Open Science/Research

Lecture 6

TU Wien, 193.067 Free and Open Technologies (WS 2019/2020)
Christoph Derndorfer and Lukas F. Lang

Lecture outline

1. ~~October 8, 2019: FLOSS (Free/Libre and Open Source Software)~~
2. ~~October 15, 2019: Open Hardware~~
3. ~~October 22, 2019: Open Data~~
4. ~~October 29, 2019: Open Content/Open Educational Resources~~
5. ~~November 5, 2019: Open Access~~
6. **November 12, 2019: Open Science/Research**
7. November 19, 2019: Open Spaces/Open Practices at Metalab Vienna
   - Introduction/guided tour by Petar Kosic and Clemens Hopfer
   - Location: Metalab Vienna, **Rathausstraße 6, 1010 Vienna**
8. November 26, 2019: Guest Lecture: Stefanie Wuschitz (Mz* Baltazar's Lab)

Open access: recap

Open access is about **peer-reviewed** articles

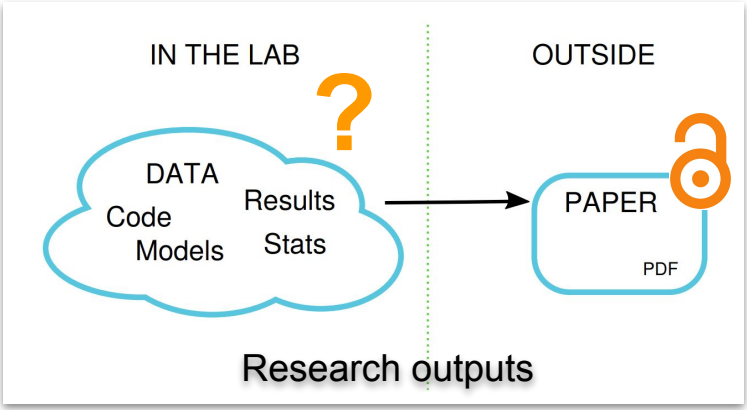
What about other research outputs?

- Data, code, results, methods, protocols, etc.

More general theme:

open science/research

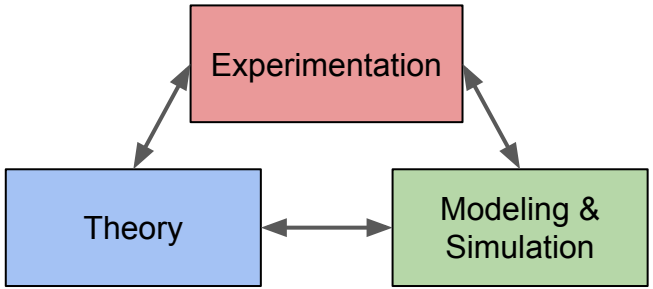
“open data, open source code, OER, open evaluation, and open methods, etc. to conduct ‘better’ science”



[1] Image by Piled Higher and Deeper (PHD Comics), “Open Access Explained!”, CC BY
[2] Image by Stephen J. Eglen, CC BY

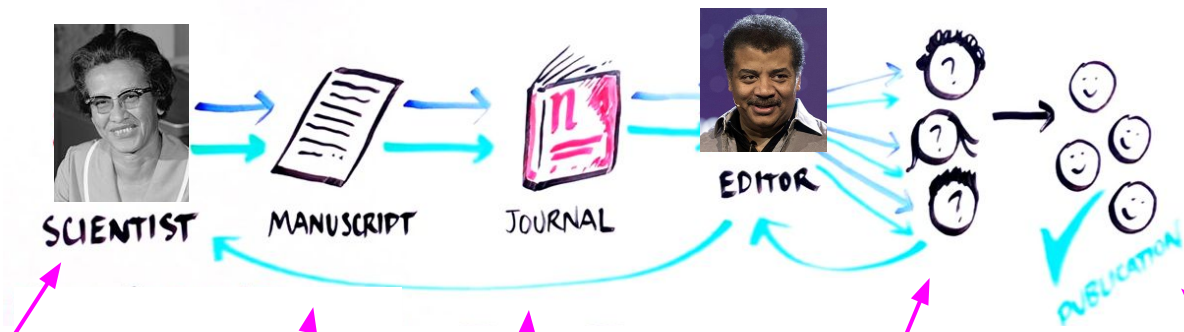
The four pillars of open science

*"An **article** about computational science in a scientific publication is not the scholarship itself, it is merely **advertising** of the scholarship. The actual scholarship is the **complete software development environment** and the **complete set of instructions** which generated the figures."* [1]



[1] Buckheit, J. B., Donoho, D. L. (1995), "Wavelab and reproducible research", Wavelets and statistics, vol. 103, Lecture Notes in Statistics, 55–81
[2] Image by Nikolaus Kriegeskorte, "The four pillars of open science", accessed 2019/11/07

At which stages could open science be useful?



You
Your collaborators
PhDs
Postdocs
Interns

Interactive
DOIs

Publishers

Reviewers

Other scientists
Companies
Citizens

Goal: better understand, use, reproduce, and improve findings!

[1] YourekaScience, "What are preprints?", CC BY
[2] Katherine Johnson, public domain [3] Neil deGrasse Tyson, by Norwegian University of Science and Technology, CC BY-SA 2.0

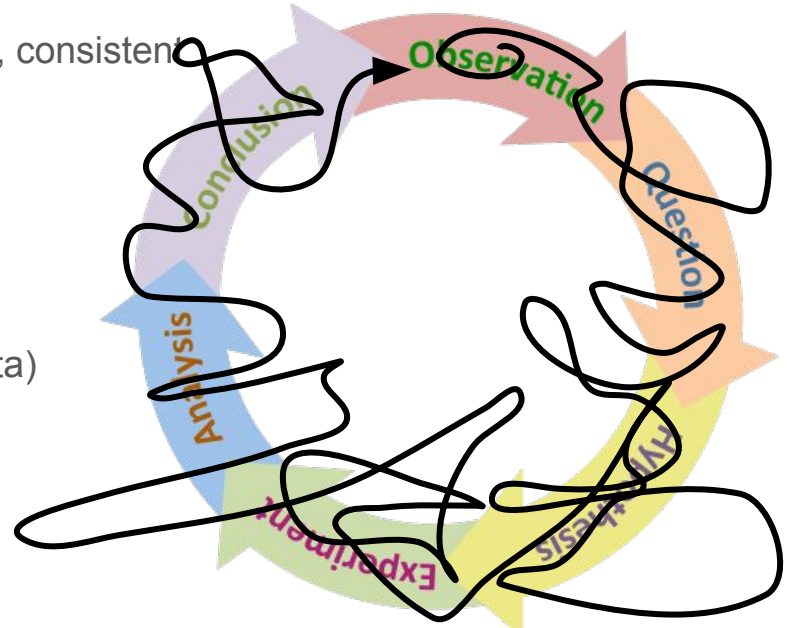
The scientific method (simplified)

Principles:

- Testable, replicable, “objective”, transparent, falsifiable, consistent

Continuous and incremental process:

1. Define a question
2. Gather information and resources (observe)
3. Form explanatory (falsifiable) hypothesis
4. Test the hypothesis (perform an experiment, collect data)
5. Analyze the data
6. Interpret the data and draw conclusions
7. Publish results
8. Retest/reproduce (frequently done by others)



Simplified view

[1] Crawford S., Stucki L. (1990), “Peer review and the changing research record”, J Am Soc Info Science, vol. 41, pp. 223–28
[2] The scientific method, by Thebiologyprimer, CC0

The reproducibility crisis

Survey among 1,600 researchers:

> *"More than **70%** of researchers have tried and failed to reproduce another scientist's experiments, and more than **50%** have failed to reproduce their own experiments."* [1]

Figure "Is there a reproducibility crisis?" from [1]

[1] Baker, M. (2016), "1,500 scientists lift the lid on reproducibility", Nature, 533, 452—454
[2] Baker, M. (2015), "First results from psychology's largest reproducibility test", Nature News
[3] Open Science Collaboration, "Estimating the reproducibility of psychological science", Science, Vol. 349, Issue 6251, aac4716
[4] Begley, C. G., Ellis, L. M. (2012), "Raise standards for preclinical cancer research", Nature 483, 531–533
[5] Hutson, M. (2018), "Artificial intelligence faces reproducibility crisis", Science, Vol. 359, Issue 6377, pp. 725-726

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Reproducibility Project: Psychology:

> *"only **39 of** the **100** replication attempts successful"* [2, 3]

"Original study effect size versus replication effect size", Figure 3 from [3]

[1] Baker, M. (2016), "1,500 scientists lift the lid on reproducibility", Nature, 533, 452—454
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Other fields:

> *"One analysis found that only **6 of 53** high-profile papers in **cancer biology** could be reproduced"* [4]

Figure "Code break" from [5]

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[3] Open Science Collaboration, "Estimating the reproducibility of psychological science", Science, Vol. 349, Issue 6251, aac4716
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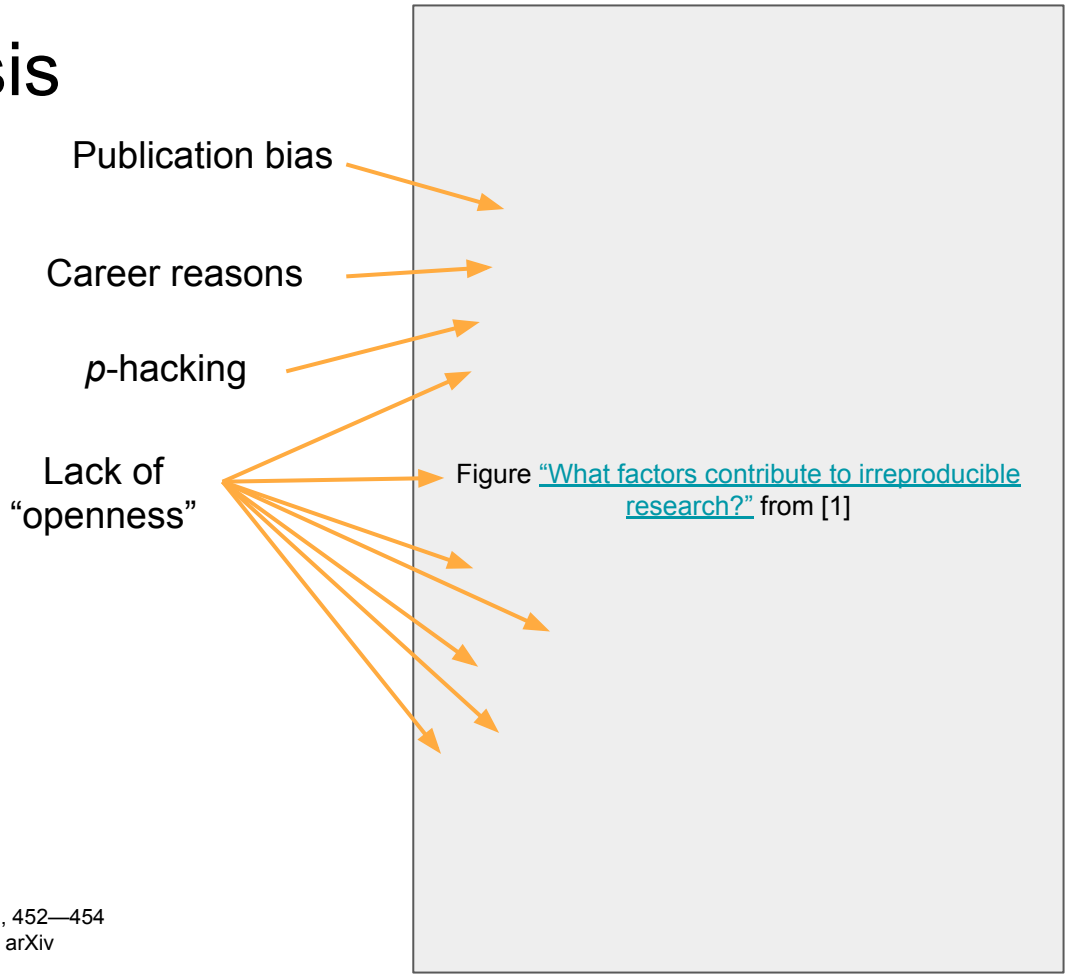
Figure "What factors contribute to irreproducible research?" from [1]

The reproducibility crisis

Warning: conflicting terminologies! [2]

		Experimental setup	
		Same	**Different**
Team	**Same**	Repeatable	
	Different	Replicable	Reproducible



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[1] Baker, M. (2016), "1,500 scientists lift the lid on reproducibility", Nature, 533, 452—454
[2] Barba, L. A. (2018), "Terminologies for Reproducible Research", preprint on arXiv

What are some of the problems?

Publication bias:

> *"The tendency for statistically significant findings to be published over nonsignificant findings."* [1]

> *"Statistically significant results **3x** more likely to be published than null results."* [2]

Spurious correlations

p-hacking [3]:

> *"...trying multiple things until you get the desired result — even unconsciously."* [3]

> *"claiming conclusive research findings solely on the basis of a single study assessed by formal statistical significance, typically for a **p-value less than 0.05**."* [4]

[1] Rosenthal, R. (1979), "The file drawer problem and tolerance for null results", Psychological Bulletin, 86, 638–641.
[2] Dickersin, K. et al. (1987), "Publication bias and clinical trials", Controlled Clinical Trials, 8 (4): 343–353
[3] Nuzzo, R. (2014), "Scientific method: Statistical errors", Nature News
[4] Ioannidis, J. P. A. (2005), "Why Most Published Research Findings Are False", PLOS Medicine

Statistical significance (simplified)

Statistical tests are common for judging the strength of scientific evidence

p-value:

> *"the probability of obtaining results 'as extreme' or 'more extreme', given that the null hypothesis is true"*

In many fields, significance threshold is set to $p < 0.05$

> *"if the **null hypothesis is true**, and all other assumptions made are valid, there is a **5% chance** of obtaining a result at least as extreme as the one observed"*

	Reject H_0	**Accept H_0**
H_0 false	True positive	False negative
H_0 true	False positive	True negative

	Reject H_0 at 5% level	**Accept H_0 at 5% level**
H_0 unknown	# positive studies	# negative studies

[1] Ioannidis, J. P. A. (2005), "Why Most Published Research Findings Are False", PLOS Medicine
[2] Bergstrom, C. T., West, J., "Calling Bullshit 7.5: Publication Bias"

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If null hypothesis is false:

	Reject H_0 at 5% level	Accept H_0 at 5% level
H_0 unknown	10	2

If null hypothesis is true:

	Reject H_0 at 5% level	Accept H_0 at 5% level
H_0 unknown	1	20

[1] Ioannidis, J. P. A. (2005), "Why Most Published Research Findings Are False", PLOS Medicine
[2] Bergstrom, C. T., West, J., "Calling Bullshit 7.5: Publication Bias"

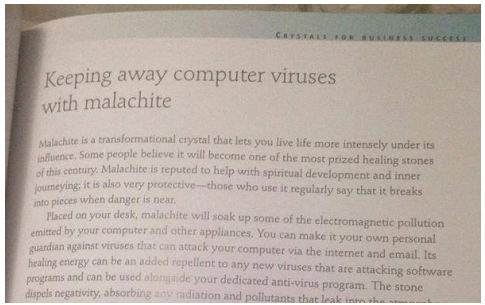
How to obtain a significant & **nonsensical** result

Question: Does a malachite reduce malware infections?

Null hypothesis: no difference in mean # of infections

Study: randomized controlled trial (RCT)

1. Take random sample 20 computer users
2. Split randomly in two groups
3. Real crystal in one group, fake crystal in control group
4. Check # of malware infections after **X** months

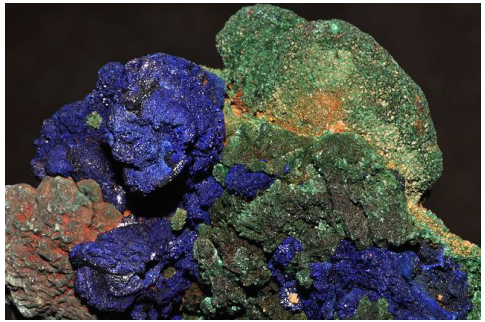


CRYSTALS FOR BUSINESS SUCCESS

Keeping away computer viruses with malachite

Malachite is a transformational crystal that lets you live life more intensely under its influence. Some people believe it will become one of the most prized healing stones of this century. Malachite is reputed to help with spiritual development and inner journeying; it is also very protective—those who use it regularly say that it breaks into pieces when danger is near.

Placed on your desk, malachite will soak up some of the electromagnetic pollution emitted by your computer and other appliances. You can make it your own personal guardian against viruses that can attack your computer via the internet and email. Its healing energy can be an added repellent to any new viruses that are attacking software programs and can be used alongside your dedicated anti-virus program. The stone dispels negativity, absorbing any radiation and pollutants that leak into the



[1] Idea by Hanno Böck, Science is broken, talk at 34c3
[2] imgur, Keep viruses away with malachite!, accessed 2019/11/11
[3] Cristaux d'Azurite et de Malachite sur Cuivre, by Parent Géry, public domain

How to obtain a significant & **nonsensical** result

Question: Does a malachite reduce malware infections?

Simulated malachite study using random data

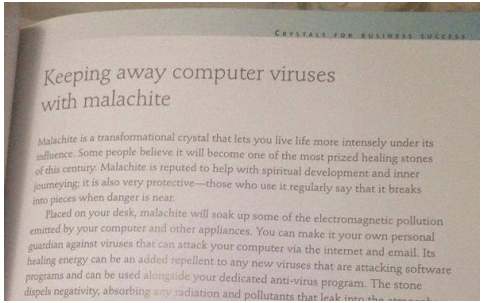
```
In [1]: # Import some packages.
        import os
        import numpy as np
        from matplotlib import pyplot as plt
        from numpy import random as rnd
        from scipy import stats

        # Initialize pseudo-random number generator.
        rnd.seed(123456789)
```

Define study protocol (randomized controlled trial)

```
In [2]: # Set number of study participants for each group.
        n = 10

        def perform_study(n):
            # Assume number of malware infections follow exponential distribution.
            a = [rnd.exponential(scale=3) for k in range(n)]
            b = [rnd.exponential(scale=3) for k in range(n)]

            return (a, b)
```

Perform single study

```
In [3]: a, b = perform_study(n)

        # H_0: crystal has NO effect beyond placebo
        # H_1: crystal HAS an effect beyond placebo
        t, p = stats.ttest_ind(a, b)

        print("Mean malware infections in each group:")
        print("malachite=%.2f, placebo=%.2f, p=%.2f" % (np.mean(a), np.mean(b), p))
```



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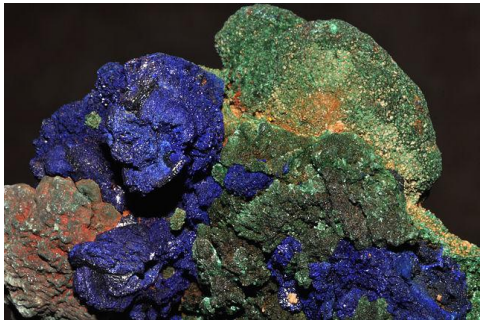

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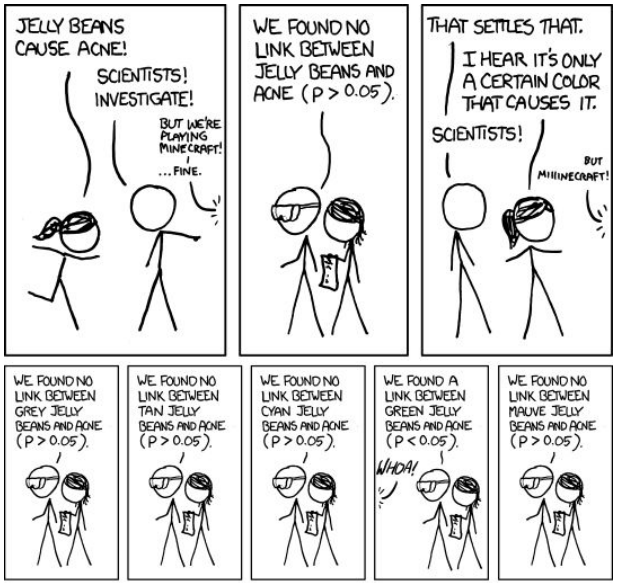
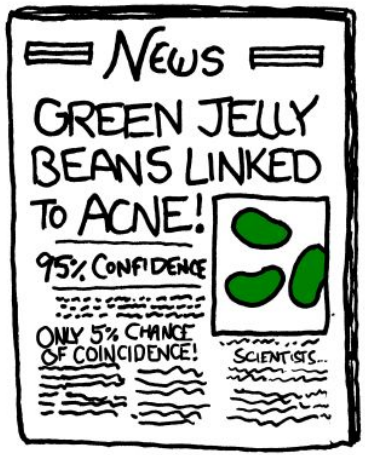
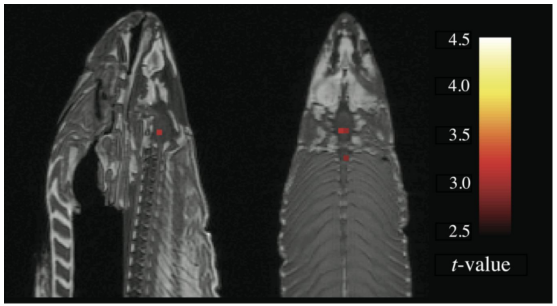
Statistical significance (simplified)



So, uh, we did the green study again and got no link. It was probably a--RESEARCH CONFLICTED ON GREEN JELLY BEAN/ACNE LINK; MORE STUDY RECOMMENDED!



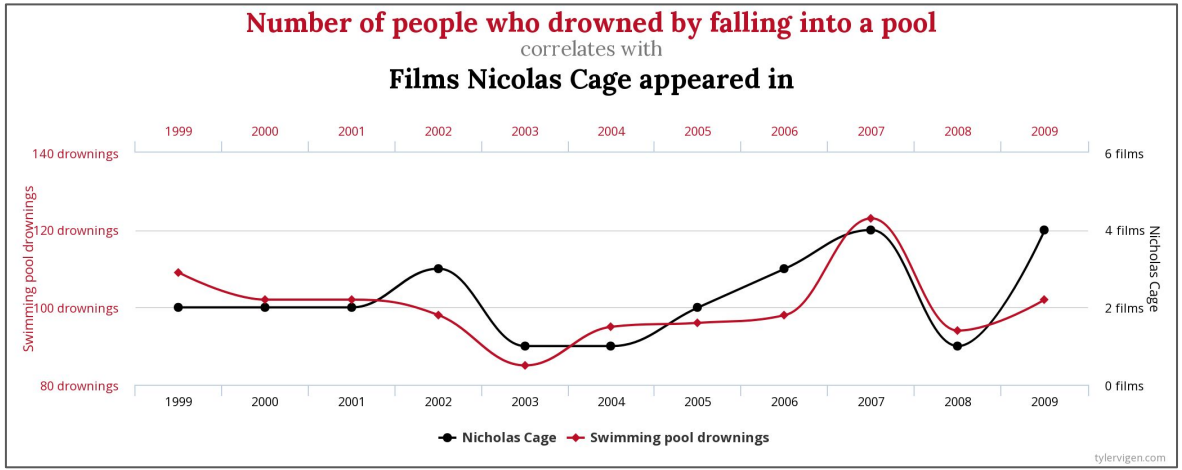


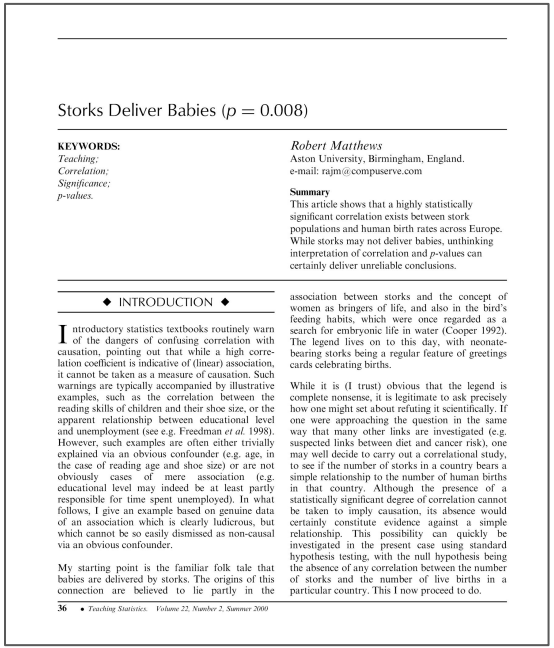
Significant activation changes in fMRI data of a dead salmon [2, 3]

[1] Significant, by XKCD, CC BY-NC 2.5
[2] Bennett, C. M. et al. (2009), "Neural correlates of interspecies perspective taking in the post-mortem Atlantic Salmon", Journal of Serendipitous and Unexpected Results
[3] Scientific American (2012/09/25), "IgNobel Prize in Neuroscience: The dead salmon study", accessed 2019/11/07

Spurious correlations

"...variables are associated but not causally related, due to either coincidence or the presence of a certain third, unseen factor" [1]





Storks Deliver Babies ($p = 0.008$)

KEYWORDS:
Teaching;
Correlation;
Significance;
p-values.

Robert Matthews
Aston University, Birmingham, England.
e-mail: rajm@compuserve.com

Summary
This article shows that a highly statistically significant correlation exists between stork populations and human birth rates across Europe. While storks may not deliver babies, unthinking interpretation of correlation and *p*-values can certainly deliver unreliable conclusions.

◆ INTRODUCTION ◆

Introductory statistics textbooks routinely warn of the dangers of confusing correlation with causation, pointing out that while a high correlation coefficient is indicative of (linear) association, it cannot be taken as a measure of causation. Such warnings are typically accompanied by illustrative examples, such as the correlation between the reading skills of children and their shoe size, or the apparent relationship between educational level and unemployment (see e.g. Freedman *et al.* 1998). However, such examples are often either trivially explained via an obvious confounder (e.g. age, in the case of reading age and shoe size) or are not obviously cases of mere association (e.g. educational level may indeed be at least partly responsible for time spent unemployed). In what follows, I give an example based on genuine data of an association which is clearly ludicrous, but which cannot be so easily dismissed as non-causal via an obvious confounder.

My starting point is the familiar folk tale that babies are delivered by storks. The origins of this connection are believed to lie partly in the association between storks and the concept of women as bringers of life, and also in the bird's feeding habits, which were once regarded as a search for embryonic life in water (Cooper 1992). The legend lives on to this day, with neonate-bearing storks being a regular feature of greetings cards celebrating births.

While it is (I trust) obvious that the legend is complete nonsense, it is legitimate to ask precisely how one might set about refuting it scientifically. If one were approaching the question in the same way that many other links are investigated (e.g. suspected links between diet and cancer risk), one may well decide to carry out a correlational study, to see if the number of storks in a country bears a simple relationship to the number of human births in that country. Although the presence of a statistically significant degree of correlation cannot be taken to imply causation, its absence would certainly constitute evidence against a simple relationship. This possibility can quickly be investigated in the present case using standard hypothesis testing, with the null hypothesis being the absence of any correlation between the number of storks and the number of live births in a particular country. This I now proceed to do.

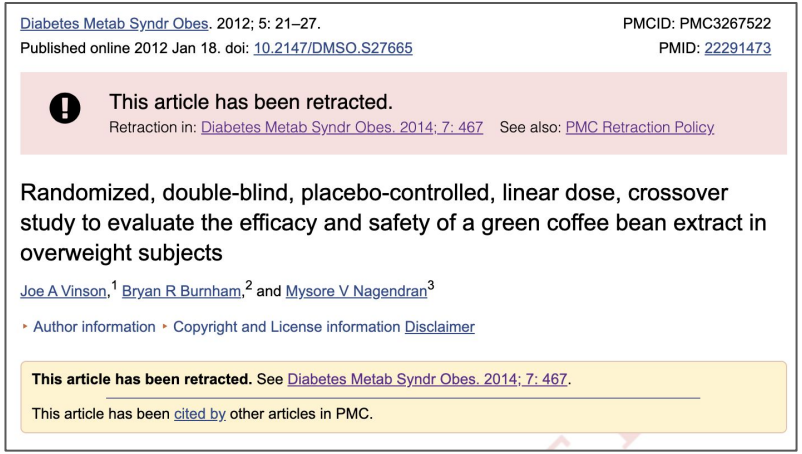
[1] Image taken from Spurious Correlations, by Tyler Vigen, CC BY 4.0
[2] Matthews, R. (2000), "Storks Deliver Babies (p=0.008)", Teaching Statistics, Volume 22, Number 2

Science is self-correcting

But: reproducibility and openness is crucial

Open science rationals [3]:

- Improve efficiency (reproduction cost, sharing)
- Increase transparency and quality (validation)
- Speed up transfer of knowledge
- Allows to built on top of others' work (companies)
- Solve global challenges more effectively
- Promote citizens' engagement (faith in science)



Diabetes Metab Syndr Obes. 2012; 5: 21–27. PMCID: PMC3267522
Published online 2012 Jan 18. doi: 10.2147/DMSO.S27665 PMID: 22291473

This article has been retracted.
Retraction in: Diabetes Metab Syndr Obes. 2014; 7: 467 See also: PMC Retraction Policy

Randomized, double-blind, placebo-controlled, linear dose, crossover study to evaluate the efficacy and safety of a green coffee bean extract in overweight subjects

Joe A Vinson,[1] Bryan R Burnham,[2] and Mysore V Nagendran[3]

Author information Copyright and License information Disclaimer

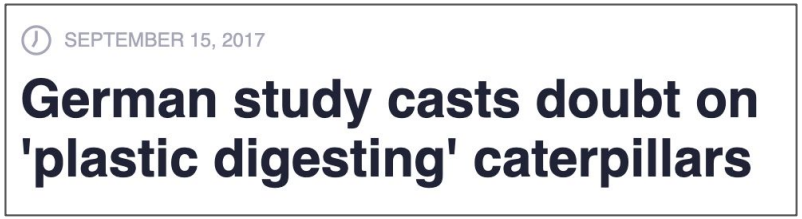
This article has been retracted. See Diabetes Metab Syndr Obes. 2014; 7: 467.

This article has been cited by other articles in PMC.

ANIMAL BEHAVIOUR · 24 APRIL 2017

This caterpillar can digest plastic

Wax-moth larvae could inspire biotechnological methods for degrading plastic.



SEPTEMBER 15, 2017

German study casts doubt on 'plastic digesting' caterpillars

See also retractionwatch.com

[1] Nature News (2014/09/17, "Why high-profile journals have more retractions", accessed 2019/11/11
[2] Fang, F. C., Casadevall, A. (2011), "Retracted Science and the Retraction Index", accessed 2019/11/11
[3] OECD (2015/10/15), "Making Open Science a Reality", OECD Science, Technology and Industry Policy Papers, No. 25, OECD Publishing, Paris.

Reproducible research

Statistical reproducibility

- Detailed info about statistical tests, model parameters
- Preregistration of studies (e.g. AllTrials, compare-trials, clinicaltrials.gov) [1]
- Registered reports [2]
  - publish a protocol for experiment, journal decides on publication, conduct study, publish results in any case

Empirical reproducibility

- Detailed info about non-computational aspects
- Making data/experiment details available
- Data, protocols, equipment info

Computational reproducibility

- Detailed info about code, software, used hardware, implementation details

[1] Guardian Science, “Trust in science would be improved by study pre-registration”, accessed 2019/11/11
[2] Center for Open Science, “Registered Reports”, accessed 2019/11/11
[3] Reproducibility Guide, “Introduction”, accessed 2019/11/07
[4] Stodden, V. (2014), "Reproducibility", accessed 2019/11/07

Brief history

1990s:

- 1992: First appearance of term “reproducible research” in paper by seismologists Jon Claerbout and Martin Karrenbach from Stanford University [1]
- 1995: “...advertising of the scholarship” quote by Jonathan Buckheit and David Donoho

2000s:

- 2006: Distinction between replication and reproducibility defined by Peng et al. [2]
- 2009: First mention of importance of open software and data for reproducible research by Donoho [3]
- 2011: Special issue of Science on “Data Replication and Reproducibility”
- 2013: Data used for an influential 2010 paper on austerity by Harvard economists Reinhart and Rogoff is shown to contain significant issues and data actually contradicts original conclusions [4]
- 2017: EU Horizon 2020 starts applying its Open Research Data Pilot to all thematic areas

[1] Claerbout, J. F. and M. Karrenbach, 1992: Electronic documents give reproducible research a new meaning. In SEG Technical Program Expanded Abstracts 1992, Society of Exploration Geophysicists, pp. 601–604, doi:10.1190/1.1822162.
[2] Peng, R. D., F. Dominici, and S. L. Zeger, 2006: Reproducible epidemiologic research. American Journal of Epidemiology, 163(9), 783–789, doi:10.1093/aje/kwj093.
[3] Donoho, D. L., A. Maleki, I. U. Rahman, M. Shahram, and V. Stodden, 2009: Reproducible research in computational harmonic analysis. Computing in Science & Engineering, 11(1), 8–18, doi:10.1109/MCSE.2009.15.
[4] Herndon, T., Ash, M., Pollin, R. (2013), “Does High Public Debt Consistently Stifle Economic Growth? A Critique of Reinhart and Rogoff”

Reproducible Research Standard [1]

"…all components of the research that are necessary for others to understand and replicate the research." [2]

1. "The full compendium is available on the Internet,
2. The media components, including the original selection and arrangement of the data, are licensed under CC BY or released to the public domain under CC0,
3. The code components are licensed under one of Apache 2.0, the MIT License, or the Modified BSD license, or released to the public domain under CC0,
4. The data have been released into the public domain according to the Science Commons Open Data Protocol."

If actual data cannot be released (embargoes, privacy, etc.): dummy / sample data

[1] Stodden, Victoria, Enabling Reproducible Research: Open Licensing for Scientific Innovation (March 3, 2009). International Journal of Communications Law and Policy, Forthcoming. Available at SSRN: https://ssrn.com/abstract=1362040
[2] Robert Gentleman & Duncan Temple Lang (2007) Statistical Analyses and Reproducible Research, Journal of Computational and Graphical Statistics, 16:1, 1-23, DOI: 10.1198/106186007X178663

Incentives and Disincentives

Incentives [1, 2]

- Requirements by funding bodies
- Higher possibility to spot issues in data or data analysis
- Prevention of data & knowledge loss (e.g. when researchers/students leave, which they do)
- More insights for peer reviewers
- Credits through transparency

Disincentives [3]

- Concerns about having to provide user support
- Time commitment
- Requires additional skills
- Not considered relevant for promotions
- Hard to enable double-blind peer review

Barriers are not technological, but psychological, cultural, and political: individual habits, institutional inertia, unhealthy incentives, and vested interests

[1] Markowetz, F. Five selfish reasons to work reproducibly. Genome Biol 16, 274 (2015) doi:10.1186/s13059-015-0850-7
[2] Eglen, S. (2018), "Simple steps to improve reproducibility of your computational research", last accessed: 2019/10/11
[3] Whitaker, K. (2017), "Showing your working: a hot to guide to reproducible research", last accessed: 2019/10/11

Tools to facilitate reproducible research

- Notebooks and literate authoring, programming, and publishing tools
  - E.g. Jupyter Notebooks to produce key figures of a paper
- Version control:
  - Bitbucket, Git, GitHub, Gitlab, etc. vs “script_version3_good_Jan31_try3.py” sent via email
- Tracking provenance of files and objects (data, source code, figures, results)
  - E.g. protocols.io
- Automation
  - E.g. Scripted automatic scripts facilitate reproducibility vs. many independent manual steps
- Configuration management (package versions, dependencies, etc.) & VMs
  - E.g. Anaconda, Apache Maven, Chef, Docker, Puppet, VMs

→ reproducibility is a key software requirement so many SE best practices / tools used

[1] V. Stodden, D.H. Bailey, J. Borwein, R.J. LeVeque, W. Rider, and W. Stein, Setting the default to reproducible: Reproducibility in computational and experimental mathematics, February 2, 2013; http://www.davidhbailey.com/dhbpapers/icerm-report.pdf.

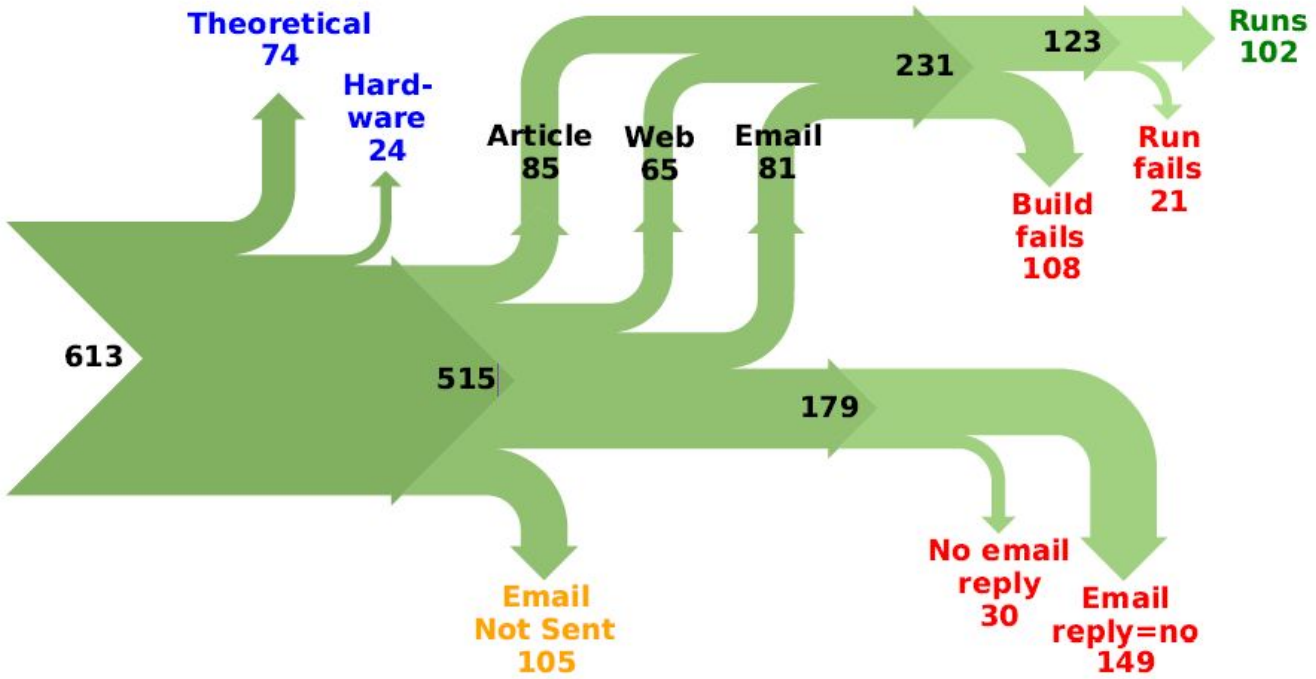
Best practices [1, 2]

- Version control (see previous slide)
- Persistent URLs (e.g. DOIs via Zenodo/figshare, code repos, websites)
- License (e.g. CC, MIT, BSD, etc.)
- Etiquette (e.g. contacting authors before publishing analysis of their work)
- Documentation (e.g. README, Makefile)
- Tools, standards (should be standard and open tools vs. proprietary ones)
- Data (e.g. separating data from code)
- Tests (e.g. CI, units tests, etc.)
- User support (e.g. forums, mailing list, GitHub issues, etc.)

→ Research Software Engineering

[1] Eglen, S. et al. (2017), "Toward standard practices for sharing computer code and programs in neuroscience", Nat Neurosci 20, 770–773
[2] Collberg, C. et al (2014), "Measuring Reproducibility in Computer Systems Research", last accessed: 2019/11/10
[3] de-RSE e.V., https://www.software.ac.uk/sites/default/files/images/content/BetterSoftwareBetterResearchImage.jpg

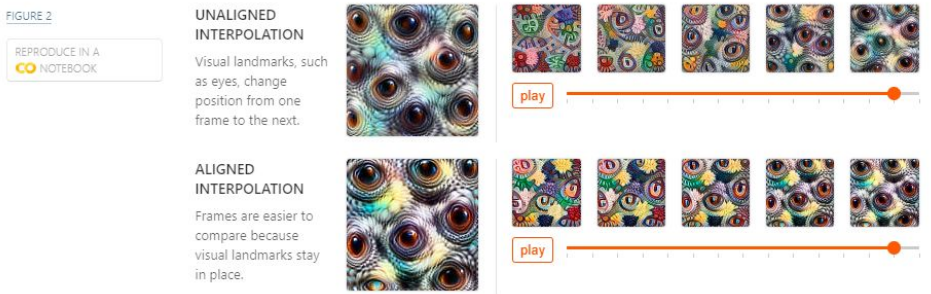
Reproducibility in Computer Science research

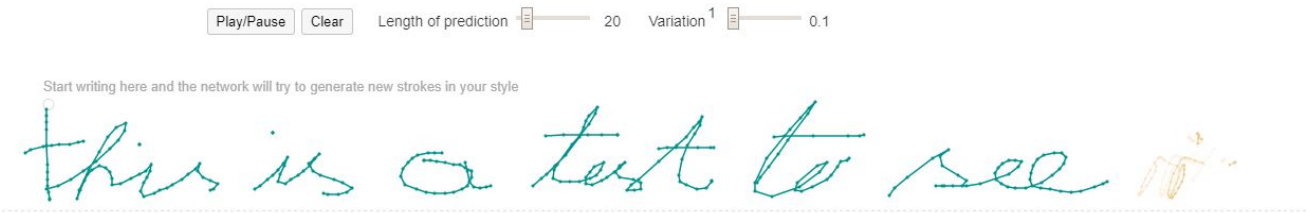


[1] Collberg, C. et al (2014), “Measuring Reproducibility in Computer Systems Research”, last accessed: 2019/11/10

New approaches

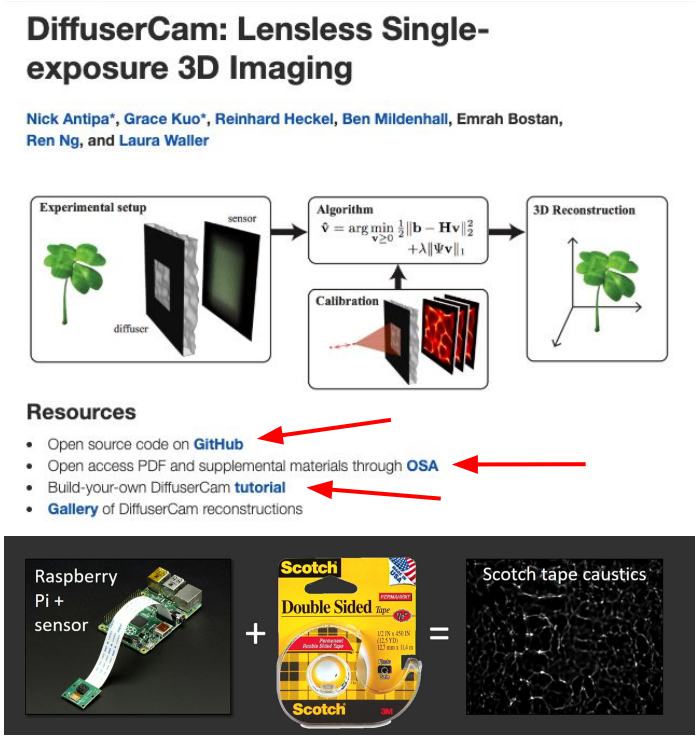
- Distill.pub (“dedicated to clear explanations of machine learning”)
  - Peer reviewed machine learning journal
  - Editors from Google, OpenAI, MIT
  - Most articles under CC BY
  - Source code available in many cases
  - Use of many images and examples
  - Some articles contain interactivity
  - Paper reviews are also included

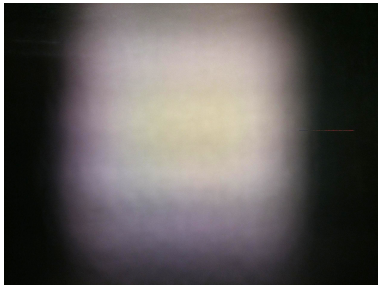




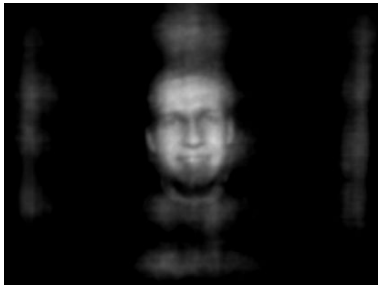
[1] Mordvintsev, et al., "Differentiable Image Parameterizations", Distill, 2018. https://doi.org/10.23915/distill.00012
[2] Carter, et al., "Experiments in Handwriting with a Neural Network", Distill, 2016. https://doi.org/10.23915/distill.00004

A prime example: DiffuserCam





Recorded image



Reconstructed image

Maths Public Open Day [3] at the Cambridge Science Festival 2019

[1] Antipa, N. et al. (2018), "DiffuserCam: lensless single-exposure 3D imaging", Optica 5, 1-9
[2] https://waller-lab.github.io/DiffuserCam/
[3] https://www.maths.cam.ac.uk/events/maths-public-open-day-cambridge-science-festival

A few practical hints

ex_1a.m

```
% Copyright 2019 Lukas F. Lang and Sebastian Neumayer
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%
%    You should have received a copy of the GNU General Public License
%    along with TBIR.  If not, see <http://www.gnu.org/licenses/>.
%
% This script requires the toolbox_optim:
%
% matlab-toolboxes: Matlab toolboxes from www.numerical-tours.com.
% GitHub: https://github.com/gpeyre/matlab-toolboxes
% URL: http://www.numerical-tours.com/
% Version used: 0cd622c
%
% Clone from github e.g. to some directory by:
%
% >> git clone https://github.com/gpeyre/matlab-toolboxes.git
%
% and set the path below accordingly. In order to work with the
% abovementioned version type:
%
% >> cd matlab-toolboxes
% >> git checkout 0cd622c
%
% This script creates the results shown in Figure 2.
clear;
close all;
clc;
```
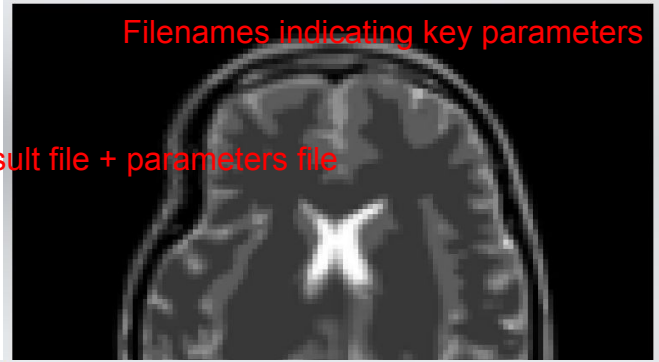

License

Dependency

Version

Brain_result_NCC_op_mfCurvatureST_LDDMMobjFctn_0.05.png



Brain_params_NCC_op_mfCurvatureST_LDDMMobjFctn_0.05.txt

```
Distance:         NCC_op
Regulariser:      mfCurvatureST
Objective:        LDDMMobjFctn
Image model:      splineInterMex
RK steps:         5
Time steps:       1
Alpha 1:          50
Alpha 2:          10
Angles (deg.):    0  12  24  36  48  60
Noise level:      0.05
SSIM (recon.):    0.896968
SSIM (ref.):      0.739703
PSNR (recon.):    -19.4426
PSNR (ref.):      -26.8028
Elapsed time:     471.502 s
```

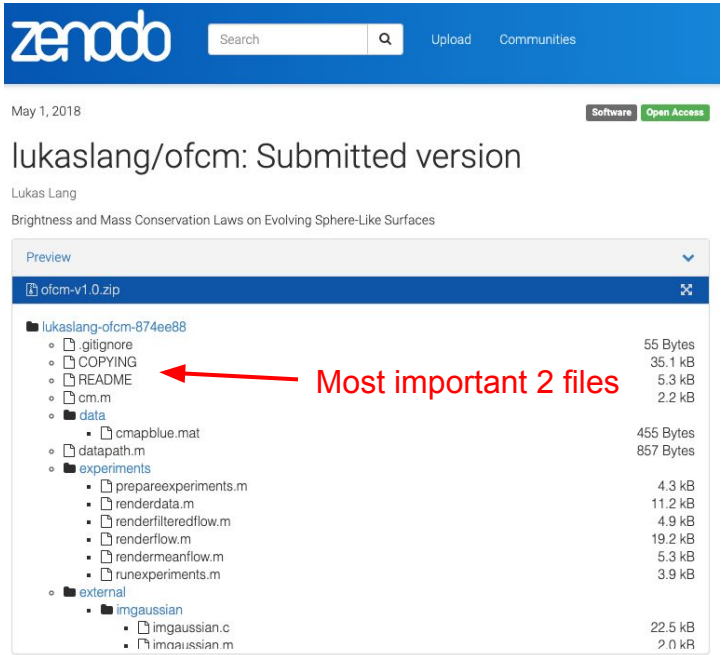
Detailed parameters and results

A few practical hints

Git + LaTeX as a great workflow

Graph	Description	Commit	Author	Date
	master origin/master origin/HEAD **Added offprint.**	**682851e**	**Lukas Lang...**	**17 May 2019 at...**
	published Added published version.	d6d2778	Lukas Lang <l...	15 May 2019 at...
	Fixed minor typos.	f4cf14c	Lukas Lang <l...	30 Apr 2019 at...
	Fixed typo.	d2013fc	Lukas Lang <l...	15 Apr 2019 at 1...
	Removed unnecessary files.	64f5945	Lukas Lang <l...	15 Apr 2019 at 1...
	accepted Removed line numbering and colouring. Fixed t...	5930460	Lukas Lang <l...	10 Apr 2019 at 1...
	revised Updated DOI to latest version of code.	334662a	Lukas Lang <l...	19 Mar 2019 at...
	Fixed typo.	f346722	Lukas Lang <l...	19 Mar 2019 at...
	Moved hand image to top of the page	01a88d4	Unknown <ne...	19 Mar 2019 at...

Tag versions



Get citable permanent DOIs and badges for your code & data

Upcoming tasks

- Next lecture: Open Spaces/Open Practices → Excursion
  - Introduction/guided tour by Petar Kosic and Clemens Hopfer
  - **Tuesday, November 19**: 17:00-19:00, **Metalab Vienna, Rathausstraße 6, 1010 Vienna!**
- Second project meeting (45 min., discussion of your project idea):
  - **Friday, November 29, 14:00–18:00**, Argentinierstraße 8, **project room**
- Paper group forming and topic selection:
  - **Friday, November 29**, via email to **both** lecturers

Literature and resources

Stodden, V., Leisch, F., Peng, R. D. (2014), Implementing Reproducible Research, CRC Press

Gorgolewski, K. J., Poldrack, R. A. (2016), A Practical Guide for Improving Transparency and Reproducibility in Neuroimaging Research, PLOS Biology

Eglen, S. et al. (2017), Toward standard practices for sharing computer code and programs in neuroscience, Nat Neurosci 20, 770–773

LeVeque, R. J. (2013), Top Ten Reasons To Not Share Your Code (and why you should anyway), SIAM News

Markowetz, F. (2015), Five selfish reasons to work reproducibly. Genome Biol 16, 274 (2015)

Other resources

- Bergstrom, C. and West, J., lecture course Calling Bullshit
- Lots of good references at the rOpenSci Project
- https://www.coursera.org/learn/reproducible-research