

Workshop Series

Open Science Skills in R

Brought to you by

Christelinda Laureijs

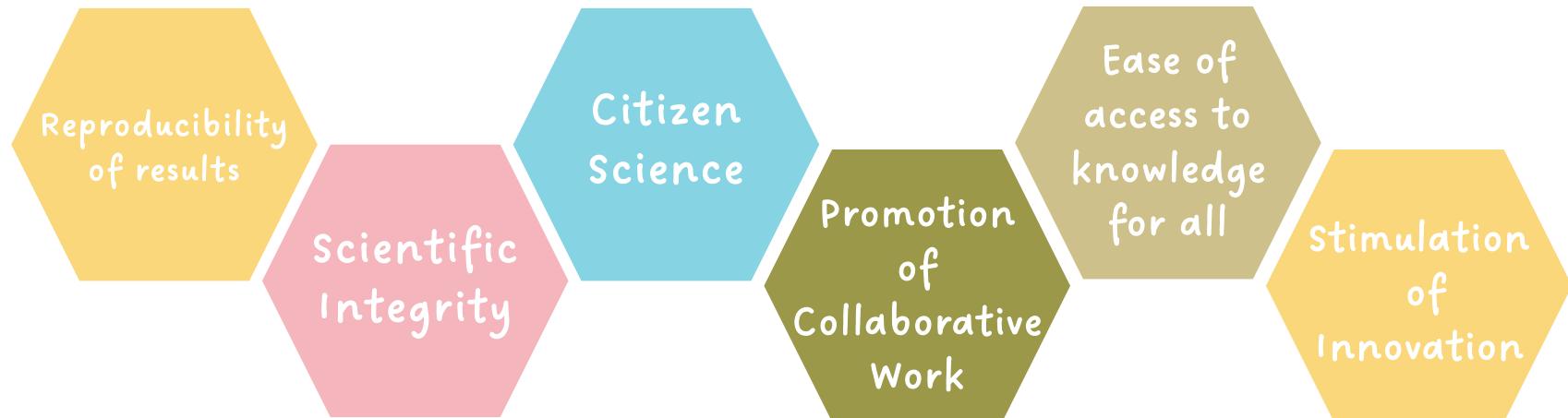
Julia Riley

Elizabeth Stregger

What is Open Science?

The process of making the content and process of producing evidence and claims transparent and accessible to others.

SUPPORTS:



Munafo et al. 2017

About this Workshop Series

THE LEADERS



Christelinda Laurejis

M.Sc. Candidate
in Biology



Elizabeth Stregger

Data and Digital
Services Librarian



Dr. Julia Riley

Assistant
Professor

We all love coding in R and open science!!!

About this Workshop Series

THE SERIES

Wednesdays from 5-6:30 PM in AVDX G10

Workshop # 1

29 Jan 2025

Welcome & Being Tidy

Dr. Riley

Workshop # 2

5 Feb 2025

Git with it!

Elizabeth Stregger

Workshop # 3

12 Feb 2025

Science Writing in R
Christelinda Laurejis

About this Workshop Series

WHAT CAN YOU EXPECT?

1

Welcome & Being Tidy

2

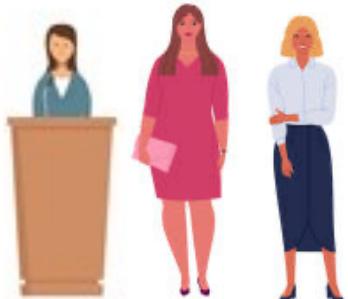
Git with it!

3

Science Writing in R

Both a mix of lecture and activities.

- 45 min hybrid lecture
- 45 min in-person activity



One person will lead each workshop, and the two others will be "floaters". If you have an issue or question, put a **RED** post-it note on top of your laptop. Floaters will be by to help you out!

Open Science Skills in R - A Workshop Series

Welcome to R & Tidy Practices for Reproducibility



R comics by Allison Horst

Let's Get Set Up in R

OUR SOFTWARE TOOLKIT FOR THESE WORKSHOPS



Excel
(or other spreadsheet
software)



R Software

- Open-source statistical programming language
- Also an environment for statistical computing and graphics that is easily extendable using packages

Let's Get Set Up in R

OUR SOFTWARE TOOLKIT FOR THESE WORKSHOPS



R Studio

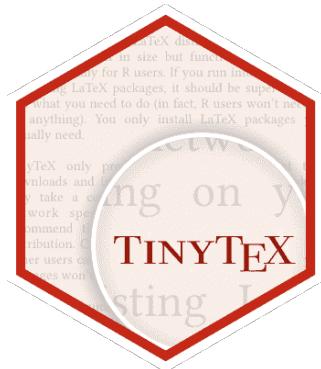
- R Studio is a convenient interface for R called an IDE (integrated development environment; e.g., "I write R code in the R Studio IDE")
 - It is not a requirement for programming with R, but it is very commonly used by data scientists

depending on your operating system you also may need to download..

R Tools

Let's Get Set Up in R

OUR SOFTWARE TOOLKIT FOR THESE WORKSHOPS



- This facilitates creation of PDF documents in R

RESTART

Let's Get Set Up in R

OUR SOFTWARE TOOLKIT FOR THESE WORKSHOPS



tinytex

- This facilitates creation of PDF documents in R

RESTART



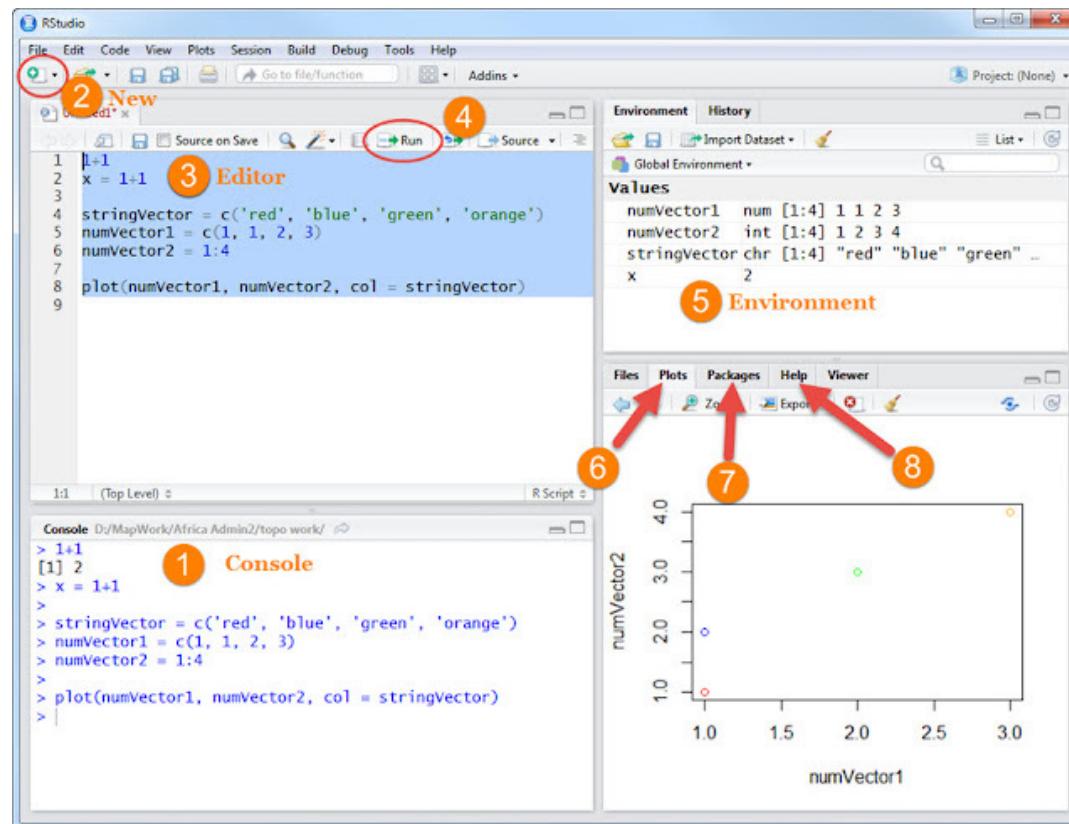
A variety of R Packages

These are the fundamental units of reproducible R code that are made up of functions, documentation on how to use them, and sample data.

Whickham and Bryan 2021



Quick Tour of RStudio



Introducing Rmarkdown

- rmarkdown and the packages that support it enable R users to write their code and prose in reproducible computational documents
- We will generally refer to R Markdown documents (with .Rmd extension; e.g., “*Do this in your R Markdown document*”) and rarely discuss loading this package



www.rmarkdown.rstudio.com

Why are we using Rmarkdown?



- rmarkdown can be easily used to generate fully reproducible reports – each time you 'knit' the document the analysis is run from the beginning



Why are we using Rmarkdown?

- rmarkdown can be easily used to generate fully reproducible reports – each time you ‘knit’ the document the analysis is run from the beginning

WAIT! What is reproducibility?

Reproducible =
Same result can be
independently reached given
the same data and analytical
pipeline

Replicable =
Same result can be reached
given a different,
independent data and
analytical pipeline

— Why do we care about reproducibility? —

- Ethical; science is a public good
 - Maximizes translation and utility of your work
 - Sets your science on a strong foundation that works against fraud & retraction
 - Huge practical benefits for collaboration
 - Easier to share and reuse your work
 - Mistakes are easier to find
 - Analyses and manuscripts easier to update
 - Minimizes duplication of your efforts
-

Back to Rmarkdown: Tour & Tips

The screenshot shows the RStudio interface with an R Markdown file named "bechdel.Rmd" open in the left pane. The code is written in R and includes YAML front matter and a code chunk. The right pane shows the rendered HTML output. Handwritten annotations with colored arrows point to specific elements:

- A yellow arrow points to the "Knit" button in the toolbar, labeled "knit".
- A green arrow points to the link in the YAML front matter, labeled "link".
- A pink arrow points to the code chunk in the R code, labeled "code chunk".
- A red arrow points to the "yaml" text in the YAML front matter, labeled "yaml".

YAML Front Matter:

```
1 ---  
2 title: "Bechdel"  
3 author: "Mine Çetinkaya-Rundel"  
4 output:  
5   html_document:  
6     fig_height: 4  
7     fig_width: 9  
8 ---
```

Code Chunk:

```
10 In this mini analysis we work with the data used  
11 in the FiveThirtyEight story titled [ "The  
12 ## Data and packages  
13  
14 We start with loading the packages we'll use.  
15  
16 ```{r load-packages, message=FALSE}  
17 library(fivethirtyeight)  
18 library(tidyverse)  
19 ...
```

R Markdown Output:

Bechdel

Mine Çetinkaya-Rundel

In this mini analysis we work with the data used in the FiveThirtyEight story titled ["The Dollar-And-Cents Case Against Hollywood's Exclusion of Women"](<https://fivethirtyeight.com/features/the-dollar-and-cents-case-against-hollywoods-exclusion-of-women/>). Your task is to fill in the blanks denoted by ____.

Data and packages

We start with loading the packages we'll use.

```
library(fivethirtyeight)  
library(tidyverse)
```

The dataset contains information on 1794 movies released between 1970 and 2013. However we'll focus our analysis on movies released between 1990 and 2013.

```
bechdel190_13 <- bechdel %>%  
  filter(between(year, 1990, 2013))
```

There are ____ such movies.

The financial variables we'll focus on are the following:

- budget_2013 : Budget in 2013 inflation adjusted dollars
- domgross_2013 : Domestic gross (US) in 2013 inflation adjusted dollars
- intgross_2013 : Total International (i.e. worldwide) gross in 2013 inflation adjusted dollars

From Data Science in a Box by Dr. Çetinkaya-Rundel

— Back to Rmarkdown: Tour & Tips —

Simple R markdown syntax for writing text:

Input:

This is a sentence in R Markdown, containing `code`,
bold text, and *italics*.

Output:

This is a sentence in R Markdown, containing **code**, **bold text**, and *italics*.

— Back to Rmarkdown: Tour & Tips —

Code is placed in 'chunks', defined by three backticks,
and the narrative goes outside of those 'chunks':

Input:

The function 'rnorm()' creates normal variates.

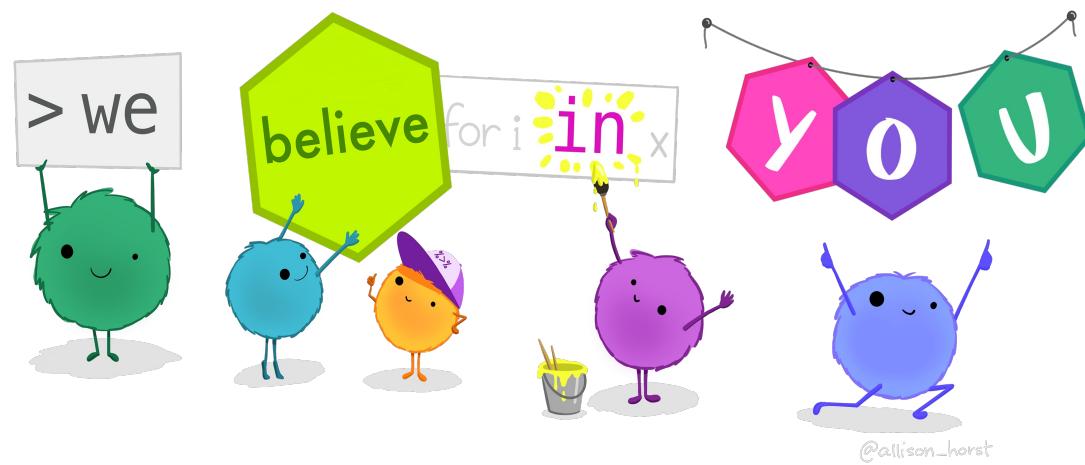
```
```{R}  
rnorm(5) # creates 5 normal variates
```
```

Output:

The function `rnorm()` creates normal variates.

```
rnorm(5) # creates 5 normal variates  
[1] 1.1281735 1.7376142 0.7629712 1.1308147 0.9969855
```

Any Questions?



TIDY PRACTICES

for efficiency, reproducibility, & collaboration

“Tidy” organized projects are
the foundation of
reproducible, efficient, and
open science!



- Tidy projects
- Tidy code
- Tidy data

What is a Tidy Project?



| R transect | | | |
|--|---------------------|--------|----------------|
| Name | Date Modified | Size | Kind |
| function for plotting outlines.R | 22/04/2013 1:44 PM | 4 KB | R Source File |
| area_output_example2222.csv | 22/04/2013 1:44 PM | 15 KB | comm...values |
| area_output_example.csv | 22/04/2013 1:41 PM | 15 KB | comm...values |
| image_outlines_complete | 22/04/2013 1:40 PM | -- | Folder |
| area_output_march13.txt | 22/04/2013 1:27 PM | 13 KB | Plain...ument |
| outlines_area_calculations (#1) function.R | 22/04/2013 11:58 AM | 4 KB | R Source File |
| LIZARD 1_COMPLETE | 18/04/2013 11:58 AM | -- | Folder |
| database_previous_versions | 18/04/2013 11:52 AM | -- | Folder |
| Concept sheets | 18/04/2013 11:51 AM | -- | Folder |
| area_output.csv | 17/04/2013 4:16 PM | 15 KB | comm...values |
| sc_database_areas.csv | 17/04/2013 4:14 PM | 46 KB | comm...values |
| fragmentation w histograms.pdf | 03/04/2013 9:02 AM | 364 KB | Portab...(PDF) |
| summary plots and glms.docx | 02/04/2013 4:04 PM | 1.5 MB | Micro...ument |
| outlines_area_calculations (#1).R | 28/03/2013 4:16 PM | 4 KB | R Source File |
| outline_files | 28/03/2013 3:16 PM | -- | Folder |
| area_script_current.R | 14/03/2013 11:46 AM | 11 KB | R Source File |
| size histograms 1989-1992.pdf | 14/03/2013 10:56 AM | 329 KB | Portab...(PDF) |
| sc_database_areas_march13.txt | 13/03/2013 7:55 AM | 27 KB | Plain...ument |
| do corals lie about their age.pdf | 27/02/2013 8:27 AM | 2.1 MB | Portab...(PDF) |
| Fitting a power model.R | 21/02/2013 3:55 PM | 2 KB | R Source File |
| R scripts for maps | 20/02/2013 9:45 AM | -- | Folder |
| trial_photos_outline_maps | 20/02/2013 8:24 AM | -- | Folder |
| Technical note/ Cu...g pdfkeywords.pdf | 19/02/2013 10:55 AM | 396 KB | Portab...(PDF) |
| old files | 15/02/2013 6:08 PM | -- | Folder |
| trial outline files_first files | 13/02/2013 8:53 AM | -- | Folder |
| image_data | 05/02/2013 1:54 PM | -- | Folder |
| images | 05/02/2013 1:53 PM | -- | Folder |

What is a Tidy Project?



my_research_project



README.md



data



analysis



writing



literature

THREE GUIDELINES

1. Make it self-contained
2. Create a consistent, sensibly-named directory structure
3. Include a README file that includes information about the layout and contents of your project

What is a Tidy Project?

ANOTHER EXAMPLE

- **informative_project_name**

- **README.txt** (a text file at the top-level of the directory that outlines the broad structure/details of the project)
- **/data** (raw data, such as images, videos, datasheets, as well as the processed products for analysis)
- **/doc** (all notes and the draft manuscript associated with the project)
- **/figs** (figures to be included in the manuscript, typically generated via code)
- **/output** (items generated from data handling and analysis, like tables of statistical results, which can be regenerated at any time)
- **/code** (code for processing and analysing data)

TIDY PROJECT

ACTIVITY # 1

Together, let's work through how to create a new R Project and set it up for taking notes on workshop discussions/activities.

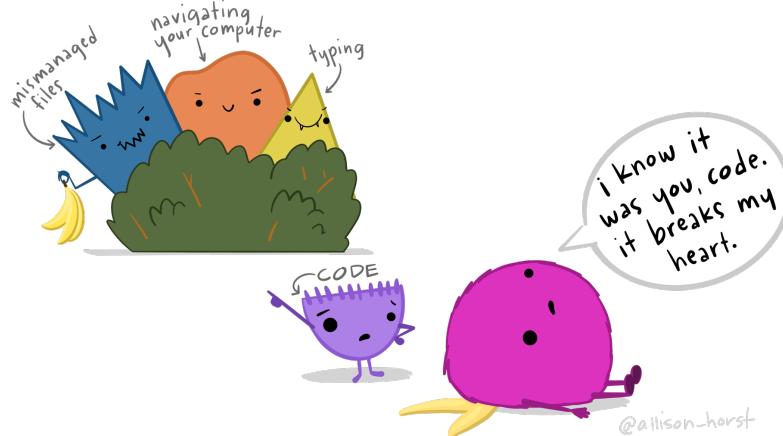
DISCUSSION

- 1) Who is a stakeholder that may have an interest in outcomes of your research (aka. who will benefit from open science)?
- 2) What is one positive and one negative consequence of conducting open, reproducible research? Let's discuss.

TIDY PROJECTS

ACTIVITY # 2

Create a tidy project template for a research project. Do this in Rmarkdown and make use of their 'list' syntax to keep it clear.



Four Steps to Tidy Code

1) Choose good names and be consistent

Good:

```
dat_mass_2020 <- read.csv('2020_field_data_mass.csv')
```

Less good (maybe):

```
dat_field <- read.csv('2020_field_data_mass.csv')
```

Bad:

```
dat <- read.csv('2020_field_data_mass.csv')
```

Four Steps to Tidy Code

- 1) Choose good names and be consistent
- 2) Write human-readable code

Space it out

Good:

```
height <- cm * 6 + mm  
mean(x, na.rm = TRUE)
```

Bad:

```
height<-cm*6+mm  
mean (x,na.rm=TRUE)
```

Four Steps to Tidy Code

- 1) Choose good names and be consistent
- 2) Write human-readable code

Space it out

Good:

```
do_something_complicated(  
    something = "that",  
    requires = many,  
    arguments = "that are very long"  
)
```

Bad:

```
do_something_complicated("that", needs, many, arguments, "that are very long")
```

Four Steps to Tidy Code

- 1) Choose good names and be consistent
- 2) Write human-readable code
- 3) Make use of your Tidy Project set-up

Use relative file paths, never absolute.

- Forget `setwd()` ever existed
- Assume the file is being run from the folder it is sitting in
 - Use paths *relative* to that

Four Steps to Tidy Code

- 1) Choose good names and be consistent
- 2) Write human-readable code
- 3) Make use of your Tidy Project set-up

Use relative file paths, never absolute.

Bad

```
data <- read.csv('C:/juliascomupter/projects/toadexp/data/behaviour_data.csv')
```

- Won't run on any computer
- Also won't run on ANY computer if I move the file or change the path to it!

Four Steps to Tidy Code

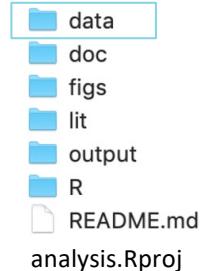
- 1) Choose good names and be consistent
- 2) Write human-readable code
- 3) Make use of your Tidy Project set-up

Use relative file paths, never absolute.

Good

```
data <- read.csv("my_project/data/behaviour_data.csv")
```

▶ my_project



Four Steps to Tidy Code

- 1) Choose good names and be consistent
- 2) Write human-readable code
- 3) Make use of your Tidy Project set-up
- 4) Keep it well-styled and use help

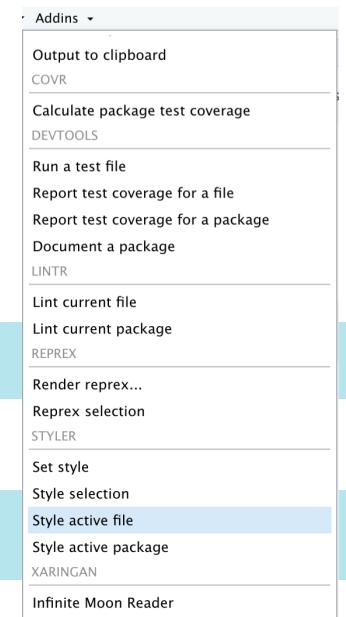
R package - styler

Before

```
height<-cm*6+mm+2; mean(x,na.rm=TRUE)
```

After

```
height <- cm * 6 + mm + 2  
mean(x, na.rm = TRUE)
```



TIDY CODE

ACTIVITY

In the Rmarkdown file for this workshop, please work through the activity using the R package [styler](#).

What is different about the code after it is reformatted using [styler](#)?

What is Tidy Data?

“**TIDY DATA** is a standard way of mapping the meaning of a dataset to its structure.”

—HADLEY WICKHAM

In tidy data:

- each variable forms a column
- each observation forms a row
- each cell is a single measurement

each column a variable

| id | name | color |
|----|--------|--------|
| 1 | floof | gray |
| 2 | max | black |
| 3 | cat | orange |
| 4 | donut | gray |
| 5 | merlin | black |
| 6 | panda | calico |

each row an observation

Whickham 2014; Lowndes and Horst 2020

An Example



How could we tidy this messy data?

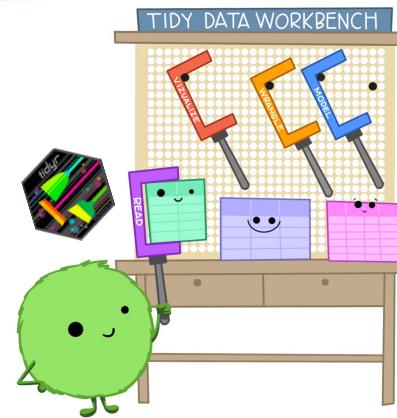
| religion | <\$10k | \$10-20k | \$20-30k | \$30-40k | \$40-50k | \$50-75k |
|-------------------------|--------|----------|----------|----------|----------|----------|
| Agnostic | 27 | 34 | 60 | 81 | 76 | 137 |
| Atheist | 12 | 27 | 37 | 52 | 35 | 70 |
| Buddhist | 27 | 21 | 30 | 34 | 33 | 58 |
| Catholic | 418 | 617 | 732 | 670 | 638 | 1116 |
| Don't know/refused | 15 | 14 | 15 | 11 | 10 | 35 |
| Evangelical Prot | 575 | 869 | 1064 | 982 | 881 | 1486 |
| Hindu | 1 | 9 | 7 | 9 | 11 | 34 |
| Historically Black Prot | 228 | 244 | 236 | 238 | 197 | 223 |
| Jehovah's Witness | 20 | 27 | 24 | 24 | 21 | 30 |
| Jewish | 19 | 19 | 25 | 25 | 30 | 95 |

| religion | income | freq |
|----------|--------------------|------|
| Agnostic | <\$10k | 27 |
| Agnostic | \$10-20k | 34 |
| Agnostic | \$20-30k | 60 |
| Agnostic | \$30-40k | 81 |
| Agnostic | \$40-50k | 76 |
| Agnostic | \$50-75k | 137 |
| Agnostic | \$75-100k | 122 |
| Agnostic | \$100-150k | 109 |
| Agnostic | >150k | 84 |
| Agnostic | Don't know/refused | 96 |

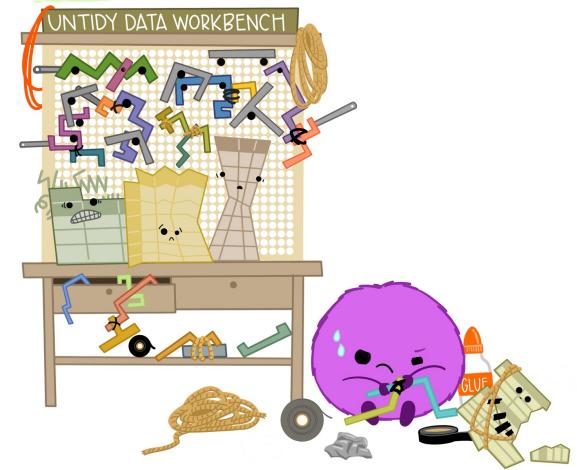
Why use a TIDY format?

1) Allows you to be more efficient

When working with tidy data,
we can use the **same tools** in
similar ways for different datasets...



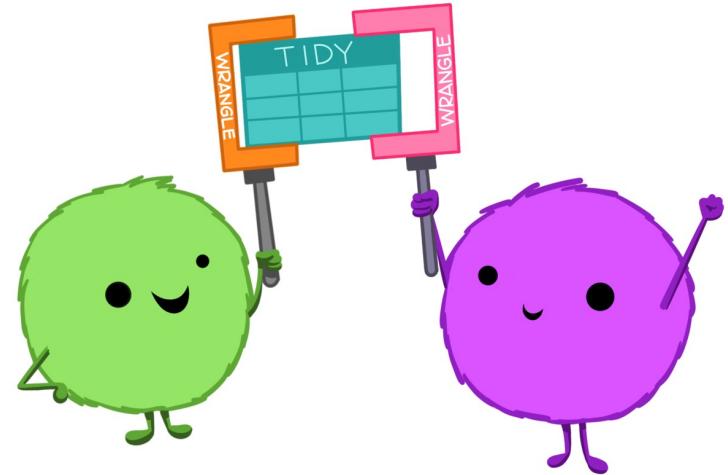
...but working with untidy data often means
reinventing the wheel with **one-time
approaches** that are hard to iterate or reuse.



Whickham 2014; Lowndes and Horst 2020

Why use a TIDY format?

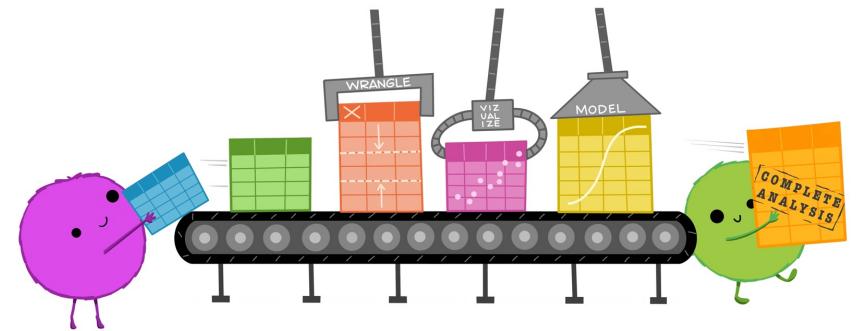
- 1) Allows you to be more efficient
- 2) Easier to collaborate because it is known what to expect & can make use of the same tools



Whickham 2014; Lowndes and Horst 2020

Why use a TIDY format?

- 1) Allows you to be more efficient
- 2) Easier to collaborate because it is known what to expect & can make use of the same tools
- 3) Makes it easier to reproduce analyses



Whickham 2014; Lowndes and Horst 2020

Seven Tips to Keep Data Tidy

- Use plain text

Versions across the ages...

| <u>Microsoft Excel</u> | <u>Text</u> |
|------------------------|-------------|
| .xls | .txt |
| .xlt | |
| .xlm | |
| .xlam | |
| .xltm | |
| .xlsx | |
| | ... |

Seven Tips to Keep Data Tidy

- Use plain text

Types of Text File

.csv – Comma-separated values. Great all-purpose format.

.txt or **.tsv** – Plain-text/tab-delimited. Future proof.

Can all be opened with anything/anywhere.

Seven Tips to Keep Data Tidy

- Use plain text
- Choose good names

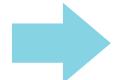
Messy
myabstract.docx
Julia's best ideas.docx
figure 1.png
newNEWv2_dontdelete_forREAL.xlsx
FINALfinal_v2_5.xlsx

Tidy
2020_abstract_hons_conf.docx
julias_ideas.docx
fig_01_scatterplot_length_width.png
2019-08-07_raw_data_hons.xlsx

Seven Tips to Keep Data Tidy

- Use plain text
- Choose good names

These are: machine-readable



Don't use: Special characters or
formatting

! @ # \$ % ^ & * () ~ + =

Do use: Underscores and dashes
for separating_metadata and
splitting-up-words

Seven Tips to Keep Data Tidy

- Use plain text
- Choose good names

These are: machine-readable

human-readable



Make sure that names contain information about **content**

Nay: `data_1.csv`

Yay: `2020-08-09_field-data_morphology.csv`

Seven Tips to Keep Data Tidy

- Use plain text
- Choose good names

These are: machine-readable
human-readable
nicely ordered



Think about how your file names will sort.

Chronological

2020-08-09_field-data_morphology.csv

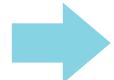
2020-08-12_field-data_morphology.csv

2020-08-18_field-data_morphology.csv

Seven Tips to Keep Data Tidy

- Use plain text
- Choose good names

These are: machine-readable
human-readable
nicely ordered



Think about how your file names will sort.

Logical

01_load_functions.R
02_clean_data.R
03_analysis.R

Seven Tips to Keep Data Tidy

- Use plain text
- Choose good names
- No empty cells or special characters!

More questions than answers!

| cow_ID | milk_volume | weight |
|---------|-------------|--------|
| moo | 12 | 1100 |
| bumbo | 2 | 1201 |
| spot | ? | 1084 |
| jeffrey | | 1044 |
| holy | 16 | 1244 |
| daisy | - | 1093 |

Seven Tips to Keep Data Tidy

- Use plain text
- Choose good names
- No empty cells or special characters!

So, use NA if NA or 0 if 0.

| cow_ID | milk_volume | weight |
|---------|-------------|--------|
| moo | 12 | 1100 |
| bumbo | 2 | 1201 |
| spot | NA | 1084 |
| jeffrey | 0 | 1044 |
| holy | 16 | 1244 |
| daisy | 0 | 1093 |

Seven Tips to Keep Data Tidy

- Use plain text
- Choose good names
- No empty cells or special characters!
- Use metadata (aka. a data dictionary)

DATA

| employee_id | first_name | last_name | nin | department_id |
|-------------|------------|------------|---------------|---------------|
| 44 | Simon | Martinez | HH 45 09 73 D | 1 |
| 45 | Thomas | Goldstein | SA 75 35 42 B | 2 |
| 46 | Eugene | Comelsen | NE 22 63 82 | 2 |
| 47 | Andrew | Petculescu | XY 29 87 61 A | 1 |
| 48 | Ruth | Stadick | MA 12 89 36 A | 15 |
| 49 | Barry | Scardelis | AT 20 73 18 | 2 |
| 50 | Sidney | Hunter | HW 12 94 21 C | 6 |
| 51 | Jeffrey | Evans | LX 13 26 39 B | 6 |
| 52 | Doris | Bemdt | YA 49 88 11 A | 3 |
| 53 | Diane | Eaton | BE 08 74 68 A | 1 |
| 54 | Bonnie | Hall | WW 53 77 68 A | 15 |
| 55 | Taylor | Li | ZE 55 22 80 B | 1 |

Seven Tips to Keep Data Tidy

METADATA

| Column | Data Type | Description |
|-----------------------|--------------|---|
| employee_id | int | Primary key of a table |
| first_name | nvarchar(50) | Employee first name |
| last_name | nvarchar(50) | Employee last name |
| nin | nvarchar(15) | National Identification Number |
| position | nvarchar(50) | Current position title, e.g. Secretary |
| department_id | int | Employee department. Ref: Department |
| gender | char(1) | M = Male, F = Female, Null = unknown |
| employment_start_date | date | Start date of employment in organization. |
| employment_end_date | date | Employment end date. Null if employee still employed. |

- Metadata = data about data
- A file describing the contents and structure of a data file
- The more detail the better
- Essential to reproducibility!

DATA

| employee_id | first_name | last_name | nin | department_id |
|-------------|------------|------------|---------------|---------------|
| 44 | Simon | Martinez | HH 45 09 73 D | 1 |
| 45 | Thomas | Goldstein | SA 75 35 42 B | 2 |
| 46 | Eugene | Comelsen | NE 22 63 82 | 2 |
| 47 | Andrew | Petculescu | XY 29 87 61 A | 1 |
| 48 | Ruth | Stadick | MA 12 89 36 A | 15 |
| 49 | Barry | Scardelis | AT 20 73 18 | 2 |
| 50 | Sidney | Hunter | HW 12 94 21 C | 6 |
| 51 | Jeffrey | Evans | LX 13 26 39 B | 6 |
| 52 | Doris | Bemdt | YA 49 88 11 A | 3 |
| 53 | Diane | Eaton | BE 08 74 68 A | 1 |
| 54 | Bonnie | Hall | WW 53 77 68 A | 15 |
| 55 | Taylor | Li | ZE 55 22 80 B | 1 |

Seven Tips to Keep Data Tidy

- Use plain text
- Choose good names
- No empty cells or special characters!
- Use metadata (aka. a data dictionary)
- Treat raw data as read-only



HANDS OFF!

Modification by hand:

- Avoid as much as possible
- If you have to, create a copy to work on & document every change you make in a separate file

Preferentially modify by code!

Seven Tips to Keep Data Tidy

- Use plain text
- Choose good names
- No empty cells or special characters!
- Use metadata (aka. a data dictionary)
- Treat raw data as read-only
- Be consistent

...WITH YOUR NAMING CONVENTIONS

- snake_case
- camelCase
- SCREAMING_SNAKE_CASE
- kebab-case
- Train-Case



PICK-one_AndUse_ItCONSISTENTLY

Seven Tips to Keep Data Tidy

- Use plain text
- Choose good names
- No empty cells or special characters!
- Use metadata (aka. a data dictionary)
- Treat raw data as read-only
- Be consistent
- Dates are awful

...SO MANY WAYS TO BE CODED

- MM/DD/YY
- DD/MM/YY
- YY/MM/DD
- DD-MM-YYYY
- MM-YY



What can we do
with this mess?

Seven Tips to Keep Data Tidy

- Use plain text
- Choose good names
- No empty cells or special characters!
- Use metadata (aka. a data dictionary)
- Treat raw data as read-only
- Be consistent
- Dates are awful

OPTION # 1

Split up the variables:

| day | month | year |
|-----|-------|------|
| 4 | 01 | 2015 |
| 25 | 01 | 2014 |
| 27 | 11 | 2010 |

OPTION # 2

Use the ISO standard: **YYYY-MM-DD**

TIDY DATA

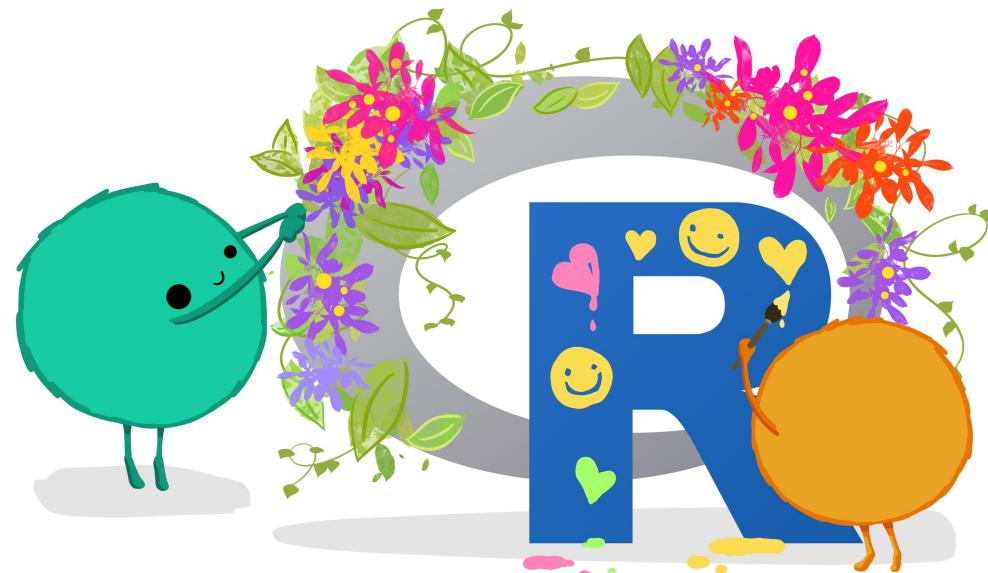
ACTIVITY

We will be spending the remainder of the workshop, making a messy dataset tidy. There is a description of the data and a link to download it in this workshop's Rmarkdown file.

The mission is simple - focus all of your tidy skills on the catastrophe that is messy survey.xls to parse it into its cleanest, tidiest, and most useful self.

Document any adjustments you make. We will chat about them to wrap up this workshop.

ANY LAST QUESTIONS?



Thank you.