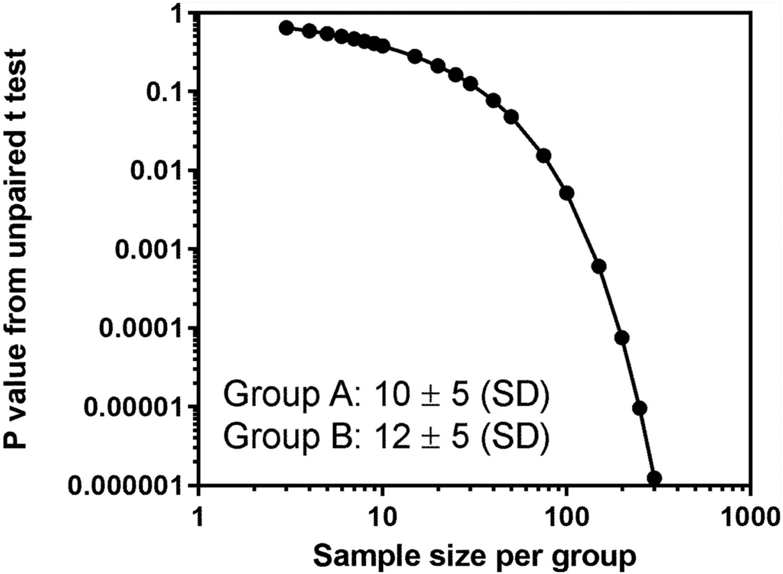
Figure 5:

http://tylervigen.com/spurious-correlations

Learning statistics through xkcd


I USED TO THINK CORRELATION IMPLIED CAUSATION.
THEN I TOOK A STATISTICS CLASS. NOW I DON'T.
SOUNDS LIKE THE CLASS HELPED.
WELL, MAYBE.

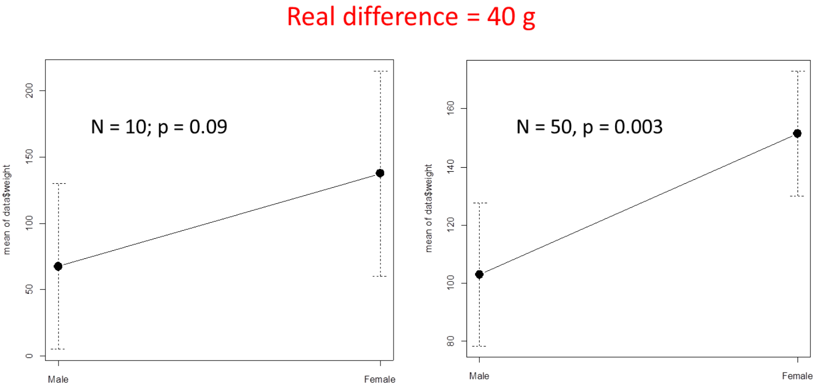
P-value depends on sample size



http://dx.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

N = 10; p = 0.09

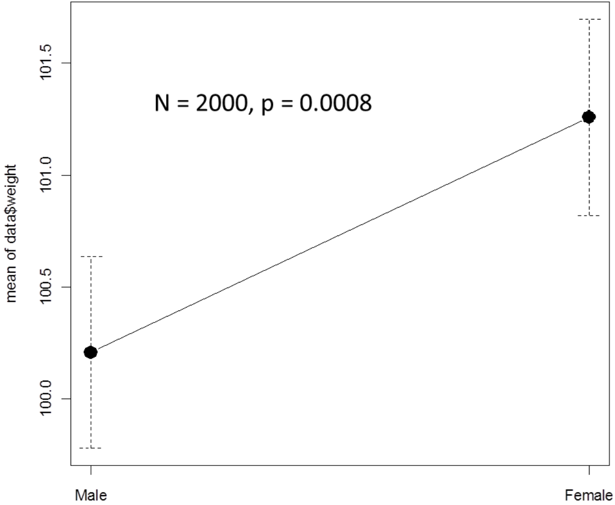
N = 50, p = 0.003

Figure 6:

Statistically significant != biologically important

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

Real difference = 1 g



Statistically significant != biologically important

- Statistically significant = unlikely to be zero

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- Suggested reading: *significantly misleading*

Statistically significant != biologically important

- Statistically significant = unlikely to be zero
- Suggested reading: *significantly misleading*
- Beyond significance, look at *effect sizes*.

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

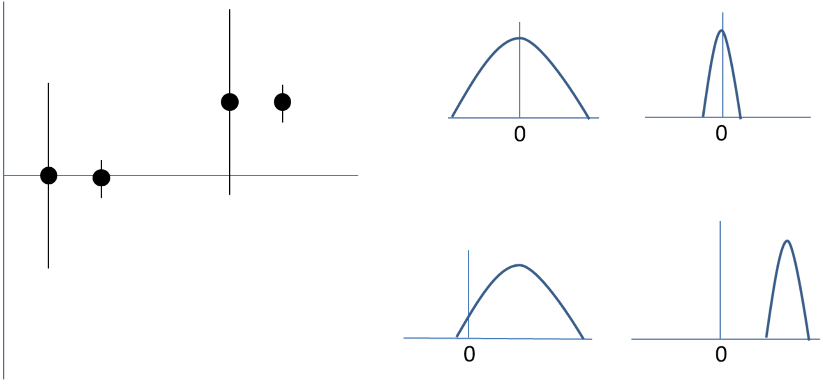


Figure 8:

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

Failure to reject H0 != H0 is true

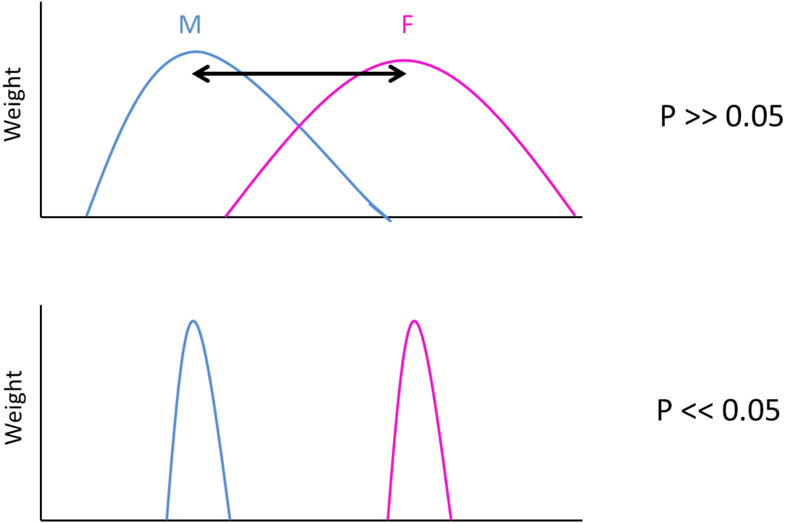
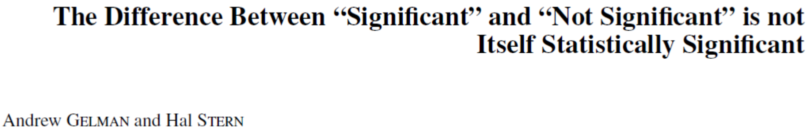


Figure 9:

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

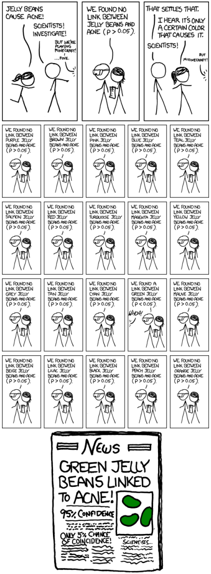
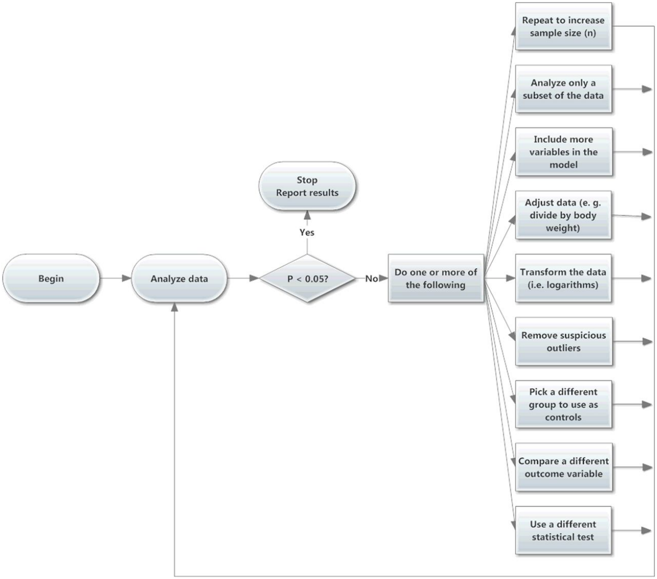

JELLY BEANS CAUSE ACNE!
SCIENTISTS! INVESTIGATE!
BUT WE'RE PLAYING MINECRAFT!
...FINE.
WE FOUND NO LINK BETWEEN JELLY BEANS AND ACNE (P > 0.05).
THAT SETTLES THAT.
I HEAR IT'S ONLY A CERTAIN COLOR THAT CAUSES IT.
SCIENTISTS!
BUT MIIINECRAFT!
WE FOUND NO LINK BETWEEN PURPLE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN BROWN JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN PINK JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN BLUE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN TEAL JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN SALMON JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN RED JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN TURQUOISE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN MAGENTA JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN YELLOW JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN GREY JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN TAN JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN CYAN JELLY BEANS AND ACNE (P > 0.05).
WE FOUND A LINK BETWEEN GREEN JELLY BEANS AND ACNE (P < 0.05).
WHOA!
WE FOUND NO LINK BETWEEN MAUVE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN BEIGE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN LILAC JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN BLACK JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN PEACH JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN ORANGE JELLY BEANS AND ACNE (P > 0.05).
NEWS
GREEN JELLY BEANS LINKED TO ACNE!
95% CONFIDENCE
ONLY 5% CHANCE OF COINCIDENCE!
SCIENTISTS...

Figure 11:

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


Begin
Analyze data
P < 0.05?
Yes
Stop
Report results
No
Do one or more of the following
Repeat to increase sample size (n)
Analyze only a subset of the data
Include more variables in the model
Adjust data (e. g. divide by body weight)
Transform the data (i.e. logarithms)
Remove suspicious outliers
Pick a different group to use as controls
Compare a different outcome variable
Use a different statistical test

http://dx.doi.org/10.1002/prp2.93

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

1. Test multiple variables, then report the ones that are significant.

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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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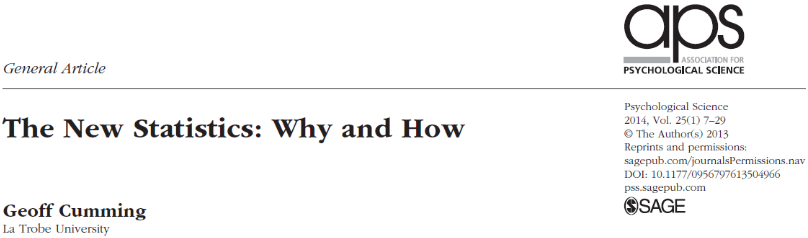
- Scientific conclusions or policy decisions should NOT be based only on **whether a p-value passes a specific threshold**.
- P-value, or statistical significance, does not measure the **size of an effect** or the **importance** of a result.
- By itself, a p-value does NOT provide a good **measure of 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.



General Article

The New Statistics: Why and How

Geoff Cumming
La Trobe University

Psychological Science
2014, Vol. 25(1) 7–29
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DOI: 10.1177/0956797613504966
pss.sagepub.com
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ASSOCIATION FOR
PSYCHOLOGICAL SCIENCE

Figure 12:

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

How many types of errors?

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