Reproducible Tools and Workflows

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17–20 February 2020

Tools we'll see this week

- R, RStudio
  - `https://cran.r-project.org/`
  - `https://www.rstudio.com/`
- make (and other command line tools)
  - For Mac/Linus: pre-installed
  - For Windows: `https://cran.r-project.org/bin/windows/Rtools/`
- git
  - git (`https://git-scm.com/`)
  - github (`https://github.com/`)
  - gitkraken (`https://www.gitkraken.com/`)
- any text editor
- any command line terminal

Introductions

- Me:
  - Thomas
  - Political Scientist, Methodology Department
  - R
- You:
  - Name
  - Field/Department
  - Tools/Software

Learning Objectives

1. Understand how to organize a reproducible research project
2. Recognize different approaches to reproducibility and tools for implementing various reproducible workflows
3. Th: Apply various workflows to your own work
4. Th: Understand how to collaborate reproducibly

1 Organizing Things

2 Building Things

3 Keeping and Changing Things

4 Thursday: Hands-On

1 Organizing Things

2 Building Things

3 Keeping and Changing Things

4 Thursday: Hands-On

Activity!

How do you organize your files for a project?

Wait, but why do we care?

If we're going to be transparent *in the end* (e.g., at verification or data archiving stage), what do we need to provide?

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A well-organized, reproducible analysis!

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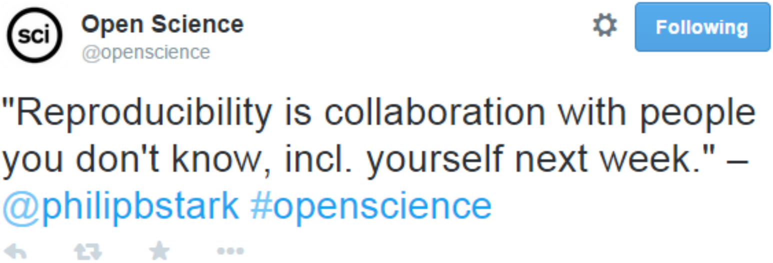
If we're going to be transparent *in the end* (e.g., at verification or data archiving stage), what do we need to provide?

A well-organized, reproducible analysis!

So rather than make that an annoying, post-hoc exercise related to publication, try to get organized and stay organized throughout your project from the very beginning.

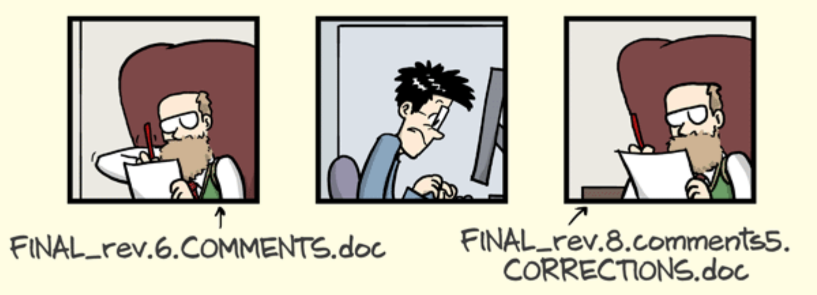


Open Science
@openscience

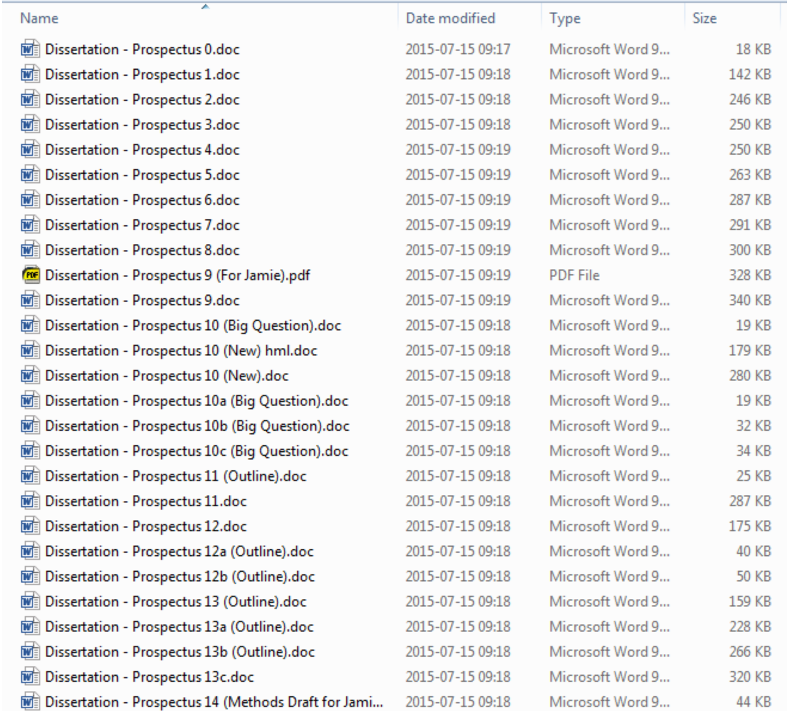
"Reproducibility is collaboration with people you don't know, incl. yourself next week." – @philipbstark #openscience

The single most important part of reproducibility is naming things!

FINAL.doc!
FINAL_rev.2.doc


FINAL_rev.6.COMMENTS.doc
FINAL_rev.8.comments5.
CORRECTIONS.doc

JORGE CHAM © 2012
track changes
FINAL_rev.18.comments7.
corrections9.MORE.30.doc
FINAL_rev.22.comments49.
corrections.10.#@$%WHYDID
ICOMETOGRADSCHOOL????.doc



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Dissertation - Prospectus 1.doc	2015-07-15 09:18	Microsoft Word 9...	142 KB
Dissertation - Prospectus 2.doc	2015-07-15 09:18	Microsoft Word 9...	246 KB
Dissertation - Prospectus 3.doc	2015-07-15 09:18	Microsoft Word 9...	250 KB
Dissertation - Prospectus 4.doc	2015-07-15 09:19	Microsoft Word 9...	250 KB
Dissertation - Prospectus 5.doc	2015-07-15 09:19	Microsoft Word 9...	263 KB
Dissertation - Prospectus 6.doc	2015-07-15 09:19	Microsoft Word 9...	287 KB
Dissertation - Prospectus 7.doc	2015-07-15 09:19	Microsoft Word 9...	291 KB
Dissertation - Prospectus 8.doc	2015-07-15 09:19	Microsoft Word 9...	300 KB
Dissertation - Prospectus 9 (For Jamie).pdf	2015-07-15 09:19	PDF File	328 KB
Dissertation - Prospectus 9.doc	2015-07-15 09:19	Microsoft Word 9...	340 KB
Dissertation - Prospectus 10 (Big Question).doc	2015-07-15 09:18	Microsoft Word 9...	19 KB
Dissertation - Prospectus 10 (New) hml.doc	2015-07-15 09:18	Microsoft Word 9...	179 KB
Dissertation - Prospectus 10 (New).doc	2015-07-15 09:18	Microsoft Word 9...	280 KB
Dissertation - Prospectus 10a (Big Question).doc	2015-07-15 09:18	Microsoft Word 9...	19 KB
Dissertation - Prospectus 10b (Big Question).doc	2015-07-15 09:18	Microsoft Word 9...	32 KB
Dissertation - Prospectus 10c (Big Question).doc	2015-07-15 09:18	Microsoft Word 9...	34 KB
Dissertation - Prospectus 11 (Outline).doc	2015-07-15 09:18	Microsoft Word 9...	25 KB
Dissertation - Prospectus 11.doc	2015-07-15 09:18	Microsoft Word 9...	287 KB
Dissertation - Prospectus 12.doc	2015-07-15 09:18	Microsoft Word 9...	175 KB
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Dissertation - Prospectus 12b (Outline).doc	2015-07-15 09:18	Microsoft Word 9...	50 KB
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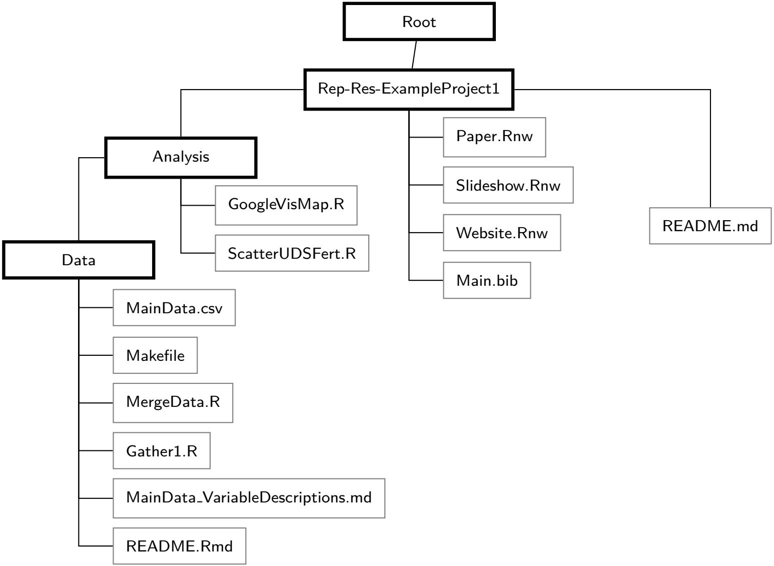
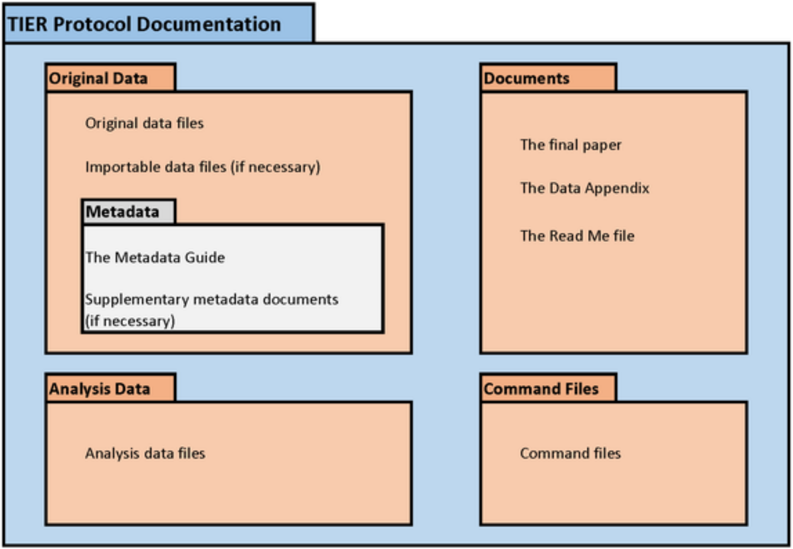
Dissertation - Prospectus 13c.doc	2015-07-15 09:18	Microsoft Word 9...	320 KB
Dissertation - Prospectus 14 (Methods Draft for Jami...	2015-07-15 09:18	Microsoft Word 9...	44 KB

What makes up the ideal reproducible research product?

- Gandrud's template
- rOpenSci's "Research Compendium"
- Project TIER
- AJPS Replication/Verification Policy


Root
Rep-Res-ExampleProject1
Analysis
GoogleVisMap.R
ScatterUDSFert.R
Data
MainData.csv
Makefile
MergeData.R
Gather1.R
MainData_VariableDescriptions.md
README.Rmd
Paper.Rnw
Slideshow.Rnw
Website.Rnw
Main.bib
README.md

```
project
|- DESCRIPTION       # project metadata and dependencies
|- README.md         # top-level description of content
|
|- data/             # raw data, not changed once created
|  +- my_data.csv    # data files in open formats
|
|- analysis/         # any programmatic code
|  +- my_scripts.R   # R code used to analyse data
```



TIER Protocol Documentation

Original Data

Original data files

Importable data files (if necessary)

Metadata

The Metadata Guide

Supplementary metadata documents (if necessary)

Documents

The final paper

The Data Appendix

The Read Me file

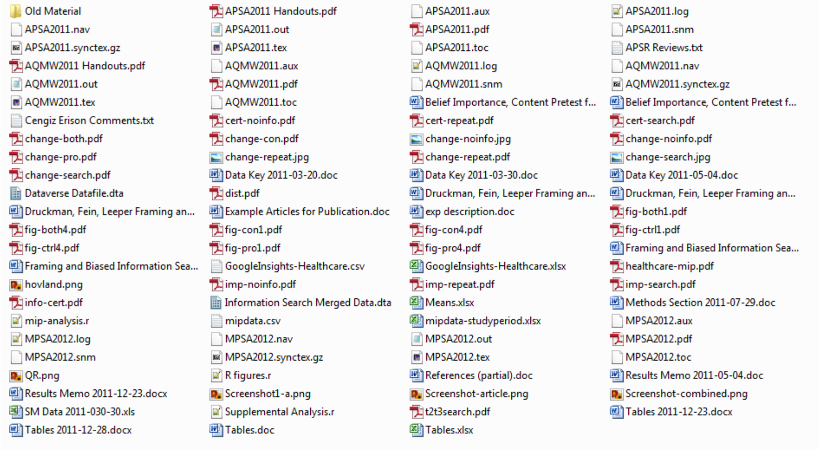
Analysis Data

Analysis data files

Command Files

Command files

Don’t be this guy:



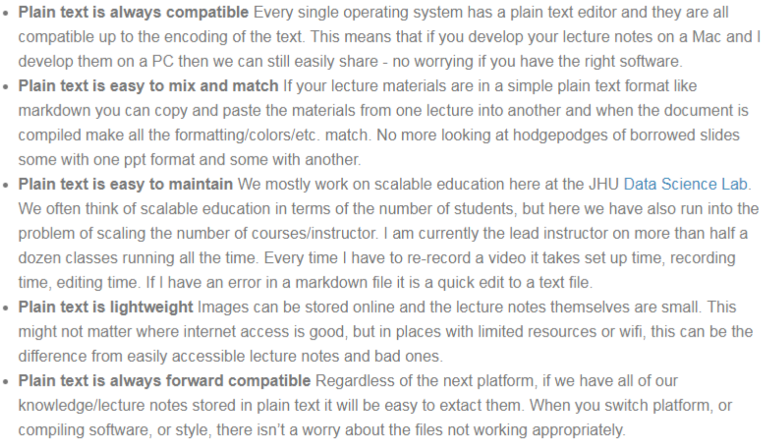
Old Material
APSA2011 Handouts.pdf
APSA2011.aux
APSA2011.log
APSA2011.nav
APSA2011.out
APSA2011.pdf
APSA2011.snm
APSA2011.synctex.gz
APSA2011.tex
APSA2011.toc
APSR Reviews.txt
AQMW2011 Handouts.pdf
AQMW2011.aux
AQMW2011.log
AQMW2011.nav
AQMW2011.out
AQMW2011.pdf
AQMW2011.snm
AQMW2011.synctex.gz
AQMW2011.tex
AQMW2011.toc
Belief Importance, Content Pretest f...
Belief Importance, Content Pretest f...
Cengiz Erison Comments.txt
cert-noinfo.pdf
cert-repeat.pdf
cert-search.pdf
change-both.pdf
change-con.pdf
change-noinfo.jpg
change-noinfo.pdf
change-pro.pdf
change-repeat.jpg
change-repeat.pdf
change-search.jpg
change-search.pdf
Data Key 2011-03-20.doc
Data Key 2011-03-30.doc
Data Key 2011-05-04.doc
Dataverse Datafile.dta
dist.pdf
Druckman, Fein, Leeper Framing an...
Druckman, Fein, Leeper Framing an...
Druckman, Fein, Leeper Framing an...
Example Articles for Publication.doc
exp description.doc
fig-both1.pdf
fig-both4.pdf
fig-con1.pdf
fig-con4.pdf
fig-ctrl1.pdf
fig-ctrl4.pdf
fig-pro1.pdf
fig-pro4.pdf
Framing and Biased Information Sea...
Framing and Biased Information Sea...
GoogleInsights-Healthcare.csv
GoogleInsights-Healthcare.xlsx
healthcare-mip.pdf
hovland.png
imp-noinfo.pdf
imp-repeat.pdf
imp-search.pdf
info-cert.pdf
Information Search Merged Data.dta
Means.xlsx
Methods Section 2011-07-29.doc
mip-analysis.r
mipdata.csv
mipdata-studyperiod.xlsx
MPSA2012.aux
MPSA2012.log
MPSA2012.nav
MPSA2012.out
MPSA2012.pdf
MPSA2012.snm
MPSA2012.synctex.gz
MPSA2012.tex
MPSA2012.toc
QR.png
R figures.r
References (partial).doc
Results Memo 2011-05-04.doc
Results Memo 2011-12-23.docx
Screenshot1-a.png
Screenshot-article.png
Screenshot-combined.png
SM Data 2011-030-30.xls
Supplemental Analysis.r
t2t3search.pdf
Tables 2011-12-23.docx
Tables 2011-12-28.docx
Tables.doc
Tables.xlsx

```
mkdir code

mkdir data

mkdir figures

echo # My Project > README.md
```

Everything you do should be plain text*

Everything you do should be plain text*

* Exceptions to this are images (sometimes)



- **Plain text is always compatible** Every single operating system has a plain text editor and they are all compatible up to the encoding of the text. This means that if you develop your lecture notes on a Mac and I develop them on a PC then we can still easily share - no worrying if you have the right software.
- **Plain text is easy to mix and match** If your lecture materials are in a simple plain text format like markdown you can copy and paste the materials from one lecture into another and when the document is compiled make all the formatting/colors/etc. match. No more looking at hodgepodges of borrowed slides some with one ppt format and some with another.
- **Plain text is easy to maintain** We mostly work on scalable education here at the JHU Data Science Lab. We often think of scalable education in terms of the number of students, but here we have also run into the problem of scaling the number of courses/instructor. I am currently the lead instructor on more than half a dozen classes running all the time. Every time I have to re-record a video it takes set up time, recording time, editing time. If I have an error in a markdown file it is a quick edit to a text file.
- **Plain text is lightweight** Images can be stored online and the lecture notes themselves are small. This might not matter where internet access is good, but in places with limited resources or wifi, this can be the difference from easily accessible lecture notes and bad ones.
- **Plain text is always forward compatible** Regardless of the next platform, if we have all of our knowledge/lecture notes stored in plain text it will be easy to extact them. When you switch platform, or compiling software, or style, there isn't a worry about the files not working appropriately.

`https://simplystatistics.org/2017/06/13/`

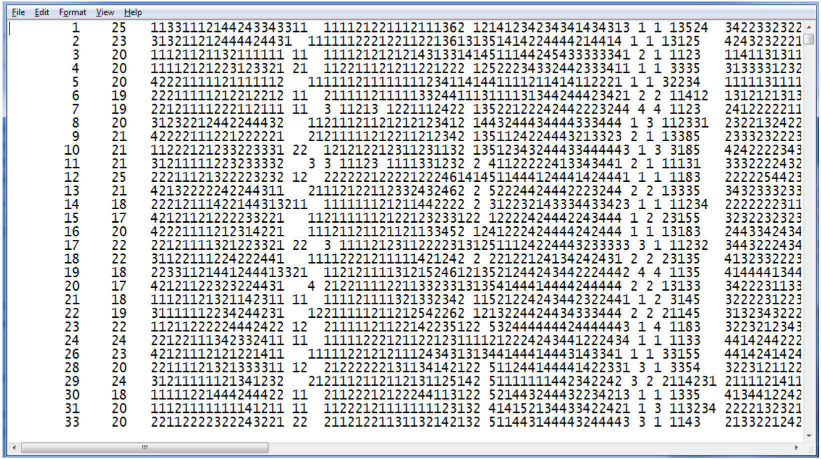
`the-future-of-education-is-plain-text/`

Additionally. . .

- Easy to use in version control
- Easy to dynamically update as part of an analysis “pipeline”

File	**Good format(s)**
Document	.md, .tex, .Rmd, .Rnw
Presentation	.tex, .Rmd, .Rnw
Code	.R, .Rmd, .py, .do, .ado
Data	.tsv, .csv
Codebook	.txt
Citations	.bib
Images	.svg, .pdf, .png
References	.bib

Is it possible to take the plain text ideology too far?



```
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        2    23   313211212444424431  1111112221221122136131351414224444214414 1 1 13125   4243232221
        3    20   11121121132111111 11  111121212121431331414511144245433333341 2 1 1123   1141131311
        4    20   11112121223123321 21  112211121211221222 12522234332442333411 1 1 3335   3133331232
        5    20   42221111121111112   1111112111111112341141441111211414112221 1 1 32234   1111131111
        6    19   22211111212212212 11  211111211111332441113111131344244423421 2 2 11412  1312121313
        7    19   22121111222112111 11  3 11213 1221112422 13522122242442223244 4 4 1123   2412222211
        8    20   31232212442244432   11211121121212123412 1443244434444333444 1 3 112331  2322132422
        9    21   42222111221222221   21211111212211212342 1351124224443213323 2 1 13385   2333232223
       10    21   11222121233223331 22  121212212311231132 13512343244433444443 1 3 3185   4242222343
       11    21   31211111223233332   3 3 11123 1111331232 2 41122222413343441 2 1 11131   3332222432
       12    25   22211121322223232 12  222222122221222461414511444124441424441 1 1 1183   2222254423
       13    21   42132222242244311   21112122112332432462 2 52224424442223244 2 2 13335   3432333233
       14    18   22212111422144313211  111111121211442222 2 312232143334433423 1 1 11234  2222222311
       15    17   42121121222233221   1121111112122123233122 12222424442243444 1 2 23155   3232232323
       16    20   42221111212314221   11121121121121133452 1241222424444242444 1 1 13183   2443342434
       17    22   22121111321223321 22  3 1111212311222231312511124222444323333 3 1 11232  3443222434
       18    22   31122111224222441   11112221211111421242 2 22122124134242431 2 2 23135   4132332223
       19    18   22331121441244413321  112121111312152461213521244243442224442 4 4 1135   4144441344
       20    17   42121122323224431   4 212221111221133233131354144414444244444 2 2 13133   3422231133
       21    18   11121121321142311 11  111121111321332342 11521224243442322441 1 2 3145   3222231223
       22    19   31111112234244231   12211111211212542262 1213224424434333444 2 2 21145   3132343222
       23    22   11211222224442422 12  21111121122142235122 532444444424444443 1 4 1183   3223212343
       24    24   22122111342332411 11  1111122212112212311112122224243441222434 1 1 1133   4414244222
       26    23   42121112121221411   1111122121211124343131344144414443143341 1 1 33155   4414241424
       28    20   22111121321333311 12  21222222131134142122 511244144441422331 3 1 3354   3223121122
       29    24   31211111121341232   2121112112112131125142 51111111442342242 3 2 2114231 2111121411
       30    18   11111221444244422 11  21122212122244113122 521443244432234213 1 1 1335   4134412242
       31    20   11121111111141211 11  11222121111111123132 414152134433422421 1 3 113234 2222132321
       33    20   22112222322243221 22  21121221131132142132 511443144443244443 3 1 1143   2133221242
```
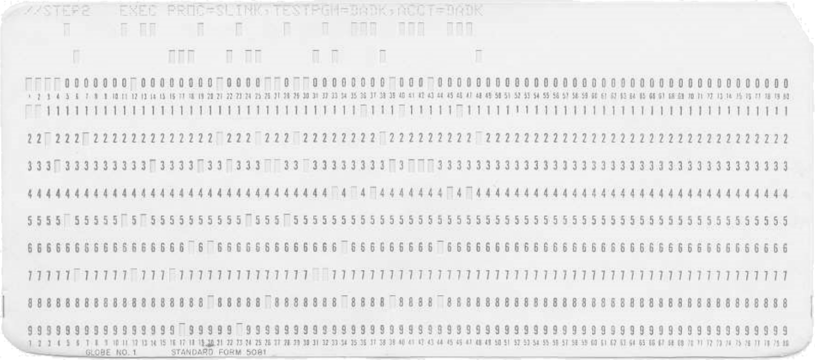
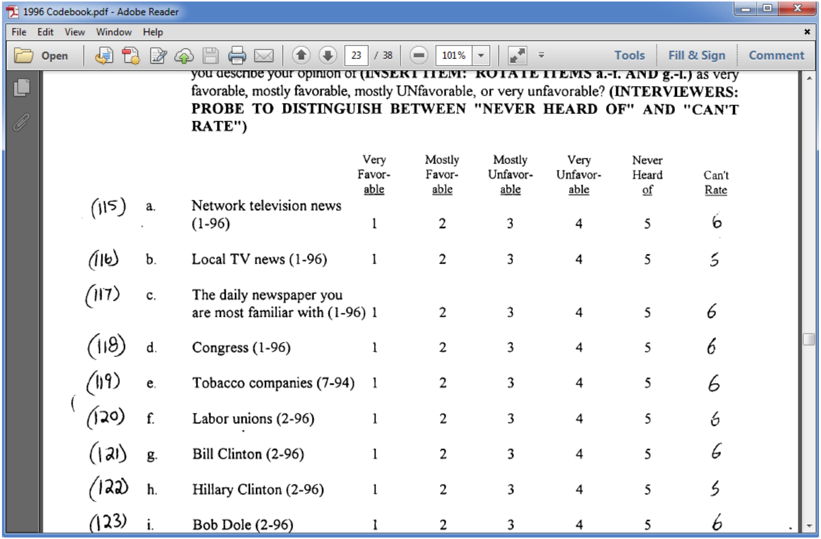



```
//STEP2   EXEC PROC=SLINK,TESTPGM=DADK,ACCT=DADK
```



you describe your opinion of (INSERT ITEM: ROTATE ITEMS a.-f. AND g.-i.) as very favorable, mostly favorable, mostly UNfavorable, or very unfavorable? **(INTERVIEWERS: PROBE TO DISTINGUISH BETWEEN "NEVER HEARD OF" AND "CAN'T RATE")**

			Very Favor-able	Mostly Favor-able	Mostly Unfavor-able	Very Unfavor-able	Never Heard of	Can't Rate
(115)	a.	Network television news (1-96)	1	2	3	4	5	6
(116)	b.	Local TV news (1-96)	1	2	3	4	5	5
(117)	c.	The daily newspaper you are most familiar with (1-96)	1	2	3	4	5	6
(118)	d.	Congress (1-96)	1	2	3	4	5	6
(119)	e.	Tobacco companies (7-94)	1	2	3	4	5	6
(120)	f.	Labor unions (2-96)	1	2	3	4	5	6
(121)	g.	Bill Clinton (2-96)	1	2	3	4	5	6
(122)	h.	Hillary Clinton (2-96)	1	2	3	4	5	5
(123)	i.	Bob Dole (2-96)	1	2	3	4	5	6

Questions?

File names

Which of these do we like best?

- PhD Comics style
- Sequential version numbers
- Datestamps

File names

Which of these do we like best?

- PhD Comics style
- Sequential version numbers
- Datestamps
- None of the above (Git!)

1 Organizing Things

2 Building Things

3 Keeping and Changing Things

4 Thursday: Hands-On

Activity!

What's your analytic workflow? How do you get results into a paper, poster, or presentation?

My First Workflow

My First Workflow

1. Make figure/table/analysis in R

My First Workflow

1. Make figure/table/analysis in R
2. Copy/paste into Word document

My First Workflow

1. Make figure/table/analysis in R
2. Copy/paste into Word document
3. Adjust figure/table numbering

My First Workflow

1. Make figure/table/analysis in R
2. Copy/paste into Word document
3. Adjust figure/table numbering
4. Double check references

My First Workflow

1. Make figure/table/analysis in R
2. Copy/paste into Word document
3. Adjust figure/table numbering
4. Double check references
5. Save as PDF
6. Change something in 1, repeat 2-5

My First Workflow

1. Make figure/table/analysis in R
2. Copy/paste into Word document
3. Adjust figure/table numbering
4. Double check references
5. Save as PDF
6. Change something in 1, repeat 2-5
7. Get feedback (f*ck!!), repeat 1-5

My First Workflow

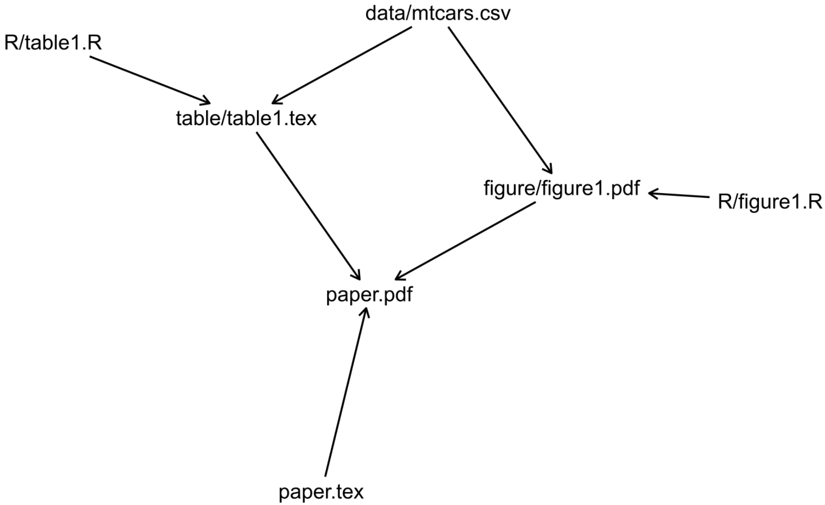
1. Make figure/table/analysis in R
2. Copy/paste into Word document
3. Adjust figure/table numbering
4. Double check references
5. Save as PDF
6. Change something in 1, repeat 2-5
7. Get feedback (f*ck!!), repeat 1-5
8. Get reviews (f*ck!!!!!), repeat 1-5

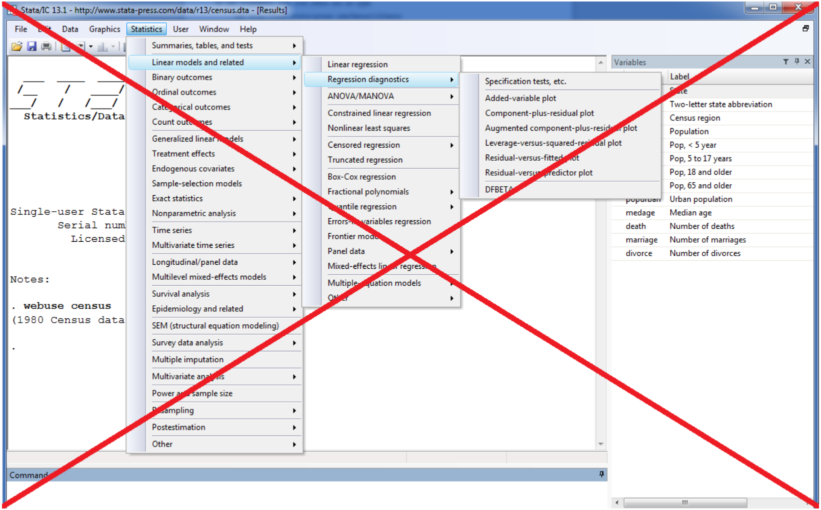
My First Workflow

1. Make figure/table/analysis in R
2. Copy/paste into Word document
3. Adjust figure/table numbering
4. Double check references
5. Save as PDF
6. Change something in 1, repeat 2-5
7. Get feedback (f*ck!!), repeat 1-5
8. Get reviews (f*ck!!!!!), repeat 1-5
9. Repeat 7 (f*ck!!!!!!!!!!!!!!!), repeat 1-5

Workflows as DAGs

- Reproducibility means executing a DAG
- DAG
  - Directed
  - Acyclic
  - Graph
- Files are *nodes*; workflows are *arrows*
- Example: `https://github.com/leeper/make-example`


data/mtcars.csv
R/table1.R
table/table1.tex
figure/figure1.pdf
R/figure1.R
paper.pdf
paper.tex



```
  ___  ____  ____
 /__    /   ____/
___/   /   /___/
  Statistics/Data

Single-user Stata
       Serial num
         Licensed

Notes:

. webuse census
(1980 Census data

.
```

	Label
	State
	Two-letter state abbreviation
	Census region
	Population
	Pop, < 5 year
	Pop, 5 to 17 years
	Pop, 18 and older
	Pop, 65 and older
popurban	Urban population
medage	Median age
death	Number of deaths
marriage	Number of marriages
divorce	Number of divorces

What’s wrong with point-and-click?

What's wrong with point-and-click?

- Lose track of the DAG

What’s wrong with point-and-click?

- Lose track of the DAG
- Won’t comply with DA-RT verification policies

What's wrong with point-and-click?

- Lose track of the DAG
- Won't comply with DA-RT verification policies
- You will make mistakes!

What's wrong with point-and-click?

- Lose track of the DAG
- Won't comply with DA-RT verification policies
- You will make mistakes!
- Eventually, you will have wasted your entire life manually fixing references, figure/table cross-references, and making sure that all of your numbers are correctly rounded and p-values have the correct number of stars next to them!

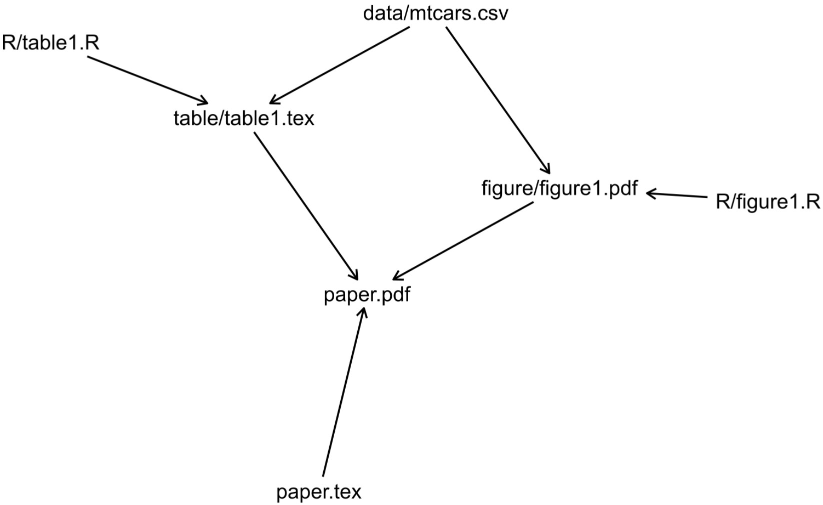
The prevalence of statistical reporting errors in psychology (1985–2013)

Michèle B. Nuijten[1] · Chris H. J. Hartgerink[1] · Marcel A. L. M. van Assen[1] · Sacha Epskamp[2] · Jelte M. Wicherts[1]

Published online: 23 October 2015

Abstract This study documents reporting errors in a sample of over 250,000 *p*-values reported in eight major psychology journals from 1985 until 2013, using the new R package "statcheck." statcheck retrieved null-hypothesis significance testing (NHST) results from over half of the articles from this period. In line with earlier research, we found that half of all published psychology papers that use NHST contained at least one *p*-value that was inconsistent with its test statistic and degrees of freedom. One in eight papers contained a grossly inconsistent *p*-value that may have affected the statistical conclusion. In contrast to earlier findings, we found that the average prevalence of inconsistent *p*-values has been stable over the years or has declined. The prevalence of gross inconsistencies was higher in *p*-values reported as significant than in *p*-values reported as nonsignificant. This could indicate a systematic bias in favor of significant results. Possible solutions for the high prevalence of reporting inconsistencies could be to encourage sharing data, to let co-authors check results in a so-called

Most conclusions in psychology are based on the results of null hypothesis significance testing (NHST; Cumming et al., 2007; Hubbard & Ryan, 2000; Sterling, 1959; Sterling, Rosenbaum, & Weinkam, 1995). Therefore, it is important that NHST is performed correctly and that NHST results are reported accurately. However, there is evidence that many reported *p*-values do not match their accompanying test statistic and degrees of freedom (Bakker & Wicherts, 2011; Bakker & Wicherts, 2014; Berle & Starcevic, 2007; Caperos & Pardo, 2013; Garcia-Berthou & Alcaraz, 2004; Veldkamp, Nuijten, Dominguez-Alvarez, Van Assen, & Wicherts, 2014; Wicherts, Bakker, & Molenaar, 2011). These studies highlighted that roughly half of all published empirical psychology articles using NHST contained at least one inconsistent *p*-value and that around one in seven articles contained a gross inconsistency, in which the reported *p*-value was significant and the computed *p*-value was not, or vice versa.


data/mtcars.csv
R/table1.R
table/table1.tex
figure/figure1.pdf
R/figure1.R
paper.pdf
paper.tex

Four Basic Workflows

Four Basic Workflows

1. Do everything in one file

Four Basic Workflows

1. Do everything in one file

2. Master file calls code for one-file-per-output

Four Basic Workflows

1. Do everything in one file
2. Master file calls code for one-file-per-output
3. make ("code within workflow")

Four Basic Workflows

1. Do everything in one file
2. Master file calls code for one-file-per-output
3. make (“code within workflow”)
4. knitr/rmarkdown (“workflow within code”)

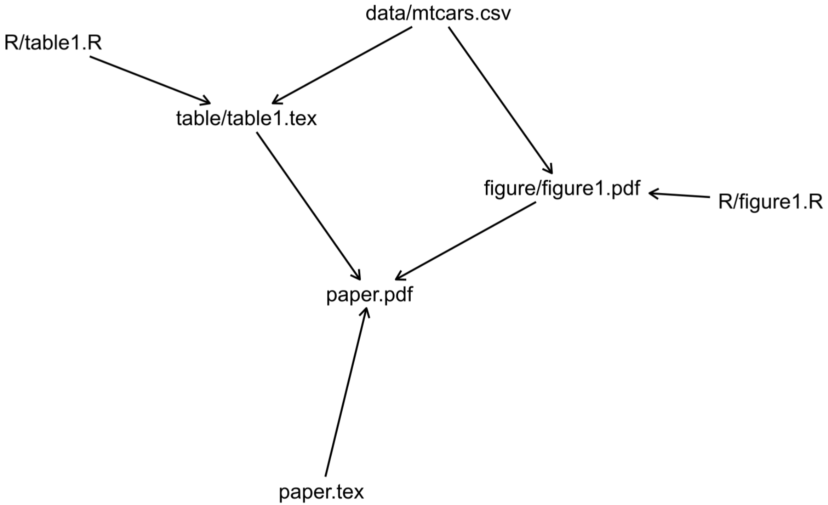
Everything in One File

```
# Brexit Deservingnes Experiment Analysis
# setwd("c:/users/thomas/dropbox/brexitdeservingness/")

# load data
dat <- rio::import("data/LSE_Hobolt_May18_Client.sav")
stopifnot(identical(dim(dat), c(3273L, 62L)))

# Regression analysis: perceived deservingness
stargazer::stargazer(
  # reduced model (only leavers and remainers) with interaction
  lm(opinion ~ identity * condition, data = subset(dat, identity %in% c("A Leav
  type = "tex",
  out = "figures/results-deservingness.tex",
  star.char = c("*"),
  star.cutoffs = c(0.05),
  notes = c("* $p<0.05$"),
  notes.append = FALSE,
  model.numbers = FALSE,
  float = FALSE,
  digits = 2,
  align = TRUE
)
```

One-File-Per-Output

```
# Preference Trial Experiment Analysis
# Thomas J. Leeper
# 2018-06-25
#setwd("C:/Users/Thomas/Dropbox/KnowledgeGaps")

# code
library("car")
library("xtable")
library("GK2011")
source("Analysis/functions.R")

# recoding
source("Analysis/experiment_cleaning.R")

# demographics
source("Analysis/experiment_demographics.R", echo = TRUE)

## Main analysis
source("Analysis/experiment_knowledge.R")

## Appendix
source("Analysis/experiment_appendix.R")
```

What’s missing from these workflows?


data/mtcars.csv
R/table1.R
table/table1.tex
figure/figure1.pdf
R/figure1.R
paper.pdf
paper.tex

make with a makefile

```
all: paper.pdf

figure/figure1.pdf: R/figure1.R data/mtcars.csv
    Rscript R/figure1.R

table/table1.tex: R/table1.R data/mtcars.csv
    Rscript R/table1.R

paper.pdf: paper.tex figure/figure1.pdf table/table1.tex
    pdflatex $<
    pdflatex $<
    bibtex $<
    pdflatex $<
```

Dynamic documents: rmarkdown

1. YAML metadata header

   ```
   ---
   title: My Manuscript
   author: Thomas J. Leeper
   ---
   ```

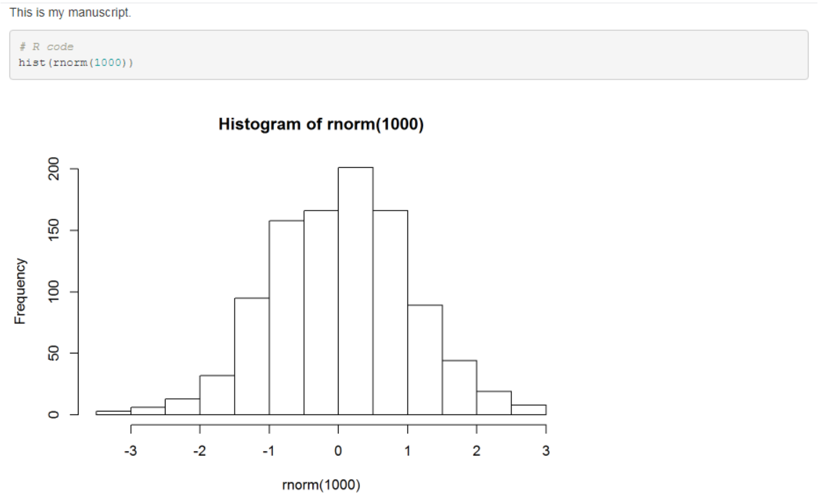
2. Document contents in **markdown**

   ```
   # A header
   ## A subhead
   This is my manuscript, **bold** and *italic*.
   ```

3. Code in “code chunks”:

   ```
   ‘‘‘{r chunk1}
   # R code
   hist(rnorm(1000))
   ‘‘‘
   ```

```
---
- title: My Manuscript
- author: Thomas J. Leeper
- date: 2017-09-21
- output: pdf_document
---

This is my manuscript.

‘‘‘{r chunk1}
# R code
hist(rnorm(1000))
‘‘‘
```



This is my manuscript.

```
# R code
hist(rnorm(1000))
```

What about Stata?

1. ✓Do everything in one file

2. ✓Master file calls code for one-file-per-output

3. ✓make ("code within workflow")

4. ? Nothing as powerful as rmarkdown/knitr

How do you pick a workflow?

- There is no one-size-fits-all workflow!
- Decide what works for you for a given project with particular collaborators
- I use multiple workflows on different projects

Questions?

1 Organizing Things

2 Building Things

3 Keeping and Changing Things

4 Thursday: Hands-On

Activity!

What tools do you use to store, share, and/or archive your research materials?

Keeping things

Three ways of thinking about how you keep and store your research materials:

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    - Going back in time for long-lived projects
    - Verification at publication stage

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    - Collaborating asynchronously

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   - Verification at publication stage
2. Collaborating with others now
   - Collaborating simultaneously
   - Collaborating asynchronously
3. Collaborating with others after you die
   - Future reproducibility requests

Keeping things

Live Collaboration

Other Collaboration

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- Google Docs
- Overleaf
- Dropbox/Box/etc.
- Email?

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Other Collaboration

- Active project: Version control (git)
- Backup: Dropbox, GDrive, S3, Github

Keeping things

Live Collaboration

- Google Docs
- Overleaf
- Dropbox/Box/etc.
- Email?

Other Collaboration

- Active project: Version control (git)
- Backup: Dropbox, GDrive, S3, Github
- Archiving: Dataverse, Zenodo, Figshare, OSF

Git

- Git is “an open-source distributed version control system”
- Developed in 2005 by Linus Torvalds
- Widely used in software development world

Why use Git for reproducibility?

Why use Git for reproducibility?

- Helps you keep and *annotate* snapshots of your project over time
  - Better than renaming your files all the time
  - Better than using within-file VCS (e.g., Word)
  - Better than single-stream sharing (e.g., Dropbox)

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  - Better than single-stream sharing (e.g., Dropbox)
- Facilitates collaboration (incl. with future you)
- It's FOSS with lots of clients, tools, and community support
  - Widely used in software development world

Version Control as Organization

- Version control helps you stay organized

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    1. What's important to keep around?

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- Think "tracked changes" for all of your files
    - Save history of changes/versions

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    1. What's important to keep around?
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    3. What is all this crap?
- Think "tracked changes" for all of your files
    - Save history of changes/versions
    - Experiment non-destructively
    - Collaborate
- You're probably already version controlling informally!

Learning Objectives

1. Understand how to organize a reproducible research project
2. Recognize different approaches to reproducibility and tools for implementing various reproducible workflows
3. Th: Apply various workflows to your own work
4. Th: Understand how to collaborate reproducibly

Key Takeaways

- Once you work reproducibly, you'll never want to go back to your old workflow

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- "Advanced" workflows (e.g., make, git) get complicated — StackOverflow is your friend
- Collaborators probably don't know how to (or want to) use these tools

Key Takeaways

- Once you work reproducibly, you'll never want to go back to your old workflow
- "Advanced" workflows (e.g., make, git) get complicated — StackOverflow is your friend
- Collaborators probably don't know how to (or want to) use these tools
- Reproducibility is selfish first and for science second!

Questions?

1. Organizing Things

2. Building Things

3. Keeping and Changing Things

4. Thursday: Hands-On

5 Hands-On

- Introductory Git
- Git Branches & History
- Collaborating with Git
- Intermediate Git
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Goal of Hands-On Practice

1. Work together on migrating a workflow
2. Dig through replication archives
3. Work individually or in pairs on making workflow more reproducible

Let's vote: What should we do?

Using Git

- Git create a “local repository” file that you can interact with using a number of tools
  - Command-line `git`
  - Git Bash
  - Git GUI
  - GitHub Desktop
  - RStudio (via “Projects”)
  - GitHub/Bitbucket/GitLab web interfaces
  - Gitkraken
  - git2r (R package)
  - …

Initializing a Project Structure

- There’s no single best way to organize a project
- But, some words of wisdom:
  - Put like with like
  - Avoid excessive hierarchy
  - Not everything needs to go into git
  - Steal others’ structures!

```
git --version
git
git config --global user.name "My Name"
git config --global user.email "me@example.com"
git config --list
git init
git status
echo Hello world! > README.md
git add README.md
git status
git rm --cached README.md
git status
git add --all
git commit -m "my first commit!"
git status
git log
```

Git Essentials

1. **stage**
2. `commit`
3. `branch`
4. `merge`
5. `push` and `pull`

Git Essentials

1. **stage**
    - `add`/**stage**: select files to be recorded in a "snapshot" of the project
    - `rm`/**unstage**: remove files from the snapshot (but not from your computer)
2. `commit`
3. `branch`
4. `merge`
5. `push` and `pull`

Git Essentials

1. **stage**
2. `commit`
    - **commit**: record a permanent snapshot of the staged files, labelled with a “commit message”
    - **amend**: modify (typically the most recent) commit with new changes or commit message
3. `branch`
4. `merge`
5. `push` and `pull`

Git Essentials

1. **stage**
2. `commit`
3. `branch`
   - produce a complete *local* copy of the project where changes can be made independently of the “master” branch
4. `merge`
5. `push` and `pull`

Git Essentials

1. **stage**
2. `commit`
3. `branch`
4. `merge`
   - update a branch with changes from another local branch (or a remote); you can change multiple branches independently.
5. `push` and `pull`

Git Essentials

1. **stage**
2. `commit`
3. `branch`
4. `merge`
5. `push` and `pull`
    - **push**: send the project (any new commits) to a remote server (like GitHub)
    - **pull**: grab new commits from a remote server

Git Essentials

1. **stage**
2. `commit`
3. `branch`
4. `merge`
5. `push` and `pull`

90% of What You Need

- `git add` (stage) or `git rm` (unstage)
- `git commit`
- `git status`
- `git log`
- `git remote`
    - `git push`
    - `git pull`
- `git branch`
    - `git merge`

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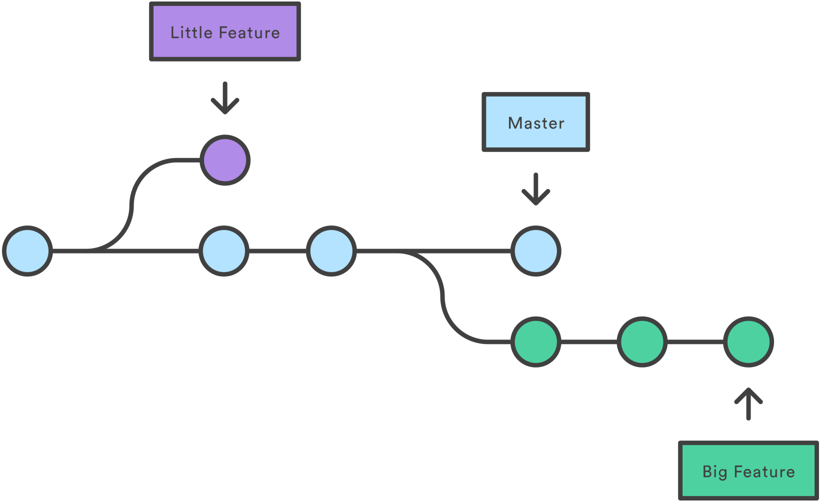
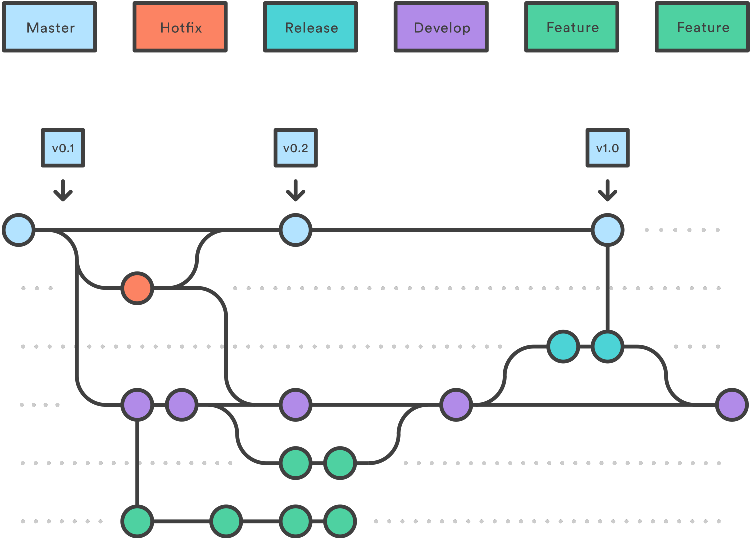
Branches

- Branches are local, parallel versions of your entire project
- Useful for multiple things:
  - Experimentation
  - Manuscript submissions
  - Collaboration



Source: `https://www.atlassian.com/git/tutorials`



Source: `https://www.atlassian.com/git/tutorials`

Simple branch and merge

```
git status
git checkout -b thomas
git status
# do something
git add --all
git commit -m "thomas's commit"
git checkout master
git branch
git log --graph --oneline
git merge thomas
```

GUIs

- You can do everything in Git on the command line
- GUIs can be helpful for:
    - Exploring history
    - Visualizing branches
    - Confirming what you're doing

Merge conflicts

```
git checkout -b thomas
git status
# do something to README.md
git add --all
git commit -m "change on thomas"
git checkout master
# do something to README.md
git add --all
git commit -m "change on master"
git merge thomas
git log
```

Navigating History

```
git status
git log
git checkout <commit hash>
git status
ls
cat README.md
git checkout master
git status
git log
git checkout <commit hash>
git status
ls
echo aaaaaah!>manuscript.txt
git checkout master
```

Remotes

- A server ("cloud") instance of the Git repository
- Useful for multiple things:
  - Collaboration
  - Transparency
  - Archiving/backups
  - Using web-based Git interfaces

Remotes

- Three major players in cloud Git
  - GitHub
  - Atlassian Bitbucket
  - GitLab
- Why choose one or the other?
  - Cost
  - Collaborators
  - Private repositories

```
git status
git remote add github
https://github.com/leeper/rt2
git remote
git remote set-url
git remote rename
git remote remove
git status
git push github master -u
git fetch github
git fetch github master
git checkout -b new-idea
git push github new-idea
git checkout master
git pull github master
git pull
```

```
git status
git tag -a v0.0.1 -m "v0.0.1"
git push --tags

git tag -d v0.0.1
```

Tags versus Branches

- *Branches* are for working versions of project
    - Collaborator-specific branches
    - Submission-specific branches
    - Experimental or “bug fix” branches
- *Tags* are for marking particular snapshots
    - Significant moments in project history
    - Journal submission or conference version
    - Formal “releases”

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Collaboration

- Technical aspects
  - Give collaborators access on GitHub (or wherever)
  - Work on separate branches
  - Merge agreed changes into **master**
- Human factors aspects
  - Requires agreeing on workflow
  - Communication about what goes in “master”
  - Can feel awkward if moving from a Dropbox- or email-based collaboration style

Try it with a partner!

1. Partner A create a GitHub repo; give Partner B access
2. Partner B should `git fetch`/`git pull` the repo
3. Partner B should create a local branch and `git push`
4. Partner A should `git fetch` the branch
5. Partner A should `git merge` the branch to **master** and `git push`
6. Partner B should `git pull` from **master**
7. Both use `git log` to compare

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```
git status
git diff README.md
git diff HEAD README.md
git diff HEAD˜1 README.md
git diff HEAD˜2 README.md
git diff HEAD˜3 README.md
git diff HEAD˜20 README.md
git diff <commit hash> README.md
git diff <commit hash>
```

!! DANGER: Amend Commit !!

```
git status
git log --oneline
# maybe add/rm files
git amend
# enter the hell of vim
```

```
git config --global core.editor
"<executable> <options>"
```

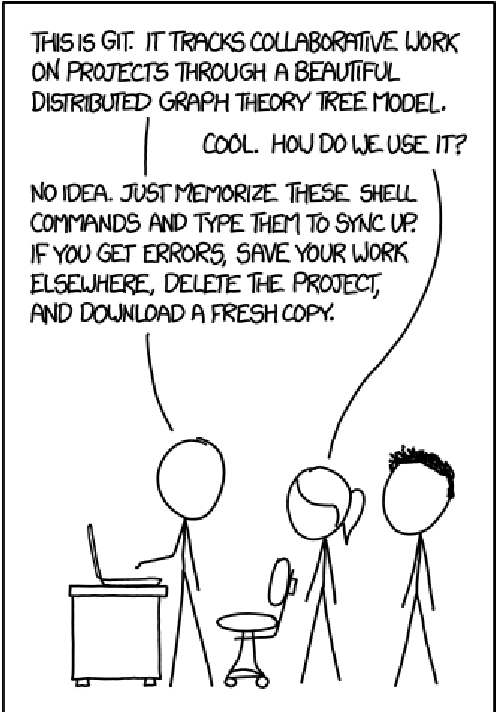
Safe reversion

```
git status
git log --oneline
git revert <commit hash>
# enter the hell of vim
# or something else terrible
git revert --abort
```

!! DANGER: Unsafe reversion !!

The StackOverflow Question

```
git status
echo "bad bad bad" > bad.txt
git status
echo bad.txt > .gitignore
git status
echo bad bad bad > bad1.txt
echo bad bad bad > bad2.txt
echo bad* > .gitignore
git status
git add bad1.txt -f
git status
```


THIS IS GIT. IT TRACKS COLLABORATIVE WORK ON PROJECTS THROUGH A BEAUTIFUL DISTRIBUTED GRAPH THEORY TREE MODEL.
COOL. HOW DO WE USE IT?
NO IDEA. JUST MEMORIZE THESE SHELL COMMANDS AND TYPE THEM TO SYNC UP. IF YOU GET ERRORS, SAVE YOUR WORK ELSEWHERE, DELETE THE PROJECT, AND DOWNLOAD A FRESH COPY.

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Rmarkdown

1. YAML metadata header

```
---
title: My Manuscript
author: Thomas J. Leeper
---
```

2. Document contents in **markdown**

```
# A header
## A subhead
This is my manuscript, **bold** and *italic*.
```

3. Code in “code chunks”:

```
‘‘‘{r chunk1}
# R code
hist(rnorm(1000))
‘‘‘
```

```
---
- title: My Manuscript
- author: Thomas J. Leeper
- date: 2017-09-21
- output: pdf_document
---

This is my manuscript.

‘‘‘{r chunk1}
# R code
hist(rnorm(1000))
‘‘‘
```

Markdown Basics

Markdown is a very simple markup language for formatting simple texts:

italics	*italics*
bold	**bold**
‘preformatted‘	`preformatted`
# Heading	Heading Level 1
## Heading	Heading Level 2
### Heading	Heading Level 3
[link](https://google.com)	link

Chunk Options

```
‘‘‘{r chunk1, eval=TRUE, echo=TRUE}
2 + 2
‘‘‘

‘‘‘{r chunk2, eval=TRUE, echo=FALSE}
2 + 2
‘‘‘

‘‘‘{r chunk3, echo=FALSE, results="hide"}
2 + 2
‘‘‘
```

Global Chunk Options

```
‘‘‘{r options, eval = TRUE, echo = FALSE}
library("knitr")
opts_chunk$set(echo = FALSE,
               cache = TRUE,
               message = FALSE)
‘‘‘
```

Basic Tables

```
‘‘‘{r table1, results = "asis"}
xtable::xtable(table(mtcars$cyl, mtcars$gear))

knitr::kable(head(mtcars))
‘‘‘
```

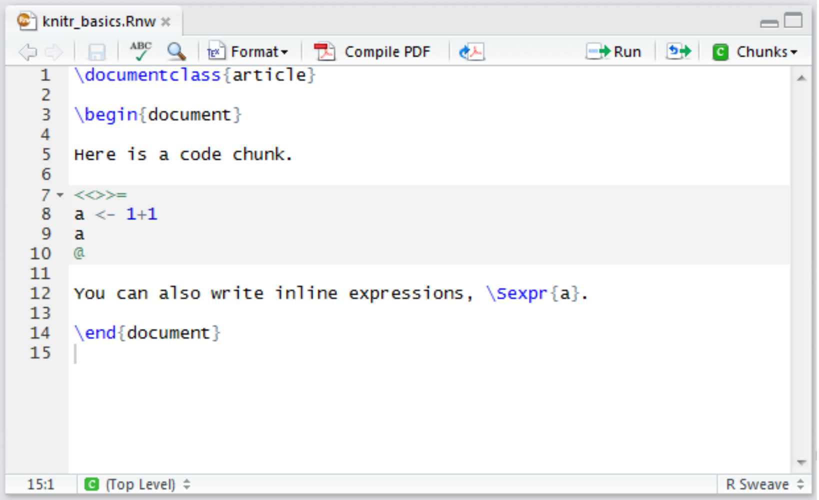
Regression Results Tables

```
‘‘‘{r table2, results = "asis"}
library("stargazer")
stargazer(
  x1 <- lm(mpg ~ disp + wt,
           data = mtcars),
  x2 <- lm(mpg ~ disp + wt + vs,
           data = mtcars),
  header = FALSE
)
‘‘‘
```

Figures

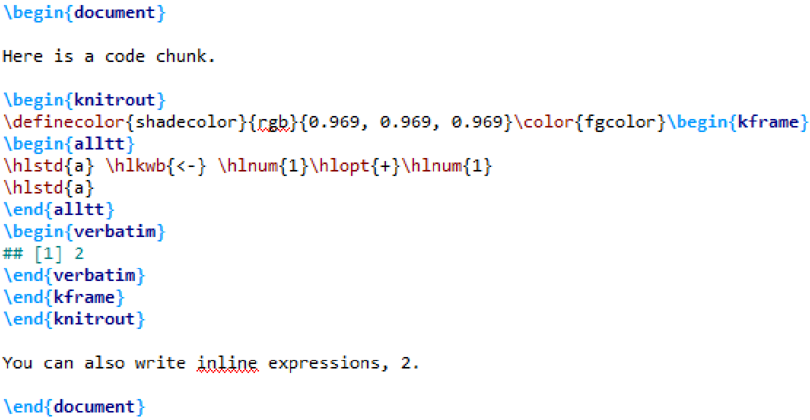
```
‘‘‘{r fig1,
    fig.cap = "Fuel Economy by Weight",
    fig.height = 4,
    fig.width = 6}
library("ggplot2")
ggplot(mtcars,
    aes(x = wt,
        y = mpg,
        colour = factor(cyl))) +
  geom_point()
‘‘‘
```

You can work in LaTeX, too!



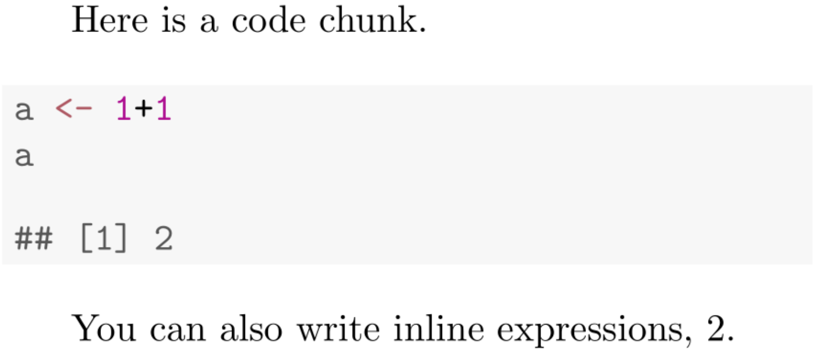
```
\documentclass{article}

\begin{document}

Here is a code chunk.

<<>>=
a <- 1+1
a
@

You can also write inline expressions, \Sexpr{a}.

\end{document}

```

You can work in LaTeX, too!



```
\begin{document}

Here is a code chunk.

\begin{knitrout}
\definecolor{shadecolor}{rgb}{0.969, 0.969, 0.969}\color{fgcolor}\begin{kframe}
\begin{alltt}
\hlstd{a} \hlkwb{<-} \hlnum{1}\hlopt{+}\hlnum{1}
\hlstd{a}
\end{alltt}
\begin{verbatim}
## [1] 2
\end{verbatim}
\end{kframe}
\end{knitrout}

You can also write inline expressions, 2.

\end{document}
```

You can work in LaTeX, too!



Here is a code chunk.

```
a <- 1+1
a

## [1] 2
```

You can also write inline expressions, 2.

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makefiles

```
all: <final-target>

<target-1>: <source-file> <source-file>
    <script to produce target from source-file(s)>

<target-2>: <source-file> <target-1>
    <script to produce target from source-file(s)>
```