Intro to R

Part 1: A Microcosm of Data Science

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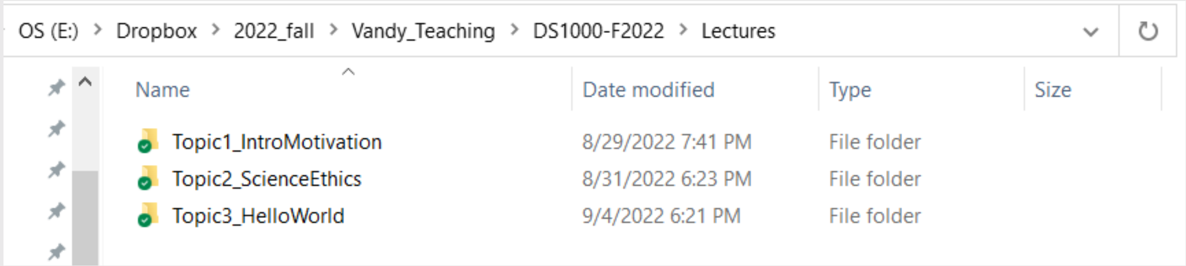
Agenda

1. Getting set up
   - Folder structure + `setwd()`
2. Installing software
   - `R: https://cran.r-project.org/`
   - `RStudio: https://rstudio.com/products/rstudio/download/`
3. Requiring packages
   - `install.packages("tidyverse")`
   - `require(tidyverse)`
4. Loading and manipulating data
   - `readRDS()`
   - `%>%`

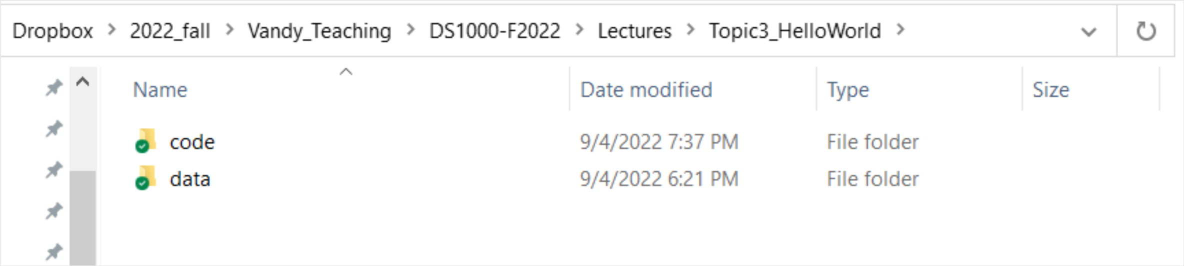
Getting set up

- Folder structure + `setwd()`
  - Concept: keep everything together...
  - ...and **related**



Getting set up

- Folder structure + `setwd()`
  - Concept: keep everything together...
  - ...and **related**



Installing software

- `R: https://cran.r-project.org/`
  - Accept all defaults
- `RStudio: https://rstudio.com/products/rstudio/download/`
  - Download the version for your OS
- Open `RStudio` and create a new rmarkdown (`.Rmd`) file
  - Accept defaults, give it a sensible name, delete the default text, then save it to your folder (again with a sensible name)
  - You should follow along with the lecture in this file! Take notes here! Try code here!

How to type in `.Rmd`

```
# This is a header

## This is a subheader

### This is a subsubheader

This is plain text.
```

This is a header

This is a subheader

This is a subsubheader

This is plain text.

How to type in `.Rmd`

```
- This is

- a bulleted

  - List

1. This is

2. a numbered list
```

- This is

- a bulleted

    - List

1. This is

2. a numbered list

How to type in `.Rmd`

```
*Bold font**, *italic font*, `code font`
```

Bold font, *italic font*, `code font`

- Most Importantly! `R` code!

````
```{r}
2+2
```
````

```r
2+2
```

```
## [1] 4
```

How R Works

- **O**bject **O**riented **L**anguage (**OOL**)
  - Objects are created with the `<-` command
  - You *can* run code directly...

```
2+2
```

```
## [1] 4
```

How R Works

- **O**bject **O**riented **L**anguage (**OOL**)
  - Objects are created with the `<-` command
  - ...but most of what we'll do involves objects

```
object1 <- 2+2
```

- Object assignment operator **saves** the output
- It **does not print** the output
- To see, just call the object

```
object1
```

```
## [1] 4
```

How R Works

- **O**bject **O**riented **L**anguage (**OOL**)
  - Objects are created with the `<-` command
  - They can be named anything (so be intuitive!)

```
three_plus_three <- 2+2
three_plus_three
```

```
## [1] 4
```

How R Works

- **O**bject **O**riented **L**anguage (**OOL**)
    - Objects are created with the `<-` command
    - Objects can store many different things

```
an_element <- 2+2
a_vector <- c(1,2,3)
a_list <- list('element1' = 2+2,
               'element2' = "hello world!",
               'element3' = runif(n = 10,min = 0,max = 10))
a_function <- function(x) {
  avg_of_x <- sum(x) / length(x)
  return(avg_of_x)
}
```

How R Works

- Objects **persist!**

```r
an_element # This object stores 2+2
```

```
## [1] 4
```

```r
a_vector   # This object stores the integers 1, 2, and 3
```

```
## [1] 1 2 3
```

```r
an_element*a_vector
```

```
## [1]  4  8 12
```

```r
an_element-a_vector
```

```
## [1] 3 2 1
```

A comment on comments

- If you use a # sign inside a code chunk, you can write a comment

```
# This is a comment. If I compile the code, nothing will happen.

# This is another comment. These are helpful for annotating my code.
```

How R Works

- Objects **persist!**

```r
# This object stores:
  # 1) 2+2 (named "element1")
  # 2) the text "hello world!" (named "element2")
  # 3) 10 numbers randomly drawn between 0 and 10
a_list
```

```
## $element1
## [1] 4
##
## $element2
## [1] "hello world!"
##
## $element3
##  [1] 2.875775 7.883051 4.089769 8.830174 9.404673 0.455565
##  [7] 5.281055 8.924190 5.514350 4.566147
```

How R Works

- Objects **persist!**

```
# Let's apply our function ("a_function") to "element3" in "a_list"
a_function(x = a_list[['element3']])
```

```
## [1] 5.782475
```

- We could also call `element3` from `a_list` with a dollar sign

```
# This does the same thing as the previous slide...it just accesses
element3 differently.
a_function(x = a_list$element3)
```

```
## [1] 5.782475
```

How `RStudio` Works

- `RStudio` is a powerful way to interact with `R`
- In base `R`, you interact with the program via the "command line"
    - For example...
- But to save your work, you can write "scripts"
    - For example...
- *This is all cumbersome!*
- Enter, `RStudio`

How `RStudio` Works

- `RStudio` allows us to:

  1. Write scripts
  2. Run scripts
  3. See results

- It is **deeply interactive**

  - We can highlight a line and press `ctrl+enter` / `cmd+enter` and see the result

  - **We can even do this with single objects!**

Give it a try

- Comment **everything**
- Create two objects
  - `a` contains the product of 3 and 5 (`3*5`)
  - `b` contains five numbers `c(10,21,43,87,175)`
- Now create object `c` which is `a - b`

```
# INSERT CODE HERE
```

Functions & Packages

- What are `packages`?
  - Basically, **functions** that someone else wrote
- `R` has many functions already installed
  - These are known as "base `R`" and contain many useful functions
  - For example, `sum()` will add up a vector of numbers

```
sum(object1)
```

- Quiz: What does the `mean()` function do? The `median()`? The `range()`?
- Other base `R` functions interact with other files
  - For example, `read.csv()` will load a `.csv` file
- And there are MANY **MANY** more

Installing Packages

- In addition to the functions included in base `R`, we want more
- For this class, we want one called `tidyverse`
  - `tidyverse` contains many (hundreds?) of functions that make `R` easier
  - But it is NOT included in the base `R` set of functions
  - Therefore, we need to add it
- Use the base `R` function `install.packages("[PACKAGE NAME]")`
  - Specifically, `install.packages("tidyverse")`

Requiring Packages

- Once installed, a package will live somewhere on your computer
- However, any new *instance* of `R` will not automatically load the packages
- We need to `require()` them to tell `R` to load them
  - Alternatively, we can use `library()` (but it's the same result)
- So load the `tidyverse` package with `require(tidyverse)`
- NB: you need quotes for the `install.packages()` function...
  - i.e., `install.packages("tidyverse")`
- but NOT for the `require()` function
  - i.e., `require(tidyverse)`

Loading Data

- So you should be using `R` via `RStudio` with the `tidyverse` package loaded
- Now let's load some data
- You can save it locally from the course github page and then load it from your computer
- Or you can load it directly from the internet with the `read_rds()` function from `tidyverse`
  - NB: `R` is an "object-oriented language" (OOL)
  - We **create** an "object" to store the data using a left-arrow: `<-`

```
df <-
read_rds('https://github.com/jbisbee1/DS1000_S2024/raw/main/data/sc_deb
```

Loading Data

- We now have the contents of `sc_debt.Rds` stored in the object `df`
    - This is a "tabular data frame", aka a `tibble`
    - **Rows** are observations
    - **Columns** are values
- We can look at this object directly

```r
df
```

```
## # A tibble: 2,546 × 16
##    unitid instnm stabbr grad_debt_mdn control region preddeg
##     <int> <chr>  <chr>          <int> <chr>   <chr>  <chr>
##  1 100654 Alaba… AL             33375 Public  South… Bachel…
##  2 100663 Unive… AL             22500 Public  South… Bachel…
##  3 100690 Amrid… AL             27334 Private South… Associ…
##  4 100706 Unive… AL             21607 Public  South… Bachel…
##  5 100724 Alaba… AL             32000 Public  South… Bachel…
##  6 100751 The U… AL             23250 Public  South… Bachel…
##  7 100760 Centr… AL             12500 Public  South… Associ…
```

Loading Data

- Or we can look at its columns

```
names(df)
```

```
##  [1] "unitid"          "instnm"          "stabbr"
##  [4] "grad_debt_mdn"   "control"         "region"
##  [7] "preddeg"         "openadmp"        "adm_rate"
## [10] "ccbasic"         "sat_avg"         "md_earn_wne_p6"
## [13] "ugds"            "costt4_a"        "selective"
## [16] "research_u"
```

Loading Data

Name	Definition
unitid	Unit ID
instnm	Institution Name
stabbr	State Abbreviation
grad_debt_mdn	Median Debt of Graduates
control	Control Public or Private
region	Census Region
preddeg	Predominant Degree Offered: Assocates or Bachelors
openadmp	Open Admissions Policy: 1=Yes, 2=No, 3=No 1st time students
adm_rate	Admissions Rate: proportion of applications accepted
ccbasic	Type of institution*
sat_avg	Average SAT scores
md_earn_wne_p6	Average Earnings of Recent Graduates
ugds	Number of undergraduates
costt4_a	Average cost of attendance (tuition-grants)
selective	Institution admits fewer than 10% of applications, 1=Yes, 0=No
research_u	Institution is a research university, 1=Yes, 0=No

Manipulating the Data

- These data are cool!
- But TMI at first
- I want to know...
  - Where is `Vanderbilt University`?
  - Who is the most selective?
  - Which schools produce the richest grads?
- There are `tidyverse` functions to answer all of these questions

Manipulating with `tidyverse`

- The code process of `tidyverse` relies on a "pipe" symbol: `%>%`
  - I don't like this name
  - I think it should be called a "chain" because it **links code together**
  - Or maybe a "do" symbol because it tells `R` what to do
- The basic grammar of `R` is: object, `%>%`, verb

```
object %>%  # This is the object
   function() # This is the verb
```

Manipulating with `tidyverse`

- `tidyverse` has many useful "verbs" (i.e., functions)
  - `filter()`: subsets **rows**
  - `select()`: subsets **columns**
  - `arrange()`: sorts **rows** based on **columns**
  - `summarise()`: collapses **rows**
  - `group_by()`: groups **rows** by **columns**

Manipulating: `filter()`

- So let's look at Vandy
- `filter` will select **rows** of the data based on some criteria

```
df %>%
  filter(instnm == "Vanderbilt University") # Only select rows with
Vandy
```

```
## # A tibble: 1 × 16
##   unitid instnm  stabbr grad_debt_mdn control region preddeg
##    <int> <chr>   <chr>          <int> <chr>   <chr>  <chr>  
## 1 221999 Vander… TN             14962 Private South… Bachel…
## # ℹ 9 more variables: openadmp <int>, adm_rate <dbl>,
## #   ccbasic <int>, sat_avg <int>, md_earn_wne_p6 <int>,
## #   ugds <int>, costt4_a <int>, selective <dbl>,
## #   research_u <dbl>
```

Manipulating: `select()`

- Still TMI!
- I only care about the admissions rate (`adm_rate`), the SAT scores (`sat_avg`), and the future earnings (`md_earn_wne_p6`)
- `select` will select **columns**

```
df %>%
  filter(instnm == "Vanderbilt University") %>%
  select(instnm,adm_rate,sat_avg,md_earn_wne_p6) # Only select four
columns
```

```
## # A tibble: 1 × 4
##   instnm                adm_rate sat_avg md_earn_wne_p6
##   <chr>                    <dbl>   <int>          <int>
## 1 Vanderbilt University   0.0912    1515          53400
```

Manipulating: `arrange()`

- How does Vandy compare...?
  - to other schools in terms of SAT scores?
  - to other schools in terms of future earnings?
  - to other schools in terms of admissions rates?
- `arrange` will sort the data based on a column (ascending!)

```
df %>%
  arrange(sat_avg) %>% # Sort data by SAT scores
  select(instnm,sat_avg) # Only look at name and SAT scores
```

```
## # A tibble: 2,546 × 2
##    instnm                          sat_avg
##    <chr>                             <int>
##  1 Morgan State University             737
##  2 Saint Augustine's University        847
##  3 Albany State University             849
##  4 Holy Names University               851
##  5 Livingstone College                 854
```

Manipulating: arrange()

- Vandy is not in the bottom 10 schools

```
df %>%
  arrange(sat_avg) %>% # Sort data by SAT scores
  select(instnm,sat_avg) # Only look at name and SAT scores
```

```
## # A tibble: 2,546 × 2
##    instnm                          sat_avg
##    <chr>                             <int>
##  1 Morgan State University             737
##  2 Saint Augustine's University        847
##  3 Albany State University             849
##  4 Holy Names University               851
##  5 Livingstone College                 854
##  6 Virginia Union University           855
##  7 Manor College                       861
##  8 Saint Louis Christian College       865
##  9 Bacone College                      875
## 10 Paine College                       876
## # ℹ 2,536 more rows
```

Manipulating: `arrange()`

- Use `desc()` to order in descending values…Vandy not in top 10 either

```
df %>%
  arrange(desc(sat_avg)) %>% # Sort data by SAT scores (descending)
  select(instnm,sat_avg) # Only look at name and SAT scores
```

```
## # A tibble: 2,546 × 2
##    instnm                                 sat_avg
##    <chr>                                    <int>
##  1 California Institute of Technology        1557
##  2 Massachusetts Institute of Technology     1547
##  3 University of Chicago                     1528
##  4 Harvey Mudd College                       1526
##  5 Duke University                           1522
##  6 Franklin W Olin College of Engineering    1522
##  7 Washington University in St Louis         1520
##  8 Rice University                           1520
##  9 Yale University                           1517
## 10 Harvard University                        1517
## # ℹ 2,536 more rows
```

Manipulating: `arrange()`

- What if we look only at "selective" schools (i.e., those who accept less than 10% of applicants)?

```
df %>%
  filter(adm_rate < .1) %>% # Only look at schools who accept less than 10%
  arrange(sat_avg,adm_rate) %>% # Sort data by SAT scores AND THEN admissions rates (breaks ties)
  select(instnm,adm_rate,sat_avg) # Only look at name, admissions rate, and SAT scores
```

```
## # A tibble: 25 × 3
##    instnm                                     adm_rate sat_avg
##    <chr>                                         <dbl>   <int>
##  1 Colby College                                0.0967    1456
##  2 Swarthmore College                           0.0893    1469
##  3 Pomona College                               0.074     1480
##  4 Dartmouth College                            0.0793    1500
##  5 Stanford University                          0.0434    1503
##  6 Northwestern University                      0.0905    1506
##  7 Columbia University in the City of New …     0.0545    1511
##  8 Brown University                             0.0707    1511
```

How does Vandy compare?

- `arrange` in descending order

```
df %>%
  filter(adm_rate < .1) %>%
  arrange(desc(sat_avg),adm_rate) %>%
  select(instnm,adm_rate,sat_avg)
```

```
## # A tibble: 25 × 3
##    instnm                                       adm_rate sat_avg
##    <chr>                                           <dbl>   <int>
##  1 California Institute of Technology             0.0642    1557
##  2 Massachusetts Institute of Technology          0.067     1547
##  3 University of Chicago                          0.0617    1528
##  4 Duke University                                0.076     1522
##  5 Rice University                                0.0872    1520
##  6 Harvard University                             0.0464    1517
##  7 Princeton University                           0.0578    1517
##  8 Yale University                                0.0608    1517
##  9 Vanderbilt University                          0.0912    1515
## 10 Columbia University in the City of New …       0.0545    1511
## # ℹ 15 more rows
```

More complicated? More %>%!

- Less selective schools by SAT with debt and state

```
df %>%
  filter(adm_rate > .2 & adm_rate < .3) %>% # Less selective schools
(accept between 20% and 30%)
  arrange(stabbr,desc(sat_avg)) %>% # Sort by state name, then by SAT
scores
  select(instnm,sat_avg,grad_debt_mdn,stabbr) # Only look at some
columns
```

```
## # A tibble: 37 × 4
##    instnm                          sat_avg grad_debt_mdn stabbr
##    <chr>                             <int>         <int> <chr>
##  1 Heritage Christian Universi…         NA            NA AL
##  2 University of California-Sa…       1370         15000 CA
##  3 California Polytechnic Stat…       1342         19501 CA
##  4 University of California-Ir…       1306         15488 CA
##  5 California Institute of the…         NA         27000 CA
##  6 University of Miami                1371         17125 FL
##  7 Georgia Institute of Techno…       1418         23000 GA
##  8 Point University                    986         26000 GA
##  9 Grinnell College                   1457         17500 IA
```

A quick aside on missingness

- Some rows have `NA` in some columns
  - `NA` is the standard code for **missing data** in `R`
  - Data can be missing for many different reasons (i.e., some schools don't require SAT scores or record them)
  - We can use a base `R` function called `is.na()` which will be `TRUE` if the value is `NA` or `FALSE` otherwise
  - And we can combine `is.na()` with the `filter()` function from `tidyverse`
- We will return to this in the lectures on **data wrangling**
- For now, how many schools don't report SAT scores?

```
df %>%
  filter(is.na(sat_avg)) %>% # Only look at schools that DON'T report
SATs
  select(instnm,stabbr) # Only look at the name and the state
```

Stepping back

- Thus far, lots of data
- Not a lot of science
- But remember the Research camp!
    1. Observation → Question
    2. Theory → Hypothesis
    3. Data Collection / Wrangling → Analysis
    4. Results → Conclusion
- We have been doing lots of Observation!
- Do we have any good Research questions?

Stepping back

- RQ: How might admissions and SAT scores be **related**?
  - Theory: selective schools have stricter criteria
  - Hypothesis: admissions and SAT scores should be **negatively** related
- How can we test this hypothesis?

Summarizing Data: `summarise()` + `mean()`

- We can combine base `R` functions with `tidyverse` functions!
  - Base `R`: `mean()`
  - `tidyverse`: `summarise()` (aka `summarize()`)
- Overall average SAT scores

```
df %>%
  summarise(mean_sat = mean(sat_avg,na.rm=T)) # Average SAT scores for entire data
```

```
## # A tibble: 1 × 1
##   mean_sat
##      <dbl>
## 1    1141.
```

Summarizing Data

- Let's unpack this

```
df %>%
  summarise(mean_sat = mean(sat_avg,na.rm=T))
```

- Create new variable `mean_sat` that contains the `mean()` of every school's average SAT score

- `na.rm=T` means we want to ignore missing data. If not?

```
df %>%
  summarise(mean_sat = mean(sat_avg))
```

```
## # A tibble: 1 × 1
##   mean_sat
##      <dbl>
## 1       NA
```

Summarizing Data

- Recall we want see if more selective schools have higher SAT scores

```
df %>%
  filter(adm_rate < .1) %>% # Only look at schools who accept less 
than 10% of applicants
  summarise(mean_sat_LT10 = mean(sat_avg,na.rm=T)) # Calculate the 
average SAT score
```

```
## # A tibble: 1 × 1
##   mean_sat_LT10
##           <dbl>
## 1         1510.
```

```
df %>%
  filter(adm_rate > .1) %>% # Only look at schools who accept more 
than 10% of applicants
  summarise(mean_sat_GT20 = mean(sat_avg,na.rm=T)) # Calculate the 
average SAT score
```

```
## # A tibble: 1 × 1
##   mean_sat_GT20
```

Summarizing Data: `group_by()`

- One final `tidyverse` function: `group_by()`
- There is a column called `selective` which is either 1 or 0
  - 1: the admissions rate is less than 10%
  - 0: otherwise

```
df %>%
  select(instnm,selective,adm_rate)
```

```
## # A tibble: 2,546 × 3
##    instnm                                selective adm_rate
##    <chr>                                     <dbl>    <dbl>
##  1 Alabama A & M University                      0    0.918
##  2 University of Alabama at Birmingham           0    0.737
##  3 Amridge University                           NA   NA
##  4 University of Alabama in Huntsville           0    0.826
##  5 Alabama State University                      0    0.969
##  6 The University of Alabama                     0    0.827
##  7 Central Alabama Community College            NA   NA
##  8 Athens State University                      NA   NA
```

Summarizing Data: `group_by()`

- Instead of running two separate `filter()` commands, use `group_by()`

```
df %>%
  group_by(selective) %>% # Group the data by selective (either 1 or 0)
  summarise(mean_sat = mean(sat_avg,na.rm=T)) # Calculate average SAT for each group
```

```
## # A tibble: 3 × 2
##   selective mean_sat
##       <dbl>    <dbl>
## 1         0    1135.
## 2         1    1510.
## 3        NA      NaN
```

Results

- Do more selective schools have higher SAT scores?
- Yes
- This Result **confirms** our Hypothesis and **answers** our Research Question

Conclusion

- What we've done today is a microcosm of data science

  1. Opened data (`readRDS`)

  2. Looked at data (`tidyverse` + `select()`, `filter()`, `arrange()`)

  3. Generated hypotheses (Admissions versus SAT scores)

  4. Tested hypotheses (`summarise()` + `mean()`)

Quiz & Homework

- Go to Brightspace and take the **1st** quiz
  - The password to take the quiz is ####
- **Homework:**
  1. Work through ds1000_hw_2.Rmd
  2. Problem set 1 due Friday by midnight