Reproducibility

Principles and Practice

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Learning Objectives

Today we will learn about…

- reproducibility rates in linguistics
- FAIR principles
- concepts for building a reproducible workflow

Reproducibility

- generating the same results with the same data and analysis scripts
  - seems obvious, but requires organisation and forethought
- bare minimum: share the code and the data (Laurinavichyute et al., 2022)
- rates of reproducibility vary across fields (Bochynska et al., 2023)
  - open access: 25-65%
  - data and analyses sharing: 11-33%
  - pre-registrations: 0-3%
- what constitutes "reproducibility"?

What should (ideally) be shared?

- materials
  - protocols
  - stimuli
  - experiment set-up
- documentation
  - README
  - metadata
- data
  - raw
    - e.g., text files, audio, video, or images
  - processed
- analysis code

- pre-processing
- analyses

- materials are helpful for replication
  - but also for inspection of e.g., design

- data and code are necessary for reproducibility
  - along with proper documentation of software used

Reproducibility rates in linguistic research

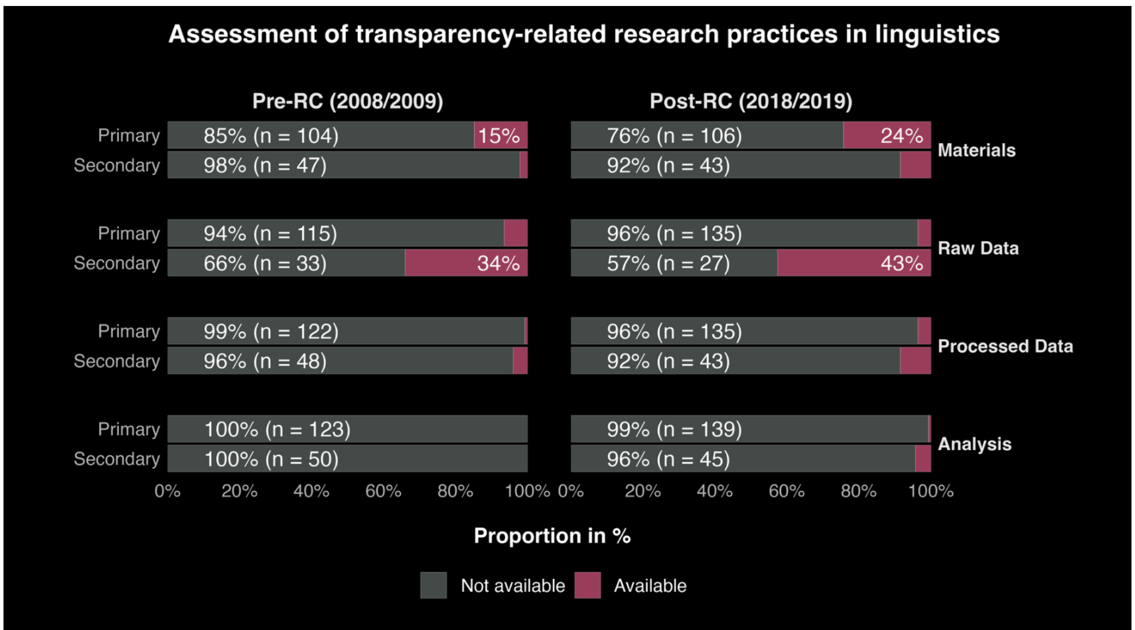


Figure 2: Percentages of the available and not available materials, raw data, processed data, and analysis scripts for the pre-RC (left) and post-RC (right) time windows, displayed separately for primary data (Primary) and secondary data (Secondary), for the empirical study articles in the sample. The Other category was excluded.

Figure 1: Source: Bochynska et al. (2023), p. 11 (all rights reserved)

- meta-analysis of 519 randomly sampled articles from various linguistic journales
  - pre- and post-reproducibility crisis (2008/9, 2018/19) (Bochynska et al., 2023)
  - differentiated between primary (collected for study) and secondary (pre-existing) data

- reported a post-RC increase in shared materials, data, and analyses

  - but still low rates of each

- higher rates of secondary data sharing, presumably due to publicly available corpora
- data shared more often than analyses, pre- and post-RC

Journal of Memory and Language

- meta-analysis of articles from JML (Laurinavichyute et al., 2022)
  - before and after an Open Science Policy was introduced in 2019

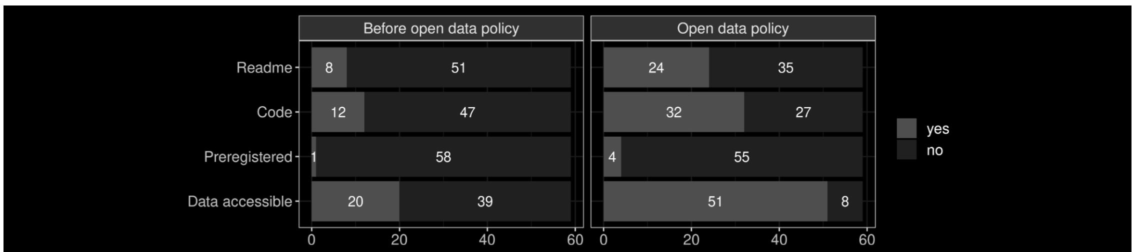


Fig. 1. A summary showing the number of papers which had a readme file or the like that provided some documentation, for which the code was available, which were preregistered, and for which the data were accessible.

Figure 2: Source: Laurinavichyute et al. (2022), p. 5 (all rights reserved)

- code and data availability improved
- but reproducibility rate ranged from 34-56%, depending on criteria
- higher rates compared to field-wide meta-analysis (Bochynska et al., 2023)

FAIR principles

- guidelines for sharing digital resources
- refers broadly to data, but we'll consider it in terms of analyses

- findable and accesssible refer to where materials are stored
  - in *findable* repositories
  - that are *accessible*, i.e., do not require an account

- interoperable and reusable emphasise the format of data (and code)
  - the importance of future use
  - and use beyond your precise computational environment

- a great way to test the FAIR principles
  - code review!

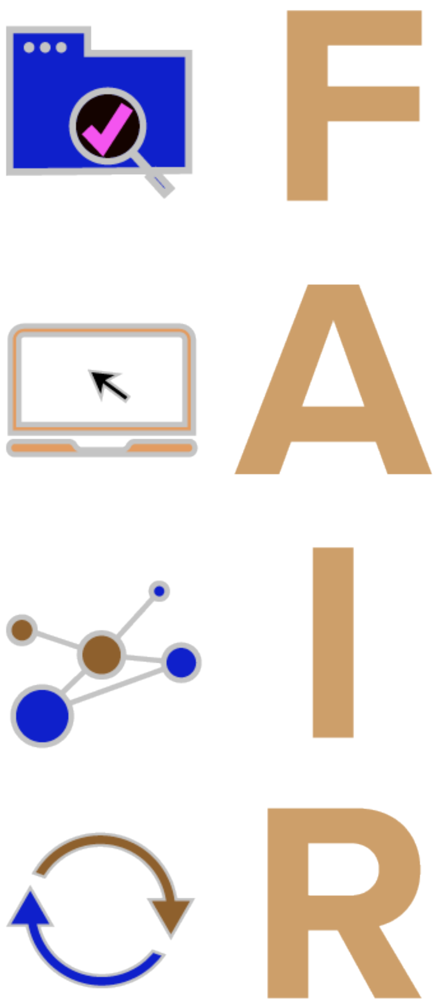


Figure 3: Source: National Library of Medicine (all rights reserved)

- i.e., have a colleague try to access your data/run your code
  - either via an online repository
  - or send them your project folder

Findable

- refers to data and supplementary materials
- materials should have a "persistant identifier"
  - e.g., Digital Object Identifier (DOI) for scholarly articles
- a digital, long-term storage of data
  - *not* on a personal or professional website
  - GitHub files don't typically have sufficient metadata
  - ideally: OSF, Zenodo or some other repository
- in recent papers, an OSF link is typically provided
- also: *discoverable*
  - e.g., in data-specific search engines (Google's Dataset search)

Accessible

- data (and code) should be
  - machine- and human-readable
  - available on a trusted repository, e.g., the OSF
  - Open Access
    - not behind a paywall
    - nor require a login

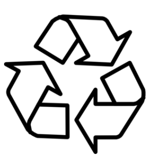
Interoperable

- data (and code) should
  - not dependent on an operating system
  - nor entirely on software/package versions
- easiest work around:
  - document your software versions

    - this doesn't automatically facilitate interoperability
    - but may help pinpoint where problems are coming from

Reusable

- data (and code) should
    - be reusable for future research
- data format should be generic
    - i.e., not tied to a specific program
    - for tabular data, I recommend `.csv` format
- we can swap with 'reproducible' in the context of analyses



Task: finding data

Go to datasetsearch.research.google.com/

- do a search for data related to a topic of interest to you

- what type of information does the search provide?
- what type of links?
- do you find analysis code, or just data?
- do the same search at osf.io
- and at zenodo.org/
  - are there the same amount of hits?

Data and code availability

- "data available upon (reasonable) request"
  - generally not true
- data was not available in 68% of the most cited psychology studies (2006-2016) (Hardwicke & Ioannidis, 2018)
  - a further 18% were available with restrictions
  - only 11% available without restriction
- data alone is not sufficient
  - 'Data Analysis' sections are rarely exhaustive/unambiguous
  - very difficult to re-create analyses without code
  - e.g., is data trimming explicitly defined?
    - this will even affect descriptive statistics

Data and code $\neq$ Reproducibility

- even including code does not guarantee reproducibility
- access to data and code do not mean analyses are reproducible
- what can go wrong? Examples from Laurinavichyute et al. (2022)

1. Data problems
   - inaccessible data
   - incomplete data (e.g., 2/3 experiments)
2. Code problems
   - incomplete code

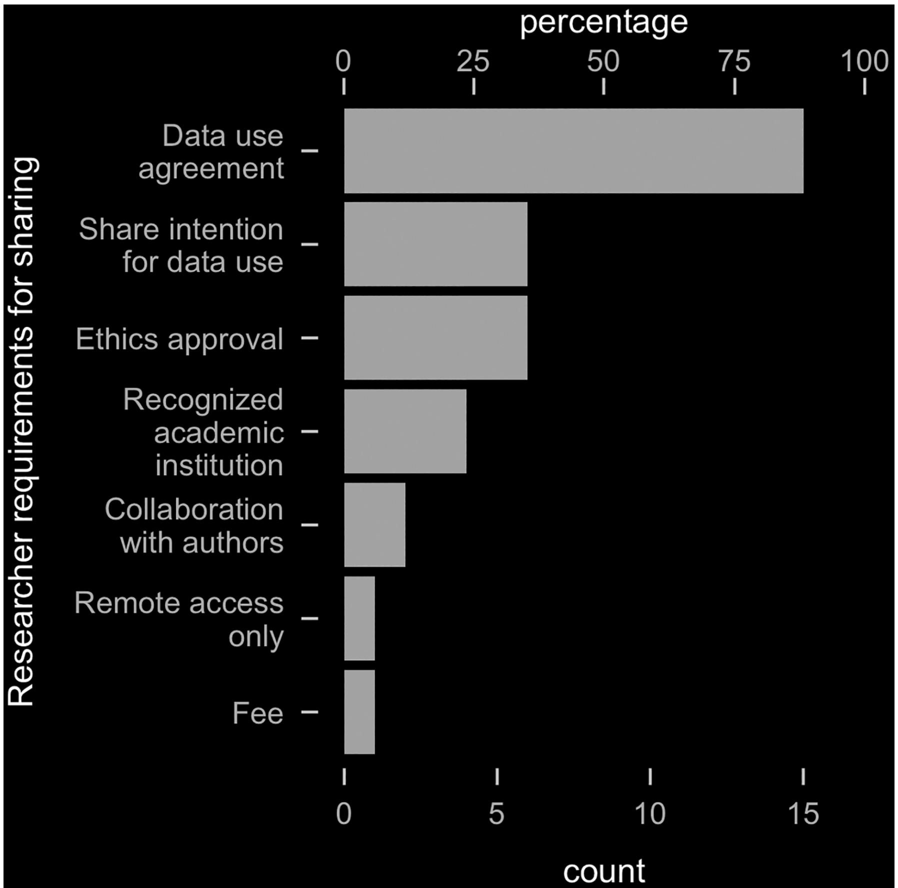


Fig 3. Requirements imposed by researchers before data can be shared. X-axes represent counts and percentages (of n = 17 with restricted data sharing systems in place). Note that these data are not mutually exclusive: individual sharing schemes often entailed multiple restrictions.

Figure 4: Source: Hardwicke & Ioannidis (2018), p. 6 (all rights reserved)

- error messages
- code rot: outdated syntax or environment
- proprietary software

3. Documentation problems

- data difficult to interpret
- no README file/data dictionary
- unclear folder/file/variable naming convention
- manuscript contradicts code

4. Unclear terms of use

- no licence specification

Share the code, not just the data

- Why?
  - key details are often missing from 'Methods' sections
- suggestions for researchers from Laurinavichyute et al. (2022)

1. Share data in usable form
   - with pre-processing code
2. Use publicly accessible repositories
   - e.g., OSF
3. Use non-proprietary data formats
   - e.g., not `.xls` files (Excel)
4. Provide documentation
   - e.g., README, data dictionaries
5. Share code *and* data
   - they estimate a 38% increase in reproducibility
6. Teach data management and computing skills
   - that's what this course is for!

Building a reproducible workflow

- there are different levels of reproducibility
    - the *bare minimum* is sharing the code and data
    - *and* including session information:
        * which operating system was used
        * which software/package versions were used
- going bigger:
    - project-oriented workflow
    - project-specific filepaths
    - contained in a single project folder
- we will be using RProjects to achieve this

Project management

- folder structure
- project-relative file paths
- appropriate documentation
    - e.g., README
- it's great to map out your project structure early on
    - but it will grow as you go along
    - reproducible principles facilitate adapting as it grows

Literate programming

> Instead of imagining that our main task is to instruct a *computer* what to do, let us concentrate rather on explaining to *human beings* what we want a computer to do.

— Knuth (1984), p. 97

- originally used to refer to writing programs
- but also applies to analysis code
    - especially if we're aiming for reproducibility
- main concepts:
    - code is linear (this pre-dates Knuth, 1984)

    - informative but concise commenting

- main benefits:
    - facilitates maintenance
    - helpful for future-you, collaborators, etc.

Documentation

- metadata
    - project README
    - codebook/data dictionary
- README should contain
    - a project description
    - relevant links
    - description of folder structure
- can be updated as the project develops
- README.md files in GitHub/Lab are automatically used as a project description
    - `.md` is a plaintext document
    - uses markdown syntax

Version control

- git: local tracking
- useful for the analysis and writing phases
    - but can be tricky for collaboration
- GitHub/GitLab: remote tracking
    - store your changes to your local git repository
    - then push them to your remote repository
- safe guards against local hardware/software issues
    - lost or damaged computer or local files
- and allows for collaboration or sharing

Persistant (public) storage

- GitHub/Lab are sub-optimal
  - developer-focused
  - typically lack thorough documentation/metadata
  - not very user-friendly for non-users
- OSF, Zenodo
  - Open Science-focused
  - can be linked to a GitHub/Lab repository
  - facilitate thorough documentation
  - user-friendly

Writing

- dynamic reports with Markdown syntax
  - e.g., Rmarkdown, Quarto
  - integration of data, code, and prose
    - facilitates cross-referencing within document
    - integration of citation management tools
    - supports LaTeX syntax for example sentences and tables
- `papaja` package for APA-formatted Rmarkdown documents
- challenge: collaboration
  - not all collaborators know these tools
  - track changes not currently possible

Setting up a project

- next week: hands-on
- required installations/recent versions of:
  - R
    - version `4.4.0`, "Puppy Cup"
    - check current version with `R.version`
    - download/update: https://cran.r-project.org/bin/macosx/
  - RStudio
    - version `2023.12.1.402`, "Ocean Storm"

    * Help > Check for updates
    * new install: https://posit.co/download/rstudio-desktop/

Learning objectives

Today we learned…

- reproducibility rates in linguistics
- FAIR principles
- concepts for building a reproducible workflow

References

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