

# Data Science for Economists

## Lecture 2b: Clean Code

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Bates College | [EC/DCS 368](#)

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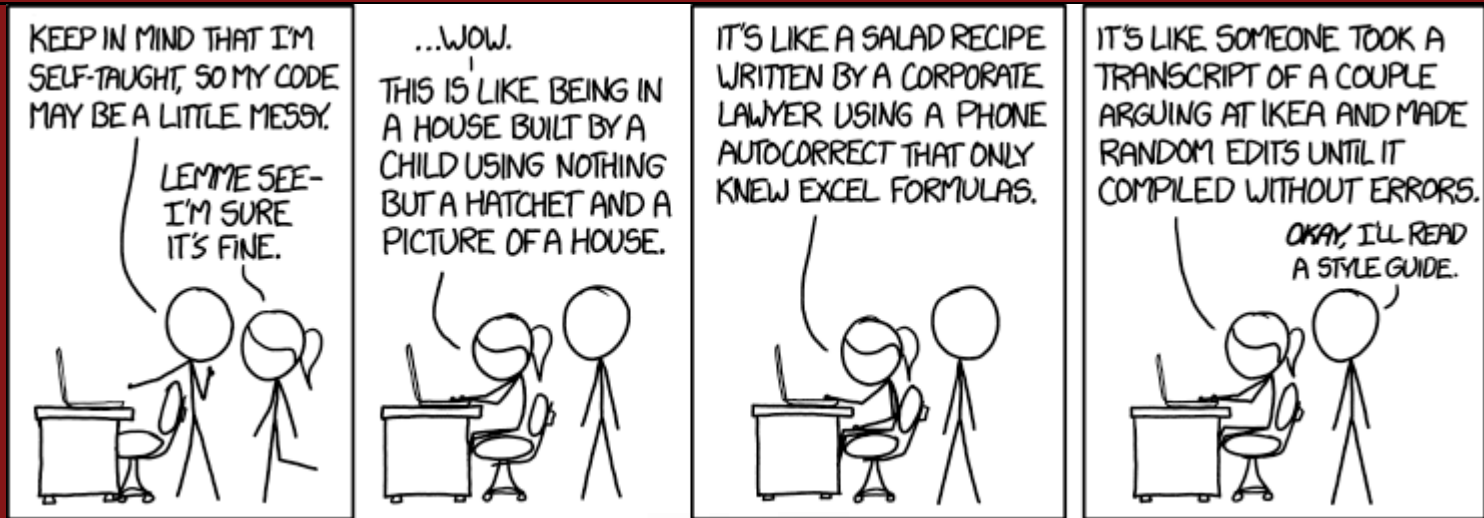
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- Organization of data and software files
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- Time / task management
- Test-driven development (unit testing, profiling, refactoring)
- Pair programming

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# Prologue



Source: [xkcd](#)

# Attribution

- Today's material comes from these sources:
  1. [Clean Code](#) by Tyler Ransom
  2. *[Code and Data for the Social Sciences: A Practitioner's Guide](#)*, by Gentzkow and Shapiro
  3. [Causal Inference and Research Design](#) by Scott Cunningham
  4. [Jenny Bryan's UseR 2018 keynote address](#)

Also a small contribution from [here](#) and other sundry internet pages

# Jargon

- There is a jargon in this class that won't make sense at first, I'll try to flag it as it comes
  - If I don't flag a term, look it up on ChatGPT
  - If it still doesn't make sense, ask me -- could be I'm using it idiosyncratically
- Here's a few terms:

**Local machine:** Your personal (or any) computer that isn't a server accessed via the internet

**Version Control:** Keep track of different iterations of a project/code

**Repository:** The location on GitHub of all project files and (commented) file revision history

**GUI:** A Graphical User Interface -- what you're used to pointing and clicking to navigate a computer and execute programs

**Command line:** Removes the "graphical" from GUI, instead you type all commands to navigate a computer and execute programs

- R operates via the Command line, RStudio is a GUI
- On Mac, this is called Terminal which uses Bash (Linux) commands
- If you installed Git for Windows, you got *Git Bash*, which uses Bash (Linux) commands
- You can also install Windows Subsystem for Linux to run Linux on a Windows machine

**Script:** A file that contains code that can be executed by a computer, i.e. `R`, `Rmd`, `do`, `py`, etc

# Reducing empirical chaos

## Sad story

- Once upon a time there was a boy who was writing a job market paper on unemployment insurance during the pandemic
- This boy presented the findings a half dozen times, spoke to the media some, and generally thought he had cool results
- Several people suggested he look at a handful of other outcome series and try changing his analysis unit frequency from monthly to weekly
- He also knew that he needed to restrict his sample to reduce noise

# The horror!

- But then after making these changes and re-running his code that took two days, his new sample dropped by 50 percent!
- He was, understandably, terrified.
- The young boy spent a week looking for the fix weeding through six different versions of the .do, .R, .dta, .csv, .sh, .py files with suffixes like *\_v1* and *\_test* and *\_test2* and *\_final\_I\_swear* and *\_okay\_i\_lied*
- Finally he discovered the phrase:

```
df %>% filter(insample_new==0)
```

## instead of

```
df %>% filter(insample_new==1)
```

- The boy was very frustrated and decided to work on these slides while re-running his code.
- Today and next class are about minimizing these struggles through Clean Code and a reproducible workflow

Clean Code



# What is Clean Code?

**Clean Code:** Code that is easy to understand, easy to modify, and hence easy to debug

## Clean code advances scientific progress

- Good science uses careful observations to iteratively test hypotheses/make predictions
- Scientific progress is impeded if
  - mistaken previous results are erroneously given authority
  - previous hypothesis tests are not reproducible
  - previous methods and results are not transparent
- Thus, for science that involves computer code, clean code is a must
- Reduces "the influence of hidden researcher decisions" (Huntington-Klein et al. 2021)

## Clean code increases personal/team sanity

- You will always make a mistake while coding -- what makes good programmers great is their ability to identify and correct mistakes
- Clean code makes it easier to identify and correct mistakes
- Saves you stress in the long-run and makes your collaborative relationships more pleasant

# Why clean code is under-produced

- If clean code is so beneficial and important, why isn't there more of it?
1. **Competitive pressure** to produce research/products as quickly as possible
  2. **End user** (journal editor, reviewer, reader, dean) **doesn't care what the code looks like**, just that the product works
  3. In the moment, clean code **takes longer to produce** while seemingly conferring no benefit

# How does one produce clean code?

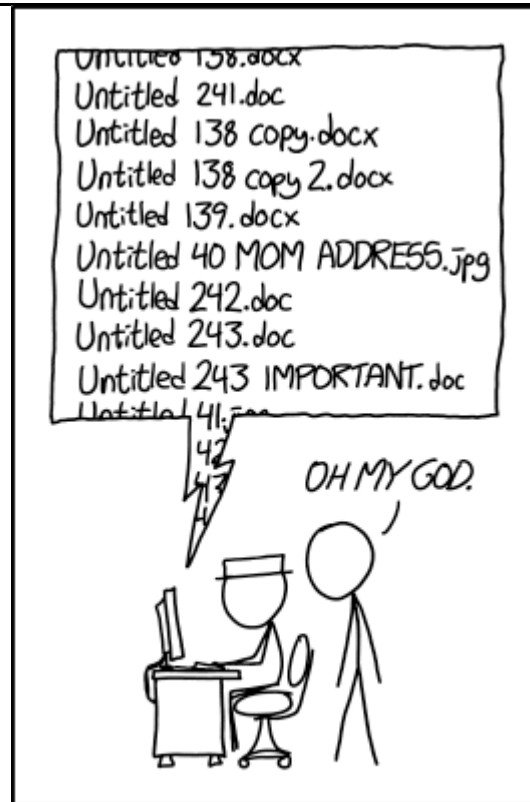
1. Organization of data and files
2. Version Control<sup>1</sup>
3. Automation
4. Abstraction
5. Documentation
6. Time / task management
7. Test-driven development (unit testing, profiling, refactoring)
8. Pair programming

<sup>1</sup> Handle in Git lecture notes.

# 1a. File organization

1. Separate directories by function
  2. Separate files into inputs and outputs
  3. Make directories portable
- To see how professionals do this, check out the source code for R's **dplyr** package
    - There are separate directories for source code (`/src`), documentation (`/man`), code tests (`/test`), data (`/data`), examples (`/vignettes`), and more
  - When you use version control, it forces you to make directories portable (otherwise a collaborator will not be able to run your code)
    - Use **relative** file paths, not absolute file paths

# Don't be like this



PROTIP: NEVER LOOK IN SOMEONE ELSE'S DOCUMENTS FOLDER.

Source: [xkcd](#)

# What is a working directory?

- All the files on your computer are organized in directories or folders
- When you are running a script, you are working from a particular directory
  - This is *not necessarily* the directory where the script is located
  - Your computer looks for `my_data.csv` in this directory when you execute `read.csv('my_data.csv')`
  - If that file is not in that directory, you will get a `FileNotFound` error
  - In **R**, you can see what directory you are in using the `getwd()` function
  - It is also above the console in RStudio
  - You can change your working directory using the `setwd()` function (avoid this within scripts)
  - Alternatively, you can double click the `.Rproj` file to set the working directory to the root of the project

```
getwd()  
## [1] "C:/Users/kgcsp/OneDrive/Documents/Education/Big Data/big-data-class-materials/lectures/02-empir.  
#setwd('lectures/02-empirical-workflow')
```

# What is a directory path?

A path defines the location of a file or directory in a file system tree. If I navigate to this file in my computer, it is:

```
C:\Users\kgcsp\OneDrive\Documents\Education\ECON368-DSE\big-data-class-materials\lectures\02-empirical-workflow\02-empirical-workflow.Rmd1
```

The name separates folders that chart the path from the **root** to the file

- **root**: the start of the file system tree (above that is `c:\`)
- Each folder along the tree is separated by a `\` or `/`

This is called an **absolute path**:

- It is long, hard to remember, and not portable across computers

**Relative paths** solve a lot of this:

- The path to a file or directory starting from the current working directory
- If my working directory is `/big-data-class-materials`, then I can write `lectures/02-empirical-workflow/02-empirical-workflow.Rmd`
- **This is portable** -- if I send this script to you and you have a copy of the `big-data-class-materials` repository, this script will work

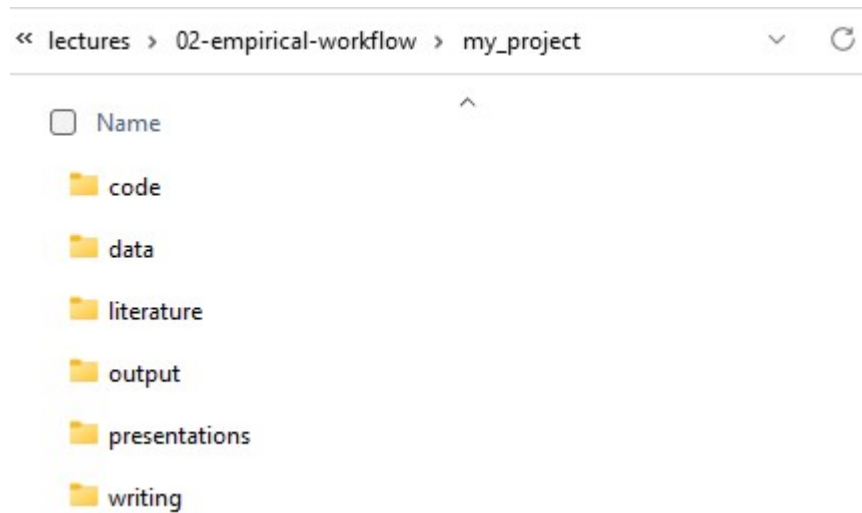
<sup>1</sup> This is a Windows path, Mac and Linux paths use `/` instead of `\`.

# How I organize research projects

- Entire projects should *ideally* live within the same directory
- I have a folder called ( `my_project` )
  - Within that folder I have subfolders:
    1. `data` for all data files a. `raw` for raw data files b. `clean` or `work` for cleaned data files c. `temp` for temporary data files
    2. `code` for all code files, and sometimes: a. `code/analysis` for code files that build/clean code a. `code/build` for code files that do analysis
    3. `output` for all output files a. `output/figures` for code files that make figures b. `output/tables` for code files that make tables
    4. `literature` or `articles` for all relevant literature
    5. `writing` for all writing files a. `writing/notes` for notes b. `writing/drafts` for drafts c. `writing/edits` for edits
    6. `presentations` for all presentations a. `presentations/slides` for slides b. `presentations/notes` for notes
- I'll further more or less as needed
- See GitHub folder for this lecture as an example



# How I organize research projects



Source: My computer

# What is the value of directories?

- All of the files in a directory are related to each other
- Can reference a file within the `data/raw` folder, from the `code/build` folder without writing out the full path

## Help! I am in `code/`, but I need `data/raw/file.csv`!

- You can use relative paths to navigate between directories
- `..` means "go up one directory"
  - `../data/raw` means "go up one directory, then down into `data/raw`"
- `.` means "stay in the current directory"
  - `./code/build` means "stay in the current directory, then down into `code/build`"
- `../..` means "go up two directories"
  - `../../data/raw` means "go up two directories, then down into `data/raw`"

Play around with them yourself!

# 1b. Data organization

- The key idea is to practice **relational data base management**
- A relational database consists of many smaller data sets
- Each data set is tabular and has a unique, non-missing key
- Data sets "relate" to each other based on these keys
- You can implement these practices in any modern statistical analysis software (R, Stata, SAS, Python, Julia, SQL, ...)
- Gentzkow & Shapiro recommend not merging data sets until as far into your code pipeline as possible

# What problems would this create?

county	state	cnty_pop	state_pop	region
36037	NY	3817735	43320903	1
36038	NY	422999	43320903	1
36039	NY	324920	.	1
36040	.	143432	43320903	1
.	NY	.	43320903	1
37001	VA	3228290	7173000	3
37002	VA	449499	7173000	3
37003	VA	383888	7173000	4
37004	VA	483829	7173000	3

Source: [Code and Data for the Social Sciences](#) (p. 19)

# What's RDBM look like?

county	state	population			
36037	NY	3817735			
36038	NY	422999			
36039	NY	324920	state	population	region
36040	NY	143432	NY	43320903	1
37001	VA	3228290	VA	7173000	3
37002	VA	449499			
37003	VA	383888			
37004	VA	483829			

Source: [Code and Data for the Social Sciences](#) (p. 19)

# 3. Automation

- Gentzkow & Shapiro's two rules for automation:
  1. Automate everything that can be automated
  2. Write a single script that executes all code from beginning to end
- There are two reasons automation is so important
  - Reproducibility (helps with debugging and revisions)
  - Efficiency (having a code base saves you time in the future)

# How to write scripts

## Keep them modular

- Each script should do one thing and one thing only
- e.g. It takes an input in, it returns an output
  - Taking in a raw file and returning a cleaned version
  - Taking in two files and merging them
  - Taking in a cleaned file and returning a figure

## Have a main script that runs all scripts in order

- A single script that shows the sequence of steps, i.e. "shows your work"
  - This script will run modular scripts in sequence to exactly reproduce your analysis
- You will rarely run it all at once, but it will be a nice way to organize your thoughts
- A benefit of a well-organized directory: easily see what scripts you need to run in what order
- In R, use `source('rscript.R')` to run a script from one script
- A main script could be a `.Rmd`, a `.R`, a `.sh`, a `.py`, a `.do` etc.

# Main script

```
#File: main.Rmd or main.R
#By: Kyle Coombs
#What: Runs the project from start to finish in Python
#Date: 2024-09-09

# Instructions:
# Run this code from the root directory of your project where the housekeeping file, build, and analysis.

#Install packages with housekeeping. Also put together paths.
source('housekeeping.R')
#User written functions can be sourced -- or you could write a package, your call
source(paste0(build, 'clean_functions.R'))
source(paste0(analysis, 'analysis_functions.R'))

#Import files
source(paste0(build, 'import_census.R'))
source(paste0(build, 'import_admin_data.R'))

#Clean files
source(paste0(build, 'clean_census.R'))
source(paste0(build, 'clean_admin_data.R'))

#Merge files 1 to 2
source(paste0(build, 'merge_census_admin.R'))

#Analysis
source(paste0(analysis, '/summary_stats.R'))
source(paste0(analysis, '/basic_regression.R'))

#Tables will likely be made with a host of R packages
source(paste0(analysis, '/make_sum_figures.R'))
```



# Main script as .Rmd

- In this class, your problem sets will be .Rmd files that you knit
- The `.Rmd` file will serve as your main script
- You can `source()` modular code files in code chunks
- It improves chances your code runs from start to finish instead of only when you are working interactively
  - Means I can run your code more easily!

# What's a housekeeping file?

A housekeeping file **automates** several tasks and goes at the start of every file in your project

1. Load packages
2. Save strings of path directories to use later using the `file.path()` function to reference elsewhere<sup>1</sup>
  - If a folder name changes, you only need to change it in one place in your code
  - Use these strings to reference files in other scripts

```
read.csv(file.path(data_raw, 'my_data.csv'))
```

3. Create directories if they don't exist

<sup>1</sup> Alternatives to `file.path()` include `paste` and `here()`. Check [appendix example](#) for more information.

```
# Housekeeping.R
# By: Your Name
# Date: YYYY-MM-DD
# What: This script loads the packages and data needed for the analysis.

## Package installation -- uncomment if running for the first time
#install.packages(c('tidyverse'))
library(tidyverse)
library(haven) # installed by tidyverse

data_dir <- file.path('data')
raw_dir <- file.path(data_dir, 'raw')
clean_dir <- file.path(data_dir, 'clean')
output_dir <- file.path('output')
code_dir <- file.path('code')
processing_dir <- file.path(code_dir, 'processing')
analysis_dir <- file.path(code_dir, 'analysis')
documentation_dir <- file.path('documentation')

# Create directories
suppressWarnings({
  dir.create(data_dir)
  dir.create(raw_dir)
  dir.create(clean_dir)
  dir.create(documentation_dir)
  dir.create(code_dir)
  dir.create(processing_dir)
  dir.create(analysis_dir)
  dir.create(output_dir)
})
```

# 4. Abstraction

- What is abstraction? "reducing the complexity of something by hiding unnecessary details from the user"
- e.g. A dishwasher. All I need to know is how to put dirty dishes into the machine, and which button to press. I don't need to understand how the electrical wiring or plumbing work.
- In programming, abstraction is usually handled with functions
- Abstraction is usually a good thing
- But it can be taken to a harmful extreme: overly abstract code can be "impenetrable" which makes it difficult to modify or debug

# Rules for Abstraction

- Gentzkow & Shapiro give three rules for abstraction:
  1. Abstract to eliminate redundancy
  2. Abstract to improve clarity
  3. Otherwise, don't abstract
- In the context of R, abstraction means:
  - Write functions
  - Name your objects sensibly

# Abstract to eliminate redundancy

- Sometimes you might find yourself repeating lines of code to accomplish a task

```
# Downloading a sequence of files from 2004 to 2020 gets tedious
download.file('https://data.nber.org/tax-stats/zipcode/2020/zipcode2020.zip',destfile=paste0(data_dir,
download.file('https://data.nber.org/tax-stats/zipcode/2019/zipcode2019.zip',destfile=paste0(data_dir,
download.file('https://data.nber.org/tax-stats/zipcode/2019/zipcode2019.zip',destfile=paste0(data_dir,
# etc.
```

Notice any problems?

```
# Downloading a sequence of files from 2004 to 2020 with a loop
lapply(2004:2020,function(y) {
  download.file(paste0('https://data.nber.org/tax-stats/zipcode/',y,'/zipcode',y,'.zip'),destfile=pas
})
```

- We'll learn more about iteration/for loops/apply statements later
- There are many forms of redundancy that can be eliminated with abstraction beyond iteration

# Abstract to improve clarity

Say you want to round a number to the nearest of different integers:

1. Divide the number by there base integer
2. Round the result to the nearest whole number
3. Multiply by the base integer

I start coding and copy and paste the code for each integer:

```
rounded_157_nearest_5 ← round(157/5)*5  
rounded_157_nearest_7 ← round(157/5)*7
```

Notice a problem?

Why not abstract with a function?

```
round_to_nearest ← function(x,base=5) {  
  return(round(x/base)*base)  
}  
  
rounded_157_nearest_5 ← round_to_nearest(157,base=5)  
rounded_157_nearest_7 ← round_to_nearest(157,base=7)
```

The second approach is easier to read and understand what the code is doing!

# Otherwise, don't abstract

1. Write/use functions for tasks that are repeated
  2. Write thoughtful variable names (e.g. `x100`, `x101` versus `household_income`, `household_size`)
- If we're only doing it once in our script, then it may not make sense to use the function version
  - This discussion points out that it can be difficult to know if one has reached the optimal level of abstraction
  - As you're starting out programming, I would advise doing almost everything inside of a function (i.e. err on the side of over-abstraction when starting out)
    - And look for opportunities to loop (or use apply functions)



# 5. Documentation

1. Don't write documentation you will not maintain
2. Code should be self-documenting
  - Generally speaking, commented code is helpful
  - However, sometimes it can be harmful if, e.g. code comments contain dynamic information
  - It may not be helpful to have to rewrite comments every time you change the code
  - Code can be "self-documenting" by leveraging abstraction: name your functions and variables thoughtfully

# A README is documentation

- A README gives high-level information about the repository or data file:
  - This repository contains code that does X task
  - Simple use case: use this repository to replicate paper X in journal Y
- Onboarding instructions:
  - Add your name to this file in repository folder `the/folder/file.md`
  - Fork the repository and pull request changes
  - Configure your computer settings in this way to run this project
  - Guidelines/rules for contributing to the project
- Licensing information:
  - You can just take this code!
  - This is proprietary and we will sue you if you haven't paid us
- Dependencies:
  - To use this code or package or data\_dir download packages `x`, `y`, `z`
- Changelog (short narrative commit history):
  - 9/23/2023 - KGC - added function `x` to do `y`

# Documentation in R

- **R Help System:** access using `?function_name`
- **Package vignettes:** access using `vignette("vignette_name")`
- **Cheatsheets:** access at [Posit Cheatsheets](#)

# 6a. Time management

- Time management is key to writing clean code<sup>2</sup>
- It is foolish to think that one can write clean code in a strained mental state
- Code written when you are groggy, overly anxious, or distracted will come back to bite you
- Schedule long blocks of time (1.5 hours - 3 hours) to work on coding where you eliminate distractions (email, social media, etc.)
- Stop coding when you feel that your focus or energy is dissipating

<sup>1</sup> Your professor needs this lecture too

# 6b. Task management

- When collaborating on code, it is essential to not use email or Slack threads to discuss coding tasks
- Rather, use a task management system that has dedicated messages for a particular point of discussion (bug in the code, feature to develop, etc.)
- I use GitHub issues and milestones for all of my coding projects including [developing this class](#)
- For my personal task management, I use GitHub Projects

# 7. Test-driven development

- The only way to know that your code works is to test it!
- Test-driven development (TDD) consists of a suite of tools for writing code that can be automatically tested
- Simplest test is to check if the code gives you the output you expected
  - Whenever you make a change, check it against the output you expect
  - Ideally, check against a small example so it runs fast and is easy to confirm
- What if the code takes too long to check completely? Meet **unit tests**
- **Unit testing** is nearly universally used in professional software development

# Unit testing

- Unit tests are scripts that check that a piece of code does everything it is supposed to do
- When professionals write code, they also write unit tests for that code at the same time
- If code doesn't pass tests, then bugs are caught immediately
- R's [dplyr package](#) shows that all unit tests are passing and that tests cover 91% of the code base
- [testthat](#) is a nice step-by-step guide for doing this in R (I use it to autograde exercises)

## Assertions

- Assert statements are extremely useful for basic unit tests
- They exist in every language
- In R it is called `stopifnot()`

```
x ← TRUE
stopifnot(x)

y ← FALSE
stopifnot(y)
```

```
## Error: y is not TRUE
```

# Minimal reproducible example

- Related to unit testing are minimal reproducible examples (aka MRE, reпреx, minreps,...)
- The best way to isolate bugs is a minimal reproducible example
- If your code throws an error message, there's likely a ton of superfluous stuff in your code that is not causing the error
  - But the superfluous stuff makes it harder to read!
- **Minimal reproducible examples** (reprex) are a great way to isolate the error
  - `.hi[Minimal]`:: Use as little code as possible that still produces the same problem
  - `.hi[Complete]`:: Provide all parts needed to reproduce your problem in the question itself
  - `.hi[Reproducible]`:: Test the code you'll provide to make sure it reproduces the problem
- That means you should be able to copy and paste the code and run it yourself
  - Name all packages and data needed to reproduce error
  - Cut out irrelevant packages, steps, and data that are not relevant to the error
- Sometimes writing one will help you find the bug, sometimes it'll help a stranger find the bug in your code faster, and sometimes it'll identify a very real bug in the package itself



# Min Reprex from RStudio community

- If someone does not have `hrbrthemes` installed, they will not be able to run the code below
  - You can remove this package from your code and still reproduce the error.

```
library(ggplot2) #For ggplot
library(datasets) #To load iris
library(hrbrthemes) #For the theme
data(iris)
df <- iris %>%
  mutate(Sepal.Length = Sepal.Length * 1000,
         Sepal.Width = Sepal.Width * 1000)

ggplot(data = df, x = Sepal.Length, y = Sepal.Width) +
  theme_modern_rc() +
  geom_point() +
  scale_x_log10() +
  labs(title = "Iris Sepal Width vs. Sepal Length",
       subtitle = "Log10 Scaled X Axis")
```

```
## Error in `geom_point()`:
## ! Problem while setting up geom.
## i Error occurred in the 1st layer.
## Caused by error in `compute_geom_1()`:
## ! `geom_point()` requires the following missing aesthetics: x and y
```

# How to write MREs

Cut out the unnecessary steps

```
library(ggplot2)
dat <- iris[1:4,]
ggplot(data = dat, x = Sepal.Length, y = Sepal.Width) +
  geom_point()
```

```
## Error in `geom_point()`:
## ! Problem while setting up geom.
## i Error occurred in the 1st layer.
## Caused by error in `compute_geom_1()`:
## ! `geom_point()` requires the following missing aesthetics: x and y.
```

- You can use [reprex](#) to make sure that your code is reproducible by others and [dput](#) to make sure that your data is reproducible by others.

```
dput(iris[1:4,]) # copy/paste output of dput into your MRE
```

```
## structure(list(Sepal.Length = c(5.1, 4.9, 4.7, 4.6), Sepal.Width = c(3.5,
## 3, 3.2, 3.1), Petal.Length = c(1.4, 1.4, 1.3, 1.5), Petal.Width = c(0.2,
## 0.2, 0.2, 0.2), Species = structure(c(1L, 1L, 1L, 1L), levels = c("setosa",
## "versicolor", "virginica"), class = "factor")), row.names = c(NA,
## 4L), class = "data.frame")
```

# A great MRE

## Summary

When I try to make a scatterplot with ggplot, I am told that `geom_point()` requires missing aesthetics `x` and `y`. But I specified `x` and `y` in the `ggplot()` function. Can you help resolve?

## Data

I used a subset of the iris dataset.

```
dat <- iris[1:4,]
```

## Code and error message

```
ggplot(data = dat, x = Sepal.Length, y = Sepal.Width) +  
  geom_point()
```

```
## Error in `geom_point()`:  
## ! Problem while setting up geom.  
## i Error occurred in the 1st layer.  
## Caused by error in `compute_geom_1()`:  
## ! `geom_point()` requires the following missing aesthetics: x and y.
```

# Now you try

- Below is some code I wrote that is throwing an error
- Try to write a MRE
- I have already raised this as a poorly-written issue on GitHub. You can see the issue [here](#)
- Tips: [https://aosmith16.github.io/spring-r-topics/slides/week09\\_reprex.html#1](https://aosmith16.github.io/spring-r-topics/slides/week09_reprex.html#1)

```
# install.packages('ggplot2')
library(ggplot2)
mtcars46carb = mtcars[mtcars$carb==4 | mtcars$carb==6]
```

```
## Error in `[.data.frame`(mtcars, mtcars$carb = 4 | mtcars$carb = 6): undefined columns selected
```

```
mtcars4carb_mean = mean(mtcars[mtcars$carb==4, 'mpg'], na.rm=TRUE)
mtcars6carb_mean = mean(mtcars[mtcars$carb==6, 'mpg'], na.rm=TRUE)

ggplot(data=mtcars46carb, aes(x=mpg, y=wt)) +
  geom_point() +
  geom_smooth(method='lm') +
  geom_vline(xintercept=mtcars4carb_mean, color='red') +
  geom_vline(xintercept=mtcars6carb_mean, color='blue') +
  annotate('text', x=mtcars4carb_mean-.25, y=5, label='4-carb mean', color='red', angle=90) +
  annotate('text', x=mtcars6carb_mean-.25, y=5, label='6-carb mean', color='blue', angle=90) +
  labs(title='Mpg vs. weight for 4 and 6 carburetor cars')
```

```
## Error in eval(expr, envir, enclos): object 'mtcars46carb' not found
```

# Troubleshooting tips

- Sometimes you've made several changes to your code and suddenly it stops running
  - Was it the new `if` statement?
  - That sick new vectorized function to replace the `for` loop?
  - A stray typo?
- How do you find the bug in hundreds of lines of code?
- Read your code to see if there is an obvious mistake
- **Binary search:** Comment<sup>1</sup> half your code, run the script, and see if the bug persists
  - If it does, the bug is in the other half
  - If it doesn't, the bug is in the commented half
  - Repeat on each half until you narrow to set of lines
  - If you can solve the bug from that line, great!
- If all else fails, make a **Minimal reproducible example!**

<sup>1</sup> Comment in R with `#`. Comment in RMarkdown with `<!-- code -->`. Or highlight and press `Ctrl+Shift+C` in RStudio.

# Troubleshooting tips (cont.)

- Step back and ask if you're solving the right problem
  - e.g. I'm trying to make a plot, but I'm getting an error about a missing variable. Maybe I should check if I'm loading the right data
  - e.g. I have to create a long data set and I have annual files, but my code is merging instead of appending...
- Check for superfluous things you can remove
  - e.g. Wait, I don't need to include absolute file paths, I can use relative paths
- Try small fixes, then apply broadly
  - e.g. I think the problem is with how I wrote my file paths, let me try to get just one file path to work
- Change one thing at a time
  - e.g. The problem is either with my `paste0()` statement or the `ggsave` function, let me try to get the `paste0()` statement to work first

# Troubleshooting tips (cont.)

- Embrace GitHub committing
  - When you have code that works, stage, commit and push it -- even if it is only a small piece of the puzzle
  - If it breaks, `revert`
  - This minimizes how much you need to re-do/keep track of
- Sometimes it is easier to change how you write something
  - e.g. Rmarkdown doesn't like the character `#` in filepaths, but I can change the filepaths rather than trying to force Rmarkdown to accept it
- There's more than one way to skin a cat
  - e.g. If I can't get `read.csv()` to work, I'll try `read.table()`
  - e.g. This `googlesheets4` package doesn't seem to work -- what about `gsheet` or `googledrive`?
- With ChatGPT or Google, make very specific asks
  - e.g. "How do I get a file named `/my/path/name/my_file.pdf` to appear when I knit `other/folder/name/file.Rmd`?"

# 8. Pair programming - work with a buddy

- An essential part of clean code is reviewing code
- An excellent way to review code is to do so at the time of writing
- **Pair programming** involves sitting two programmers at one computer
- One programmer does the writing while the other reviews
- This is a great way to spot silly typos and other issues that would extend development time
- It's also a great way to quickly refactor code at the start
- **I strongly encourage you to do pair programming on problem sets in this course!**
  - (Sometimes I will require it)



Next lecture: R basics, data wrangling,  
tidyverse and data.table

---

# Appendix

# Main script with functions

name: main-with-functions

```
#File: main.Rmd or main.R
#By: Kyle Coombs
#What: Runs the project from start to finish in Python
#Date: 2023/09/12

#Install packages with housekeeping. Also put together paths.
source('housekeeping.R')
#User written functions can be sourced -- or you could write a package, your call
source(paste0(build, 'clean_functions.R'))
source(paste0(analysis, 'analysis_functions.R'))

#Import files
df1 ← read_csv(paste0(raw, 'file1.csv'))
df2 ← read_parquet(paste0(raw, 'file2.parquet'))
df3 ← read_dta(paste0(raw, 'file3.dta'))

#Clean files
cleaned_df1 ← clean_df1(df1)
cleaned_df2 ← clean_df2(df2)
cleaned_df3 ← cf.clean_df3(df3)

#Merge files 1 to 2
merged_df1_df2 = merge(cleaned_df1, cleaned_df2, on=c('merge', 'vars'))

#Append file 1 to
append_df1_df2_df3 = rbind(merged_df1_df2, cleaned_df2)

#Analysis
```

# Textbooks: Smarter people than me

- Cunningham (2021) [Causal Inference: The Mixtape](#) (Also, [free version on his website](#))
- Huntington-Klein (2022) [The Effect](#)
- Angrist and Pischke (2009) [Mostly Harmless Econometrics](#) (MHE)
- Morgan and Winship (2014) [Counterfactuals and Causal Inference](#) (MW)
- Sweigart (2019) [Automate The Boring Stuff With Python](#)
- Wickham (2023) [Advanced R](#)
- Wickham and Grolemund (2023) [R for Data Science](#)
- Peng (2022) [R Programming for Data Science](#)

# Non-textbook readings

- The help documentation associated with your language (no really)
- Jesse Shapiro's "How to Present an Applied Micro Paper"
- Gentzkow and Shapiro's coding practices manual
- Ljubica "LJ" Ristovska's language agnostic guide to programming for economists
- Grant McDermott on Version Control using Github [Link](#)

# Helpful for troubleshooting

- The help documentation associated with your language (no really)
- All languages: [Stack Overflow](#), [Stack Exchange](#)
- Stata-specific (all hail Nick Cox): [Statalist](#)
- Cheatsheets: [Stata](#), [RStudio](#), [Python](#)
- Me: [Sign up for office hours](#)

# Learn by Immersion

- Just like learning a real language, no amount of talking today will teach you how to use any program.
  - You have to need to use it (immersion) to learn it.
  - Google is your dictionary.
  - Help files are your grammar books.
  - ChatGPT is your phrasebook.
  - A great way to start coding is to see lots of other people's code and copy what you read.
- You must learn how to ask the “right” question:
  - Never: "Importing csv file into R not working."
  - Better: "read\_csv R [specific error message]."
  - Better still: "read\_csv tidyverse [specific error message]."

# Abstract to eliminate redundancy (cont.)

What if you can't find an R function? Write your own!

```
set.seed(16)
prod1 = rnorm(1, 0, 1)*rnorm(1,4,6)
prod2 = rnorm(2, 0, 1)*rnorm(2,0,1)
prod3 = rnorm(3, 0, 1)*rnorm(3,15,78)
print(prod1)
## [1] 1.547257
print(prod2)
## [1] 1.2582691 0.6764943
print(prod3)
## [1] -60.06036 10.11156 24.32342
```

```
set.seed(16)
multiply_normals = function(count,mean1=0,sd1=1,mean2=0,sd2=1) {
  prod = rnorm(count,mean1,sd1)*rnorm(count,mean2,sd2)
  return(prod)
}
prod1=multiply_normals(1,mean2=4,sd2=6)
prod2=multiply_normals(2,mean2=0,sd2=1)
prod3=multiply_normals(3,mean2=15,sd2=78)

print(prod1)
## [1] 1.547257
print(prod2)
## [1] 1.2582691 0.6764943
print(prod3)
## [1] -60.06036 10.11156 24.32342
```



# Note on seeds

- When randomizing in any language, you aren't really randomizing
- You're producing pseudo-random numbers that return in a deterministic ordered list
- If you set the seed, you can reproduce the same "random" numbers
- This is useful for debugging and sharing code
- Use `set.seed` in R

```
set.seed(0)
print(rnorm(1)+rnorm(1,5)+rnorm(1,10))
## [1] 17.26652
print(rnorm(1)+rnorm(1,5)+rnorm(1,10))
## [1] 15.14712
# New seed
set.seed(1)
print(rnorm(1)+rnorm(1,5)+rnorm(1,10))
## [1] 13.72156
print(rnorm(1)+rnorm(1,5)+rnorm(1,10))
## [1] 16.10432
# Reset seed
set.seed(0)
print(rnorm(1)+rnorm(1,5)+rnorm(1,10))
## [1] 17.26652
print(rnorm(1)+rnorm(1,5)+rnorm(1,10))
## [1] 15.14712
```

# Make your own documentation

- R has excellent built-in documentation called `Roxygen2`
- These make great documents above functions to increase readability
- Here's an example:

```
library(roxygen2)
#' This is a sample function
#'
#' This function does something amazing.
#'
#' @param x A numeric input.
#' @return The result of the amazing operation.
#' @examples
#' amazing_function(5)
amazing_function <- function(x) {
  # function implementation
}
```

- Use `roxygen::roxygenise()` to generate documentation for all functions in a file
- Read more [here](#)

# Refactoring

- Refactoring refers to the action of restructuring code without changing its external behavior or functionality. Think of it as "reorganizing"

```
get_some_data ← function(config, outfile) {  
  if (config_ok(config)) {  
    if (can_write(outfile)) {  
      if (can_open_network_connection(config)) {  
        data ← parse_something_from_network()  
        if(makes_sense(data)) {
```

after refactoring becomes

```
get_some_data ← function(config, outfile) {  
  if (config_bad(config)) {  
    stop("Bad config")  
  }  
  
  if (!can_write(outfile)) {
```

- Nothing changed in the code except the number of characters in the function
- The new version may run faster, is more readable. The output is unchanged.
- Refactoring could also mean reducing the number of input arguments
- Jenny Bryan gave a [great talk](#) on refactoring

# Profiling

- Profiling refers to checking the resource demands of your code
- How much processing time does your script take? How much memory?
- Clean code should be highly performant: it uses minimal computational resources
- Profiling and refactoring go hand in hand, along with unit testing, to ensure that code is maximally optimized
- Here are two intro guides to profiling in R:
  - Using `system.time` and `Rprof` from R Programming for Data Science[<https://bookdown.org/rdpeng/rprogdatascience/profiling-r-code.html>]
  - Using `lineprof` from Advanced R[<http://adv-r.had.co.nz/Profiling.html>]

[Back to MREs](#)

# Neat R functions to help reduce

```
set.seed(16)
list1 = list() # Make an empty list to save output in
for (i in 1:3) { # Indicate number of iterations with "i"
  list1[[i]] = multiply(i) # Save output in list for each iteration
}
list1
```

```
## [[1]]
## [1] 1.547257
##
## [[2]]
## [1] 11.934479 -1.717951
##
## [[3]]
## [1] -7.4831177  0.9587218  4.7882622
```

A better way to eliminate this redundancy is to use the `map` function:

```
set.seed(16)
map(1:3, multiply)
```

```
## [[1]]
## [1] 1.547257
##
```

# Alternative to file.path is `here()`

- Better yet is the [here](#)
  - `here()` will find the root directory of your project and then you can navigate from there

```
#install.packages('here')  
library(here)
```

```
## here() starts at C:/Users/kgcsp/OneDrive/Documents/Education/Big Data/big-data-class-materials
```

```
here::i_am('my_project/code/build/.placeholder')
```

```
## here() starts at C:/Users/kgcsp/OneDrive/Documents/Education/Big Data/big-data-class-materials/lectures/02-empirical-
```

```
here('data/raw', 'my_data.csv')
```

```
## [1] "C:/Users/kgcsp/OneDrive/Documents/Education/Big Data/big-data-class-materials/lectures/02-empirical-
```

- Can be less clunky than `paste()` and `sep="/"`
- Get lost in your directories? Use `file.path()` to identify your root directory