A scientific mindset is good for the world, and for science

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Scientific culture in society

We'd probably agree that the progress of scientific culture, or simply of a general scientific attitude (curiosity, use of logic, basic scientific knowledge, attention to quantitative aspects), is nowhere near where it should be in society.

- People's decisions are often driven by clamor, emotionally charged communication, "bubbled" or tribal communication *("they vs us")*, herding behavior. Almost everyone is affected by some of these phenomena... it's human.
- A scientific approach to matters of our world has many competitors! (Not that this is always bad...)
- Even our élites don't always help...

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Btw, you are — or will be — élite!

Scientific culture in politics

Random examples of élites not helping

- Italy's Ministry of Environment and Energy (several governments ago): *"Is it solar?"*

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- Italy's political elections of June 1984: interview of Italian politician after exit poll...
- Italy's constitutional reform of 2020: expected savings vs country's deficit...

Scientific culture in politics

- In general, lots of non sequiturs and logical fallacies in the political discourse

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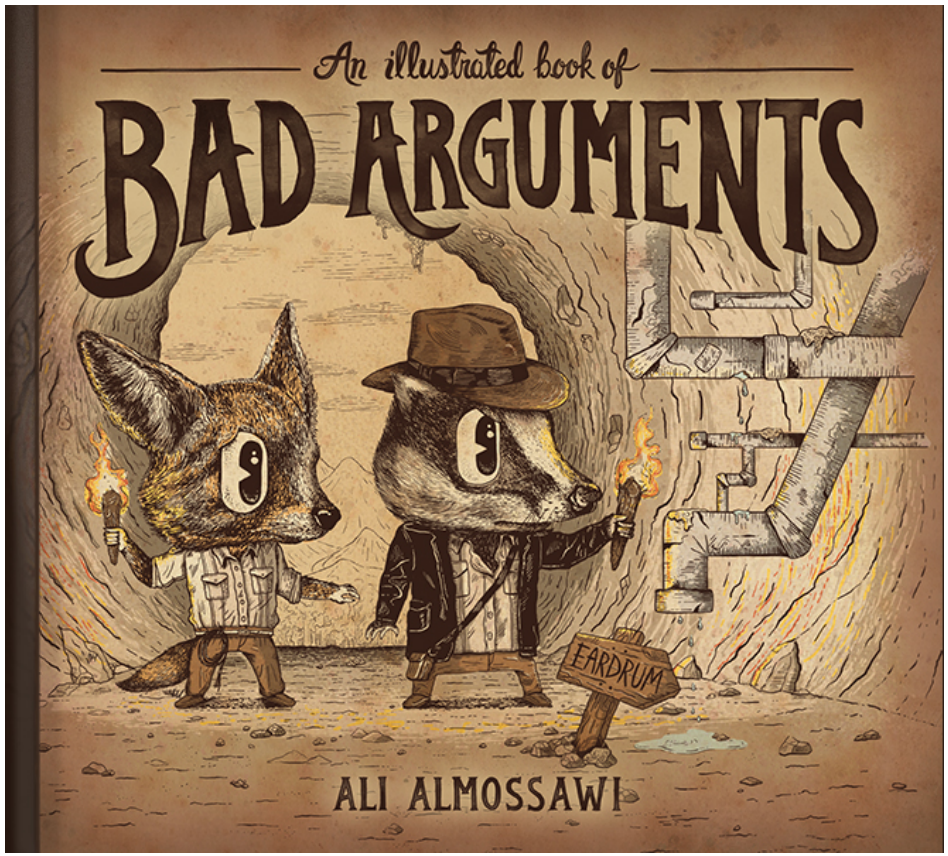

Read for free at: https://bookofbadarguments.com/

Scientific culture in politics

- The Covid pandemic was an interesting time...

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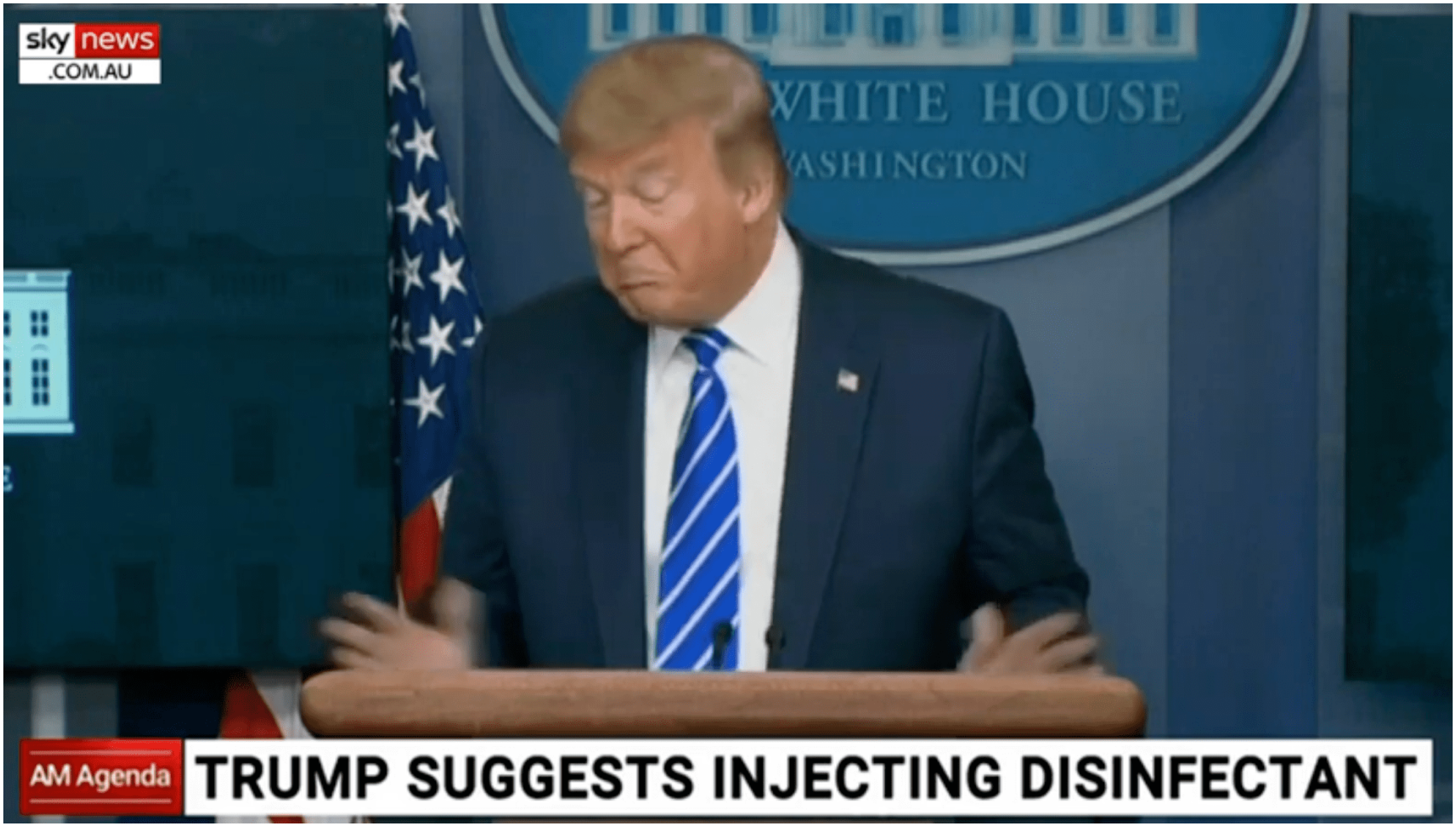

Scientific culture in the press

Press isn't always helping either...

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  "Air travel crisis: flight reservations to Italy down 195%"

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  - 'epicenter' instead of 'ipocenter'
  - etc.

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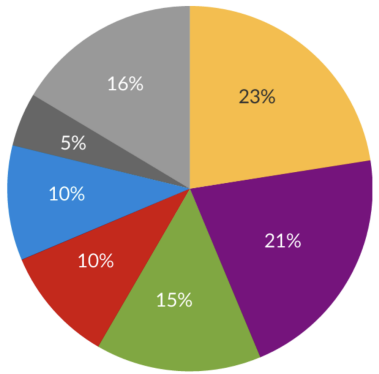
A blatant case:

- Error bars in political polls!!



Scientific culture in the press

- Science reporters have a though job and many of them are very professional. Nonetheless the final result is often this:

Scientific culture in society: scientists

We scientists carry our share of blame in the communication game:

- The Covid pandemic was an interesting time...

Coronavirus, Zangrillo: "Il Covid non esiste più, qualcuno terrorizza il paese". Richeldi: "No, il virus circola"

(La Repubblica, May 31, 2020)

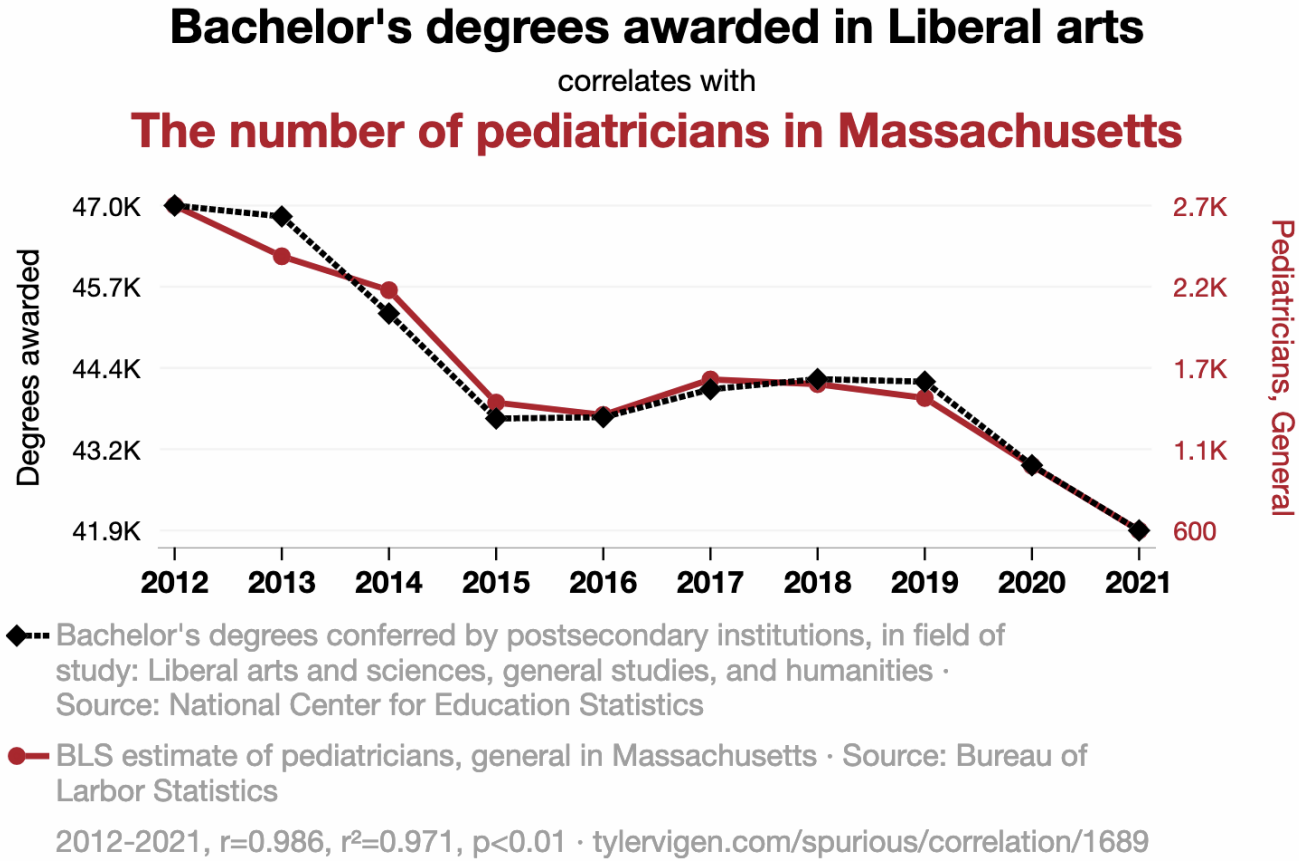
Scientists were more attracted to the blue screen than mosquitoes.
And you could hardly tell them apart from other TV starlets!

Science communication

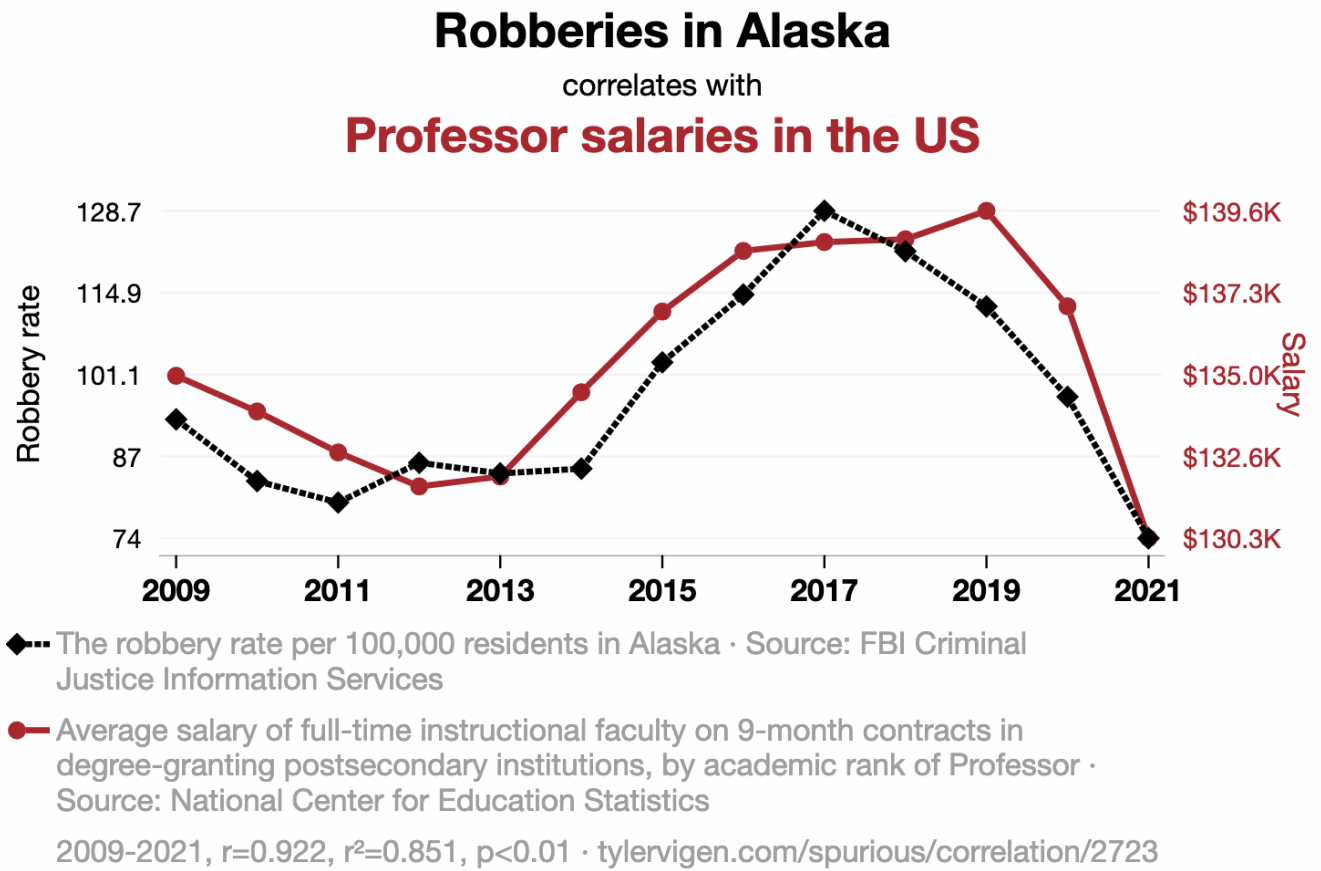
A propos of logical fallacies and correctly interpreting and communicating scientific data and findings,

correlation doesn't imply causation!

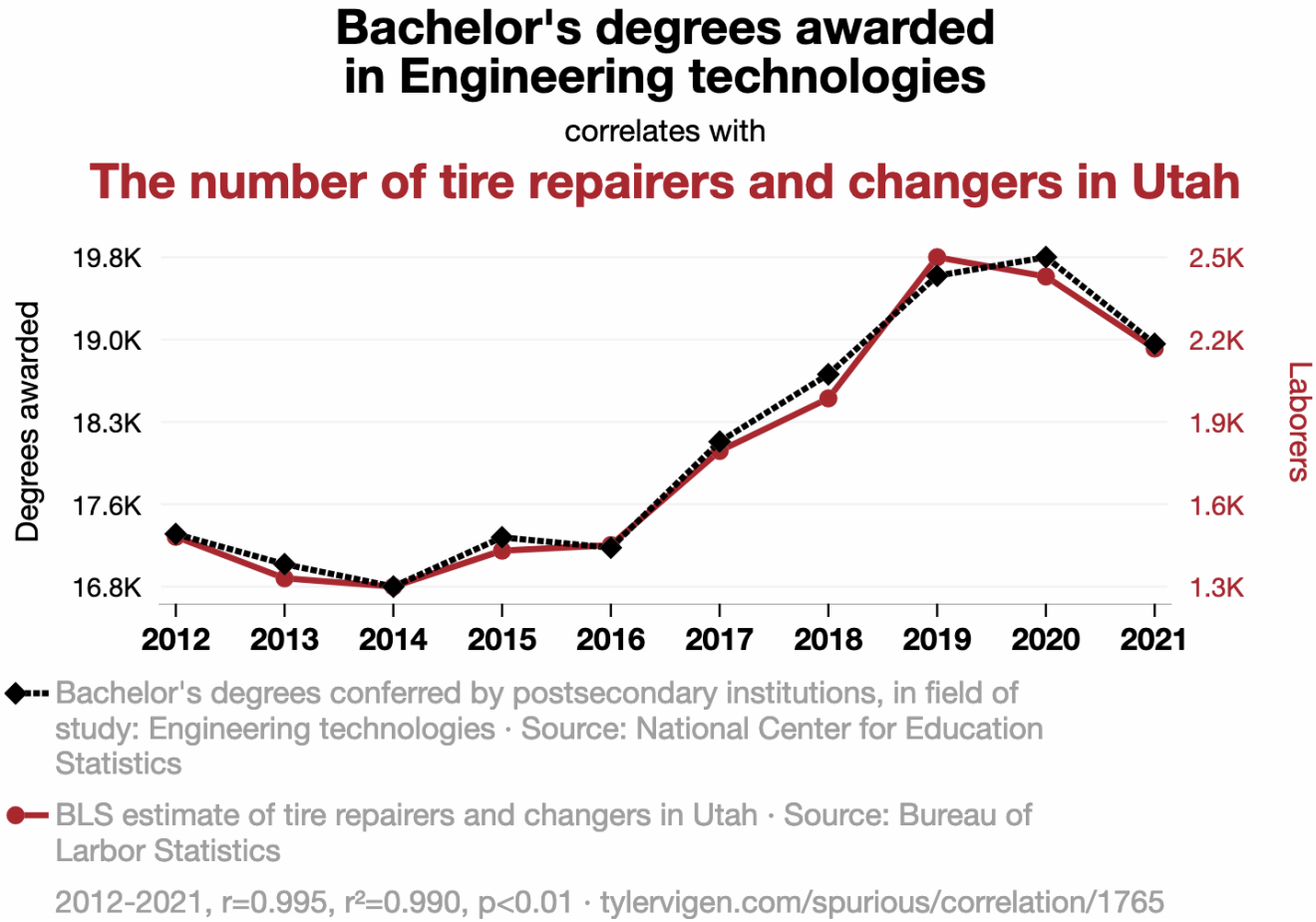
Science communication



Science communication



Science communication



More bizarre correlations: ▸ Link

Science communication

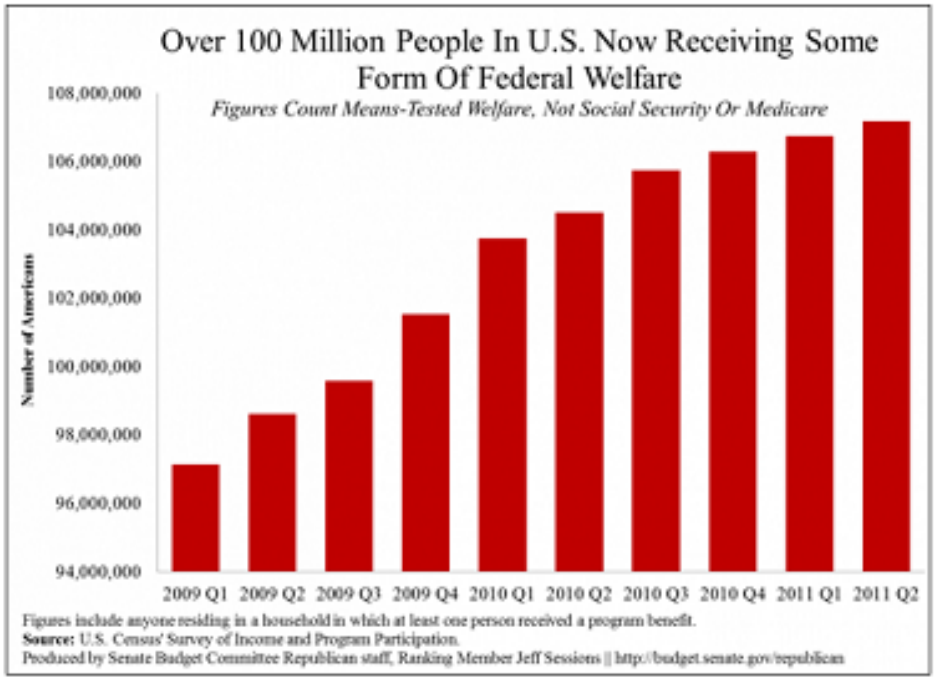
Sometimes bad communication is intentional...

Science communication

Over 100 Million Now Receiving Federal Welfare

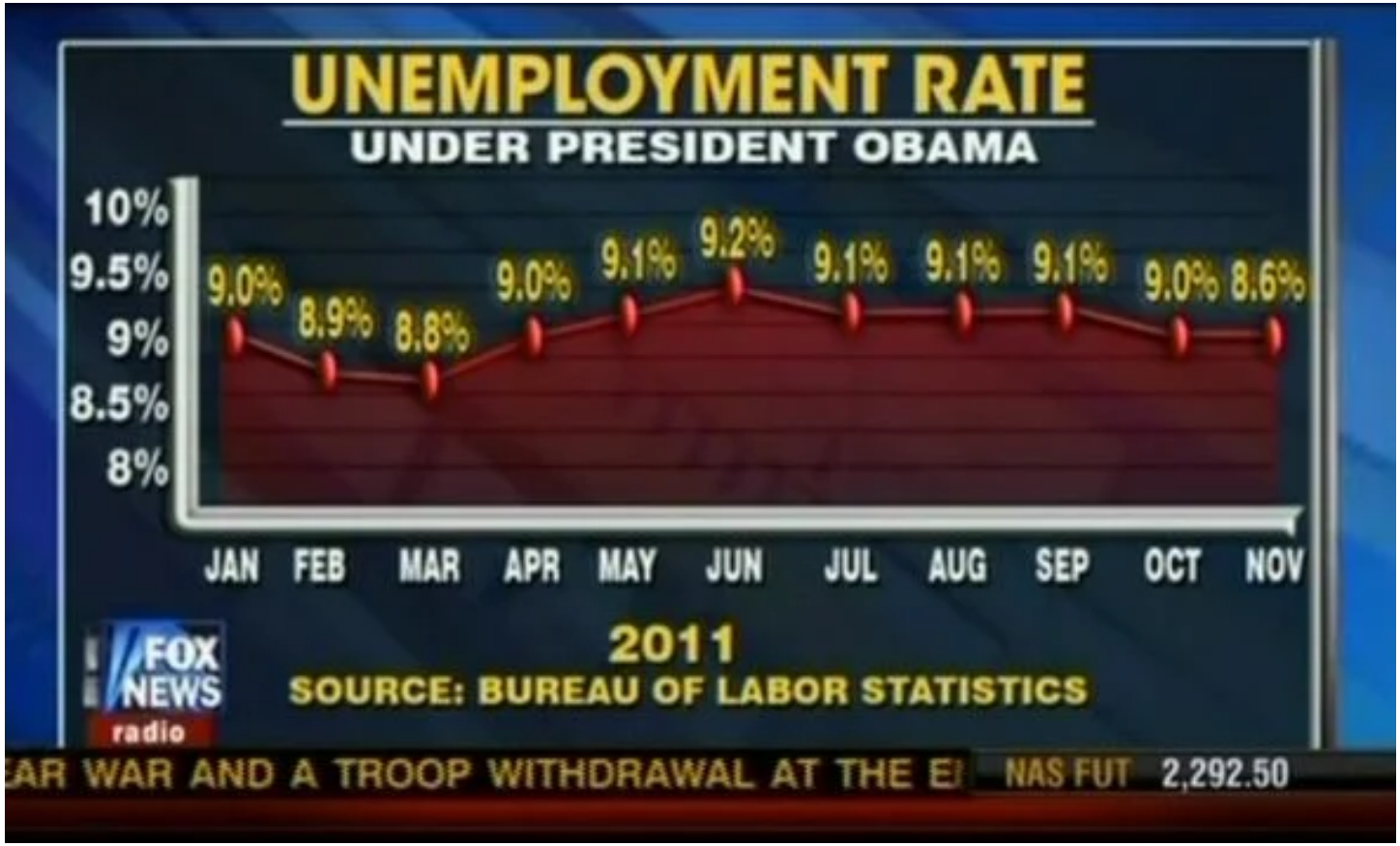
2:40 PM, AUG 8, 2012 • BY DANIEL HALPER

A new chart set to be released later today by the Republican side of the Senate Budget Committee details a startling statistic: "Over 100 Million People in U.S. Now Receiving Some Form Of Federal Welfare."



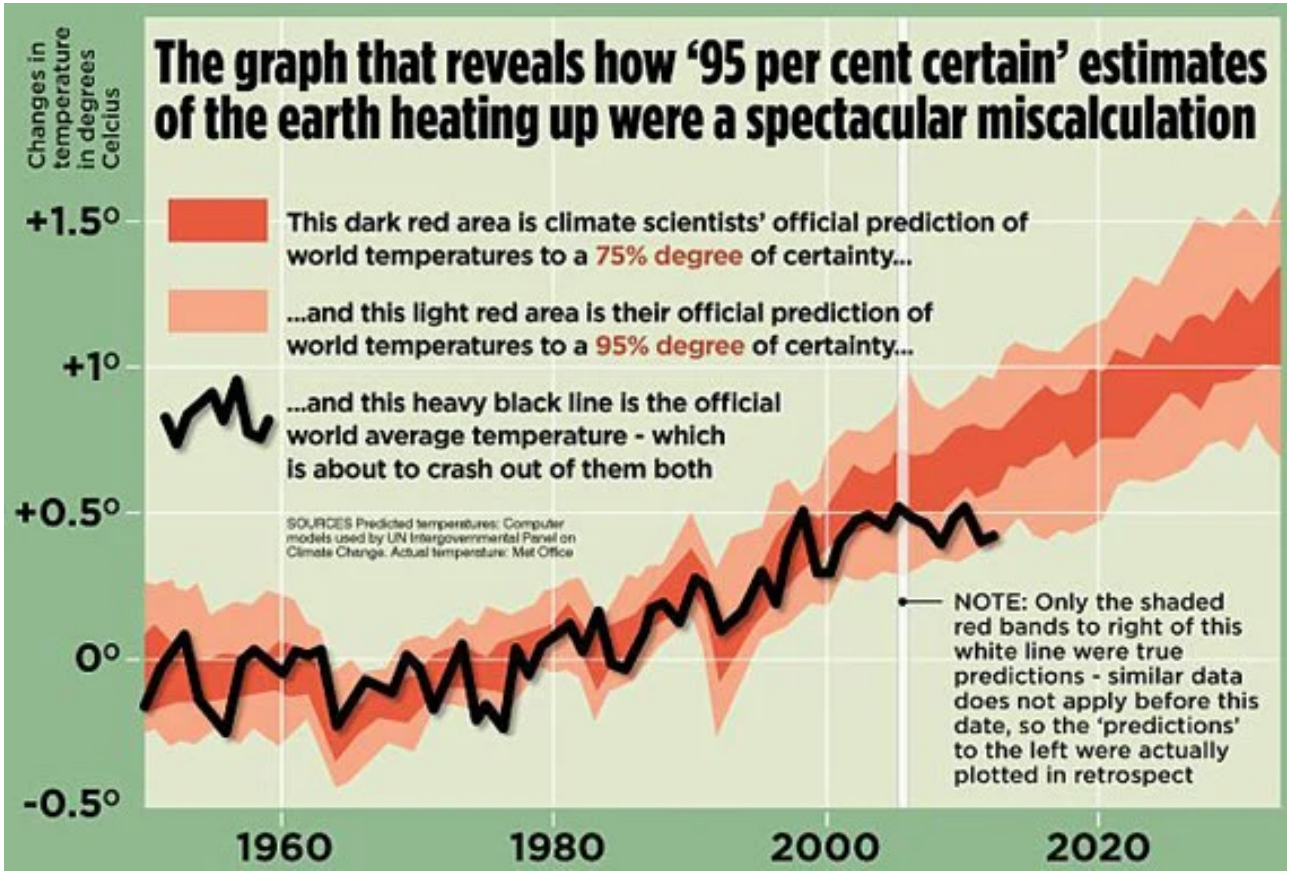
Big growth?

Science communication



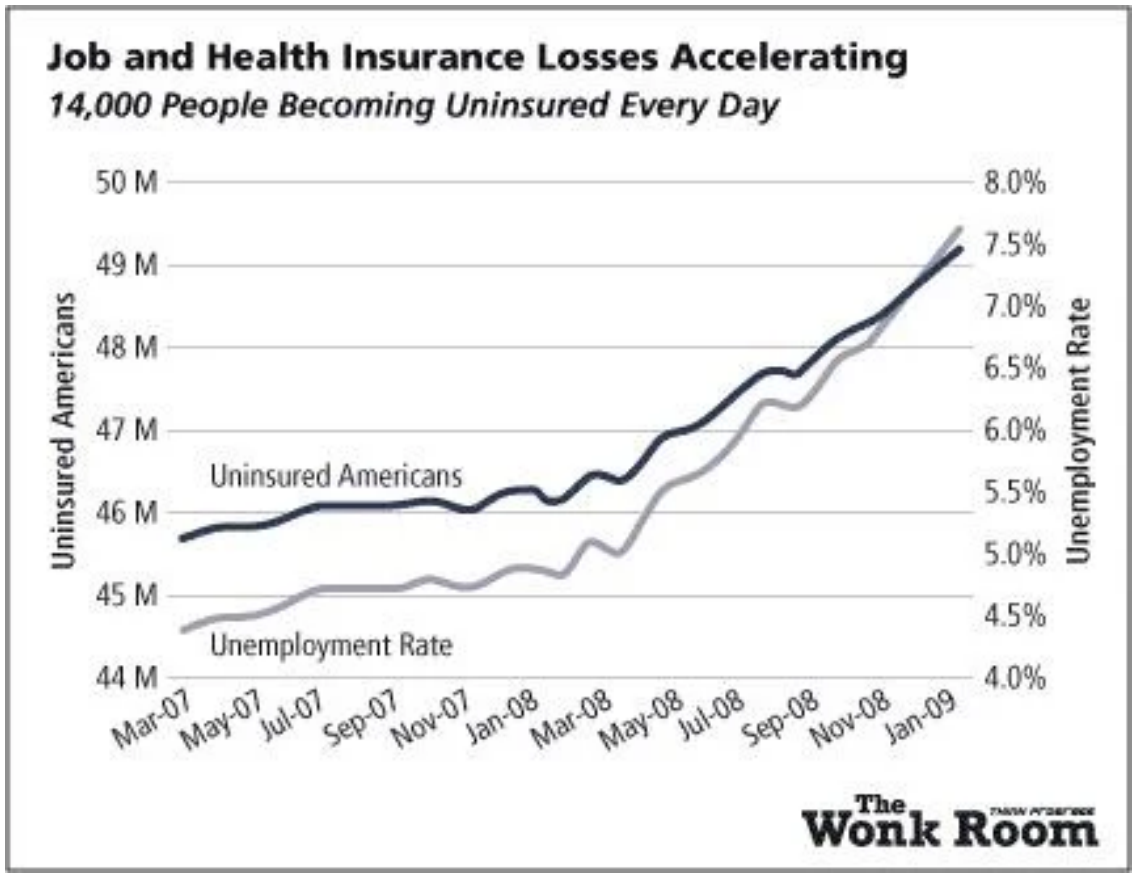
Pure disonesty!

Science communication



So what? (Not to mention that surface temperature is not the problem)

Science communication



Quite different rescalings (making correlation not so significant)

Science communication

"There are three types of lies: lies, damned lies, and statistics."

Mark Twain

Cognitive aspects: the framing effect

The framing effect is a cognitive bias in which people decide between options based on whether the options are presented with positive or negative connotations.

Classical example *(A. Tversky, D. Kahneman, 1981)*: *"600 people are affected by a deadly disease. Treatment A will very likely save 200 people and let 400 people die. Treatment B has a 33% chance that all patients will survive and a 66% chance that all will die. Which one do you choose?"*

Framing	**Treatment A**	**Treatment B**
positive	will save 200 lives	33% chance of saving 600 people
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Framing	**Treatment A**	**Treatment B**
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Positive framing: 72% of participants chose A, 28% chose B

Negative framing: 22% of participants chose A, 78% chose B

Cognitive aspects: science can be counterintuitive

Let's take a little (applied) math test:

1. The vaccination rate for Covid in a certain country is 90%. In the Covid wards of that country's hospitals one finds that 50% of the patients are vaccinated and 50% of the patients are not vaccinated. What is the probability for a vaccinated person to be hospitalized for Covid relative to a non-vaccinated person (i.e., what is the ratio of the two probabilities)?

2. Solve the above problem with these different data: in the country's hospitals 30% of the patients are vaccinated and 70% of the patients are not vaccinated.

(Actual data in Italy in Dec 2021, for general Covid wards and I.C. Covid wards, respectively)

Cognitive aspects: science can be counterintuitive

3. You are summoned by the local health authorities for a general screening for the terrible disease D, whose incidence in the general population is 1 in 100,000 individuals. The test you are given is very accurate: the probability of false positives is 1% and that of false negatives is 2%. The test result is positive and you're scared. What is the probability that you have the disease D?

Solutions to the test

Given A, B two events in a probability space, where $\mathbb{P}$ denotes the probability and A^c the complement of A (alternative event):

Bayes' Theorem (a.k.a. Bayes' formula)

$$\mathbb{P}(A|B) = \frac{\mathbb{P}(B|A)\,\mathbb{P}(A)}{\mathbb{P}(B)}$$

Formula of total probability

$$\mathbb{P}(B) = \mathbb{P}(B|A)\,\mathbb{P}(A) + \mathbb{P}(B|A^c)\,\mathbb{P}(A^c)$$

Second Bayes' formula

$$\mathbb{P}(A|B) = \frac{\mathbb{P}(B|A)\,\mathbb{P}(A)}{\mathbb{P}(B|A)\,\mathbb{P}(A) + \mathbb{P}(B|A^c)\,\mathbb{P}(A^c)}$$

Solutions to the test

Solution to no. 3:

$D =$ "you have the disease D" $\quad \mathbb{P}(D) = 10^{-5}$

$P =$ "you are positive to the test" $\quad \mathbb{P}(P) = ?$

$\mathbb{P}(P|D) = 0.98$ (2% of false negatives = 98% of true positives)

$\mathbb{P}(P|D^c) = 0.01$ (1% of false positives)

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2nd Bayes' formula:

$$\begin{aligned}\mathbb{P}(D|P) &= \frac{\mathbb{P}(P|D)\,\mathbb{P}(D)}{\mathbb{P}(P|D)\,\mathbb{P}(D) + \mathbb{P}(P|D^c)\,\mathbb{P}(D^c)} \\ &= \frac{0.98 \cdot 10^{-5}}{0.98 \cdot 10^{-5} + 0.01\,(1 - 10^{-5})} \\ &\simeq 0.000979 \simeq 1/1000\end{aligned}$$

Solutions to the test

Solutions to no. 1:

Consider a random person in the general population and define:

$V =$ "the person is vaccinated" $\quad \mathbb{P}(V) = 0.9 \;\Rightarrow\; \mathbb{P}(V^c) = 0.1$

$H =$ "the person is hospitalized for Covid" $\quad \mathbb{P}(H) = ?$

$\mathbb{P}(V|H) = \mathbb{P}(V^c|H) = 0.5$

Our goal: $\dfrac{\mathbb{P}(H|V^c)}{\mathbb{P}(H|V)}$ though we don't know $\mathbb{P}(H)$

$$\mathbb{P}(H|V^c) = \frac{\mathbb{P}(V^c|H)\,\mathbb{P}(H)}{\mathbb{P}(V^c)} \qquad \mathbb{P}(H|V) = \frac{\mathbb{P}(V|H)\,\mathbb{P}(H)}{\mathbb{P}(V)}$$

Finally: $\dfrac{\mathbb{P}(H|V^c)}{\mathbb{P}(H|V)} = \dfrac{\mathbb{P}(V^c|H)}{\mathbb{P}(V^c)}\,\dfrac{\mathbb{P}(V)}{\mathbb{P}(V|H)} = \dfrac{0.5 \cdot 0.9}{0.1 \cdot 0.5} = 9$

Solutions to the test

Solutions to no. 2:

Consider a random person in the general population and define:

$V =$ "the person is vaccinated" $\quad \mathbb{P}(V) = 0.9 \;\Rightarrow\; \mathbb{P}(V^c) = 0.1$

$H =$ "the person is hospitalized for Covid" $\quad \mathbb{P}(H) = ?$

$\mathbb{P}(V|H) = 0.3 \qquad \mathbb{P}(V^c|H) = 0.7$

Our goal: $\dfrac{\mathbb{P}(H|V^c)}{\mathbb{P}(H|V)}$ though we don't know $\mathbb{P}(H)$

$$\mathbb{P}(H|V^c) = \frac{\mathbb{P}(V^c|H)\,\mathbb{P}(H)}{\mathbb{P}(V^c)} \qquad \mathbb{P}(H|V) = \frac{\mathbb{P}(V|H)\,\mathbb{P}(H)}{\mathbb{P}(V)}$$

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Cognitive aspects: base rate fallacy

These were examples of **base rate fallacy**, whereby one tends to neglect base-rate information (such as the relative sizes of different sets, or a prior probability) in favor of case-specific information (such as information on the set of interest, or conditional probability).

Cognitive aspects: science can be counterintuitive

Problem: (based on admission to UC Berkeley 1973, *Bickel et al (1975)*)

In a small university with 5 study programs, there's great attention to gender balance in the admission process. As a matter of fact, in a given academic year, the admission rate (= accepted/applicants) was higher for females than males in all 5 programs. Nevertheless the total admission rate was higher for males than females. How's that possible?

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Prog.	A	B	C	D	E	TOTAL
M	60/90	70/80	10/150	20/100	20/40	180/460 (39%)
F	8/10	10/10	15/150	20/90	30/50	83/110 (27%)

This is an example of **Simpson's Paradox**

Cognitive aspects: Simpson's Paradox

Can be reinterpreted in many ways, e.g.,

Five studies compare treatments A and B for a certain medical condition is 5 age brackets. All five studies show that treatment B lead to a higher recovery rate. Then a meta-analysis is published suggesting that, globally, treatment A give the highest chance of recovery. How's that possible?

Age	0-15	15-25	25-55	55-70	70-	TOTAL
A	60/90	70/80	10/150	20/100	20/40	180/460 (39%)
B	8/10	10/10	15/150	20/90	30/50	83/110 (27%)

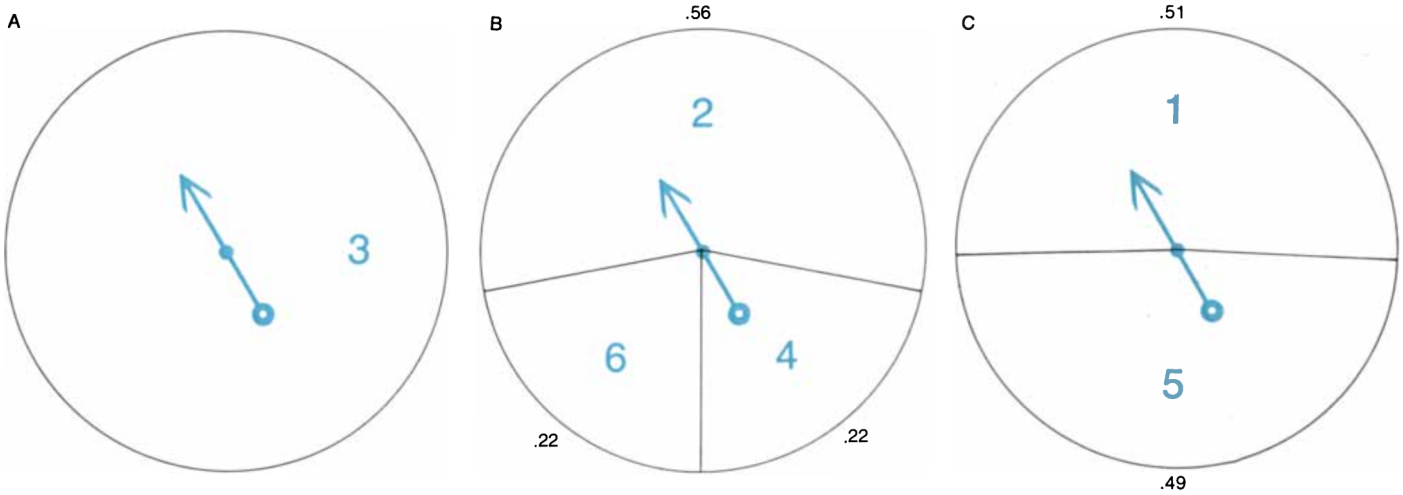
Cognitive aspects: Simpson's Paradox

Real data: 1974 vs 1978 US federal tax rate *(Wagner 1982)*:

Table 2. Total Income and Total Tax (in thousands of dollars), and Tax Rate for Taxable Income Tax Returns, by Income Category and Year

Adjusted Gross Income	1974 Income	1974 Tax	1974 Tax Rate	1978 Income	1978 Tax	1978 Tax Rate
under $ 5,000	41,651,643	2,244,467	.054	19,879,622	689,318	.035
$ 5,000 to $ 9,999	146,400,740	13,646,348	.093	122,853,315	8,819,461	.072
$ 10,000 to $14,999	192,688,922	21,449,597	.111	171,858,024	17,155,758	.100
$ 15,000 to $99,999	470,010,790	75,038,230	.160	865,037,814	137,860,951	.159
$ 100,000 or more	29,427,152	11,311,672	.384	62,806,159	24,051,698	.383
Total	880,179,247	123,690,314		1,242,434,934	188,577,186	
Overall Tax Rate			.141			.152

Cognitive aspects: Blyth's variant



Gardner 1976: Flicking the 3 spinners independently,

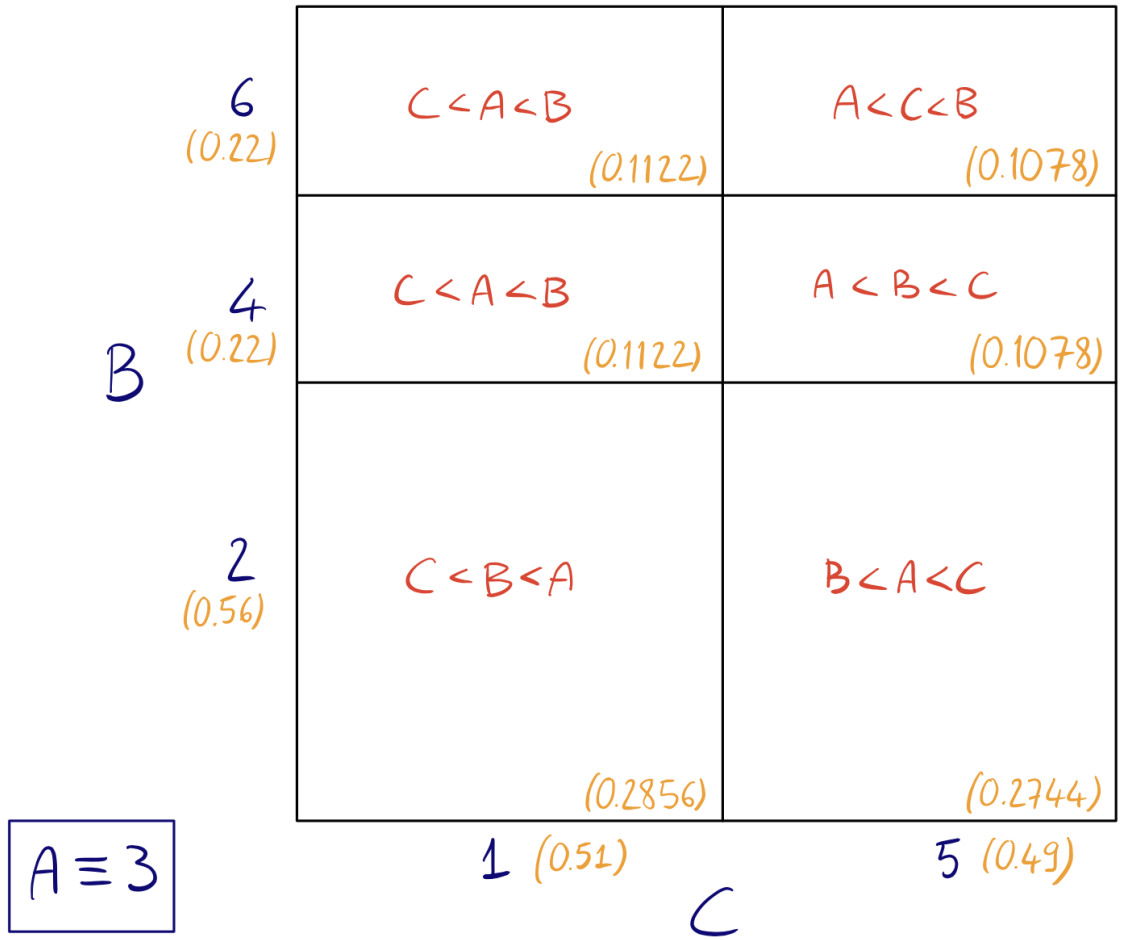
$$\mathbb{P}(\text{A beats B}) = 56\%, \quad \mathbb{P}(\text{A beats C}) = 51\%, \quad \mathbb{P}(\text{B beats C}) = 61.78\%$$

but, comparing all 3 spinners,

$$\mathbb{P}(\text{A is maximum}) = 28.56\%$$
$$\mathbb{P}(\text{B is maximum}) = 33.22\%$$
$$\mathbb{P}(\text{C is maximum}) = 38.22\%$$

Cognitive aspects: Blyth's variant

A convenient probability space for the problem (probability = area):



Functioning of the scientific community

How do we scientists function as a community? Is the system organized to always promote the best practices? In ways that as truthful, efficient and fair as possible?

In other words, is the functioning of the scientific community scientific?

According to many, the answer is **NO!**

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In other words, is the functioning of the scientific community scientific?

According to many, the answer is **NO!** (At least, not fully.)

Of course the scientific community is a community of people and is naturally affected by the phenomena that affect every group of humans (mistakes, rivalries, dishonesty, etc.).

But there are structural aspects that need to be focused on.

Functioning of the scientific community

Here we describe just one phenomenon out of many that affects all scientific research that uses the statistical tool of the *p*-value (a large corpus, including most quantitative research in the life, medical, social sciences).

Reference:

Essay

Why Most Published Research Findings Are False

John P. A. Ioannidis

PLoS Medicine | www.plosmedicine.org 0696 August 2005 | Volume 2 | Issue 8 | e124

with big credit (pics too) to this very recommended YouTube channel:

p-value

When one makes observations that seem to support a certain hypothesized phenomenon, a standard way to give a quantitative measure of the degree of confidence that the phenomenon is indeed at play is to consider the null hypothesis H_0, i.e., the hypothesis that the phenomenon isn't there. One is assumed to have a probabilistic model to describe the occurrence of the observation under the hypothesis H_0.

Definition

The p-value of a certain observation/experiment is by definition the probability that, assuming the null hypothesis, the outcome of your observation/experiment would be as good as or better than you have actually observed, i.e., more supportive of your hypothesized phenomenon.

p-value

For example, suppose that you and your friend Pierluigi go to the bar for coffee together every day. One day you decide to make this habit more exciting by tossing a coin before going. If the outcome is Heads, you buy both coffees; if it is Tails, Pierluigi buys both coffees. You play this game for 20 days and it so happens that you pay 17 times out of 20. You also notice that Pierluigi has provided the coin all this time.

Your hypothesis is that Pierluigi is cheating you with a biased coin.

H_0: the coin was fair

Under H_0, the probability of getting 17 or more Heads is

$$p = \sum_{i=17}^{20} \binom{20}{i} 2^{-i}\, 2^{-20+i} = 0.00129 \text{ (0.13\%)}$$

Scientific publishing

It is generally accepted that a p-value of 0.05 or less is statistically significant *(Fisher, 1925)*.

This means that in 1 case out of 20 you believe you have observed a phenomenon that didn't really exists (a.k.a. 95% confidence).

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If this is the standard in scientific publishing, you expect that 1 every 20 scientific publications using the p-value are wrong.

Good? Bad? Reasonably ok?

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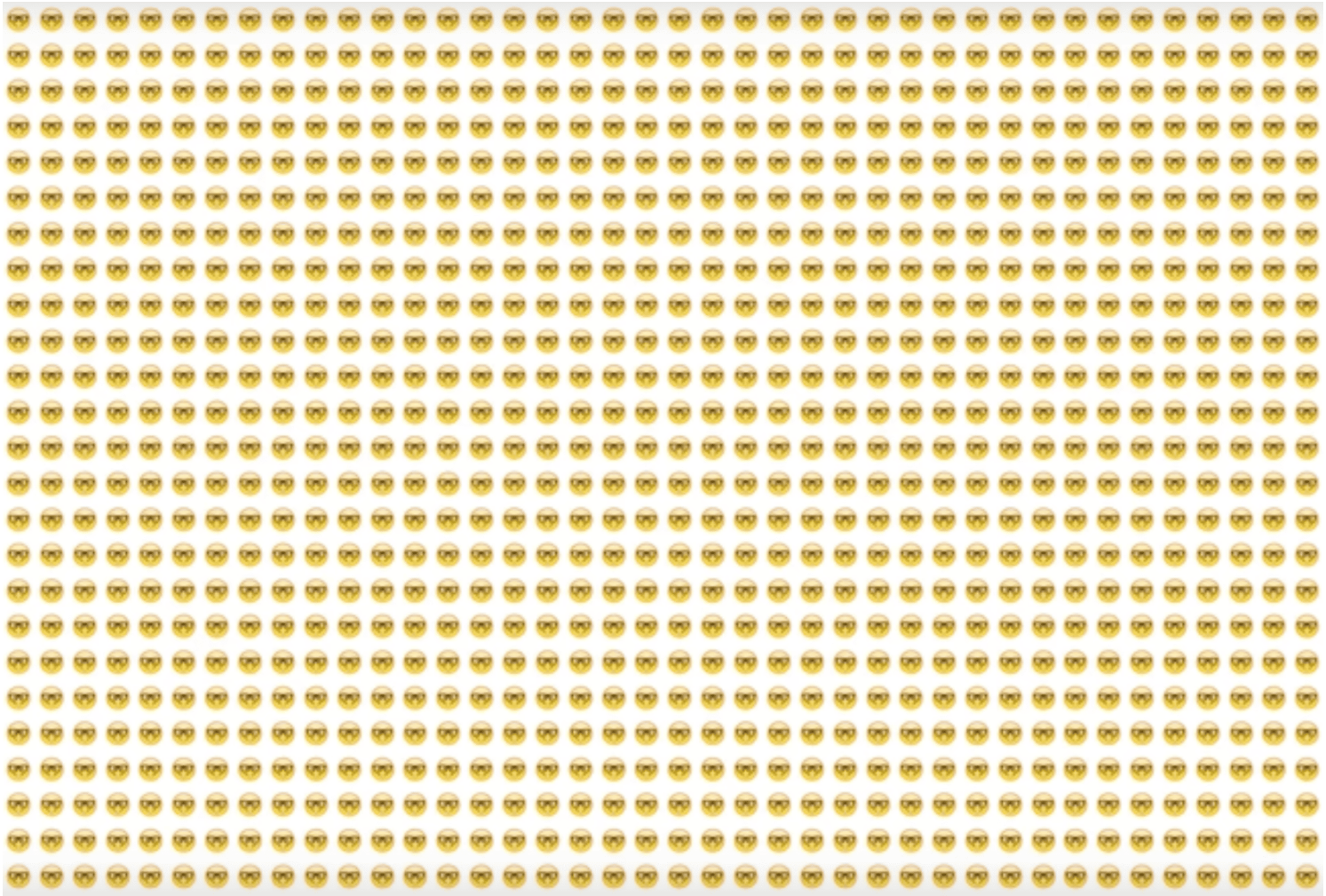
But things are far more disheartening! Let's model this process assuming common practices and no cheating.

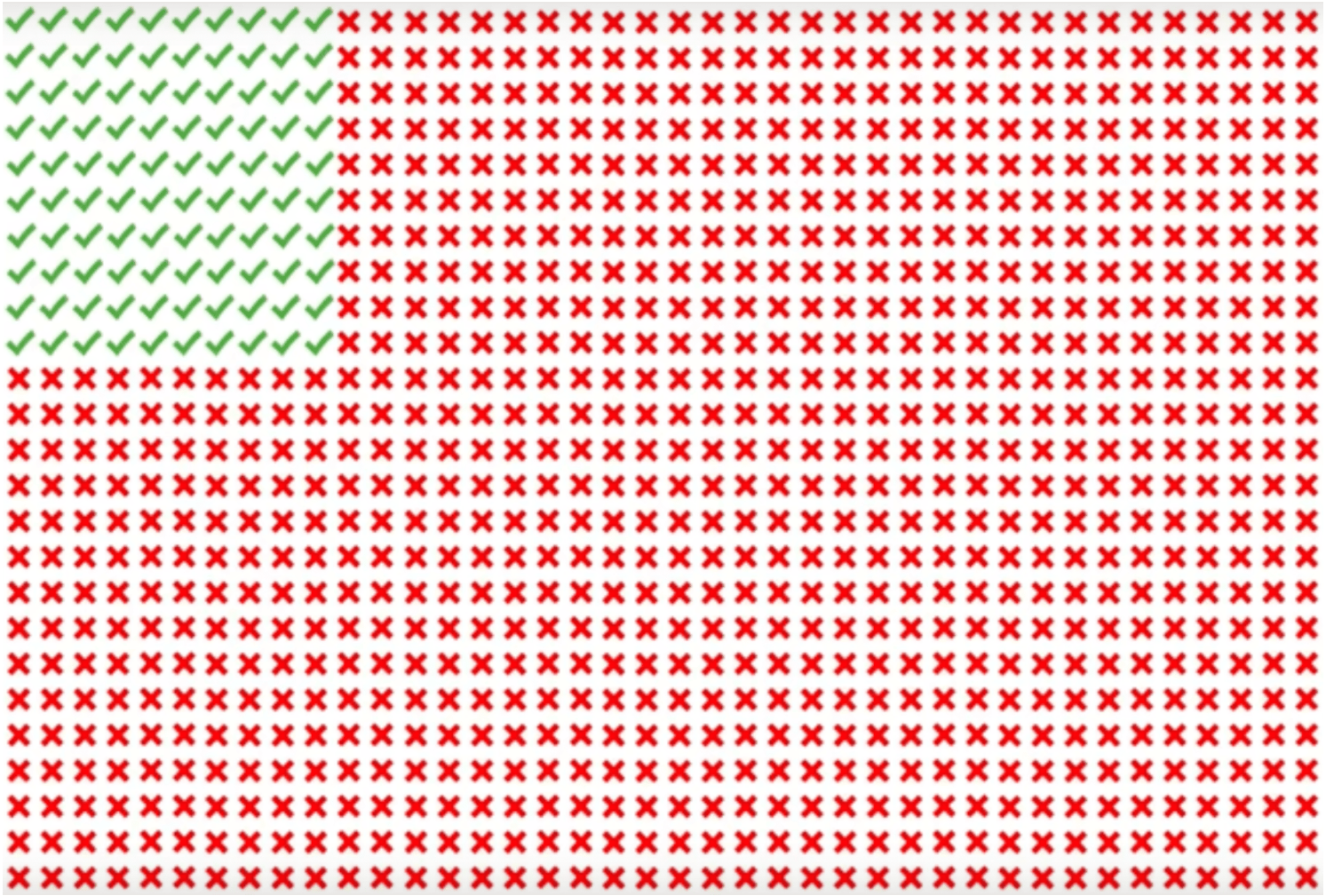
Model of scientific publishing

Many researchers, many hypotheses



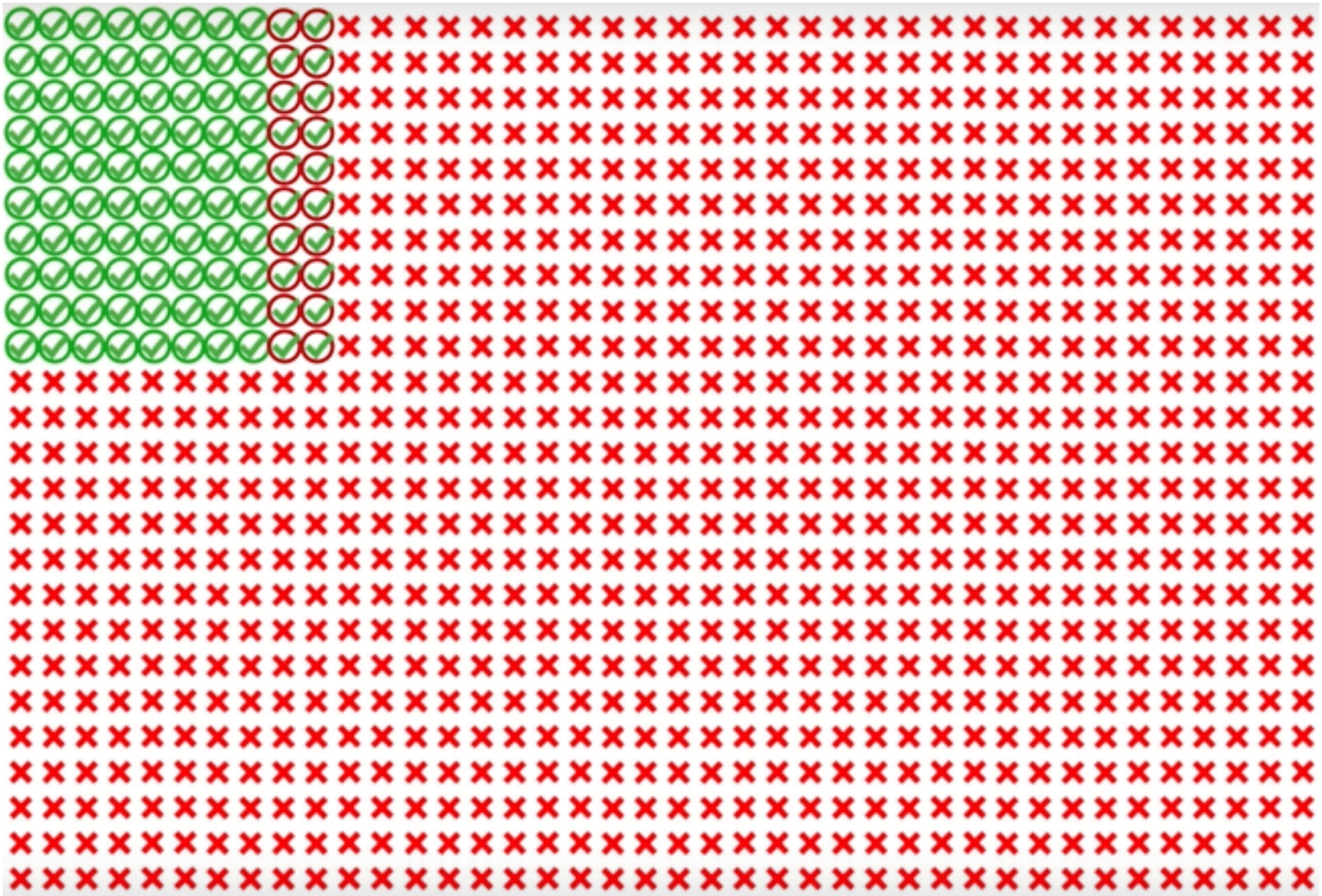
Model of scientific publishing

Only a fraction f of the hypotheses are true, e.g. $f = 10\%$



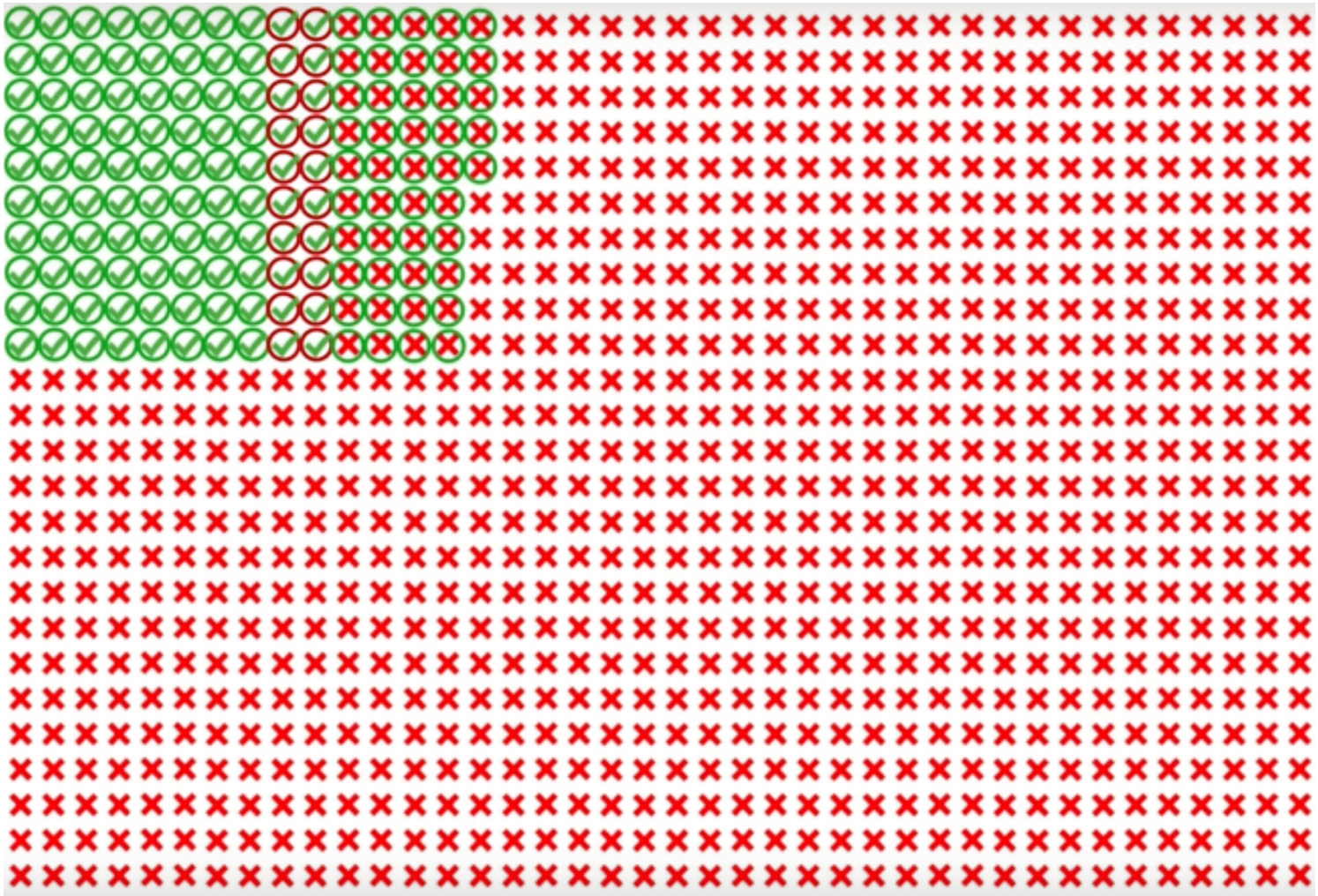
Model of scientific publishing

95% of all true hypotheses are found to be true: true-found-true



Model of scientific publishing

5% of all false hypotheses are found to be true: false-found-true



Model of scientific publishing

Fact is that journals tend to publish only positive findings!

So, among all studies:

Fraction of true-found-true hypotheses: $0.95f$

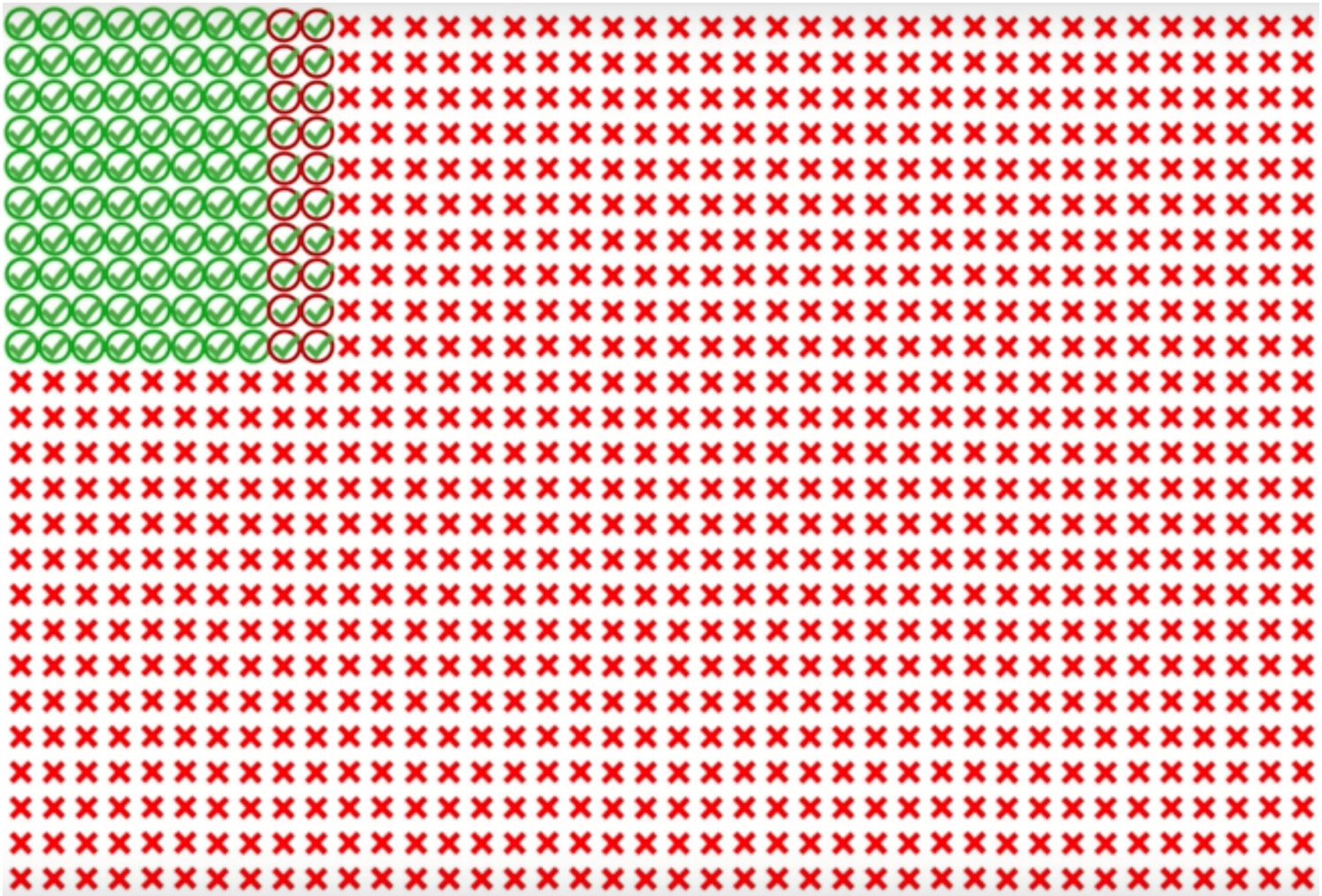
Fraction of false-found-true hypotheses: $0.05(1-f)$

Ratio of wrong papers in the literature: $\dfrac{0.05(1-f)}{0.9f+0.05}$

For $f = 5\%$, ratio $= 1/2$; for $f = 10\%$, ratio $= 32.1\%$;
for $f = 15\%$, ratio $= 23.0\%$; for $f = 20\%$, ratio $= 17.4\%$.

More realistic model of scientific publishing

80% of all true hypotheses are found to be true



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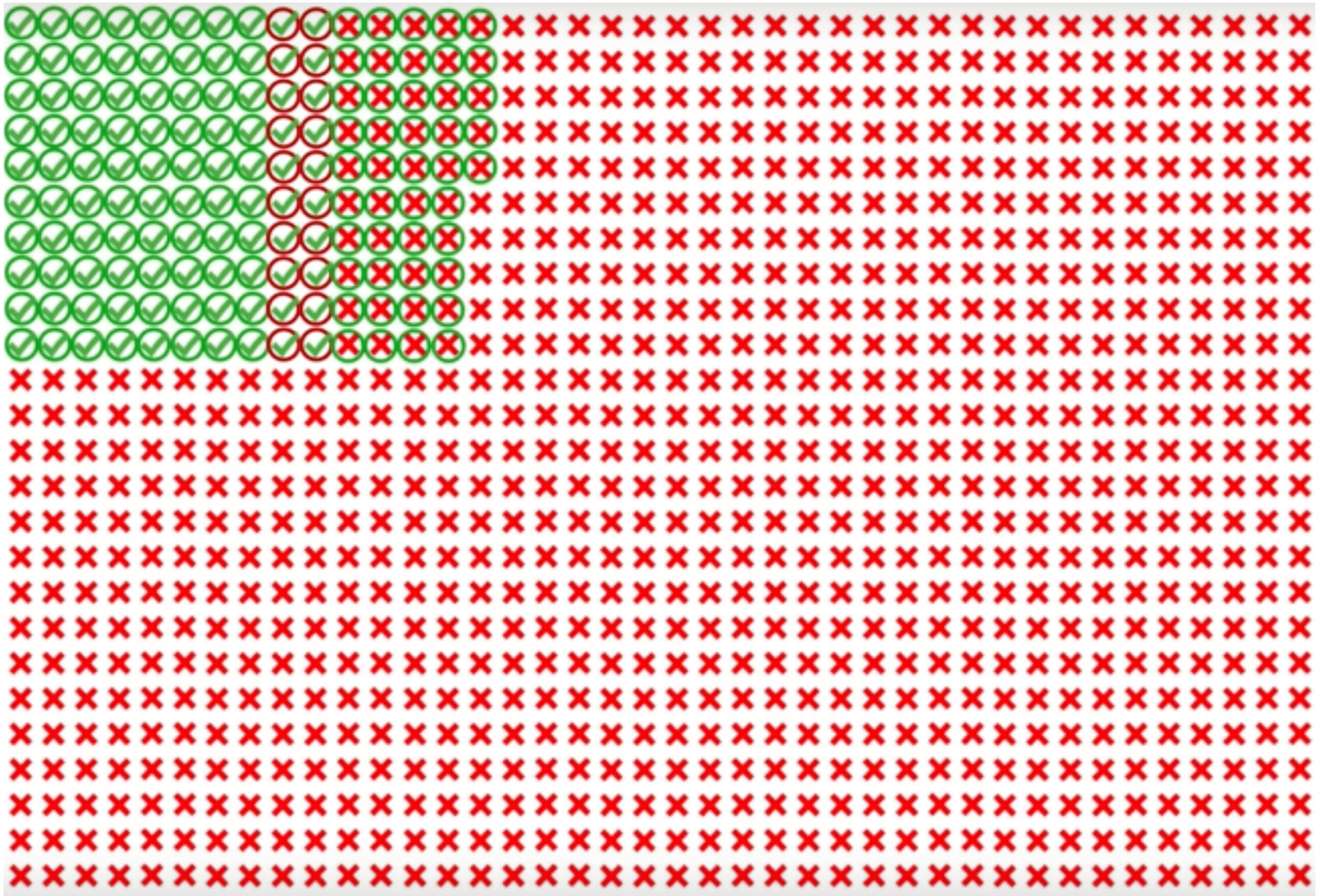
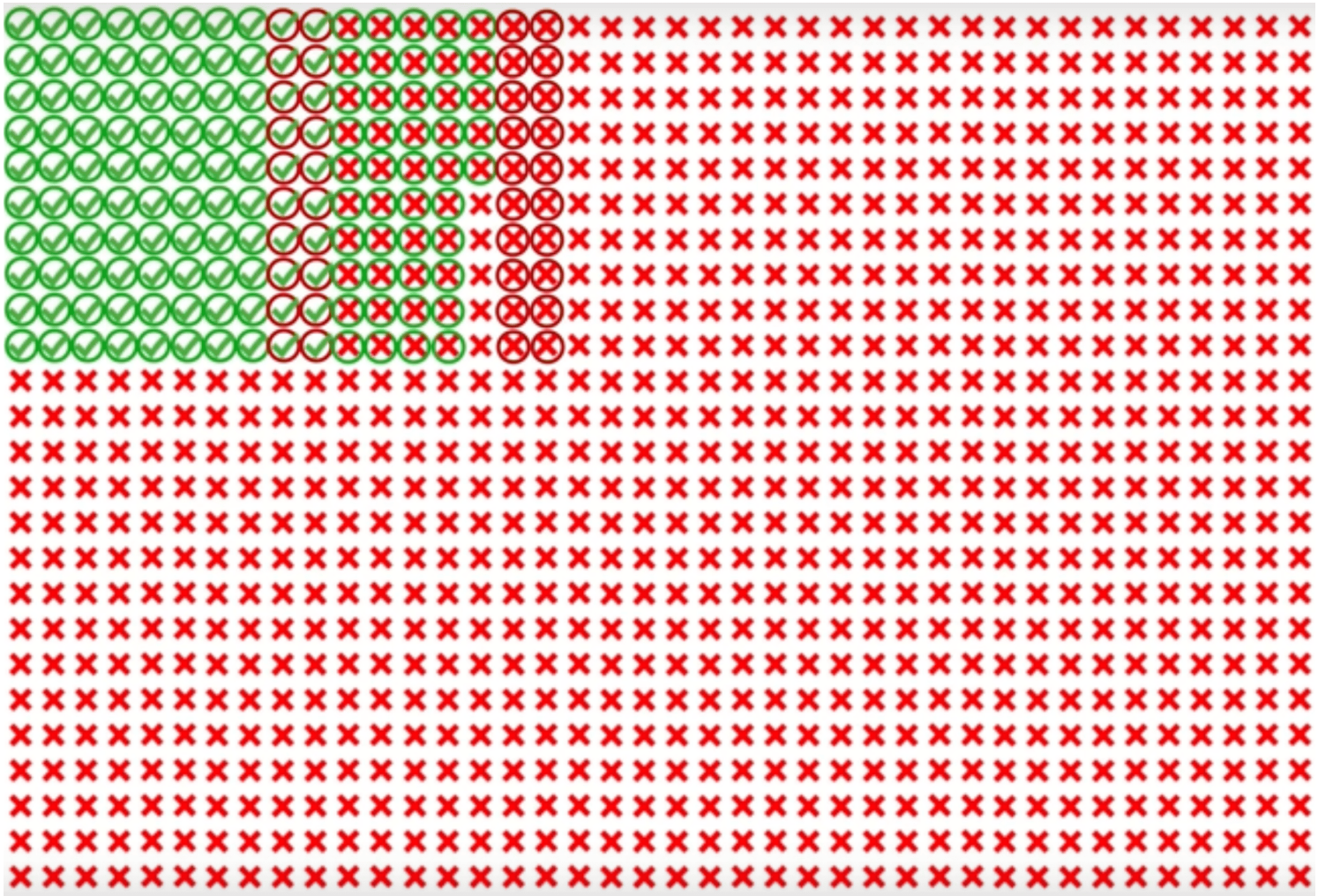


More realistic model of scientific publishing

20% of all published findings are negative: assume all false-found-false



More realistic model of scientific publishing

In this model:

Fraction of true-found-true hypotheses: $0.8f$

Fraction of false-found-true hypotheses: $0.05(1-f)$

Fraction of found-true hypotheses: $0.8f + 0.05(1-f) = 0.75f + 0.05$

Fraction of published papers: $1.25(0.75f + 0.05)$

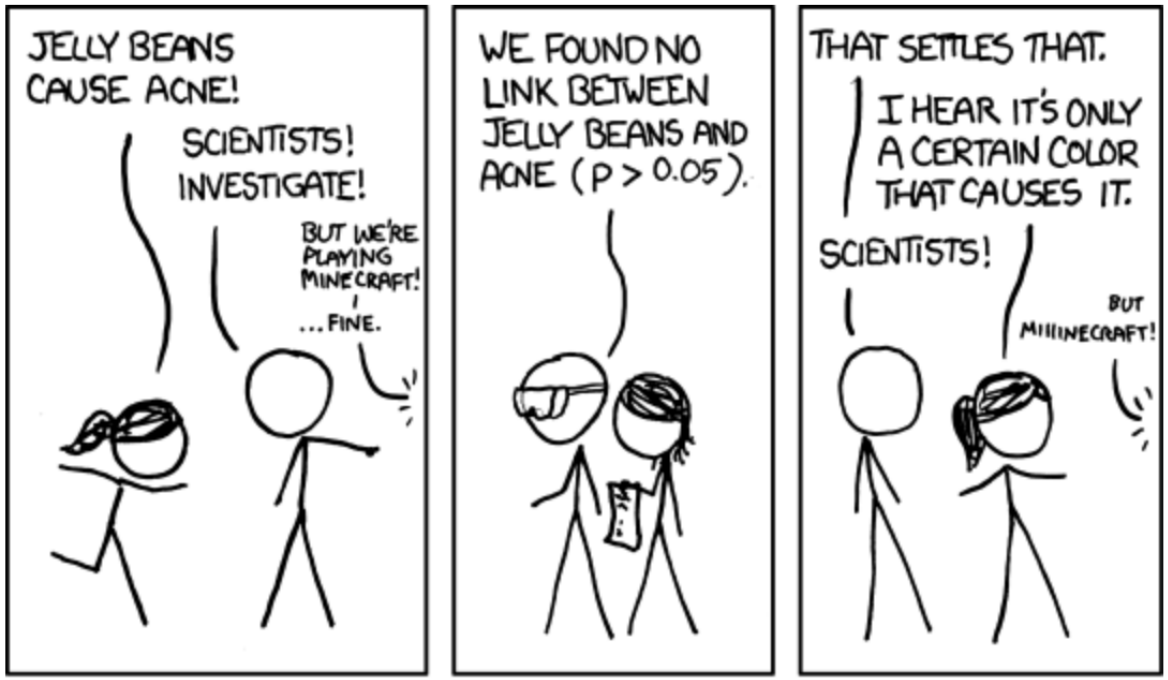
Ratio of wrong papers in the literature: $\dfrac{4-4f}{75f+1}$

For $f = 5\%$, ratio $= 43.4\%$; for $f = 10\%$, ratio $= 28.8\%$;
for $f = 15\%$, ratio $= 20.9\%$; for $f = 20\%$, ratio $= 16.0\%$.

p-hacking

The above models don't include the practice of *p*-hacking, the tendency of researchers who are fixated on a given hypothesis to try all sorts of experiments in order to obtain a "statistically significant" finding.

A good illustration is offered by this exquisite cartoon by xkcd:



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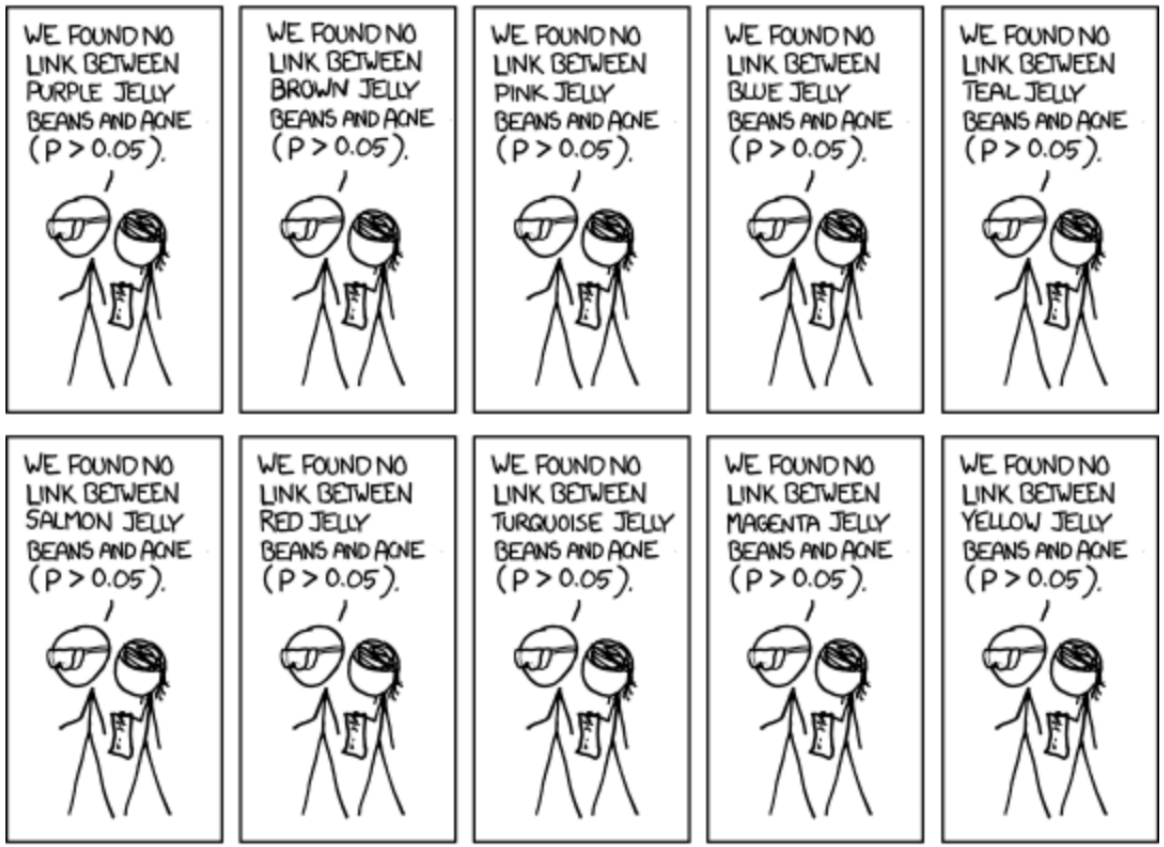

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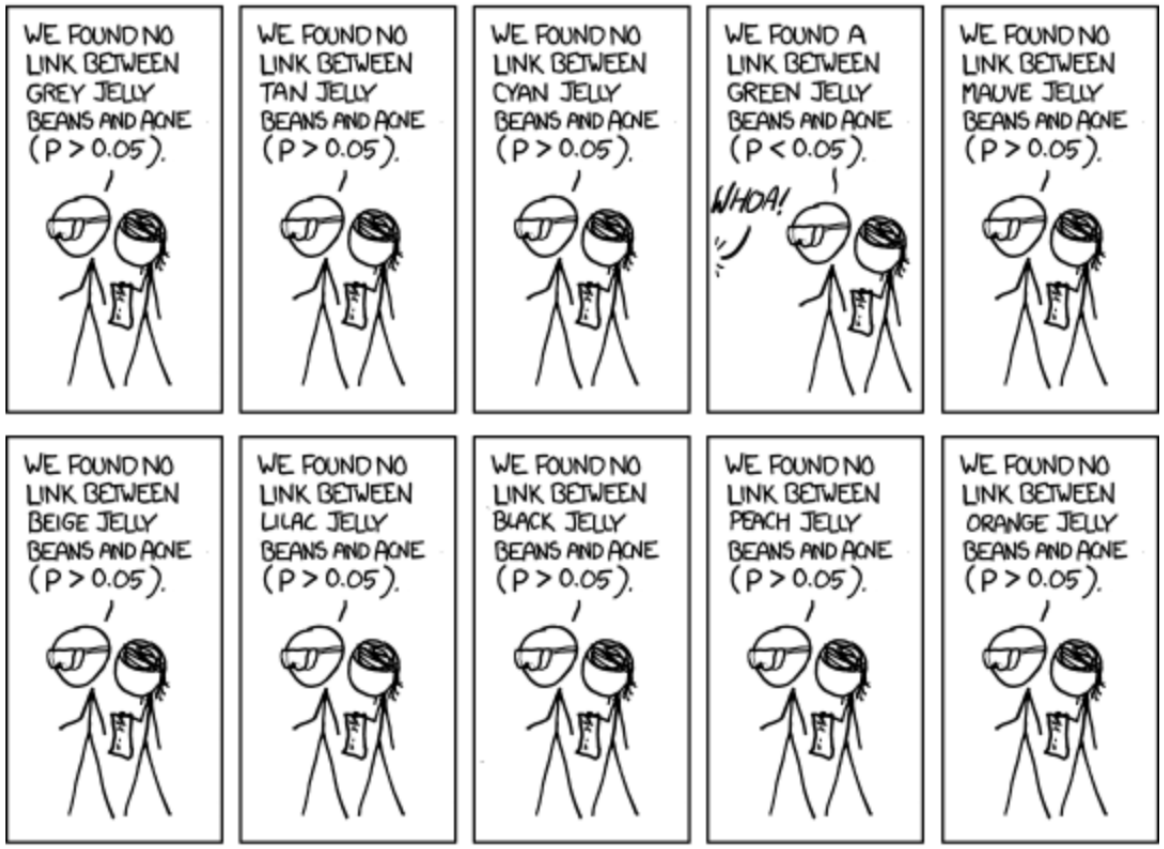

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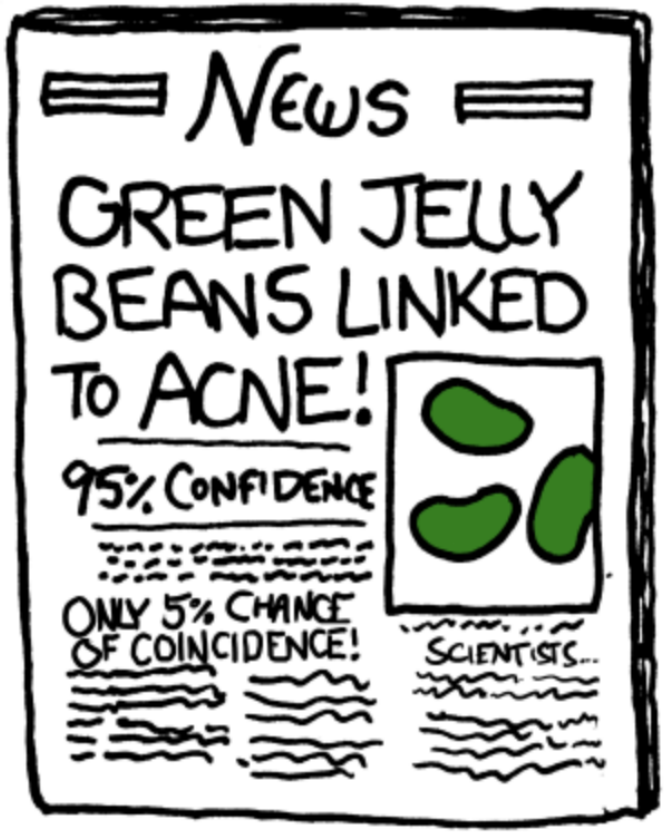

p-hacking

None of these phenomena involve dishonesty or even incompetence!

p-hacking

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"If you torture data long enough, it will confess to anything"

p-hacking

None of these phenomena involve dishonesty or even incompetence!

> *"If you torture data long enough, it will confess to anything"*

Not that dishonesty or incompetence are absent in our community...

Other worthy topics

There would be many other interesting topics to discuss if we had time:

1. What is the bar for Science? When does a study qualify as scientific?
2. Basic vs applied research, funding.
3. Evaluation of research, driving mechanisms.
4. Is the scientific community really open (inclusive, non-hierarchical, non-exploiting)?
5. etc.
6. etc.
7. etc.

Conclusions

We've discussed — to a very small extent — the scientific "mindset" of

1. society
2. its élites and stakeholders (people who carry interests)
3. us scientists (that includes you students!) as individuals
4. the scientific community

I believe that we are not much different. We face the same challenges and share the same traits as the general population.

Only we bear more responsibility toward this precious instrument called science.

Conclusions

Let us promote a true scientific attitude,
within and outside our workplaces.

Conclusions

Let us promote a true scientific attitude,
within and outside our workplaces.

For a better world.

References

A minimal list of references:

- Veritasium YouTube Channel: "Is most published research wrong?" ▸ Link
- TED-Ed YouTube Channel: "Is there a reproducibility crisis in science? - Matt Anticole" ▸ Link
- J.P.A. Ioannidis, "Why most published research findings are false", PLoS Med 2(8): e124 (2005) ▸ Link
- P.E. Smaldino, R. McElreath, "The natural selection of bad science", R. Soc. Open Sci. 3160384 (2016) ▸ Link