

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

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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 living 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-

P value

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- ▶ Probability of observing data as or more extreme than these *if H_0 was true*.
- ▶ Low P-value: data unlikely if H_0 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 H_0 was true*.
- ▶ Low P-value: data unlikely if H_0 was true.
- ▶ Large P-value: data not unusual if H_0 was true.

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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:

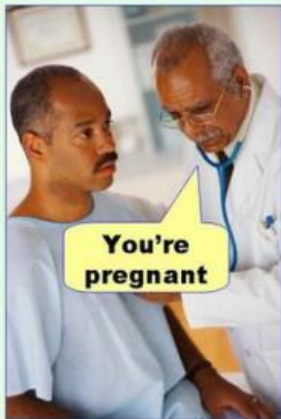
mean of x mean of y

169.8 177.5

Are heights different then?

Rejecting hypotheses: two types of error

Type I error
(false positive)



Type II error
(false negative)



Figure 1:

Rejecting hypotheses: two types of error

Statistics: Hypothesis Test	Null Hypothesis is True	Null Hypothesis is False
	Type I Error	Correct
	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 Greenland¹ · Stephen J. Senn² · Kenneth J. Rothman³ · John B. Carlin⁴ · Charles Poole⁵ · Steven N. Goodman⁶ · Douglas G. Altman⁷

<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. STANOVICK⁴

Figure 3:

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

Also <http://www.statisticsonewrong.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

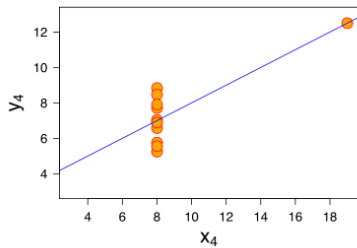
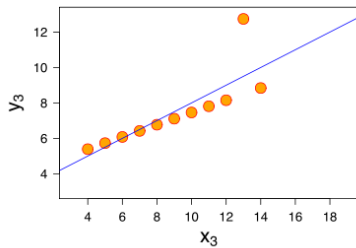
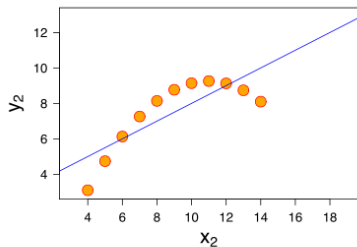
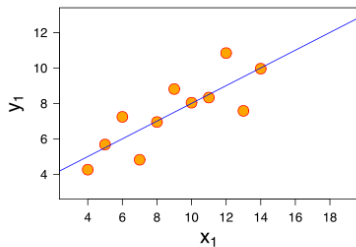
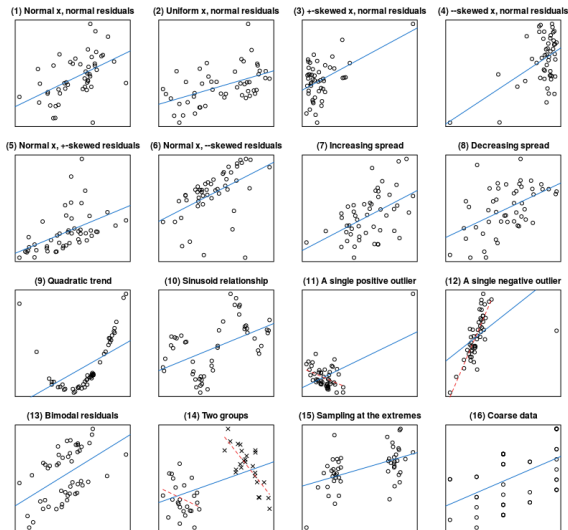


Figure 4:

Don't use statistics blindly: *Visualise*

All correlations: $r(50) = 0.5$

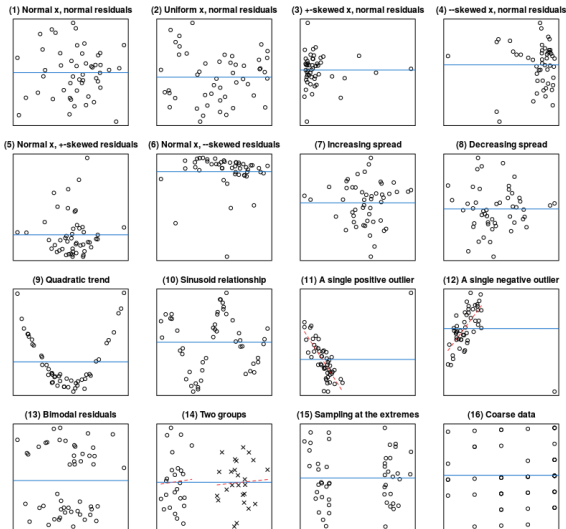


[https:](https://janhove.github.io/teaching/2016/11/21/what-correlations-look-like)

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All correlations: $r(50) = 0$

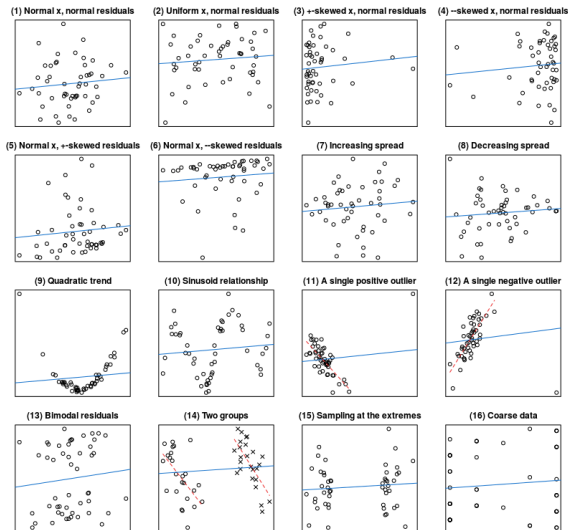


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Don't use statistics blindly: *Visualise*

All correlations: $r(50) = 0.1$



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[//janhove.github.io/teaching/2016/11/21/what-correlations-look-like](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.

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. . .

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- ▶ We found that plants with big flowers produced 30% more seeds. . .
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Correlation vs Causation

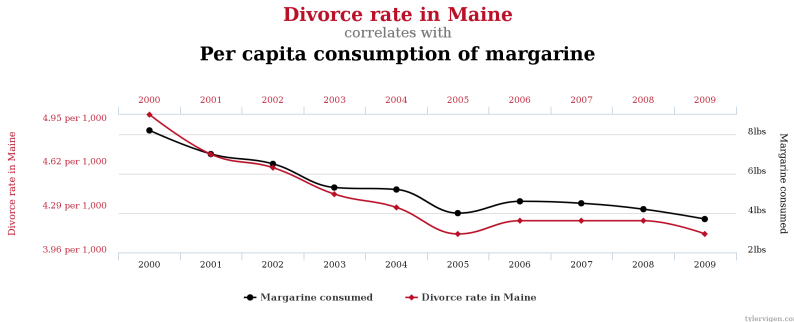
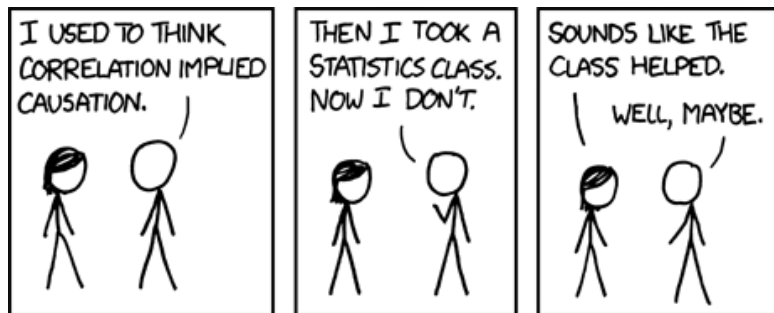


Figure 5:

<http://tylervigen.com/spurious-correlations>

Learning statistics through xkcd



NHST and p-values

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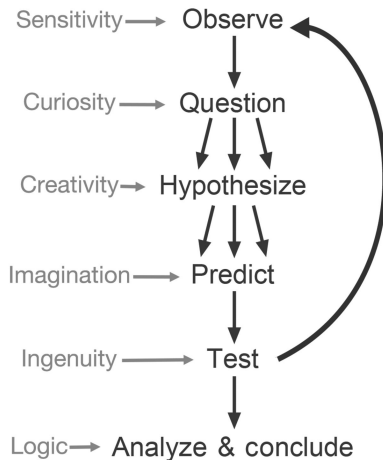
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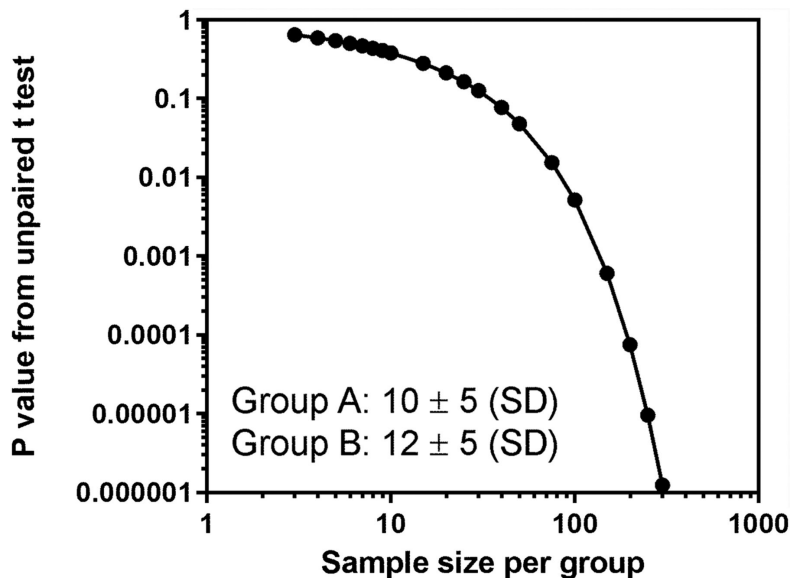
ABSTRACT

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 living 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-

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



P-value depends on sample size



P-value depends on sample size

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

Real difference = 40 g

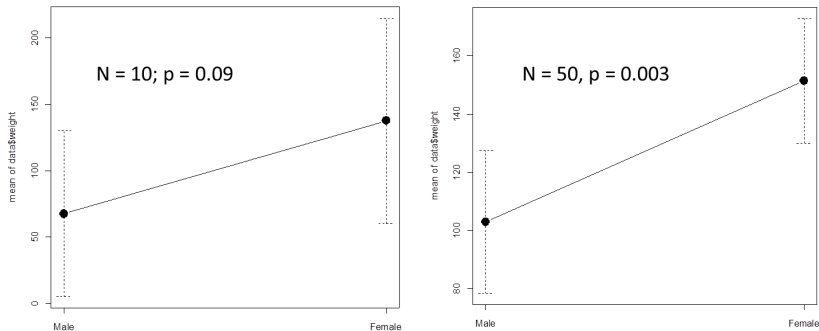
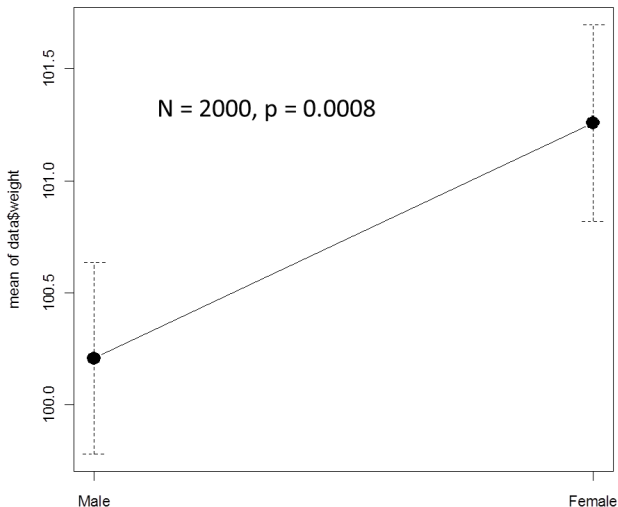


Figure 6:

Statistically significant \neq biologically important

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

Real difference = 1 g



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- ▶ Good read: *significantly misleading*

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- ▶ My suggestion: avoid significant/not significant (and maybe p-values too)

Statistically significant \neq biologically important

- ▶ Statistically significant = unlikely to be zero
- ▶ 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'

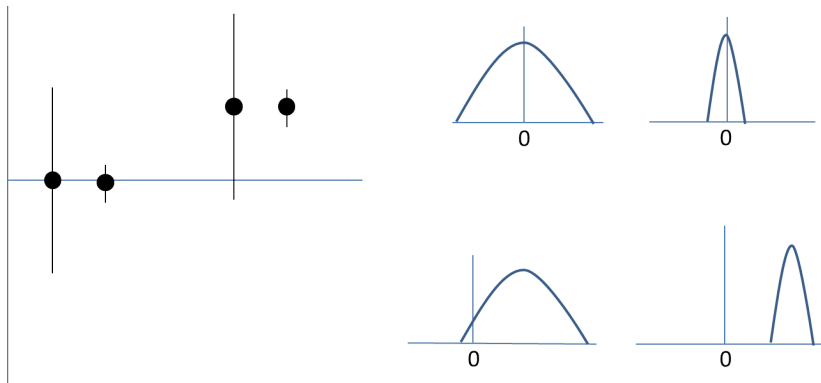
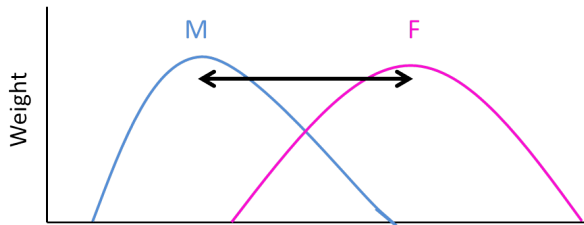


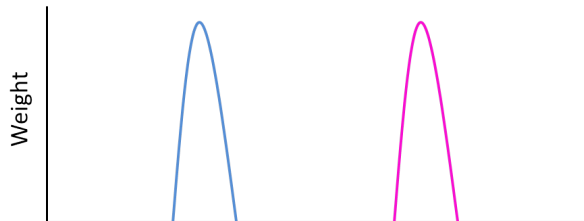
Figure 8:

► Absence of evidence \neq Evidence of absence

Failure to reject $H_0 \neq H_0$ is true



$P \gg 0.05$



$P \ll 0.05$

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.statisticsonewrong.com/power.html#the-wrong-turn-on-red](https://www.statisticsonewrong.com/power.html#the-wrong-turn-on-red)

Is it safe to allow right turn with red lights?

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- ▶ Misinterpretation of underpowered study cost lives

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[//www.statisticsonewrong.com/power.html#the-wrong-turn-on-red](https://www.statisticsonewrong.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

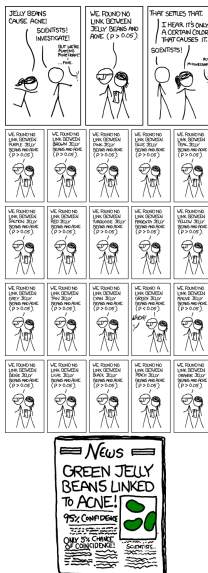
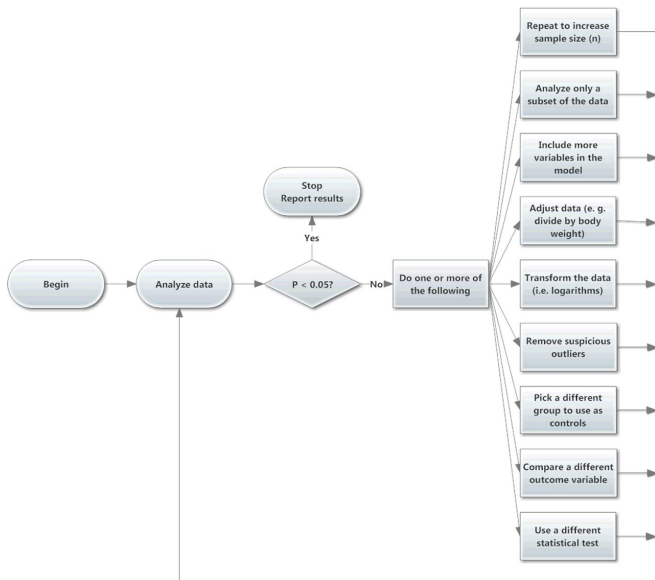


Figure 11:

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



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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>

ASA statement on p-values

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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 (SE, CI...)

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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sagepub.com/journalsPermissions.nav
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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- ▶ **Type M (Magnitude):** Misestimating magnitude of the effect (under or overestimating).
- ▶ Beyond Power Calculations: Assessing Type S (Sign) and Type M (Magnitude) Errors