

**There's Not Much Science in Science
with borrowings from
'The need for cognitive science and causality
in statistics teaching and practice'
and many previous talks**

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Key Points:

- **We need to learn how to systematically deal with and teach about cognitive biases, as we have done with mechanical biases like confounding.**
- **These biases are larger, more pervasive and socially more important than recognized in current methodologic texts and literature.**
- **Their coverage deserves to displace many finer points of statistical methodology.**

- **Classical methods for reducing cognitive biases include playing “devil’s advocate” (arguing for disdained positions) and “alien observer” (arguing as if indifferent to the welfare of humans or other species).**
- **More detailed methods have long existed in applied psychology, but much work will be needed to adapt them to our fields.**
- **More essential than theory and abstractions are case studies – which the pandemic has supplied an abundance!**

Some lessons case studies can provide:

- Examine and present absolute proportions and rates when discussing importance.
- Beliefs are based on webs of trust; no one has the capacity to validate all their sources.
- Those who do attempt verification will catch falsehoods, which will destroy trust.
- We should not dismiss criticisms or treatments simply because their proponents are biased or use faulty data, logic, or methodology to support their views.

An alien viewpoint: Imagine communications, claims, and actions labeled as “science” and “following the science” from the perspective of an alien space probe with no stake in any aspect of the events such as human welfare.

Its goal could be to delineate the entire causal system in which these events emerge, just as a biologist tries to delineate systems in which species emerge and disappear, or a historian or sociologist tries to delineate systems in which societies form and disintegrate...

An emergentist thesis: The alien would find that all humans and their groups fall far short of comprehending the social subsystems they are in, due to their profoundly limited data acquisition and processing capacities – much like all individual animals and colonies fall far short of comprehending the ecology they are in. In particular: All scientists and **philosophers of science** fall far short of comprehending the science system they are in; their asserted demarcations of science are wishful thinking.

- those limits apply to me, you, and everyone.
In the words of some, we are apes with brains enlarged to coordinate action in large groups.
Evidence for this view: Those who study and debate cognitive biases exhibit the same cognitive errors as everyone else – even or especially when discussing these problems.
Accessible discussions of this topic can be found in blogs (perhaps more illuminating those that found in magazines and journals) ...

Example: posts by Gelman highly critical of popular **advocates** of “behavioral economics” even if not critical of the topic of cognitive biases, describe how the advocates suffer from (apparently inescapable) biases – including those called “hubris” in ordinary language:

<https://statmodeling.stat.columbia.edu/2020/03/31/stasis-back-in-town-my-last-post-on-cass-sunstein-and-richard-epstein/>

<https://statmodeling.stat.columbia.edu/2021/02/07/nudgelords/>

My revision of Gelman's 2021 list:

1: Cognitive biases are pervasive - People are unable to reason neutrally when they have investments in conclusions (as they always do).

2: Uncertainty triggers emotional reactions.

Most people are upset by uncertainty when the issue is perceived as affecting their ego, status, wealth, etc. They will then deny uncertainty, or offer downwardly biased evaluations of uncertainties (perhaps unconsciously), often aided by warped statistical conventions.

3, 4: 1 and 2 together almost guarantee theoretically avoidable mistakes will be made when making decisions under uncertainty, including by designated experts and agencies.

5. The problems have been studied in depth at least since the 1960s, yet methods for dealing with them remain limited and controversial.

- **Francis Bacon** discussed cognitive problems at length in his “Idols” in *Novum Organum* (1620), a founding work of modern science
<https://sirbacon.org/the-four-idols-of-sir-francis-bacon/>

Yet our “modern” methodologies for dealing with uncertainty – statistics, sensitivity and bias analysis – are based on idealizations that ignore these problems and use assumptions that are patently false in some of the most important health and medical research:

- That the analyst is unprejudiced, neutral, free of bias; all COIs have been “managed”.
- That all important sources of uncertainty have been captured by formulas, or else can be managed intuitively in light of outputs.

This idealization meshes well with the prevalent individualist or heroic story in which

- Science is a reliable system for finding “facts” or “truths” independently of what others claim, and
- Scientists can comprehend the science system in a complete and reliable manner.

In this story, individuals achieve official recognition as a “scientist” via familiar social mechanisms: degrees, grants, publications, etc.

Contrast to: Science is a social subsystem self-identified as making “scientific inferences”, offering explanations, predictions and recommendations through merging of carefully (and often biasedly) curated data with

- incompletely explicated (partially implicit and often unrecognized) assumptions,
- incomplete and often fallacious logic, and
- evocative semantics (e.g., “significance”) that confuses precise abstract theoretical entities with distantly related ordinary concepts.

Any instruction purporting to cover the basics of inference needs to include cognitive science to deal with social delusions and biases such as

- **Nullism:** Confusion of our need for parsimony and noise filtering with reality.
- **Dichotomania:** Confusion of our need for summarization and decision criteria with our preference for black-or-white thinking.
- **Reification:** Faith that **formal methods** for reasoning, inference, and decision suffice for **real-world** reasoning, inference, and decision.

One form of nullism: The bias toward assuming all incentives are to “discover” rather than to refute effects. This meta-bias is rampant in the “replication crisis” literature, which ignores differences in incentives across topics and authors. E.g.,

- Those invested in a treatment are biased toward reporting no excess of adverse side effects (ASEs).

As illustrated below, there are other settings in which statistical norms will aggravate null bias.

Fact: we're all cognitively blind in some way

Amos Tversky: “**My colleagues study artificial intelligence; me, I study natural stupidity.**”

“Whenever there is a simple error that most laymen fall for, there is always a slightly more sophisticated version ... that experts fall for.”

Example: Compare

The fool's “P-value = probability of the null” to

The expert's “P-value = probability chance alone produced the association” – They are the same mistake, for “chance alone” is the null!

Overconfidence bias: Kahneman - “People assign much higher probability to the truth of their opinions than is warranted.”

Statistical version: People assign much higher credibility to their interpretation of data and statistics than is warranted.

Value bias: We are all biased and corrupted by our values and conflicts of interest, such as our valuation of “saving lives”. For example, as wars show, not everyone holds that saving lives should be the dominating goal of life or society.

Many other cognitive biases contribute to design, analysis, reporting, publication biases

https://en.wikipedia.org/wiki/List_of_cognitive_biases

All of the following and more should form part of basic training for moderating inferences:

- **Anchoring** to perceived consensus and desired yet erroneous belief, **even after correction.**
- **Confirmation bias:** selective focus on desirable evidence and neglect of undesirable evidence.
- **Courtesy bias:** Tendency to be obscure about criticisms that will cause offense.

- **Failure to test alternatives** (“congruence bias”)
- **Selective criticism** of undesirable evidence.
- **Selective reasoning** to desired conclusions via selective assumptions, explanations, and data.
- **Dunning–Kruger effects**: The less expertise, the more the overestimation of one’s competence (as in researcher, reviewer, and editor overestimation of their own statistical expertise).
- **Reification of mathematical validity**: The tendency to think methods or judgments are as accurate about the world as they are in the math (thought experiments) used to derive them.

- **Familiarity bias** – over-reliance on familiar methods, ignoring alternative approaches (“gets me grants and papers, so no need to change”).
- **Territorial (exclusionary) bias** – promoting familiar methods as exclusively correct approaches, thus protecting self-authority and preventing competition from gaining ground (“Strictly Ballroom” effect: You can’t be an authority about what you haven’t studied and used extensively).
- **Groupthink and herd-behavior biases such as repetition bias** (echo-chamber effect, group reinforcement causing overcount of evidence).

- **Mind-projection fallacies:** Imbuing inert quantities with attitudes, opinions, values, inferences, judgments, and decisions.
 - Rampant in statistical discussions, thanks to using **value descriptors** like “significance”, “confidence” and “severity” for narrow math concepts that cannot capture the word meanings.
- **Top example of nonsense: “P-values overstate evidence.”** P-values only provide the position of a statistic in a reference distribution (e.g., a chi-squared) derived from a model. **Any evidence overstatement is by the viewer.**

These are not absolute or sharp categories, but rather are heuristic triggers to avoid getting lulled or suckered by colleagues (however well-meaning), “experts,” and most of all **ourselves**. Example:

- A Dunning-Kruger form of **overconfidence bias that is rampant among medical pundits** (and not only when they comment on statistical methods): We may know our specialty superbly, but not realize how that expertise doesn't instantly generalize to other topics. **True even for topics we think are close to our specialty, but actually have a lot more literature than we are aware of.**

Empirical fact:

Incompetence among the exalted is the norm

Tversky: “It's frightening to think that you might not know something, but more frightening to think that, by and large, the world is run by **people who have faith that they know exactly what is going on.**”

- Equally true in research **and** methodology!
- **The Covid-19 pandemic has supplied us with vivid real-world examples – despite no agreement about who those examples are.**

Daniel Kahneman:

- **“We can be blind to the obvious, and we are also blind to our blindness.”**

And most relevant to statistics in soft sciences:

- **“...illusions of validity and skill are supported by a powerful professional culture. We know that people can maintain an unshakeable faith in any proposition, however absurd, when they are sustained by a community of like-minded believers.”**

- See: Most any defense of nullism or NHST...

Example: “if the p-value for the effect is greater than the journal’s threshold p-value, then the editor can immediately reject the paper, which saves the journal from spending any more time on the (unconvincing) paper...if a result is statistically significant, this means no more than that there is enough weight of evidence for the studied effect to make the paper reporting the effect **worth considering for publication.**”

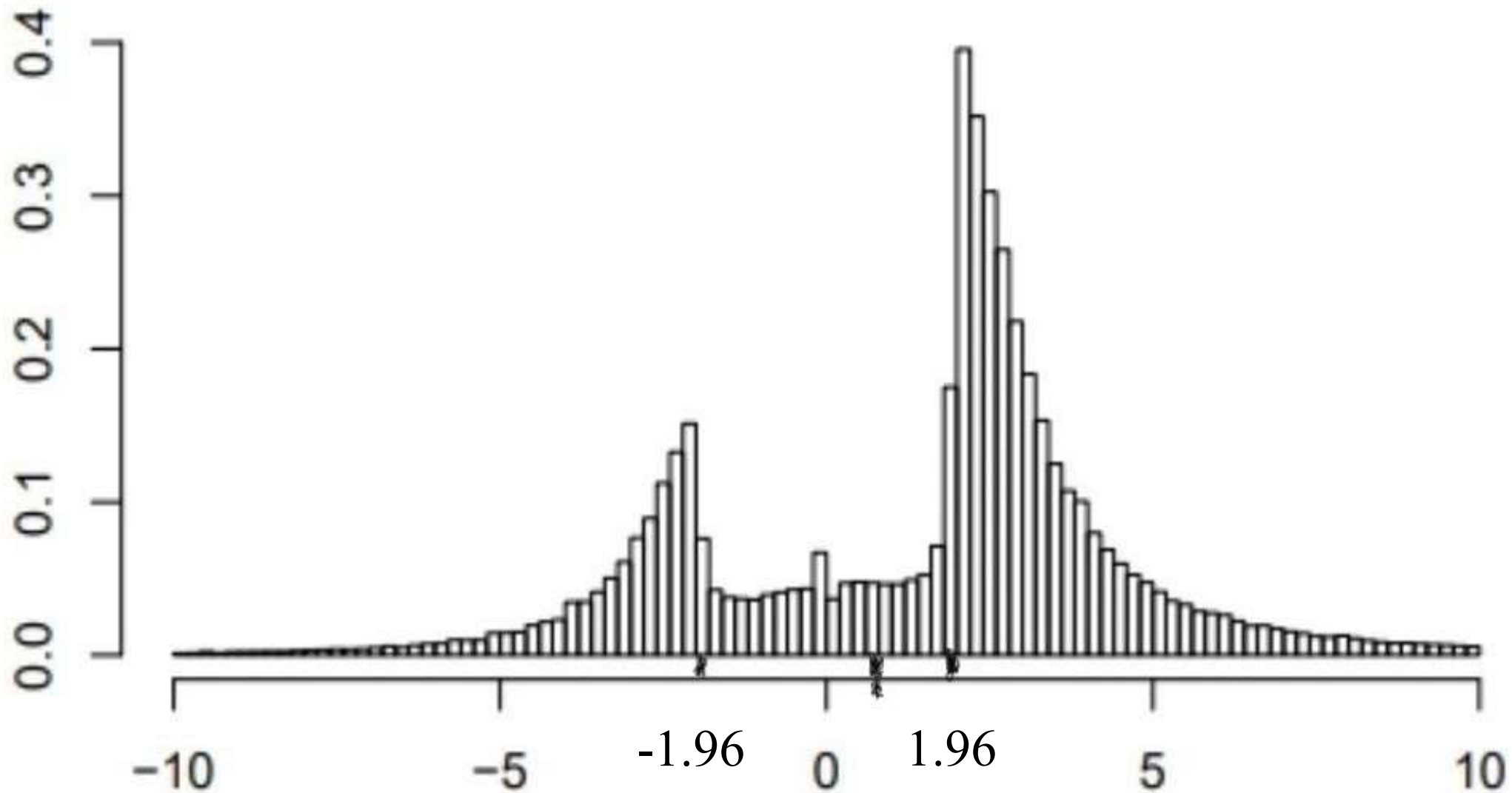
- Fisher 1920s? No, Mcnaughton 2021, *The War on Statistical Significance*.

The literature damage from such nonsense:

Fig. 1 from van Zwet & Cator 2021:

Over a million z-values from Medline 1976-2019.

Imputed histogram has $>75\%$ above 0



Articles decrying null misinterpretation of nonsignificance date at least back to Karl Pearson **1906**:

- “The absence of significance relative to the size of the samples is too often interpreted by the casual reader as a denial of all differentiation, and this may be disastrous.”

Many others have repeated this caution since, including R.A. Fisher.

Why then does null misreporting continue and even remain enforced by some medical journals?

Some reasons: Because it enables

- maintaining an illusion of simplicity where none exists (the religion of parsimony)
forgetting that “nature is under no obligation to be understandable to you” (cf. Tyson)
- creating an illusion of learning and knowledge or certainty when information is actually sparse and results are ambiguous.
- imposing values and preferences of those who believe in or have stakes on the null.

This is NOT a matter of statistics philosophy!

- Declarations like "there was no association..." when there **was** an association but $p > 0.05$ or the CI included the null aren't the fault of the statistics or frequentism...
- They are the fault of a statistics and science culture that encourages and even demands declarations of "findings" from ambiguous results, which most results are.
- This vice is synergized by the low publication prospects for honestly reported ambiguity.

Some still claim that frequentist methods use no *explicit* prior, and so are “objective” or “let the data speak for themselves.”

This is pure delusion because all statistical methods are filled with *implicit* priors, and

DATA SAY NOTHING AT ALL!

Data are markings on paper or bits in computer media that just sit there...

If you hear the data speaking, seek psychiatric care immediately!

But Bayesians don't do any better than frequentists in practice - they just substitute other misleading rules for making declarations (e.g., Bayes-factor cutoffs). Some of those rules would make misreporting and publication bias even more severe, such as those that translate to using $p \leq 0.005$ instead of $p \leq 0.05$. **Statistical traditions that distort cognition are a chronic problem in research reports and policy rationales that claim to be based on “following the science”, where...**

- **Reasoning motivated by commitment to past teaching, past practice, and financial stakes drives resistance to serious reform**

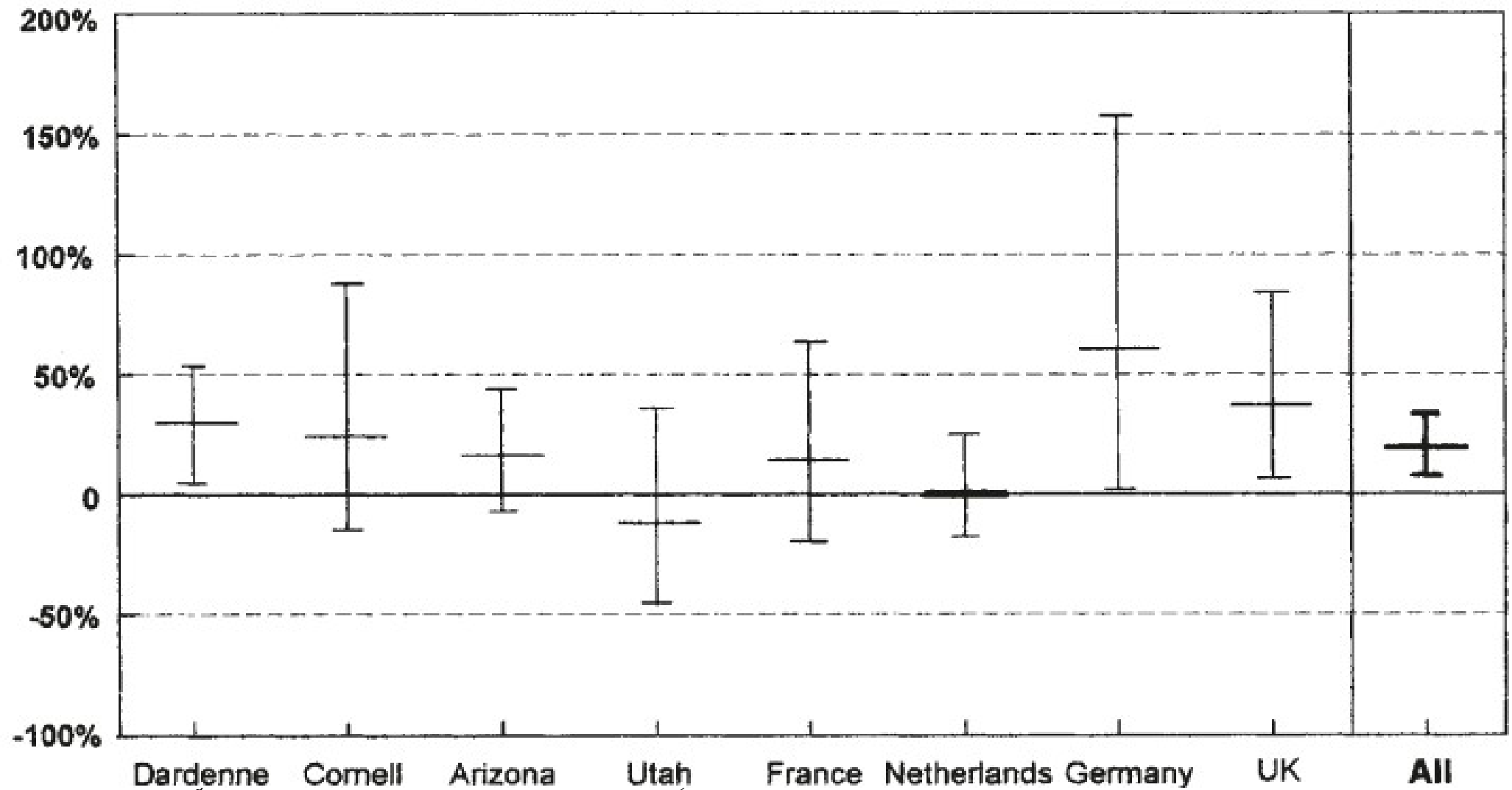
Example – a common label on dairy products:

“*MILK from cows not treated with rBST.

***No significant difference** has been shown between milk derived from cows treated with rBST and those not treated with rBST”

- Here, to protect their interests an industry group forced a statement of fact to be accompanied by an erroneous technical claim.

Millstone et al. *Nature* 1994: 8 trials, 19% average increase in somatic cell count (**pus**) in milk from cows treated with rBST (meta $p=0.004$):



- When there are stakes on what others perceive, data sets become more akin to propaganda sources than information sources, insofar as we can introduce causal stories to explain the data in a way consistent with any hypothesis we prefer.
- If needed in this process, entire studies may be discounted or ignored; others may be elevated to oracle status with claims of showing definitive results for outcomes that were in fact ambiguous...

- This phenomenon is obvious in the covid-pandemic literature, where many have claimed the literature supports vaccinating everyone down to age 6 months (“vaxmania”; see also “maskmania”), and some will call anyone who challenges this claim an “antivaxxer”.
 - The same literature is claimed by others to show the vaccines kill more than they save.
- The differences between those who advocate these extremes reflect the sources they follow and trust – or learn to mistrust. Example:



AP Fact Check
@APFactCheck

Pfizer never claimed to have tested the impact of its COVID-19 vaccine on transmission ahead of its 2020 release, despite misleading claims suggesting the company lied about this issue. Such studies were conducted after its rollout. Here are the facts.

[Translate Tweet](#)



apnews.com

Posts mislead on Pfizer COVID vaccine's impact on transmission

0:27 · 14 Oct 22 · [SocialFlow](#)

1 May 2023



Thread



Pfizer Inc.
@pfizer

The ability to vaccinate at speed to gain herd immunity and stop transmission is our highest priority. There is a lot of work ahead, and our focus is on supporting points of vaccination , as that's key to increasing the volume of people getting vaccinated every day.

[#JPM2021](#)

[Translate Tweet](#)

19:24 · 13 Jan 21 · [Twitter Web App](#)

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“the *paradox of tolerance*: Unlimited tolerance must lead to the disappearance of tolerance. If we extend unlimited tolerance even to those who are intolerant, if we are not prepared to defend a tolerant society against the onslaught of the intolerant, then the tolerant will be destroyed, and tolerance with them.”
(Popper, *The Open Society and its Enemies*)

In the pandemic, the intolerant exercised power over mainstream media to censor and suppress dissent in the name of “saving lives”. Some called the suppression “Nazism” but I find a closer parallel in Stalinism (e.g., Lysenko).

Claim: Science is characterized by open-minded comparison of theories against data.

Counterclaim: Scientists are characterized by committing to theories through ideology, advocacy, teaching, financial and other stakes, then defending them as long as it serves those stakes, to the point of using sophistry disguised as methodology.

[Sophistry (OED): “use of fallacious arguments, especially with the intention of deceiving”; some include use of cites that don’t show what’s claimed]

Example: "Bombshell: New Study on Long COVID in kids and young adults FAILS to link COVID to Long COVID"

<https://vinayprasadmdmph.substack.com/p/bombshell-new-study-on-long-covid>

“Long covid has no link to prior COVID19...how many kids have post-infective fatigue syndrome (PIFS)? The answer is 14.0% and 8.2%, and it is not significant... COVID19 had nothing do with either of these two conditions.” [PCC,PIFS]

But the 5.7% difference is clinically quite significant and the cited paper gives a 95% CI for the difference of -2.0% to 12.0% !

Of course, to present the results with the warranted uncertainty does not fit into the headline or blog narrative against vaccinating children and young adults...

[I e-mailed Prasad about the misinterpretation, to no response; and to post a comment on his blog requires becoming a paying member - What a modern way to filter criticism!]

Prasad also supports the EBM promotion of randomized trials as “gold standards” when they are no such thing in general, due to

- **Huge generalization bias** from exclusion of high-risk patients on ethics and liability grounds, and from placebos that have real side effects
- **Numbers too small or follow-up too short to discern effects, resulting in reporting $p > 0.05$ (or 95% CI including the null) as “no effect”**
- **Protocol mistakes and violations; selective publication, reporting, and discussion ...**

A typical example: RCT by Vallejos et al.

‘Ivermectin to prevent hospitalizations in patients with COVID-19’ BMC ID 2 July 2021...

- Abstract: OR = **0.65**; 95% CI **0.32, 1.31**; $p = .23$ reported as “Ivermectin had no significant effect on preventing hospitalization”.
- Medical news sources reported that the trial “found no benefit for ivermectin on death” –
- **BUT** on p. 5 of paper: OR = 1.34, 95% CI **0.30, 6.07** from **4** ivermectin, **3** placebo deaths.
- **The trial was too small to show anything!**

Note too that, in the above long-covid example, Prasad is not above using an observational study to support questionable conclusions, so there is a lack of consistency...

Nonetheless, Prasad presents many examples from his own field (hematologic oncology) in which nonrandomized studies have been abused to obtain treatment authorizations when randomized trials should have been demanded, e.g., see

<https://vinayprasadmdmph.substack.com/p/the-tragedy-of-oncology>

- The point is **not** to argue which design, treatment, or policy is “correct”, but rather that
- **“Spin” is the driver through The Garden of Forking Paths: “objective” statistics are perceived, selected, and described based on preferred causal stories and, in high-stakes settings, political and litigation concerns.**
 - **Examples abound throughout health and medical sciences – which should scare you!**
 - **Methodologies that pretend to be objective obscure and foster this manipulation.**

- **The causal stories that “we” (researchers, reviewers, and editors) want believed causally affects analysis choices and output interpretations. The result is that reports often function as **lawyering** for those stories.**
- **A major source of blindness to the problem is that pundits in statistics and “meta-research” are blind to their own biases and deficiencies, which synergizes with biases and deficiencies of methods **developers**, instructors, users, and readers.**

- **Romantic heroic-fantasy science:**
Committed to fact-finding and dissemination of valid facts, regardless of the social consequences.
- **Harsh reality: Almost no one would disseminate all valid facts regardless of the consequences.**
- **Much health science serves commitments of major social networks to warp portrayal of facts in order to direct society according the network's values and special interests.**

Some argue that vaccines or boosting are safer than getting covid for immunity by pointing to much higher rates of SAEs among unvaccinated covid cases compared to vaccinees - a comparison is severely biased in favor of vaccines/boosters in several ways, e.g., because

- **The causal comparator is all unvaccinated or unboosted, not just their covid cases.**
- **The unvaccinated or unboosted study cases are further selected by getting covid severe enough to be recorded.**

The scientific role of dissent from consensus

Despite the fallacies in his columns, Prasad serves as a counterweight to those who spin foregone conclusions in the opposite direction.

Example: **“More dishonest statements about boosters by the FDA's Marks and Califf”**

<https://vinayprasadmmp.substack.com/p/more-dishonest-statements-about-boosters>

“In response to Paul Offit’s NEJM editorial Peter Marks and Robert Califf from FDA have a reply that argues **falsely** that good evidence shows boosters benefit young people.”

<https://www.nejm.org/doi/full/10.1056/NEJMp2215780>

Offit, NEJM 9 Feb 2023: “booster dosing is probably best reserved for the people most likely to need protection against severe disease.”

Marks & Califf letter re Offit NEJM 01 Mar 2023: “...available evidence supports the vaccination of all currently eligible persons with updated Covid-19 vaccines”.

Offit response: “the protection against hospitalization that was afforded by bivalent boosters...was limited to people over 65 years of age⁴ and those with a median age of 76.⁵”

An opinion on covid boosters, from the editor of MedPage:

<https://www.medpagetoday.com/opinion/faustfiles/103792>

“...there were never great data showing booster benefit against severe disease or death for standard-risk younger adults. Only when all booster data from all demographics - young and old - were lumped together did it appear on the surface that everyone benefited from boosters across the age and risk spectrum.” →

“Why? Because the booster benefit was so large in older and other high-risk populations that including younger healthy people in the analyses did not change the apparent overall vaccine effectiveness that much...

the main thing going forward is that high risk people need to be boosted at some interval (be it yearly or more often) **while the rest of the population does not need a booster.”**

A number of respectable health agencies have ceased to promote or even offer covid boosters for those with no identified risk factors for serious covid. E.g., accessed 14 Apr 2023: <https://www.sst.dk/en/english/Corona-eng/Vaccination-against-covid-19>

“Autumn/winter 2022-23 the Danish Health Authority has recommended booster vaccination for people over 50 and selected target groups. The offer of booster vaccination against covid-19 expired on 1 March 2023” ...

“Why are people aged under 50 not to be re-vaccinated?:

- The purpose of the vaccination programme is to prevent severe illness, hospitalisation and death. Therefore, people at the highest risk of becoming severely ill will be offered booster vaccination. **The purpose of vaccination is not to prevent infection with covid-19, and people aged under 50 are therefore currently not being offered booster vaccination.”** →

“People aged under 50 are generally not at particularly higher risk of becoming severely ill from covid-19. In addition, younger people aged under 50 are well protected against becoming severely ill from covid-19, as a very large number of them have already been vaccinated and have previously been infected with covid-19, and there is consequently good immunity among this part of the population.”

...

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“Vaccination of children against covid-19: Children and adolescents rarely become severely ill from the Omicron variant of covid-19. From 1 July 2022, it was no longer possible for children and adolescents aged under 18 to get the first injection and, from 1 September 2022, it was no longer possible for them to get the second injection. A very limited number of children at particularly higher risk of becoming severely ill will still be offered vaccination...”

UK NHS, accessed 14 April 2023 from <https://www.nhs.uk/conditions/covid-19/covid-19-vaccination/getting-a-booster-dose-of-the-covid-19-vaccine/>

“You may be offered a seasonal booster if you:

- are **aged 75 or over...**
- live in a care home for older adults
- are aged 5 or over and have a weakened immune system”

Contrast all that to this policy accessed on 18 April 2023 <https://covid-19.ucla.edu/get-vaccinated-and-upload-your-info/>

“students, faculty, staff and others who work, live or study on campus or at other UCLA facilities need to be fully vaccinated (**and up to date on boosters**) — with limited medical exceptions and accommodations based on disabilities or religious beliefs, as well as temporary deferrals for those who are pregnant or have recently had COVID-19...”

“The current UC interim policy - introduced Dec. 12, 2022 - also allows individuals who have received their primary vaccinations to opt out of receiving COVID-19 boosters by signing a declination statement, receiving education on vaccines and agreeing to certain non-pharmaceutical interventions, which may include mask-wearing and/or other mitigations. (UCLA health care workers, however, may **not** opt out of their first booster; only those who have received an official exception or deferral will be exempt)”

... or this policy accessed on 14 April 2023 at <https://huhs.harvard.edu/covid-19-vaccine-requirement-faqs#gsc.tab=0>

“Harvard requires being up-to-date on COVID vaccination for all students who will be on campus. As we work to continue the high levels of vaccination needed to protect our community, Harvard highly recommends being up-to-date **per the CDC definition** for all Harvard community members, including faculty, staff, and researchers who will have any on-campus presence.”

Accessed on 15 April 2023 from
<https://www.cdc.gov/coronavirus/2019-ncov/vaccines/stay-up-to-date.html>

“CDC recommends 1 updated COVID-19 vaccine dose for everyone aged 6 months and older.” – Recommendation adopted by the AAP and AAFP:

<https://www.aafp.org/family-physician/patient-care/prevention-wellness/immunizations-vaccines/immunization-schedules/birth-through-age-18-immunization-schedule.html>

A tale of two drugs: The EUA for molnupiravir was based on OR = 0.48 (95% CL 0.28, 0.79) for hospital or death (DoH) at ~50% of planned recruitment. Among problems noted by Thorlund et al. Am J Trop Med Hyg 2022 were

- When trial was halted another ~40% of recruitment was available, with OR = 1.35 (0.64, 2.88) $p = 0.03$ (reported as $p = 0.01$)
- Combined (Merck): OR=0.69 (0.48,1.01)

Molnupiravir became and remains a standard treatment - at \$700 a course paid by the U.S. govt.

Yet subsequent trials were arguably as or more marginal, e.g., PANORAMIC trial, Lancet 2023: OR for DoH = 1.06, 95% CL 0.81, 1.41

Contrast those to RCTs of HCQ prophylaxis for covid, García-Albéniz et al Eur J Epid 2022:

Pooled RR estimate from 7 pre-exposure prophylaxis trials: 0.72 (0.55, 0.95) [4 post-exposure trials: 0.91 (0.62, 1.35)], cautiously reported as “A benefit cannot be ruled out based on the available evidence from these trials”.

Similar observations apply for ivermectin.

Some background and further readings on my views

(should be open access where links are given)

Greenland S. Transparency and disclosure, neutrality and balance: shared values or just shared words? *J Epidemiol Comm Health* 2012;66:967–970.

Greenland S. The need for cognitive science in methodology. *Am J Epidemiol* 2017;186:639-645.

<https://academic.oup.com/aje/article/186/6/639/3886035>

Greenland S. For and against methodology: Some perspectives on recent causal and statistical inference debates. *Eur J Epidemiol*, 2017;32:3-20.

<https://link.springer.com/article/10.1007%2Fs10654-017-0230-6>

Greenland S. The causal foundations of applied probability and statistics. In Dechter R, Halpern J, Geffner H, eds. *Probabilistic and Causal Inference: The Works of Judea Pearl*. ACM Books 2022; 36: 605-624,

<https://arxiv.org/abs/2011.02677> (version with corrections)

Greenland S. Analysis goals, error-cost sensitivity, and analysis hacking: essential considerations in hypothesis testing and multiple comparisons. *Ped Perinatal Epidemiol* 2021;35:8-23. <https://doi.org/10.1111/ppe.12711> 20-01105-9

Some educational readings for authors, reviewers, editors, students and **instructors** on reducing statistics misinterpretations

Lash TL, Heuristic thinking and inference from observational epidemiology. *Epidemiology* 2007;18:67–72.

Greenland S, Senn SJ, Rothman KJ, Carlin JC, Poole C, Goodman SN, Altman DG. Statistical tests, confidence intervals, and power: A guide to misinterpretations. *The American Statistician* 2016;70 suppl. 1, https://amstat.tandfonline.com/doi/suppl/10.1080/00031305.2016.1154108/suppl_file/utas_a_1154108_sm5368.pdf

Greenland S, Mansournia M, Joffe, M. To curb research misreporting, replace significance and confidence by compatibility. *Prev Med* 2022;164, <https://www.sciencedirect.com/science/article/pii/S0091743522001761>.

- for more detailed coverage of the latter topic see:

Rafi Z, Greenland S. Semantic and cognitive tools to aid statistical science: Replace confidence and significance by compatibility and surprise. *BMC Med Res Methodol* 2020;20:244

<https://bmcmmedresmethodol.biomedcentral.com/articles/10.1186/s12874-020-01105-9>