

Registered Reports as a vaccine against research bias

Past, present and future

Chris Chambers

Cardiff University Brain Research Imaging Centre (CUBRIC)

School of Psychology, Cardiff University

Email: chambersc1@cardiff.ac.uk

Twitter: [@chrisdc77](https://twitter.com/chrisdc77)

About me

- Professor of cognitive neuroscience at Cardiff University, UK
- Co-founder of Registered Reports in 2012/13
- Section editor for Registered Reports at *Cortex*, *European Journal of Neuroscience*, *Royal Society Open Science*, *BMJ Open Science*, *Collabra: Psychology*; Advisory Board for *Nature Human Behaviour*
- Edited 78 Registered Report submissions
- Chair of the Registered Reports Committee supported by the Center for Open Science: <https://cos.io/rr/>

Science is changing

...and those changes are revealing a fundamental conflict

Which part of a research study should be beyond your control?

The results

Which part of a research study is most important for publishing in 'top journals' & advancing your career?

The results

Results-driven culture distorts incentives

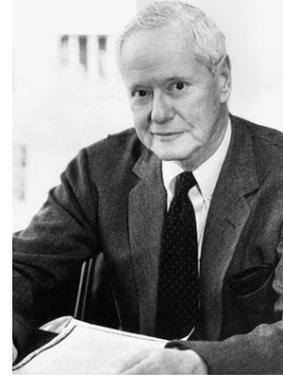
**What's best for
science**

High quality research,
published regardless
of outcome

**What's best for
scientists**

Producing a lot of
“good results”

Mertonian norms and counternorms



Norms

Communality

Open Sharing

Universalism

Evaluate research on own merit

Disinterestedness

Motivated by knowledge and discovery

Organised skepticism

Consider all new evidence, even against one's prior work

Quality

Publish the most methodological rigorous work that addresses important questions for theory or applications

Counternorms

Secrecy

Closed

Particularism

Evaluate research by reputation

Self-interestedness

Treat science as a competition

Organised dogmatism

Invest career in promoting one's own theories, findings

Quantity

Publish as many papers as possible

'Publish or Perish'

How Mertonian counternorms affect reproducibility

Counternorm

Secrecy over Communal

Self-interestedness over disinterestedness

Organised dogmatism over skepticism

Quantity over quality

Bad Practice

Lack of sharing of data and materials
– no time, too hard, no incentive, exposes author to critical scrutiny

Significance chasing – “*p-hacking*”,
selective reporting

Changing the hypothesis to fit the results – *hypothesizing after results are known (HARK)*

Publication bias – *suppression of negative findings by journals or researchers in order to preserve ‘brand’ and status quo*

Lack of replication – *seen as boring, lacking in intellectual prowess, risky*

Low statistical power – *better to churn out large number of undersampled studies*



Reproducibility and reliability of biomedical research: improving research practice

Symposium report, October 2015



<https://acmedsci.ac.uk/policy/policy-projects/reproducibility-and-reliability-of-biomedical-research>

How did we get to this point?

By placing too much importance on the **results** of research and not enough on the **processes** that produce them

Results make science exciting but judging the quality of science (and scientists) according to the results is “soft” science

Fixing this requires a change in mindset

Philosophy:

What gives hypothesis-testing its scientific value is

- the QUESTION it asks
- the QUALITY of the method it uses
- never the RESULT it produces

If we accept this philosophy then editorial decisions at journals should be *blind* to results



The first principle is that you must not fool yourself – and you are the easiest person to fool.

- Richard Feynman

This is not a new idea

Robert Rosenthal (1966). *Experimenter effects in behavioral research*. New York.

“What we need is a system for evaluating research based only on the procedures employed. If the procedures are judged appropriate, sensible, and sufficiently rigorous to permit conclusions from the results, the research cannot then be judged inconclusive on the basis of the results and rejected by the referees or editors. Whether the procedures were adequate would be judged independently of the outcome.”

A Proposal for a New Editorial Policy in the Social Sciences¹

G. WILLIAM WALSTER and T. ANNE CLEARY
The University of Wisconsin, Madison

“... there's this desert prison, see, with an old prisoner, resigned to his life, and a young one just arrived. The young one talks

A virtual prerequisite for the publication of research in the social sciences is the attainment of statistical

The American Statistician, 1970

Towards a reduction in publication bias

ROBERT G NEWCOMBE

British Medical Journal, 1987

This is not a new idea

Neuroskeptic

...has moved to <http://blogs.discovermagazine.com/neuroskeptic/>

Tuesday, 24 May 2011

How To Fix Science



Over at *Bad Science*, Ben Goldacre [discusses](#) a big problem with modern science



Neuroskeptic

« Psychology vs Astrology

How A Stroke Changed Katherine Sherwood's Art »

Fixing Science – Systems and Politics

By Neuroskeptic | April 14, 2012 8:49 am



Modern revival of preregistration in basic science in 2011/2012

How it finally happened

NeuroChambers

Tuesday, 25 September 2012

Why I will no longer review or publish for the journal Neuropsychologia

A quick post.

I recently had an interesting experience with the journal [Neuropsychologia](#), which led to a personal decision that some of my colleagues will probably think is a bit rash (To which my answer is: hey, it's me, what do you expect?!)

How it finally happened

NeuroChambers

Monday, 8 October 2012

Changing the culture of scientific publishing from within

Stage 1: Registration Review

- Background and rationale
- Hypotheses
- Methods
- Analysis pipeline
- Power analysis
- Pilot data only

Accept, Revise or Reject



In principle acceptance (IPA) awarded

- Author conducts study, adhering precisely to approved methods



Stage 2: Full Manuscript Review

- Upload raw data and lab log to Figshare
- Approved analyses reported
- Manuscript assessed according to whether the conclusions are supported by the results
- Manuscript **not** assessed

What happened next

60 comments:



[Neuroskeptic](#) 8 October 2012 at 12:37

Great work! I'm very impressed by this and think it would be a big step in the right direction.

Some random thoughts:

1) Authors should be given the *option* of publishing their registered Protocol after the Registration Review. Either as an online mini-article or they could publish it themselves.

This would help to guard against idea stealing, because it would clearly establish precedent - anyone could steal the idea, but it would be obvious that they'd done so, which would make it much less desirable.

Also, this would help to guard against the possibility of misbehaviour by the second-stage reviewers. If these reviewers decided that they didn't like the data, and tried to block the paper for that reason, the authors would then be able to appeal to the court of public opinion, by pointing to their published (and therefore certified a priori) protocol and saying "Here's what we said we'd do and here's our data - form your own opinions". This is unlikely to happen often, but it would be a crucial check on the power of reviewers.

2) I'm not entirely happy with allowing people to change their Introduction, even for bona fide reasons like new literature emerging. I think it would be a slippery slope. But I can see that without that, you might end up with some really irrelevant Introductions. So why not just allow authors to change the Introduction at will, **but**, also publish the originally approved one as a Supplement? That would allow readers to judge whether the Intro had been altered for 'naughty' purposes or not.

3) Scientists will rightly object to any proposal that would cause an increase in bureaucracy. On its face, this proposal would "double the amount of peer review" which would be a hassle. I wonder if it could be coupled to some system for integrating peer review with the process of applying for a grant e.g. the journal could agree with Grant Body X that any protocol awarded money by X would be treated ipso facto as "reviewed" and would be fast-tracked through the Registration Review (but not the final review) with only minimal oversight?

[Reply](#) [Delete](#)

Replies



[Chris Chambers](#) 8 October 2012 at 12:57

Thanks, I'm glad you like it!

1) Good idea. Of course, one aim of this model is to prevent reviewers from rejecting manuscripts based on data, but its true that reviewers could do so under some other guise, so offering the option for separate publication of the protocol would provide additional insurance to the authors.

2) I like this too. In fact, to make life easy, how about we just publish the original approved paper completed separately as a supplement. Then readers can compare every aspect between IPA and final version, including the Introduction. I do think some leeway is needed in terms of updating the literature or it will detract from readability, which will in turn reduce impact.

3) This is a concern - and it does seem unavoidable that this model will increase load on reviewers (on the other hand, perhaps it would also lead, in the long run, to fewer publications per scientist and less salami slicing). The idea of integrating with funding agencies is appealing in principle but I suspect would be very difficult in practice: grant applications often don't allow space for the kind of methodological detail required for IPA under this proposed model.

[Delete](#)

Registered Reports

CORTEX 49 (2013) 609–610



Available online at www.sciencedirect.com

SciVerse ScienceDirect

Journal homepage: www.elsevier.com/locate/cortex



Editorial

Registered Reports: A new publishing initiative at Cortex

Christopher D. Chambers

Cardiff University Brain Research Imaging Centre (CUBRIC), School of Psychology, Cardiff University, United Kingdom

Four central aspects of the Registered Reports model:

- Researchers decide hypotheses, experimental procedures, and main analyses *before* data collection
- Part of the peer review process takes place before experiments are conducted
- Passing this stage of review virtually guarantees publication
- Original studies and high-value replications are welcome

How it works

Authors submit **STAGE 1** manuscript with Introduction, Proposed Methods & Analyses, and Pilot Data (if applicable)



Stage 1 peer review

Are the hypotheses well founded?

Are the methods and proposed analyses feasible and sufficiently detailed?

Is the study well powered? ($\geq 90\%$)

Have the authors included sufficient positive controls to confirm that the study will provide a fair test?



If reviews are positive then journal offers **in-principle acceptance (IPA)**, regardless of study outcome (*protocol not published yet*)

How it works

Authors do the research



- Authors resubmit completed **STAGE 2** manuscript:
- **Introduction** and **Methods** (virtually unchanged)
 - **Results (new)**: Registered confirmatory analyses + unregistered exploratory analyses
 - **Discussion (new)**
 - **Data deposited in a public archive**

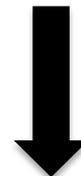


Stage 2 peer review

Did the authors follow the approved protocol?

Did positive controls succeed?

Are the conclusions justified by the data?

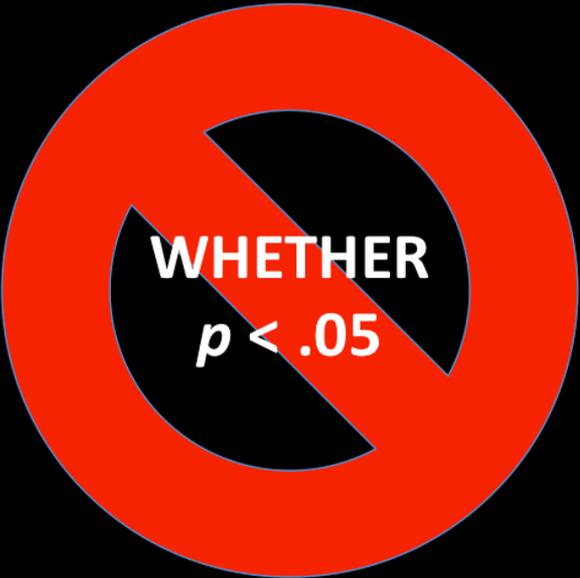


Manuscript published!

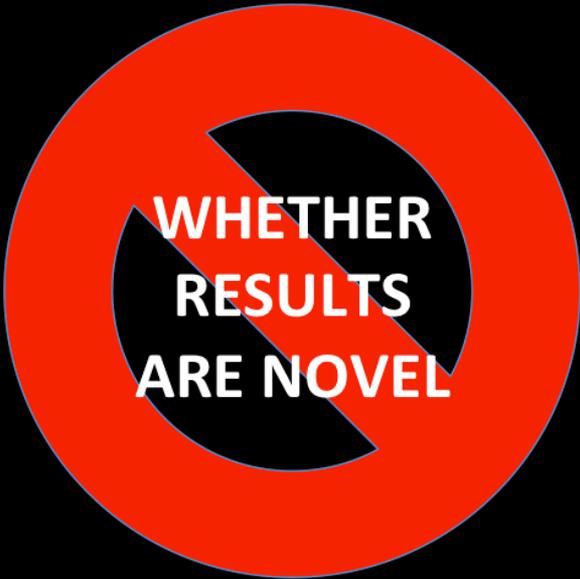
None of these things matter

A red circle with a diagonal slash through it, indicating prohibition or negation.

**WHETHER
HYPOTHESIS
SUPPORTED**

A red circle with a diagonal slash through it, indicating prohibition or negation.

**WHETHER
 $p < .05$**

A red circle with a diagonal slash through it, indicating prohibition or negation.

**WHETHER
RESULTS
ARE NOVEL**

A red circle with a diagonal slash through it, indicating prohibition or negation.

**WHETHER
RESULTS
HAVE
"IMPACT"**

Published examples at *Cortex*

Registered report

The effects of AMPA blockade on the spectral profile of human early visual cortex recordings studied with non-invasive MEG

Suresh D. Muthukumaraswamy ^{a,b,*}, Bethany Routley ^c, Wouter Droog ^d,
Krish D. Singh ^c and Khalid Hamandi ^{c,e}

Registered report

The functional subdivision of the visual brain: Is there a real illusion effect on action? A multi-lab replication study

Karl K. Kopiske ^{a,f,*}, Nicola Bruno ^b, Constanze Hesse ^c,
Thomas Schenk ^d and Volker H. Franz ^{a,e}

Registered report

Mu suppression – A good measure of the human mirror neuron system?

Hannah M. Hobson ^{*} and Dorothy V.M. Bishop

– Reproducible –

- detailed, repeatable methods
- high statistical power (2-3x > sample sizes)

– Transparent –

- accompanied by open data & materials
- outcomes of confirmatory and exploratory analyses distinguished

– Credible –

- no publication bias
- no hindsight bias
- no selective reporting

<http://www.journals.elsevier.com/cortex/virtual-special-issues/virtual-special-issue-registered-reports>

See also:

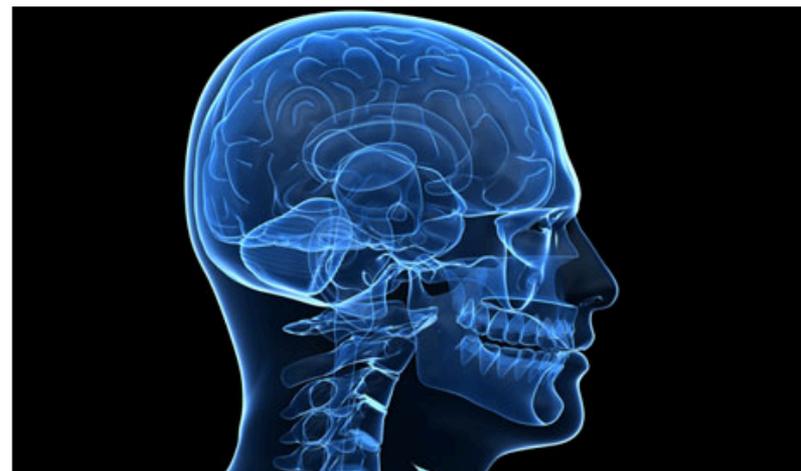
Social Psychology special issue: <http://econtent.hogrefe.com/toc/zsp/45/3>

Trust in science would be improved by study pre-registration

Open letter: We must encourage scientific journals to accept studies before the results are in

Chris Chambers, Marcus Munafo and more than 80 signatories
theguardian.com, Wednesday 5 June 2013 12.45 BST

Jump to comments (43)



The quest: a better understanding of nature. Photograph: Sebastian Kaulitzki/Alamy

In an ideal world, scientific discoveries would be independent of what scientists *wanted* to discover. A good researcher would begin with an idea, devise a method to test the idea, run the study as planned, and then decide based on the evidence whether the idea had been supported. Following this approach would lead us step-by-step toward a better understanding of nature.

Unfortunately, the life sciences are becoming increasingly estranged from this way of thinking. Early in their training, students learn that the quest for truth needs to be balanced against the more immediate pressure to



Pre-registration would put science in chains

The pre-registration of study designs must be resisted, says Sophie Scott

July 25, 2013

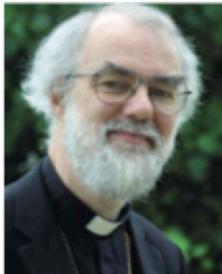


Science is not well served by people deciding that their methodology is the only legitimate one

“Looking at the Chambers letter, I was struck by the lack of scientific weight of the signatories.”

“The leaders of this ‘head prefect’ movement bemoan the pressures and careerism in science, while making very good career progress based on telling others how science should be carried out.”

the ‘emergence of high priests’



‘fascism’



a ‘head prefect movement’



designed to stop fraud



a ‘panacea’ for the life sciences



a ‘witch hunt’



‘compulsory’



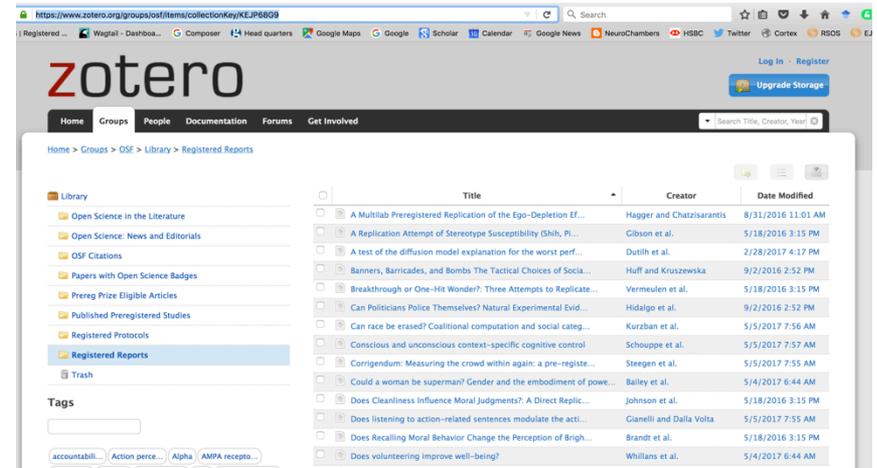
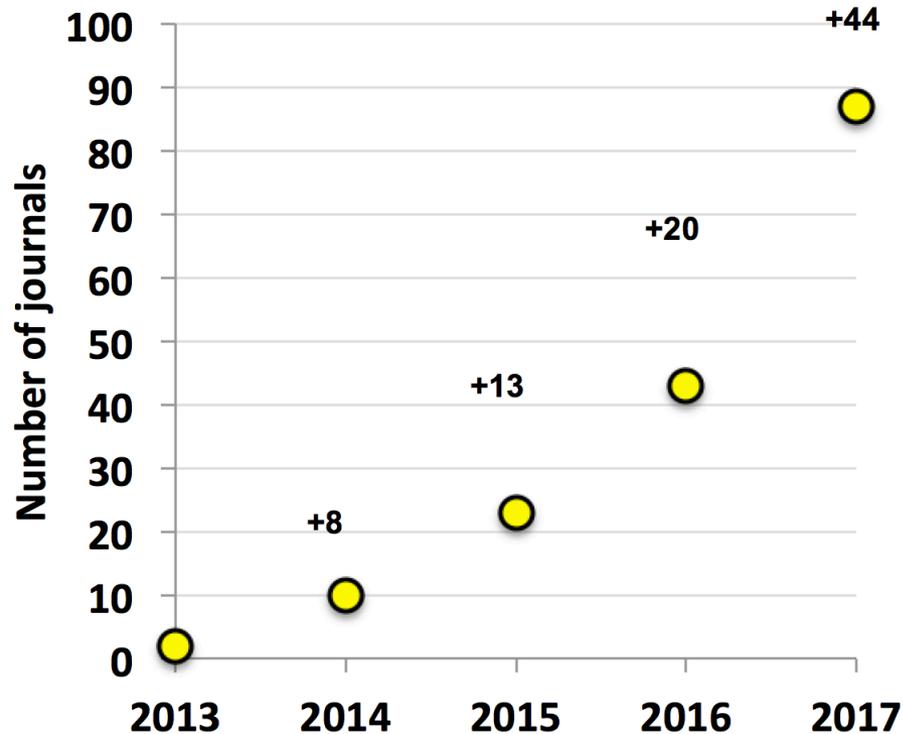
‘universal’



Four and a half years later...

Registered Reports are here to stay

- **88** journals have adopted them so far
- Fields covered
 - **Life/medical sciences:** neuroscience, nutrition, psychology, psychiatry, biology, cancer research, ecology, clinical & preclinical medicine
 - **Social sciences:** political science, financial and accounting research
 - **Physical sciences:** chemistry, physics, computer science etc.



<https://www.zotero.org/groups/osf/items/collectionKey/KEJP68G9>

80 fully completed RRs have been published so far

Registered Reports at *Royal Society Open Science*

Now available in all STEM areas, from physics to psychology

ROYAL SOCIETY OPEN SCIENCE

search 

[Advanced](#)

[Home](#) [Content](#) [Information for](#) [About us](#) [Sign up](#) [Submit](#)

Registered Reports

1. [Summary and benefits](#)
2. [Stage one](#)
3. [Stage two](#)
4. [Reviewer guidelines](#)
5. [More information](#)

Summary and Benefits

A Registered Report (RR) is a form of journal article in which methods and proposed analyses are pre-registered and peer-reviewed prior to research being conducted (stage 1). High quality protocols are then provisionally accepted for publication before data collection commences. The format is open to attempts of replication as well as novel studies. Once the study is completed, the author will finish the article

May 2016

Alert me to new content

A fast, open journal publishing high quality research across all of science, engineering and mathematics

[Find out more](#)

BROWSE BY SUBJECT

acoustics	algebra
algorithmic information theory	analysis
analytical chemistry	applied mathematics
artificial intelligence	astrobiology

<http://rsos.royalsocietypublishing.org/content/registered-reports>

Registered Reports at *Nature Human Behaviour*

nature
human behaviour

Search E-alert Submit Login

May issue
Our May issue is now available to read.

Announcement
[Join our editorial team](#)
We are looking for an Associate or Senior Editor with a background in psychology and cognitive neuroscience to join... [show more](#)

Announcement
[Registered reports](#)
Have your article accepted in principle before data collection has started by submitting a registered report. With... [show more](#)

Announcement
[Preregistration Challenge](#)
Nature Human Behaviour is participating in the Center for Open Science \$1,000,000 Preregistration challenge: 1,000... [show more](#)

Disciplines covered in the journal include:

Anthropology	Evolution
Artificial Intelligence	Genetics
Business Studies	Geography
Cognitive Science	Linguistics
Communication	Management
Criminology	Neurology
Cultural Studies	Neuroscience
Ecology	Political Science
Economics	Psychiatry
Education	Psychology
Epidemiology	Public Policy
Ethology	Sociology

Registered Reports at *BMC Medicine*

The screenshot shows the BMC Medicine website header with the BioMed Central logo and navigation links: HOME, ABOUT, ARTICLES, and SUBMISSION GUIDELINES. Below the navigation is a sidebar menu with the following items: Aims and scope, Fees and funding, Language editing services, Copyright, Preparing your manuscript (with sub-items: Research articles, Software articles), and Registered Reports. The main content area is titled "Registered Reports" and includes an "Overview" section. The overview text states: "Registered Reports are intended to strengthen the methodology and the transparency of research papers seeking to answer defined questions. Submission is a two-stage process. In the first, the authors submit a proposed study protocol. If the study protocol passes initial review, *BMC Medicine* will post it in the Registered Reports section of its website and make a commitment to publish the results,"

- **The first Registered Reports model for clinical trials**
 - Prevents hidden outcome switching (AKA outcome reporting bias; see <http://www.compare-trials.org/>)
 - Eliminates publication bias and ensures all trials are published regardless of outcome
 - Raises the issue of whether all clinical trials should be published as Registered Reports

Curated list

<https://cos.io/rr/>

Registered Reports: Peer review before results are known to align scientific values and practices.

Registered Reports

Participating Journals

Details and Workflow

Resources for Editors

For Funders

FAQ

Currently, **88** journals use the Registered Reports publishing format either as a **regular submission option** or as part of a single **special issue**. Other journals offer **some features** of the format. This list will be updated regularly as new journals join the initiative. See also our [table](#) that compares the specific features of Registered Reports at different outlets.

For an article type to qualify as a registered report, the journal policy must include at least these features:

- Peer review occurs prior to observing the outcomes of the research.
- Manuscripts that survive pre-study peer review receive an in-principle acceptance that will not be revoked based on the outcomes, but only on failings of quality assurance, following through on the registered protocol, or unresolvable problems in reporting clarity or style.

Journals that have adopted Registered Reports

Special Issues

Some Features

Journal	Notes
Advances in Methodologies and Practices in Psychological Science	Guidelines for Registered Reports Guidelines for Registered Replication Reports
AIMS Neuroscience	Editorial Guidelines

Policy features tables

https://docs.google.com/spreadsheets/d/1D4_k-8C_UENTRtbPzXfhjEyu3BfLxdOsn9j-otrO870/edit#gid=0

Comparison of Registered Reports ☆ 🗑️

File Edit View Insert Format Data Tools Add-ons Help Last edit was on 12 December 2017

chambersc1@cardiff.ac.uk

Comments Share

100% \$ % .0 .00 123 Arial 10 B I S A -

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1		Return to the Registered Reports page at the COS														
2	Journal	1. Includes pre-study peer review	2. Offers provisional pre-study acceptance	3. Permanence of adoption	4. Offered for novel studies	5. Offered for replication studies	6. Offered for meta-analysis	7. Offered for analyses of existing data sets	8. Publishes Registered Reports only	9. Allows reporting of unregistered analyses	10. Includes post-study peer review	11. Allows inclusion of unregistered pilot studies	12. Requires public data deposition	13. Specifies structured criteria for editorial decisions	14. Requires submitted protocols to have prior ethical approval	15. Specifies minimum statistical power requirements
3	JOURNALS OFFERING REGISTERED REPORTS															
4	Advances in Methodologies and Practices in Psychological Science	✓	✓	Indefinite	✓	✓	✓	✓		✓	✓	✓		✓		
5	AERA Open	✓	✓	Special issue	✓	✓	✓	✓		✓	✓	✓				
6	AIMS Neuroscience	✓	✓	Indefinite	✓	✓				✓	✓	✓	✓	✓	✓	✓
7	American Journal of Political Science	✓	✓	Special issue: 2016 ANES Preacceptance Initiative	✓			✓		✓	✓					
8	American Political Science Review	✓	✓	Special issue: 2016 ANES Preacceptance Initiative	✓			✓		✓	✓					
9	American Politics Research	✓	✓	Special issue: 2016 ANES Preacceptance Initiative	✓			✓		✓	✓					
10	Animal Behavior and Cognition	✓	✓	Indefinite	✓	✓	✓	✓		✓	(discretionary)			✓		
11	Attention, Perception & Psychophysics	✓	✓	Indefinite	✓	✓				✓	✓	✓	✓	✓	✓	✓
12	Behavioral Neuroscience	✓	✓	Indefinite	✓	✓				✓	✓	✓	✓	✓	✓	✓
13	BMC Biology	✓	✓	Indefinite	✓	✓				✓	✓	✓	✓	✓	✓	✓
14	BMC Ecology	✓	✓	Indefinite	✓	✓				✓	✓	✓	✓	✓	✓	✓
15	BMC Medicine	✓	✓	Indefinite	✓	✓	✓	✓		✓	✓	✓		✓	✓*but negotiable for trials	✓
16	BMJ Open Science	✓	✓	Indefinite	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓
17	Campbell Systematic Reviews	✓	✓	Indefinite			✓	✓	✓		✓	✓		✓		
18	Canadian Journal of School Psychology	✓	✓	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA
19	Cochrane Reviews	✓	✓	Indefinite			✓	✓	✓		✓	✓		✓		

Going further...

Can we integrate grant funding and Registered Reports?

- **Registered Reports funding model**
- Authors submit their research proposal *before* they have funding.
- Following review by the both the funder and the journal, the strongest proposals are offered financial support by the funder AND in-principle acceptance for publication by the journal. **Grant funded and article(s) accepted on same day!**



Registered Report: Journal/Funder Partnerships

Journals/publishers

Nicotine and Tobacco Research

PLOS Biology

PLOS ONE

Royal Society Open Science

BMC, including BMC Medicine

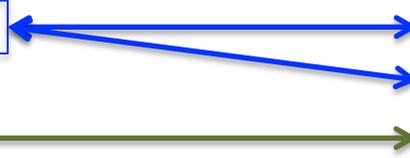
Funders

Cancer Research UK

Pfizer

Children's Tumor Foundation

CHDI



NICOTINE & TOBACCO RESEARCH



Issues More Content ▾ Publish ▾ Purchase Alerts About ▾

All Nicotine & Tobac ▾

Advanced Search



Volume 19, Issue 7
1 July 2017

Article Contents

References

Improving the Efficiency of Grant and Journal Peer Review: Registered Reports Funding ^{FREE}

Marcus R. Munafò, PhD

Nicotine Tob Res (2017) 19 (7): 773. DOI: <https://doi.org/10.1093/ntr/ntx081>

Published: 06 April 2017

PDF Cite Permissions Share ▾

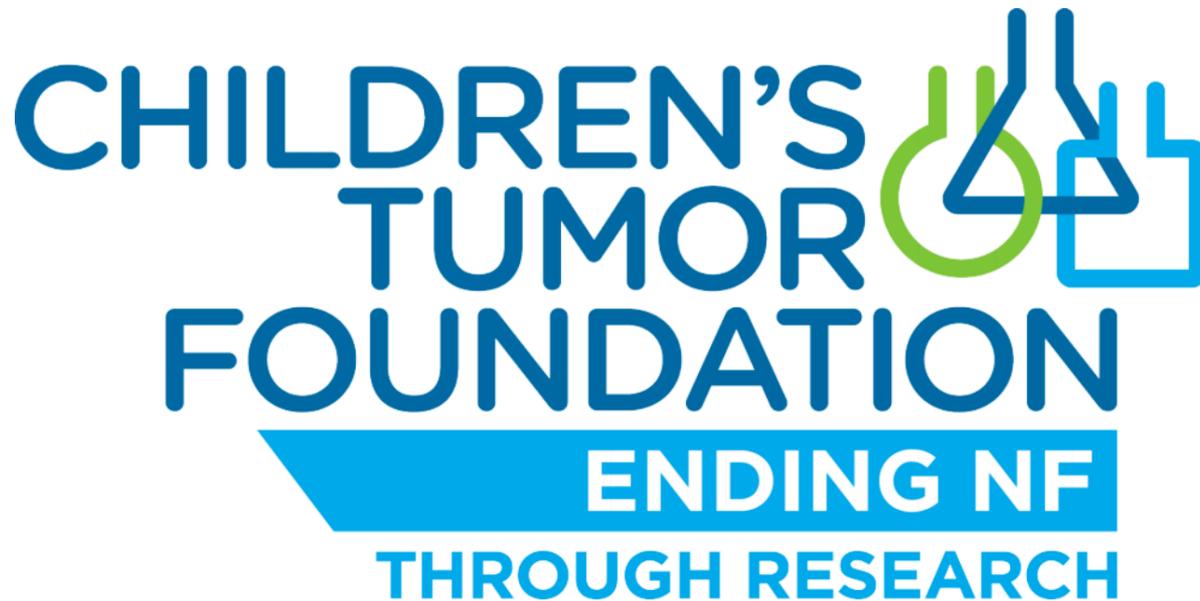
Peer review—the process whereby scientific research is evaluated by independent experts within the field—remains a cornerstone of scientific research, and acts as a critical gatekeeper in relation to both grant funding



<https://doi.org/10.1093/ntr/ntx081>

Registered Report: Journal/Funder Partnerships

[← Previous](#)

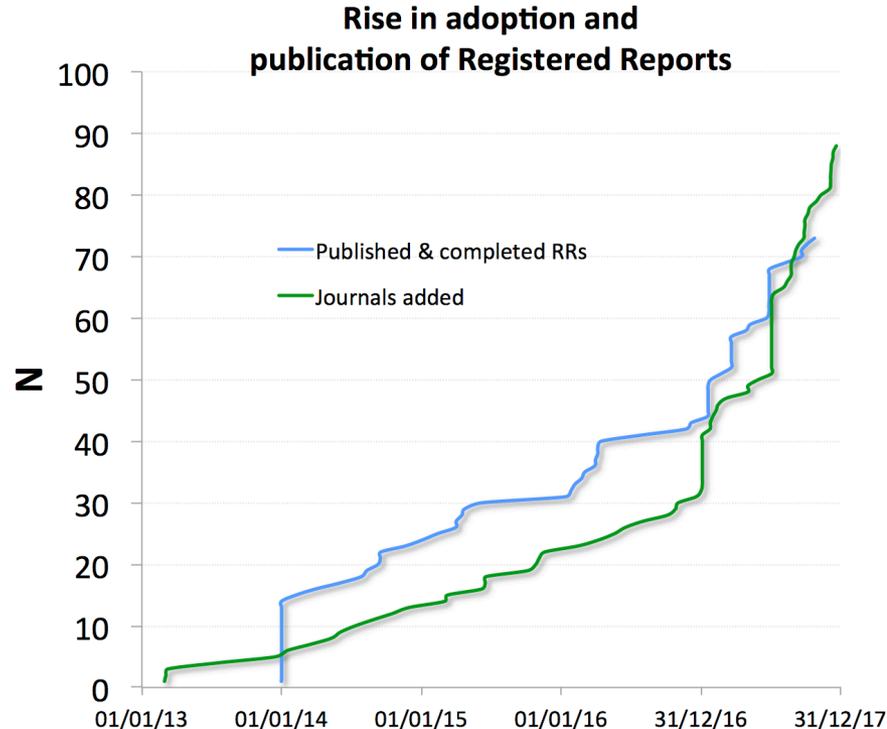


PLOS ONE partners with the Children's Tumor Foundation to trial Registered Reports

<http://blogs.plos.org/everyone/2017/09/26/registered-reports-with-ctf/>

Our goals for the future

- Registered Reports offered as an article type at all reputable empirical journals



- Registered Report grants offered by all major funding agencies
- All registered clinical trials should be published as Registered Reports
- Continual innovation and refinement of the format, and assessment of impact

Ten ways to avoid having your Registered Report rejected

1. Make sure the cover letter says what it needs to about ethics, funding, Withdrawn Registration policy, public preregistration etc.
2. Build sufficient methodological detail into the protocol to enable replication and to convince reviewers that you have closed off researcher degrees of freedom.
3. Ensure a tight correspondence between theory, scientific hypotheses, power (where applicable) and the pre-registered statistical tests.
4. Make sure the power analysis (or alternative sampling plan) reaches the minimum threshold required by journal policy (e.g. 90% power, $BF > 6$).
5. When conducting power analysis, avoid trap of proposing an over-optimistic or insufficiently justified estimate of the effect size.

Ten ways to avoid having your Registered Report rejected

- 6.** Don't rely on conventional null hypothesis significance testing if you want to be able to conclude *evidence of absence* from negative results (instead use equivalence testing or Bayesian methods).
- 7.** Remove all exploratory analysis sections from Stage 1. Include at Stage 2 only.
- 8.** Be sure to clearly distinguish work that has already been done (e.g. pilot experiments) from work yet to be done.
- 9.** Include pre-specified positive controls or other data quality checks, or justify their absence.
- 10.** When reporting positive controls that rely on inferential testing, be sure to include a sampling plan or power analysis.

Information Hub at the Center for Open Science

Registered Reports: Peer review before results are known to align scientific values and practices.

Registered Reports

Participating Journals

Details and Workflow

Resources for Editors

For Funders

FAQ

Registered Reports emphasize the importance of the research question and the quality of methodology by conducting peer review prior to data collection. High quality protocols are then provisionally accepted for publication if the authors follow through with the registered methodology.

This format is designed to reward best practices in adhering to the hypothetico-deductive model of the scientific method. It eliminates a variety of questionable research practices, including low statistical power, selective reporting of results, and publication bias, while allowing complete flexibility to report serendipitous findings.



<https://cos.io/rr/>

- Detailed FAQs
- Table comparing journal features

These slides are available here: <https://osf.io/d4fh5/>

For more info, email me (chambersc1@cardiff.ac.uk) or David Mellor at the COS (david@cos.io)

Exploratory Reports at Cortex

Open-ended, Open Science



De-emphasis on *a priori* hypotheses and p values

Greater emphasis on parameter estimation and hypothesis generation

In this special guest post, [Rob McIntosh](#), associate editor at Cortex and long-time member of the Registered Reports editorial team, foreshadows a new article type that will celebrate scientific exploration in its native form.

<http://neurochambers.blogspot.de/2017/07/open-ended-open-science.html>

<https://www.sciencedirect.com/science/article/pii/S0010945217302393>