

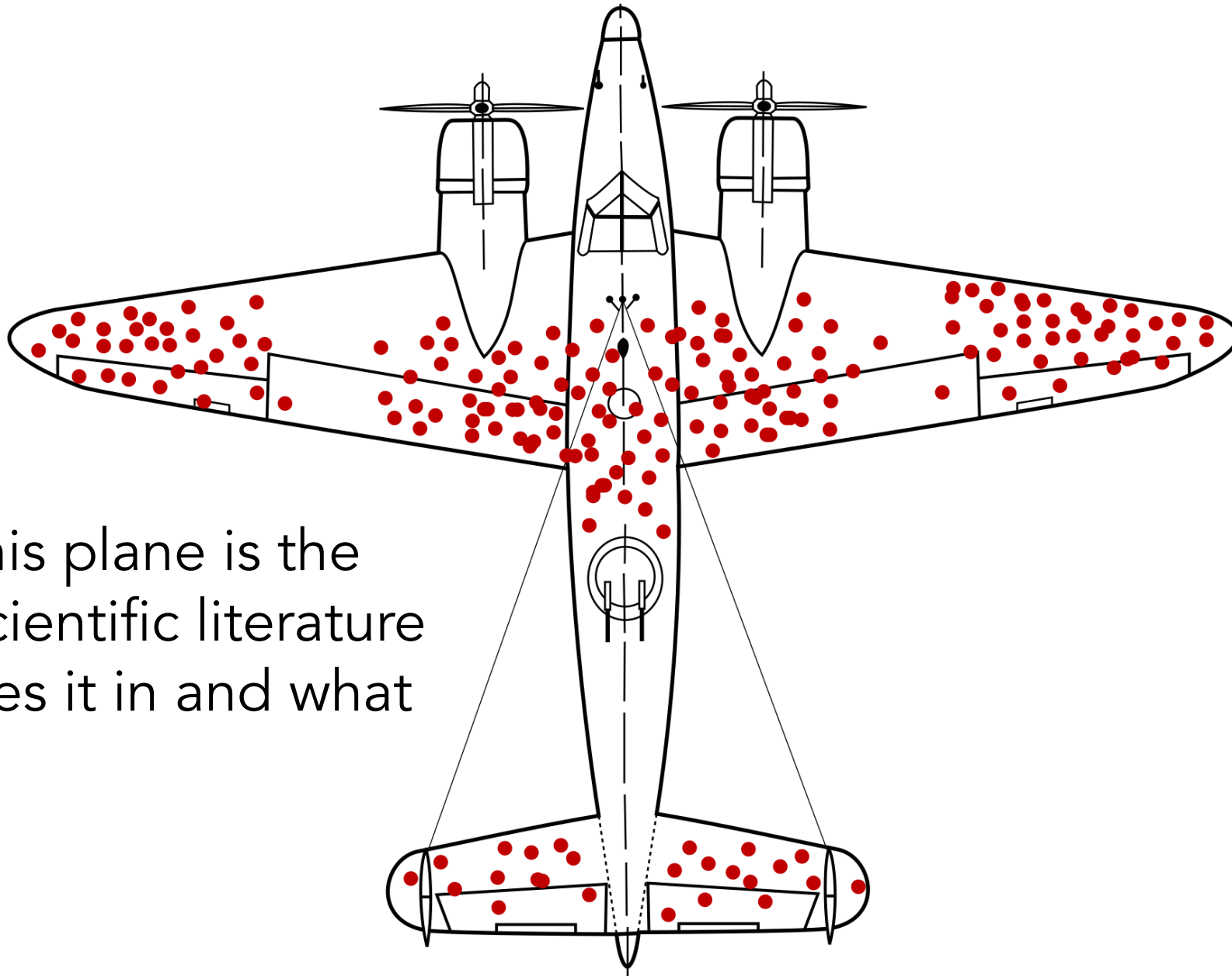
# *Improving your research with preregistration*

Dr William Xiang Quan Ngiam (he/him)



# My **goals** for this talk

- An introduction to what a **preregistration** is and why it came about
- Suggest what I think are the **best practices** with preregistration
- Describe the **benefits** of preregistration (especially for **early-career researchers**)

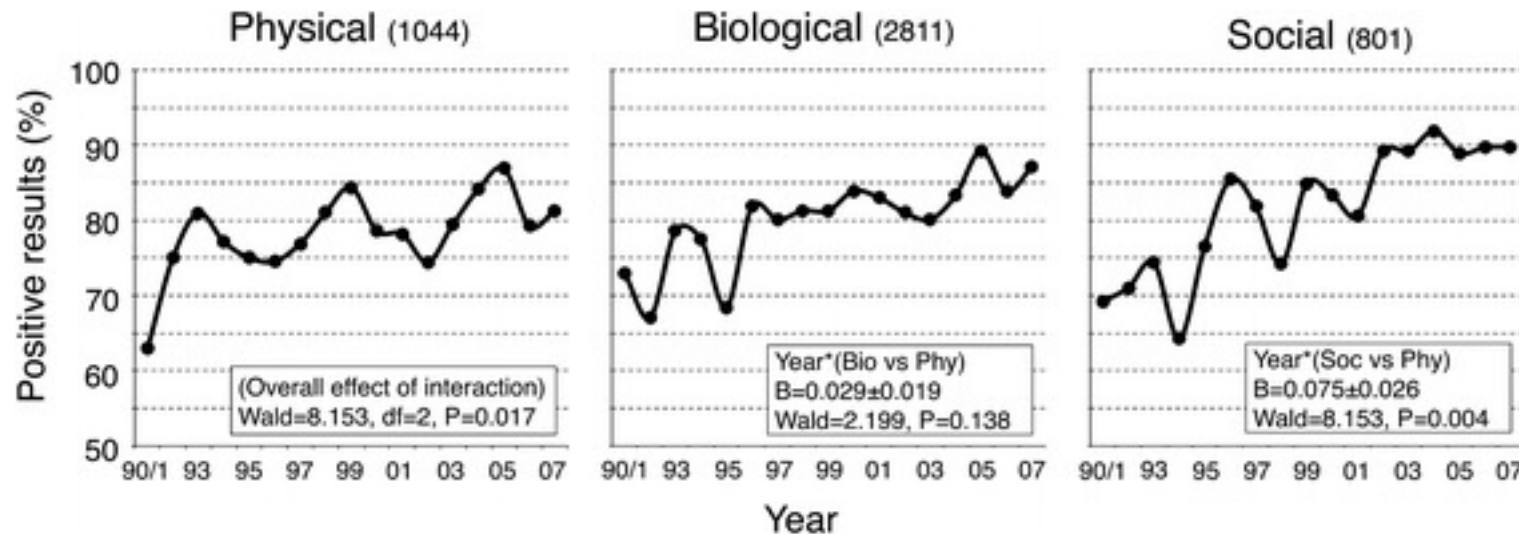


Imagine if this plane is the  
published scientific literature

- What makes it in and what  
doesn't?

# The decline of negative results

- The proportion of papers reporting a positive result has been **increasing** from **~70%** in 1990 to **~90%** by 2005 (Fanelli, 2012)



- In the recent psychology literature, this proportion is estimated to be **~95%** (Scheel, Schijen and Lakens, 2021)

Figure from Fanelli, D. (2012). Negative results are disappearing from most disciplines and countries. *Scientometrics*, 90(3), 891-904.

Scheel, A. M., Schijen, M. R., & Lakens, D. (2021). An excess of positive results: Comparing the standard Psychology literature with Registered Reports. *Advances in Methods and Practices in Psychological Science*, 4(2), 25152459211007467.

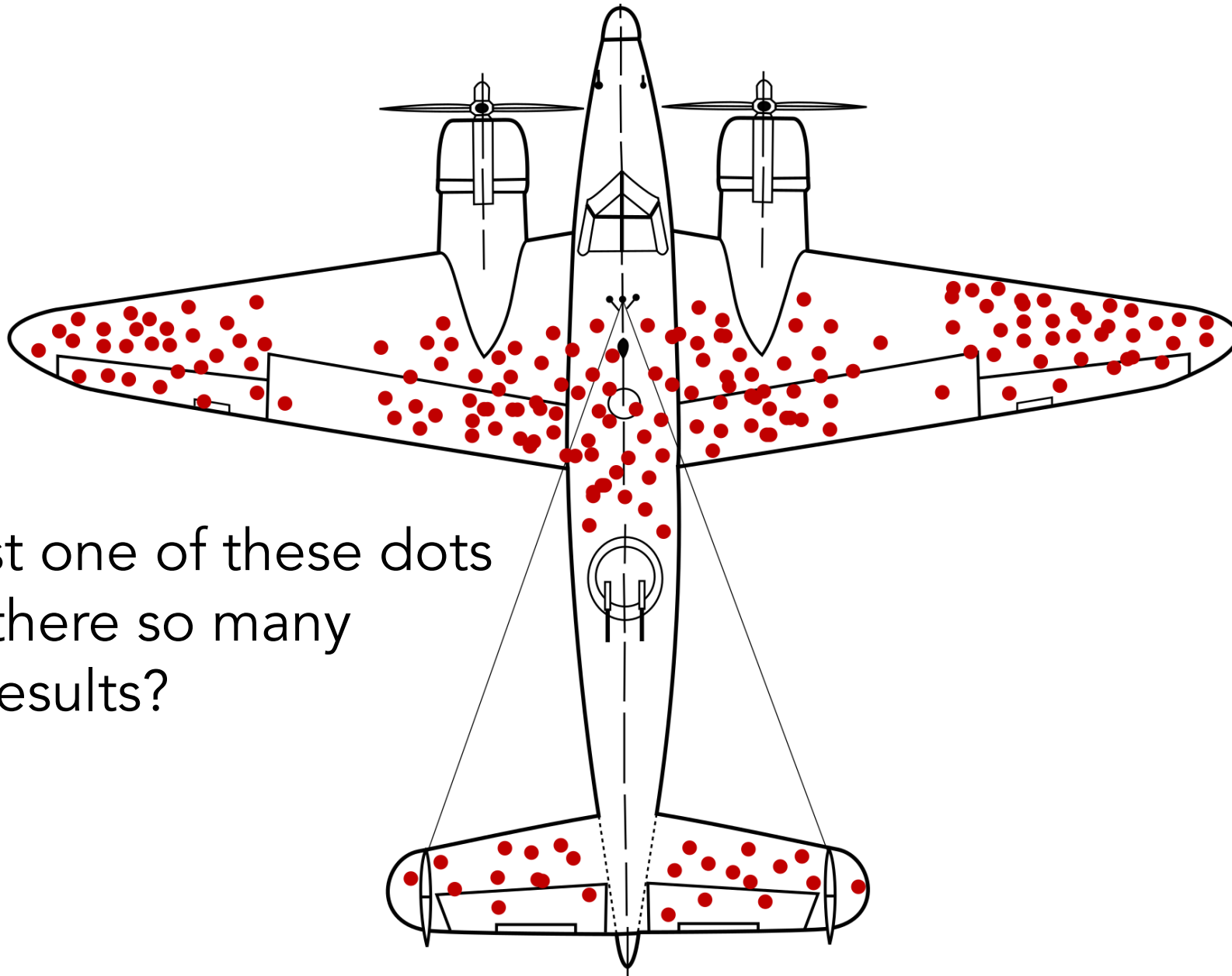
# The reproducibility crisis

- The widespread concern that published studies do not replicate or cannot be reproduced in the first place
  - Psychology – 35 out of 97 studies (36.1%) reproduced the positive result originally published in journals. (*Reproducibility Project: Psychology* – Open Science Collaboration, 2015)
  - Cancer Biology – 39 out of 97 studies (40.2%) reproduced the positive result originally reported in high-impact articles. (*Reproducibility Project: Cancer Biology* – Errington et al., 2021)
  - Economics – 11 out of 18 studies (61.1%) reproduced the positive result originally published in high-ranking journals. (Camerer et al., 2016)
- The replications often report smaller effect sizes than the original publications

Open Science Collaboration. (2015). Estimating the reproducibility of psychological science. *Science*, 349(6251), aac4716.

Errington, T. M., Mathur, M., Soderberg, C. K., Denis, A., Perfito, N., Iorns, E., & Nosek, B. A. (2021). Investigating the replicability of preclinical cancer biology. *Elife*, 10, e71601.

Camerer, C. F., Dreber, A., Forsell, E., Ho, T. H., Huber, J., Johannesson, M., ... & Wu, H. (2016). Evaluating replicability of laboratory experiments in economics. *Science*, 351(6280), 1433-1436.



Consider just one of these dots

- Why are there so many positive results?

# *Feeling the future?* The story of Bem (2011)

- Daryl Bem, a well-respected professor of social psychology at the time, publishes positive evidence for precognition and premonition
  - 9 experiments, over 1000 participants
  - Standard statistical analyses
  - Published in the prestigious *Journal of Personality and Social Psychology*
- A clear **false positive**. What happened? (Alcock, 2011)
  - Changing procedures halfway through experiments / unprincipled combining of various datasets
  - Post-hoc combination of various dependent variables to create new measures
  - Many marginally significant results, due to incorrect use of one-sided *t*-tests
  - Changing significance (alpha) levels across various experiments

Bem, D. J. (2011). Feeling the future: experimental evidence for anomalous retroactive influences on cognition and affect. *Journal of personality and social psychology*, 100(3), 407.

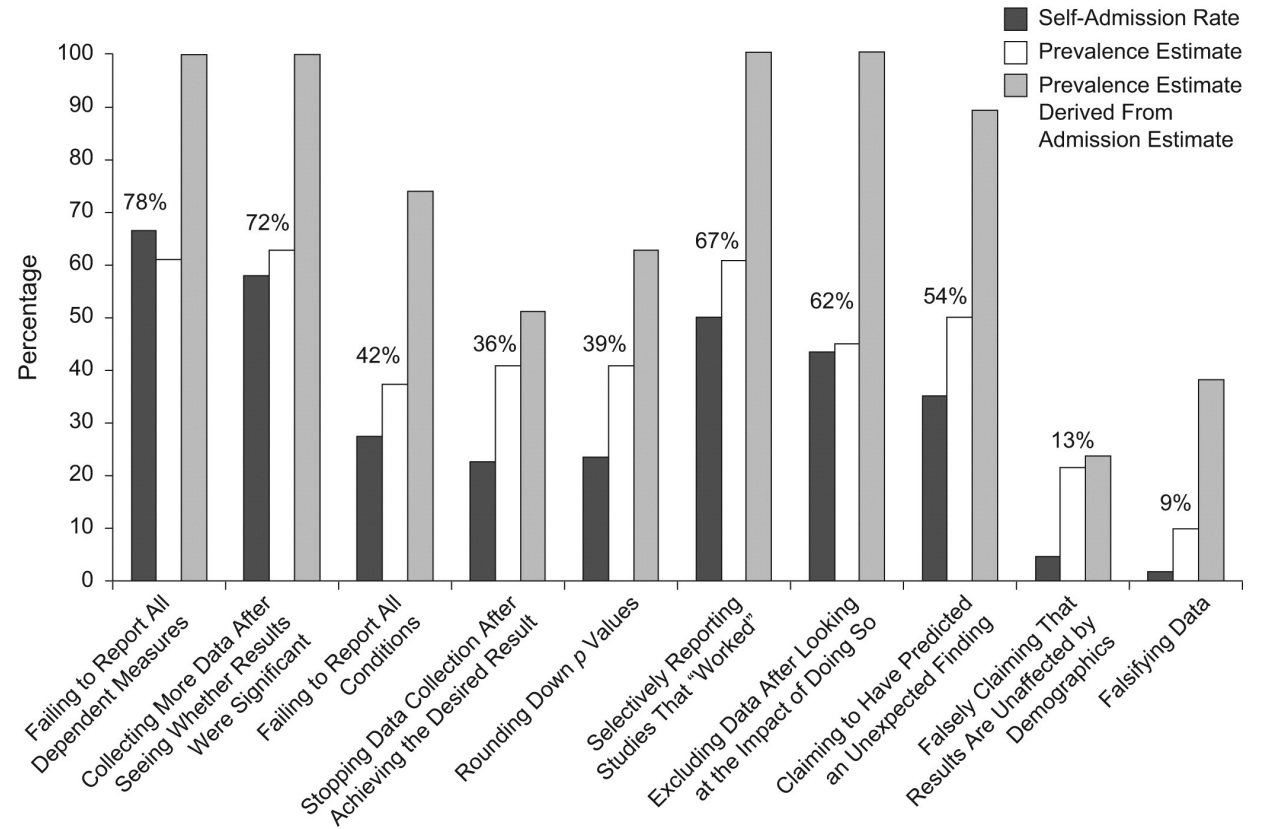
Alcock, J. (2011). Back from the future: Parapsychology and the Bem affair. *Skeptical Inquirer*, 35(2), 31-39.

# The reproducibility crisis

- One cause is the preponderance of **questionable research practices** (QRPs) leading to a high proportion of false-positive findings (John et al., 2012)

- Examples:

- Stopping or continuing data collection **after** checking significance of results (**p-hacking**)
- **Selective reporting** of significant tests/omission of non-significant tests
- Claiming to have predicted an unexpected finding (also known as **HARKing**)





# A proposed reform: preregistration


The practice of **publishing the plan for a study**, including research questions/hypotheses, research design, data analysis **before the data has been collected or examined.**

# What is a preregistration?

- Transparent documentation of what was planned at a certain time point
- Allows third parties to assess deviations from the research plan
  - Checking the validity of the analyses and preventing questionable research practices (QRPs) such as  $p$ -hacking and HARKing
- A useful framework for increasing research rigor and reproducibility

# Choosing a registry

- The preregistration template hosted by the [Open Science Framework](#) is a great place to start
  - Timestamped, indexed and persistent
- See Haroz (2022) for a comparison of platforms and useful tips!



	GitHub	ASPredicted	Zenodo	OSF template	OSF open
★ Timestamp	✗	✓	✓	✓	✓
★ Indexed Registry	✗	✗	✓	✓	✓
★ Persistence	✗	✓	✓	✓	✓
Anonymity	✗	✓	✗	✓	✓
Additional Materials	✓	✗	✓	✓	✓
Sandbox	✓	✓	✓	✓	✓
Template	✗	✓	✗	✓	✗
Rich Formatting	✓	✗	✓	✗	✓
Versioned Updates	✓	✗	✗	✓	✗
Flexibility	external	limited	external	limited	external
Collaboration	external	approval	external	sequential	external
Usability	skill	very easy	moderate	easy	moderate

# Best preregistration practices – Hypotheses

## Study Information

### Hypotheses \*

List specific, concise, and testable hypotheses. Please state if the hypotheses are directional or non-directional. If directional, state the direction. A predicted effect is also appropriate here. If a specific interaction or moderation is important to your research, you can list that as a separate hypothesis.

- Think about whether your work is exploratory (outcome-dependent) or confirmatory (outcome-independent)
  - Is hypothesis-testing appropriate?
- Justify your hypotheses
  - Specify the **theories and formal models** that make predictions about the effect
  - Indicate what will constitute evidence for or against the theories
  - Use unambiguous language

# Best preregistration practices – Data collection

## **Data collection procedures \***

Please describe the process by which you will collect your data and your inclusion and exclusion criteria. If you are using human subjects, this should include the population from which you obtain subjects, recruitment efforts, payment for participation, how subjects will be selected for eligibility from the initial pool, and your study timeline. For studies that don't include human subjects, include information about how you will collect samples, duration of data gathering efforts, source or location of samples, or batch numbers you will use.

- **Pilot** your experimental procedures
- State **all measured variables**
- Include the **experimental code**
  - Have the code reviewed for readability and reproducibility
- Be clear about data handling and cleaning procedures
  - Specify any data exclusion procedures and treatment of missing values and outliers

# Best preregistration practices – Sample size

## Sample size \*

Describe the sample size of your study. How many units will be analyzed in the study? This could be the number of people, birds, classrooms, plots, or countries included. If the units are not individuals, then describe the size requirements for each unit. If you are using a clustered or multilevel design, describe how many units are you collecting at each level of the analysis. This might be the number of samples or a range, minimum, or maximum.

- Provide justifications for your sample size and number of trials
  - Estimate statistical power for the critical effect or test
    - NB: Power for the overall main effect is not the same for the interaction!
- Include a justified stopping rule or endpoint
  - Can be a date or deadline when the experiment needs to be completed by

# Best preregistration practices – Analysis plan

## Analysis Plan

### Statistical models \*

What statistical model will you use to test each hypothesis? Please include the type of model (e.g. ANOVA, RMANOVA, MANOVA, multiple regression, SEM, etc) and the specification of the model. This includes each variable that will be included, all interactions, subgroup analyses, pairwise or complex contrasts, and any follow-up tests from omnibus tests. If you plan on using any positive controls, negative controls, or manipulation checks you may mention that here. Provide enough detail so that another person could run the same analysis with the information provided.

Remember that in your final article any test not included here must be noted as exploratory and that you must report the results of all tests.

- Conduct analysis on **simulated or pilot data** prior to preregistration
  - Can inform your power analysis
  - Share and upload analysis code
- Include all specific analyses that are planned
  - New analyses after the data is collected is totally fine! Simply be transparent and state the analyses that were not preregistered in the manuscript

# NB: Preregistration $\neq$ 'good science'

- Preregistration is **not sufficient** to produce robust and reliable research
- Preregistration is **not necessary** to produce robust and reliable research
- Example:
  - One could preregister a simple  $t$ -test in one condition predicting an effect.
  - One could preregister a simple  $t$ -test in another condition predicting no effect.
  - One could then incorrectly interpret this as a significant moderation of the effect across conditions.



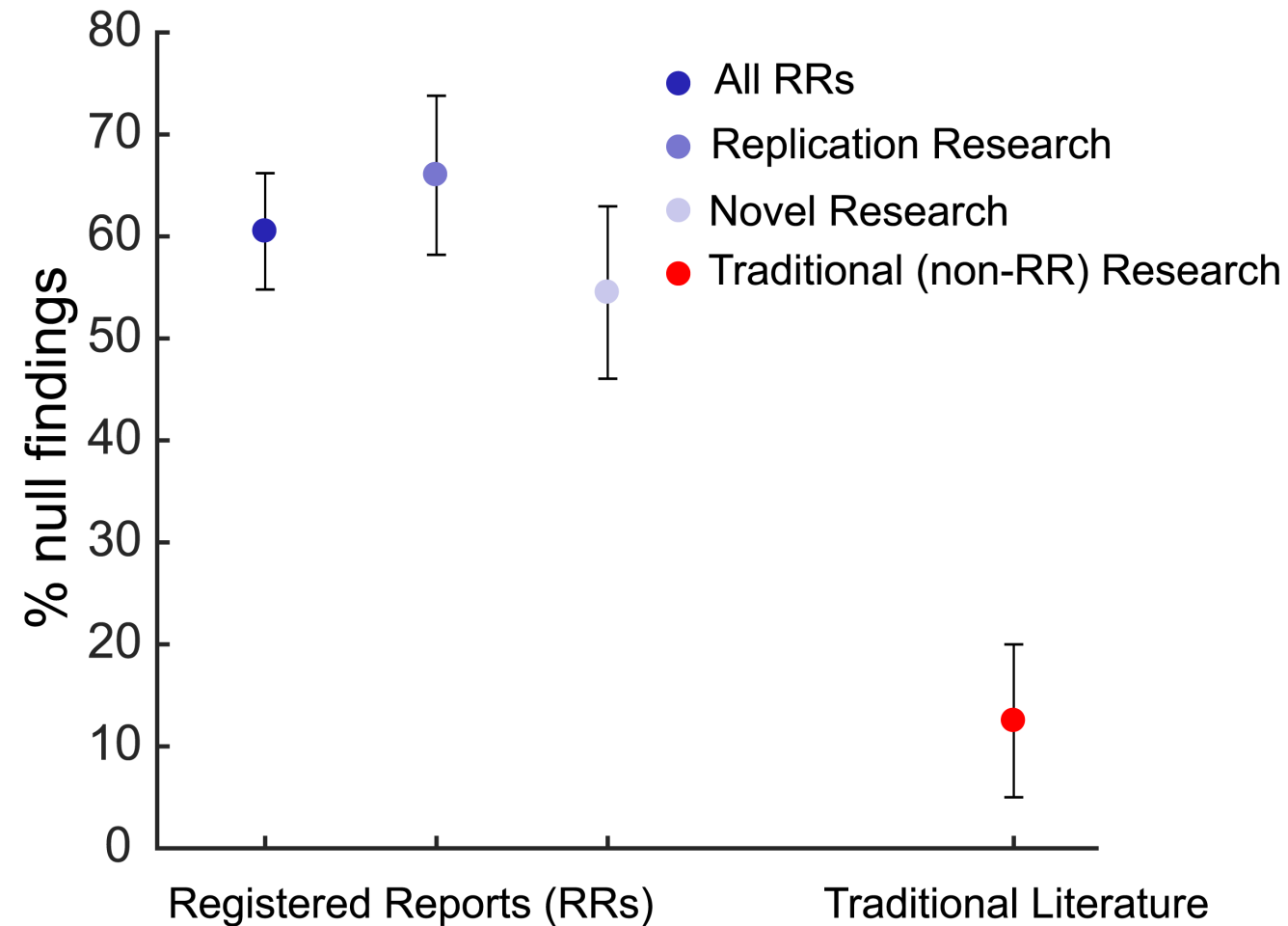
# Preregistration is not a panacea

- Not the most efficient method to **slow** researchers down and improve experimental design
- Not a clear method of **producing better theories** or experimental designs in of itself (Szollosi et al., 2019)
- Probably not a good hallmark of rigorous and reproducible research
  - But preliminary evidence that preregistration reduces the proportion of 'positive' results (~66% compared to 96% in standard papers) (Akker, 2021)

# Registered Reports (RRs)

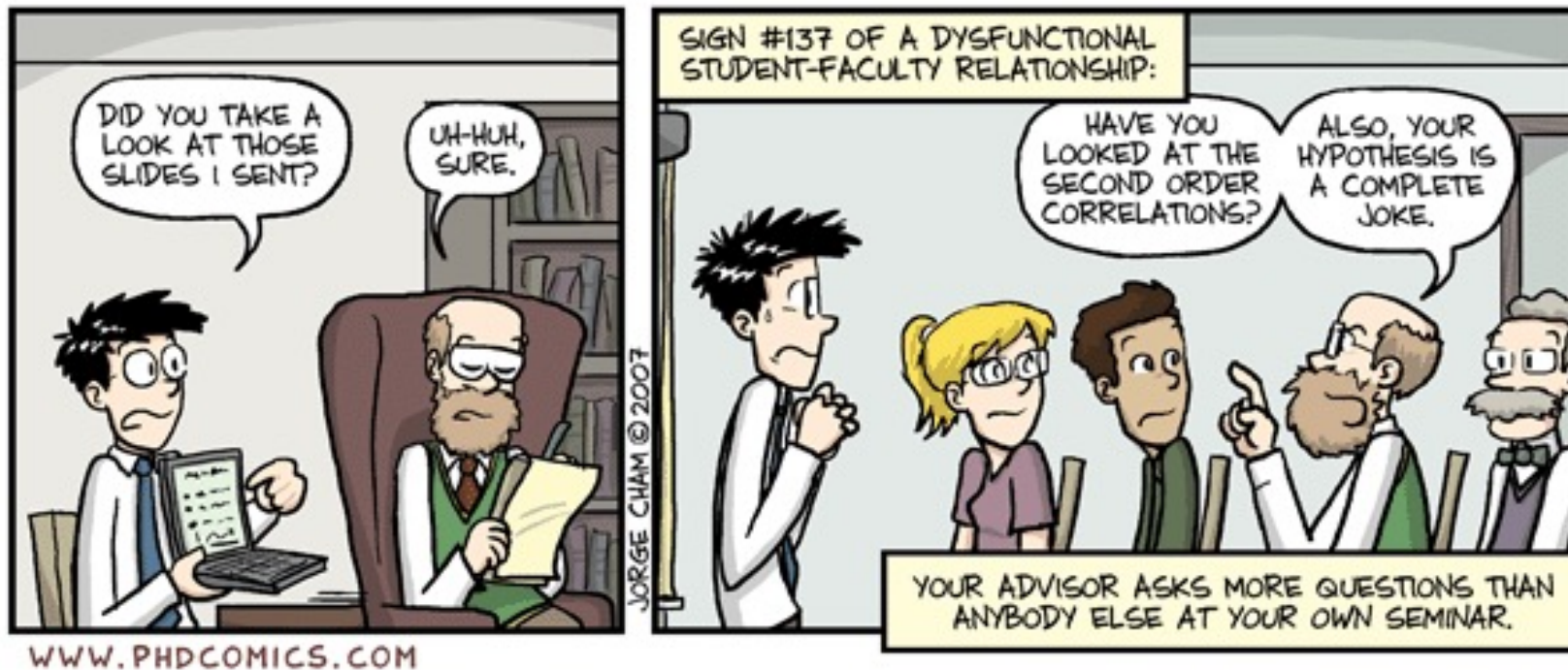
- Stage 1: A research plan (preregistration) is reviewed prior to data collection
  - Reduces research waste – addresses potential mistakes or unconsidered decisions
  - Addresses reviewer requests for additional experiments
- Stage 2: Peer review of the research manuscript (accepted publication-in-principle)
  - Addresses publication bias/the ‘file drawer problem’ – that significant results are more likely to be accepted for publication, and perceived as more impactful for higher-tier journals.

# Percentage of null findings



# Benefits of preregistration for ECRs

- A **good framework** for communicating and discussing experimental design with your supervisor and collaborators
  - A **record** of the experiment design and analysis decisions and the reasons for them
    - Answering a reviewer (or a forgetful PI) who may ask "Why did you do this?"



# Benefits of preregistration for ECRs

- Brings review and feedback to an **earlier stage** in the research process
  - Can initiate illuminating discussions (perhaps arguments!) about theory or experiment rationale
- Prevents research waste
  - Encourages a justified sample size calculation
  - Increases likelihood of publishing (especially with a negative result)
    - Can protect you from reviewer critiques based on results (known as CARKing)
  - Reduces chance of erroneous experiments

# Benefits of preregistration for ECRs

- Can accompany writing of experimental and analysis code
  - Encourages code review by collaborators to ensure reproducibility
- Is helpful with the writing process
  - Essentially the methods section of a paper already written!
  - A record of the rationale and theory for the experiment

# Potential **barriers** to preregistration

- Additional time cost from extra step in research workflow *but...*
  - Time saved in preventing research mistakes
  - Time saved in writing – the methods essentially already written!
  - Analysis code could already be written for when the data comes in!
- An additional venue for scrutiny of errors *but...*
  - This is caught prior to data being collected and responsibility is shared amongst all collaborators
  - And a culture of taking responsibility for errors should be applauded
- Being locked in to a research plan *but...*
  - Deviations of preregistration are allowed! As long as that is made clear in the manuscript



## ReproducibiliTea Reading List on Preregistration

Preregistration is one of the new reforms to scientific research from the Open Science movement in response to the reproducibility crisis. These ten papers were selected to provide an introduction to preregistration. They are separated by themes that your journal club may choose to explore in further detail in following meetings! We have also provided a summary, keywords and additional online resources to help inform your discussions.

# Further reading

- You can find a reading list with summaries and relevant videos and articles here:

<https://osf.io/9tf6e/>

Order	Block	Paper	Summary	Keywords	Resources
1	The issues at hand	Vazire, S., & Holcombe, A. O. (2020). Where are the self-correcting mechanisms in science?. <i>Review of General Psychology</i> , 10892680211033912. <a href="https://doi.org/10.1177/10892680211033912">https://doi.org/10.1177/10892680211033912</a>	<b>Self-correction in science.</b> This review of the current mechanisms in science, such as journal-based peer review and institutional committees, finds they have been inadequate for self-correction. The authors advocate for transparency, such as that via preregistration, to promote scientific credibility.	self-correction, transparency	Talk by Simine Vazire on "Where are the self-correcting mechanisms in science?" for the University of Sydney: <a href="https://www.youtube.com/watch?v=QdErf_OQqQU">https://www.youtube.com/watch?v=QdErf_OQqQU</a>
2		Fanelli, D. (2012). Negative results are disappearing from most disciplines and countries. <i>Scientometrics</i> , 90(3), 891-904. <a href="https://doi.org/10.1007/s11192-011-0494-7">https://doi.org/10.1007/s11192-011-0494-7</a>	<b>The loss of negative data.</b> Competitive pressures to publish frequently may have produced enduring changes in scientific content, one of which could be the loss of negative data. This paper shows the proportion of positive results has increased since 1990 towards 90%, more rapidly in the social sciences and psychology.	bibliometrics, publication bias, incentives	A talk by Ulrich Dirnagl on the scientific ritual of significance testing for eLife: <a href="https://youtu.be/TCH5_JKXNac">https://youtu.be/TCH5_JKXNac</a>
3	What is preregistration?	Nosek, B. A., Ebersole, C. R., DeHaven, A. C., & Mellor, D. T. (2018). The preregistration revolution. <i>Proceedings of the National Academy of Sciences</i> , 115(11), 2600-2606. <a href="https://doi.org/10.1073/pnas.1708274114">https://doi.org/10.1073/pnas.1708274114</a>	<b>Preventing biases in reasoning.</b> Preregistration distinguishes between predictions and postdictions (post-hoc explanations), which can be often confused due to biases in reasoning. The authors also alleviate numerous perceived challenges to doing preregistrations with clear examples.	prediction, inference, hypothesis testing	Webinar by Brian Nosek on the practice of preregistration and how it increases rigor of research: <a href="https://youtu.be/PboPpcg6ik4">https://youtu.be/PboPpcg6ik4</a>
4		P Simmons, J., D Nelson, L., & Simonsohn, U. (2021). Pre-registration: why and how. <i>Journal of Consumer Psychology</i> , 31(1), 151-162. <a href="https://doi.org/10.1002/jcpy.1207">https://doi.org/10.1002/jcpy.1207</a>	<b>Best practices with preregistration.</b> An overall guide on why to preregister that also addresses common concerns with preregistration, and the best practices to writing 'good' answers to preregistration questions with many examples.	how-to, barriers and challenges	A practical guide by Alex DeHaven and Sara Bowman from the Center of Open Science on preregistration with the Open Science Framework registry <a href="https://www.youtube.com/watch?v=8QK2-udwoK8">https://www.youtube.com/watch?v=8QK2-udwoK8</a>
5	Why do a preregistration?	Szollosi, A., Kellen, D., Navarro, D., Shiffrin, R., van Rooij, I., Van Zandt, T., & Donkin, C. (2019). Is preregistration worthwhile?. <a href="https://doi.org/10.1016/j.tics.2019.11.009">https://doi.org/10.1016/j.tics.2019.11.009</a>	<b>Preregistration does not lead to better theories.</b> A challenge to whether preregistration improves theory development or inferences. Preregistration will do little to improve theories if the mapping of statistical models to underlying theories is weak, and it is unclear why preregistration will aid the development of better theories	theory development, inference	A talk by Chris Donkin on whether "Is preregistration worthwhile?" for the University of Melbourne <a href="https://youtu.be/ThcGiZFg000">https://youtu.be/ThcGiZFg000</a>
6		Nosek, B. A., Beck, E. D., Campbell, L., Flake, J. K., Hardwicke, T. E., Mellor, D. T., ... & Vazire, S. (2019). Preregistration is hard, and worthwhile. <i>Trends in cognitive sciences</i> , 23(10), 815-818. <a href="https://doi.org/10.1016/j.tics.2019.07.009">https://doi.org/10.1016/j.tics.2019.07.009</a>	<b>The attitudes towards preregistration.</b> Preregistration is a skill that promotes intellectual humility and encourages the calibration of confidence in scientific claims. To maximize the credibility of findings, one should clarify confirmatory and exploratory findings, transparently report deviations from the preregistration and provide identification of error.	transparency, approach to preregistration	A RIOT Science Club talk by Agata Bochynska on the benefits, challenges and practical tips to preregistration: <a href="https://www.youtube.com/watch?v=SgF6iQhPURY&amp;ab_channel=RIOTScienceClub">https://www.youtube.com/watch?v=SgF6iQhPURY&amp;ab_channel=RIOTScienceClub</a>
7		Hardwicke, T. E., & Wagenmakers, E. J. (2021). Preregistration: A pragmatic tool to reduce bias and calibrate confidence in scientific research. <a href="https://doi.org/10.31222/osf.io/d7bcu">https://doi.org/10.31222/osf.io/d7bcu</a>	<b>The evaluation of preregistrations.</b> A thorough article that shows how preregistration addresses the issue of analytical flexibility and provides recommendations on how preregistrations should be evaluated and interpreted.	experimenter bias, metaresearch, transparency	An editorial by Eric-Jan Wagenmakers and Gilles Dutilh in the APS observer on Seven Selfish Reasons for Preregistration: <a href="https://www.psychologicalscience.org/observer/seven-selfish-reasons-for-preregistration">https://www.psychologicalscience.org/observer/seven-selfish-reasons-for-preregistration</a>
8	Registered Reports	Chambers, C. D., & Tzavella, L. (2021). The past, present and future of Registered Reports. <i>Nature human behaviour</i> , 1-14. <a href="https://doi.org/10.1038/s41562-021-01193-7">https://doi.org/10.1038/s41562-021-01193-7</a>	<b>The Registered Report.</b> A detailed overview of the Registered Report, a new publication format where preregistrations are peer reviewed and publication is accepted-in-principle before data is collected. This new format incentivizes research rigor and transparency but has some current limitations in its implementation.	registered reports, publication bias,	A RIOT Science Club talk by Charlotte Pennington on "A new way of publishing: Registered Reports 2.0": <a href="https://youtu.be/6tTukfUutzY">https://youtu.be/6tTukfUutzY</a>
9		Scheel, A. M., Schijen, M. R., & Lakens, D. (2021). An excess of positive results: Comparing the standard Psychology literature with Registered Reports. <i>Advances in Methods and Practices in Psychological Science</i> , 4(2), 25152459211007467. <a href="https://doi.org/10.1177/25152459211007467">https://doi.org/10.1177/25152459211007467</a>	<b>Registered Reports reduces inflation of positive results.</b> The majority of psychology articles in the standard literature (92%) report positive evidence for the first tested hypothesis, but this is an unrealistic representation of the research that is being conducted. Only 43.6% of Registered Reports find support for the first hypothesis, which seems to indicate that the format is addressing publication bias.	registered reports, publication bias, hypothesis testing	A RIOT Science Club talk by Anne Scheel on "The importance of Registered Reports": <a href="https://youtu.be/d_gT2GLH1jM">https://youtu.be/d_gT2GLH1jM</a>
10		Kiyonaga, A., & Scimeca, J. M. (2019). Practical considerations for navigating registered reports. <i>Trends in neurosciences</i> , 42(9), 568-572. <a href="https://doi.org/10.1016/j.tins.2019.07.003">https://doi.org/10.1016/j.tins.2019.07.003</a>	<b>A guide to Registered Reports.</b> A set of practical recommendations to navigating the Registered Report process: delineating confirmatory hypotheses, determining sufficient statistical power and ensuring reproducibility and replicability.	registered reports, how-to	An article by Christopher Allen and David Mehler on the challenges and benefits for early-career researchers to engage in Open Science: <a href="https://doi.org/10.1371/journal.pbio.3000246">https://doi.org/10.1371/journal.pbio.3000246</a>



# Summary

- Preregistration can be a useful tool for improving the quality of your research
  - Inform the preregistration with formal theories, pilot studies, power analysis and reproducible code
  - A good framework to discuss and agree upon research decisions between collaborators
  - Receive external feedback of your experimental design to prevent research waste
  - Increase credibility of research during peer review

These slides will be available at <https://williamngiam.github.io/>

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