Re-analysis and replication practices in reproducible research

Daniele Fanelli

METRICS
META·RESEARCH INNOVATION CENTER AT STANFORD

Conceptual challenges concerning

Re-analysis and replication practices in reproducible research

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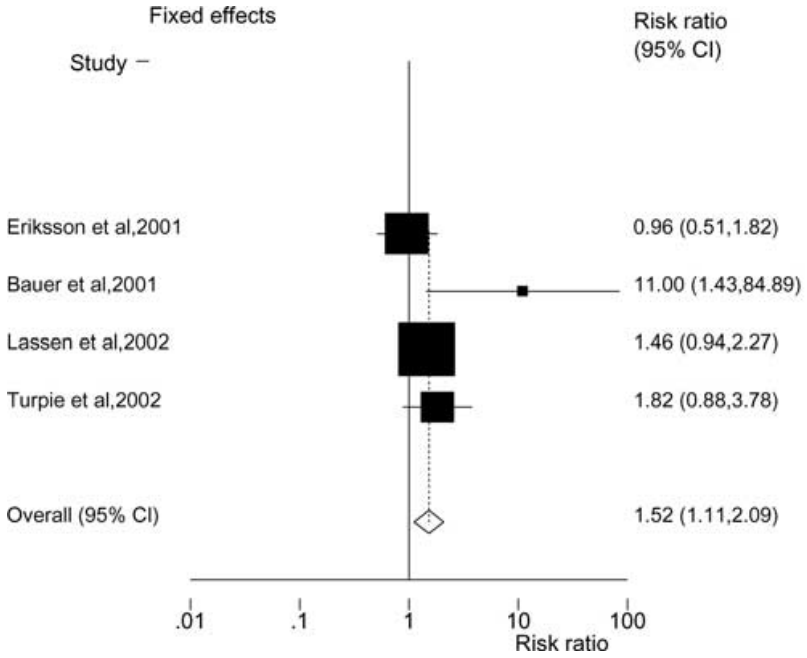
Conceptual challenges concerning Re-analysis and replication practices in reproducible research

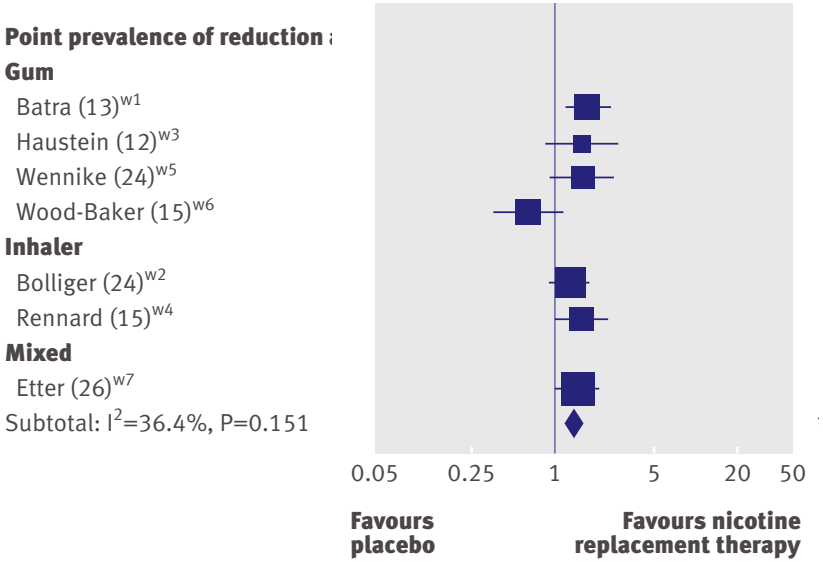
- In what sense can we talk of a "replicability" or "reproducibility" crisis?
  - Look at data on selective reporting
    - small-study effects
    - grey literature bias
    - decline effect
  - Where and what might the problem be?
  - What does "reproducibility" mean?
- What narrative can most productively support transparency and reproducibility?

The main causes of irreproducibility? selective reporting, as manifest in:

Small-study effects

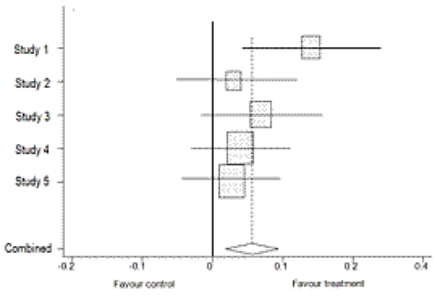


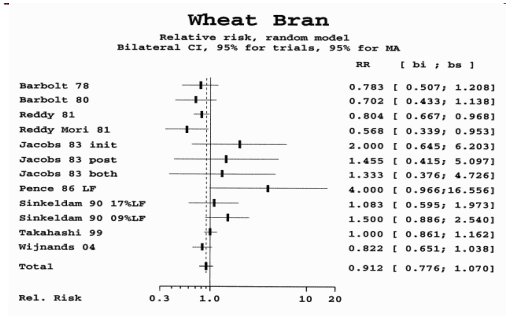
Grey literature bias



Meta-assessment of bias in science

N 1910 meta-analyses from all disciplines





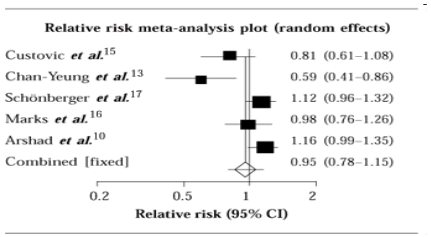
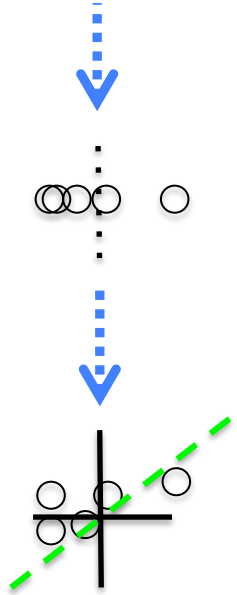
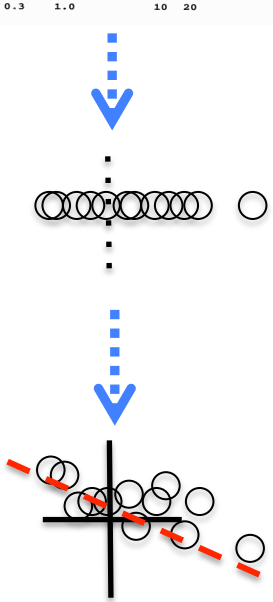
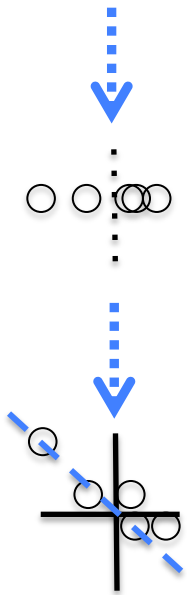


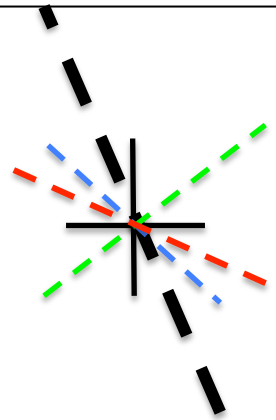
Figure 2. Meta-analysis [RR (95% CI)] of interventions to prevent parent-reported wheeze. Error bars indicate 95% CIs.



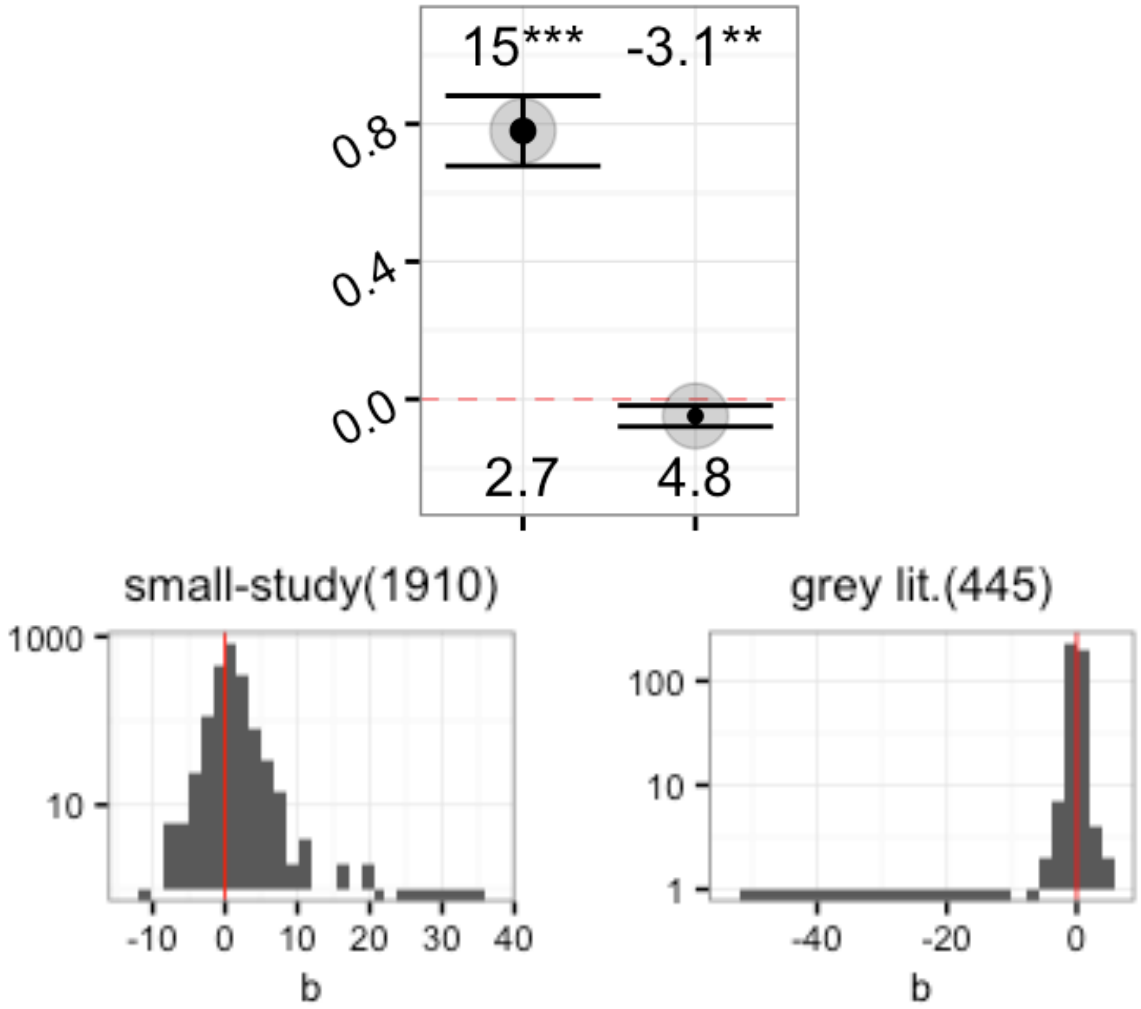




Average bias-pattern across all meta-analyses

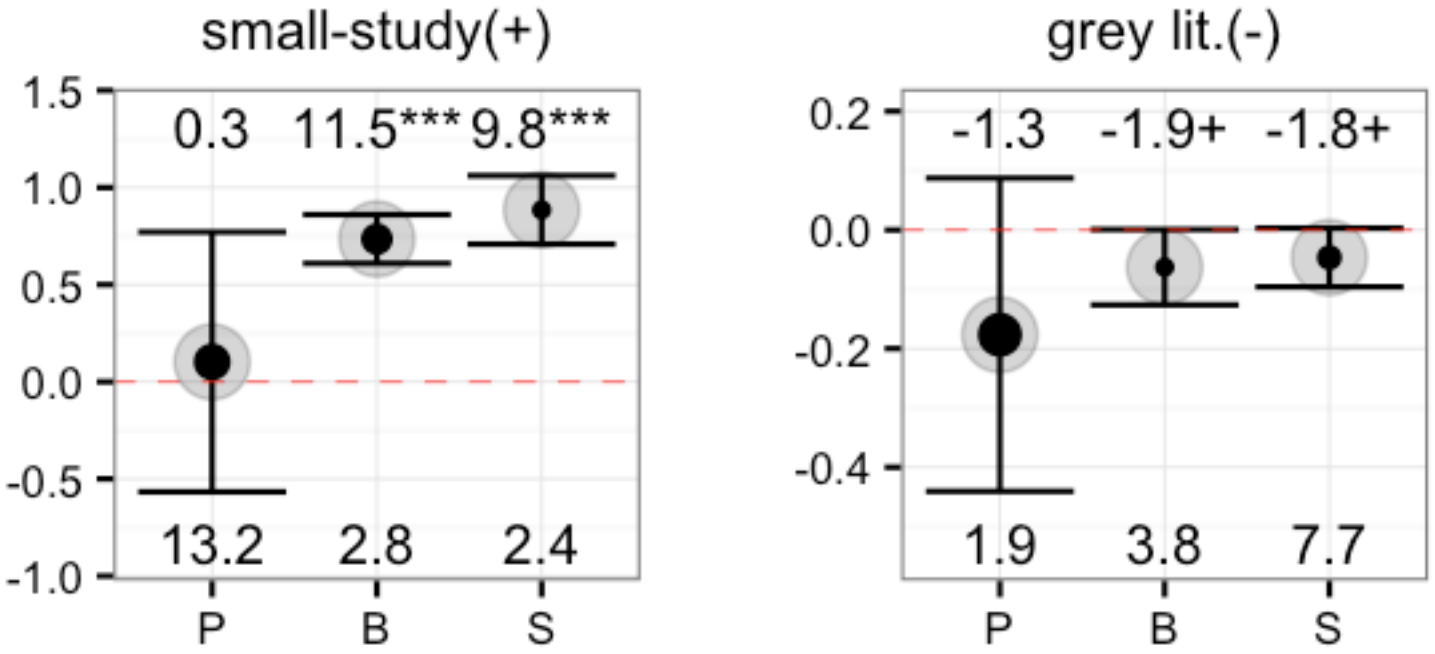


Meta-meta regression
1,910 MA: 33,355 individual studies



(Fanelli, Costas & Ioannidis, 2017, PNAS)

Biases vary, e.g. across domains



- **Conceptual challenge n1: science is not all the same, biases vary widely across fields**

(Fanelli, Costas & Ioannidis, 2017, PNAS)

Conceptual challenge n2: Not all bias is due to QRPs

- Small studies may be perfectly justified, e.g.
  - Based on intuition/preliminary observations
  - Carefully design a study to maximize chances of seeing an effect, with minimal investment
  - The bias is created by meta-analysts (or readers, journalists etc.) who ignore the context of a study
- Not publishing some (e.g. negative) results may be justified too
  - e.g. study that is clearly of poor quality
  - but also when quality is not poor…
  - **Anathema!** For many, including myself, before…

A mathematical theory of bias

$$K(Y;XM) = \frac{H(Y) - H(Y|XM)}{H(Y) + H(X) + H(M)}$$

with $H(X) = -\sum_x p(x)log(p(x))$

(Shannon's Entropy)

A conclusive negative result ("falsification" of a hypothesis) yields information:

$$\Delta K_{falsif} \quad \propto \quad log(\frac{|\Omega|}{|\Omega| - 1})$$

$|\Omega|$ number of possible hypotheses, explanations, variables, methods, confounders…

As |Ω| grows,
value of a negative result rapidly approach zero!

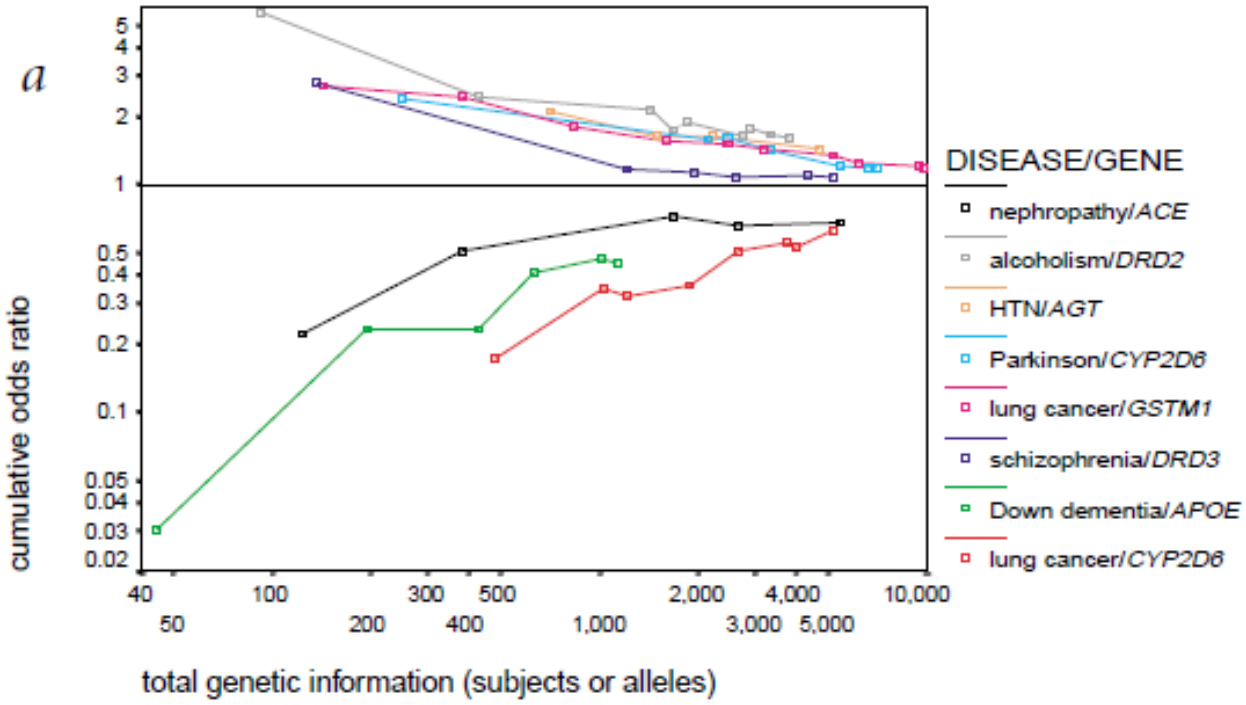
(Fanelli 2016, PeerJ Preprints – **2nd UPDATED VERSION COMING SOON!**)

Conceptual challenge n2: Not all biases are unjustified

- Small studies may be perfectly justified, e.g.
  - Based on intuition/preliminary data
  - Carefully design a study to maximize chances of seeing an effect, with minimal investment
- Not publishing some (e.g. negative) results may be justified too
  - If the costs of allowing for some publication bias exceed the costs of publishing lots of negatives
    - e.g. costs of increasing noise in the literature
- **Cost/benefits tradeoff likely field-specific**

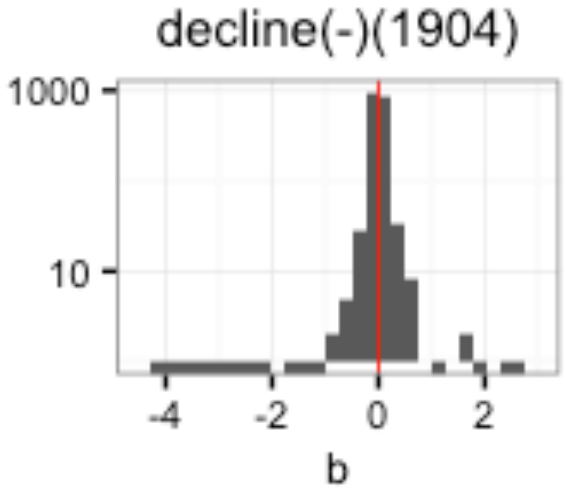
Challenge n 3: Doesn't meta-analysis show that replication occurs?

- Ok, but the "decline effect" reveals a problem



(Ioannidis et al. 2001, Nature Genetics)

The decline effect occurs, but is not ubiquitous



Highly significant "first-year effect"

b[95%CI]=0.077[0.022,0.132]

On average, circa 8% larger ES

- Aren't failed replications supposed to occur at least some times?
- **Doesn't the decline effect show that science works?**

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Open Science Collaboration*,†

WIRED Psychology Is in Crisis Over Whether It's in Crisis

BUSINESS CULTURE DESIGN GEAR SCIENCE SECURITY TRA

KATIE M. PALMER SCIENCE 03.03.16 2:00 PM

PSYCHOLOGY IS IN CRISIS OVER WHETHER IT'S IN CRISIS

←

Conceptual challenge n 4: What does reproducibility mean?

- **Methods** repr.
  - original, literal sense
- issues with
  - missing information
    - poor/selective reporting
    - lack of expertise
- improved by
  - better reporting, transparency etc.
- **ideally 100%**

- **Results** repr.
  - e.g. decline effect
- mainly issues with
  - methodological flaws
  - poor/selective reporting, QRP etc.
  - intrinsic complexity of phenomena
- may be improved by
  - better reporting
  - transparency
- **but is never 100%**

- **Inferential** repr.
  - e.g. RIP's debate on conclusions to draw
- mainly issues with
  - theoretical/ methodological disagreement
- improved by
  - scholarly process

(Goodman, Fanelli and Ioannidis, 2016, Science Tr. Med.)

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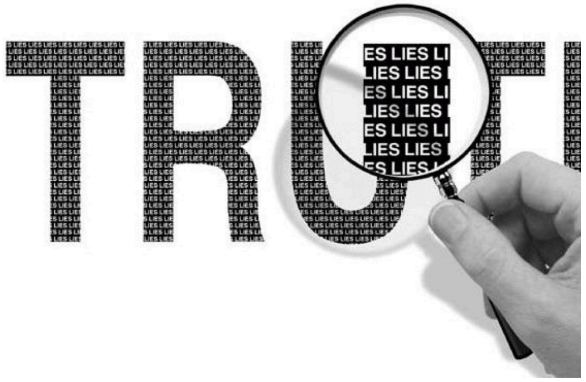
PRODUCIBILITY CRISIS?

3% 52%



Science is broken: Fraudulent studies, non-reproducible r money influence... it's all falling apart

April 25th, 2016, by D. Samuelson

When the scientific method is no longer ab

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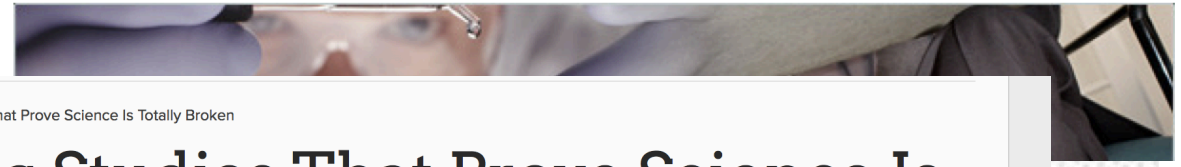

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Conceptual challenges

- 1) bias and other issues are not ubiquitous
- 2) selective study design or selective reporting may at times be justified
- 3) meta-analysis and the (occasional) decline effect show that science works
- 4) reproducibility has different values and meanings in different contexts
  - repr. of results and inference are complex issues
  - reproducibility of methods is unobjectionable and sustains any form of reproducibility
- 5) aren't we living evidence that science is healthy?

In what sense can we talk of a reproducibility "crisis" in science?

- Not in the sense that "science is broken"
- A clear simple message such as "science is in crisis" can have, and had up to this point benefits, but:
  - times have changed
  - our evidence and understanding has matured
  - a crisis narrative is no longer supported
  - **nor is it necessary**

In what sense can we talk of a reproducibility "crisis" in science?

- More in the sense that we face "new opportunities and challenges"
- computers and the internet are making science mightier than ever
  - tackle more subtle, complex phenomena
  - ever more complex, computational analyses
  - increasingly global collaborations
- new challenges for RI but also the promise of a science fully "reproducible", shared, communal, organically skeptical, etc.
- **We don't need a "crisis" to embrace the future!**

email@danielefanelli.com