Reproducibility

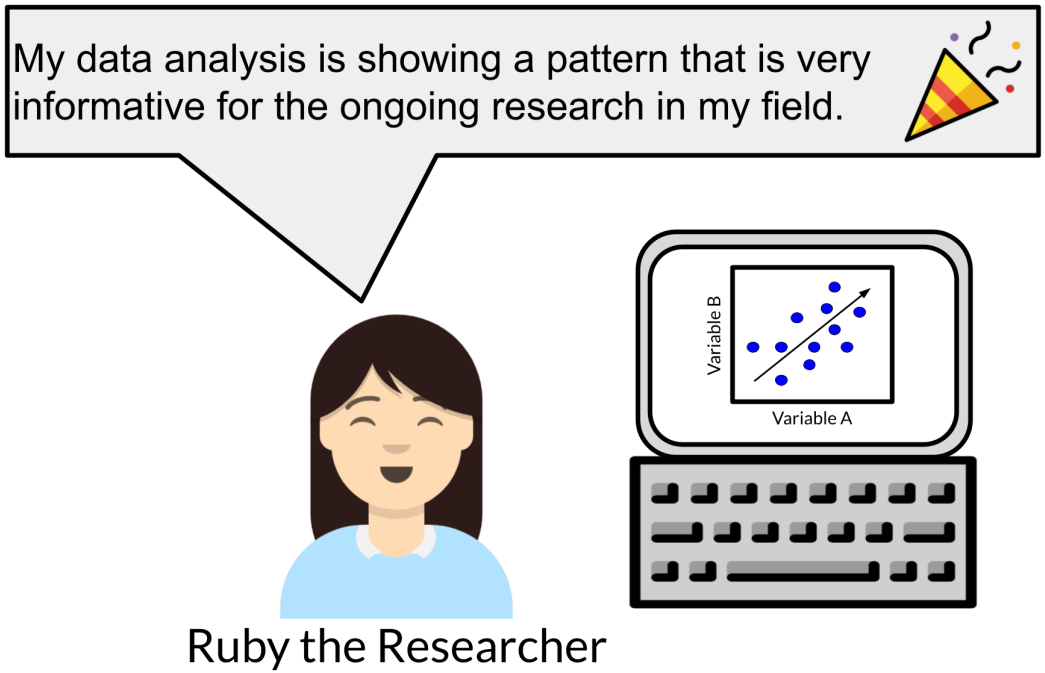
What's Reproducibility

Reproducibility:

a different analyst re-performs the analysis with
the **same code** and
the **same data** and obtains
the **same result**.

Patil, Peng, Leek (2016) https://www.biorxiv.org/content/10.1101/066803v1

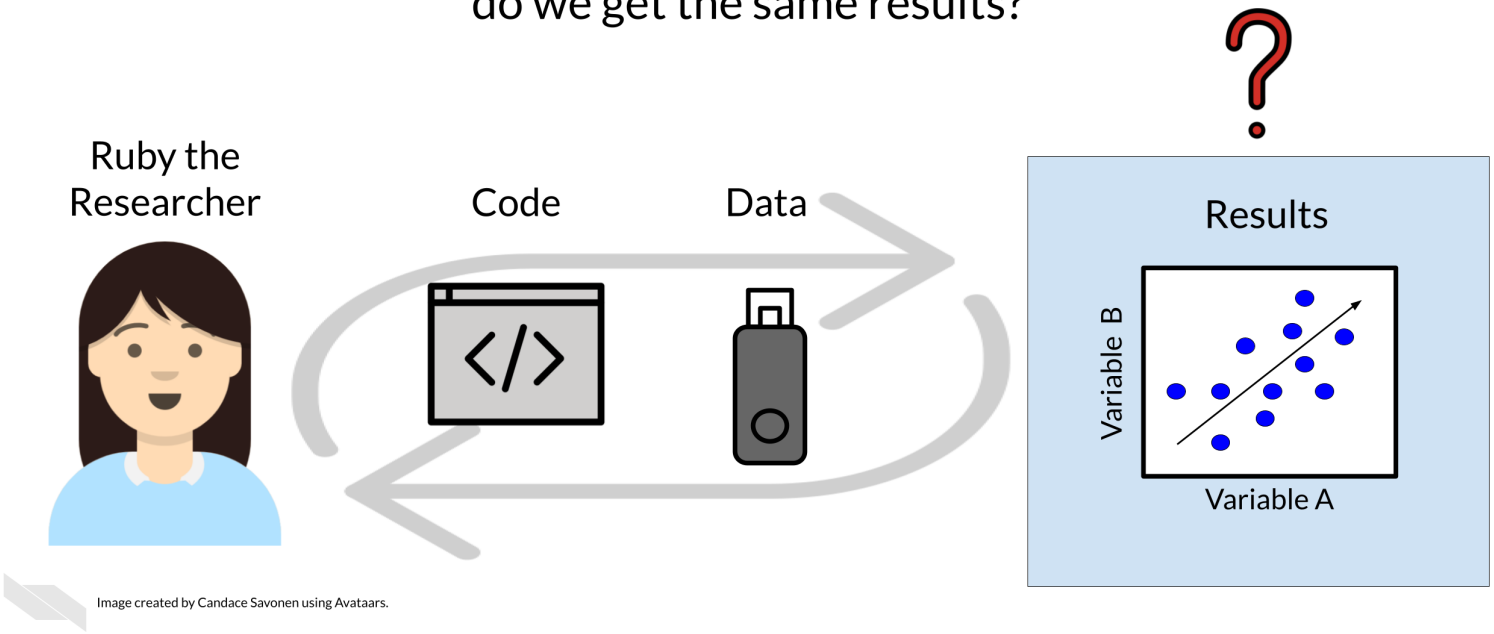
Content adapted from Candace Savonen.



Ruby the Researcher

Image created by Candace Savonen using Avataars.

Repeatable: keeping everything the same but repeating the analysis - do we get the same results?



Reproducible: using the same data and analysis but in the hands of *another researcher* - do we get the same results?

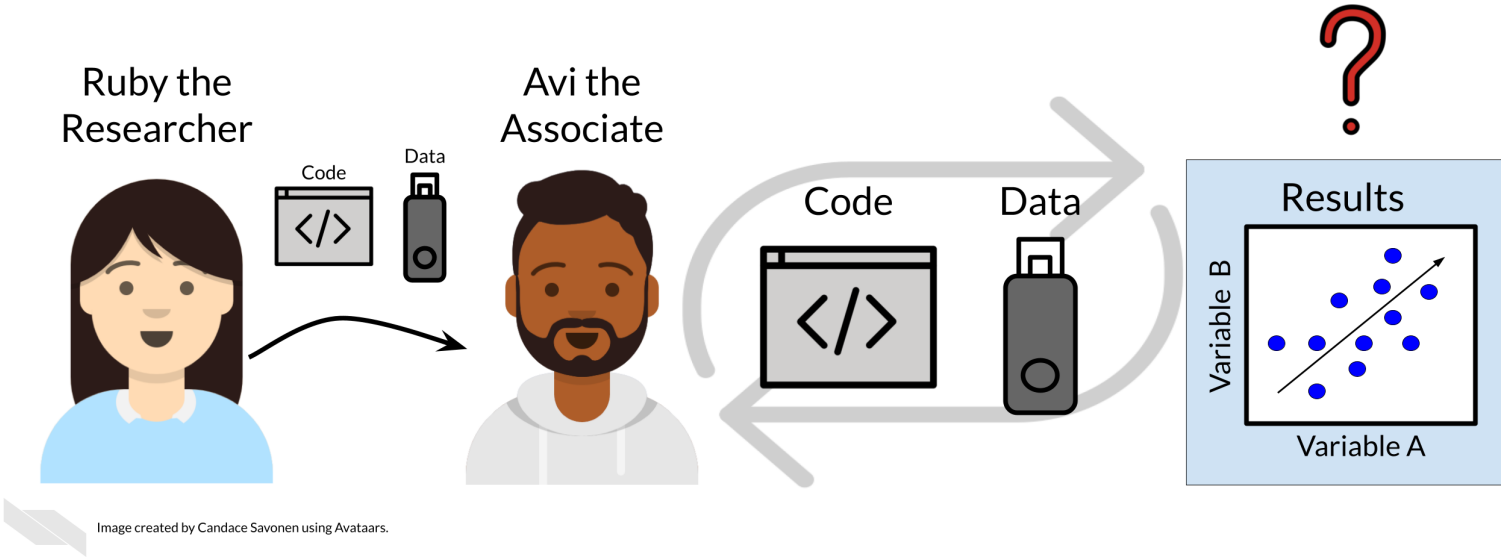
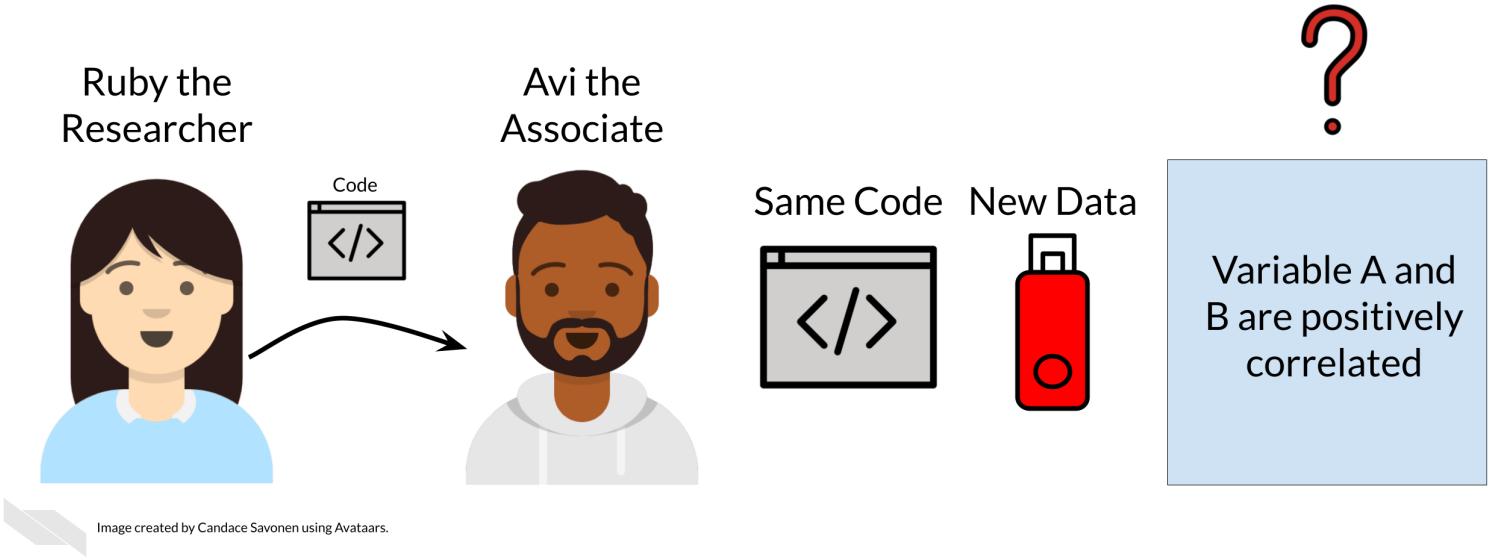
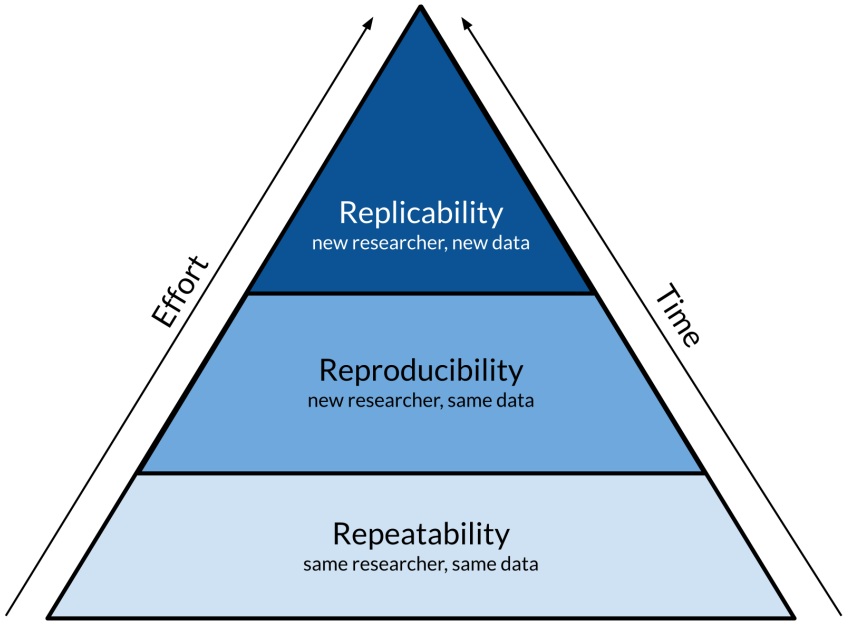


Image created by Candace Savonen using Avataars.

Replicable: with new data do we obtain the same inferences?



Reproducibility vs Repeatability vs Replicability



Based off of a figure from Essawy et al, 2020 https://doi.org/10.1016/j.envsoft.2020.104753

Why Reproducibility is important…

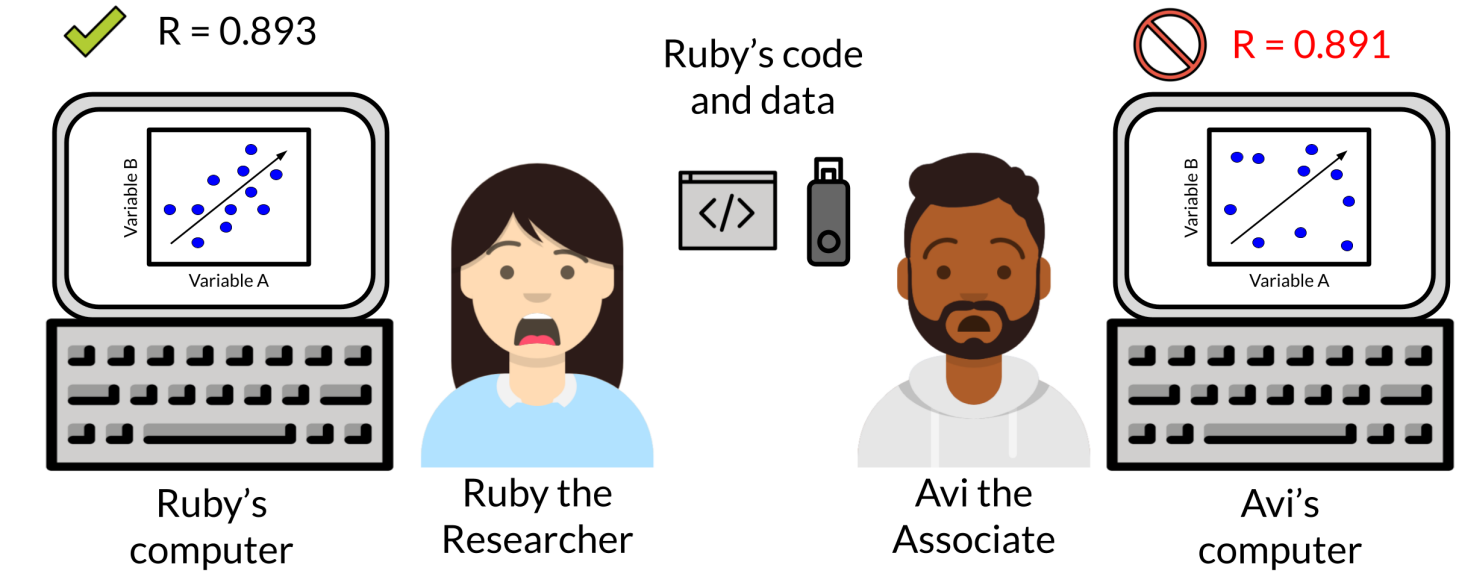


Image created by Candace Savonen using Avataars.

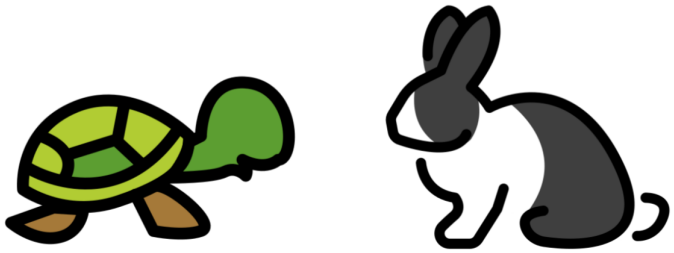
We can't get to replicability without reproducibility

Just because something is reproducible doesn't mean it is correct.

But it is a necessary step to help **check for correctness** and get to **replicability**.

It's worth the wait

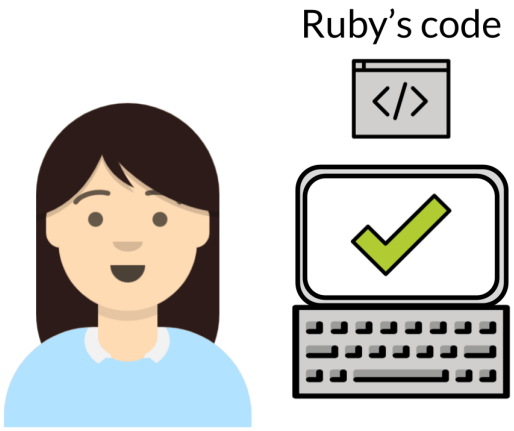
Reproducibility is a tortoise's game - it's an incremental and slow process *but* **it has high payoffs!**




Trying to understand your code from last year
%>%
purrr
rmarkdown
test that
ggplot2
tidyverse
lubri
stringr
forcats
usethis
rsample
TIBBLE
dplyr
parsnip

Reproducibility can also be for your future self!

Now Ruby



Future Ruby

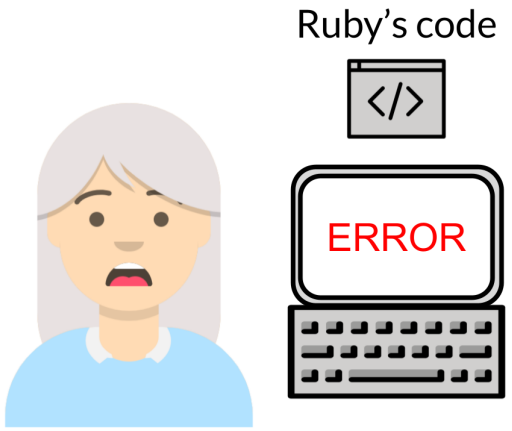
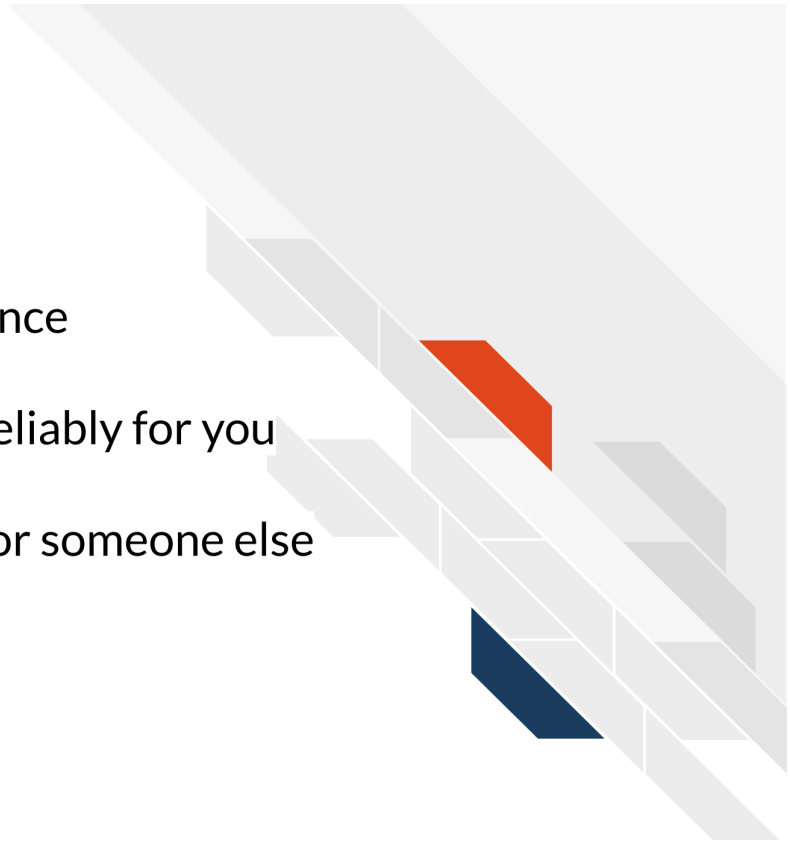


Image created by Candace Savonen using Avataars.

The process



Step 1) Get your code to work once

Step 2) Get your code to work reliably for you

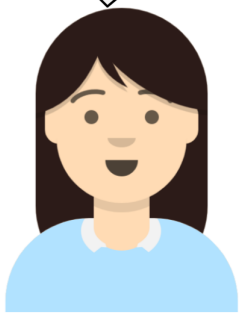
Step 3) Get your code to work for someone else

R Markdown

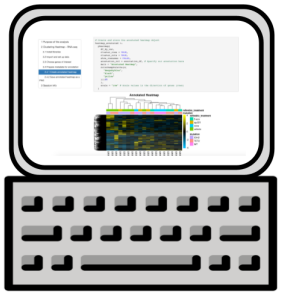
R Markdown notebooks are a handy tool for reproducibility!

R Markdown lets you test your work

Working from this notebook allows me to interactively develop on my data analysis and write down my thoughts about the process all in one place!



Ruby the Researcher



RMarkdown is conducive to interactive development!

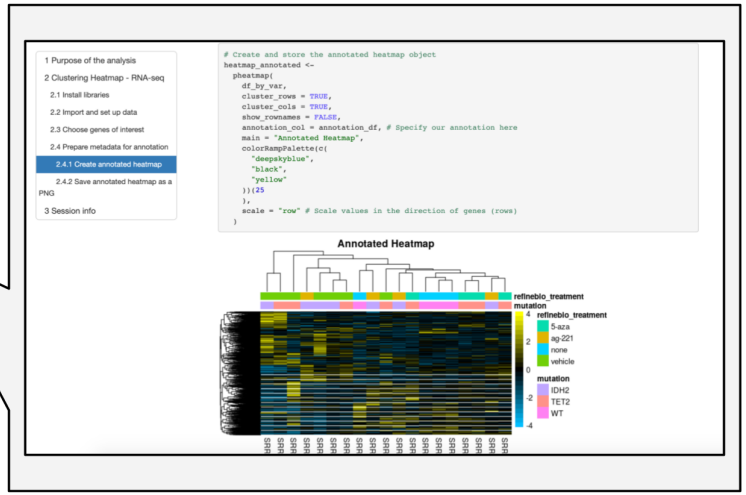
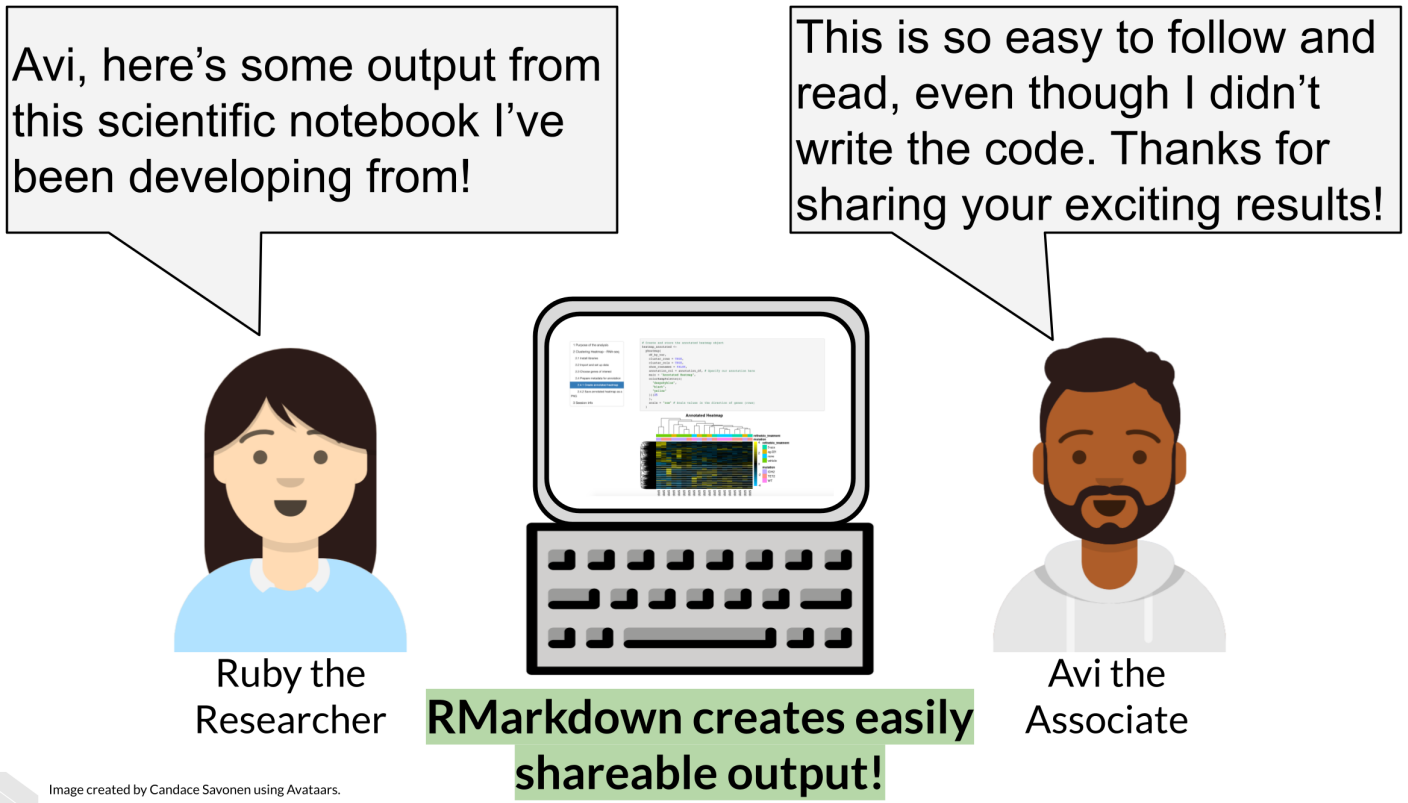


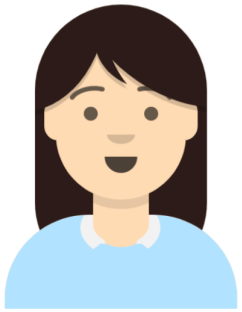
Image created by Candace Savonen using Avataars.

R Markdown allows you to more clearly show what you did

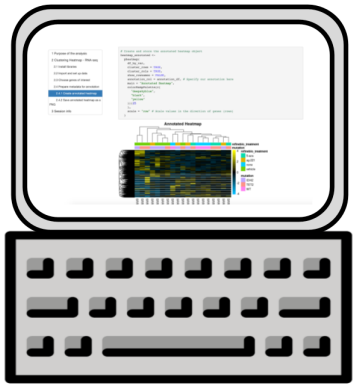


R Markdown makes it easier to update code and see results

Yay! I just got the data for 5 more samples. Because of my handy notebook set up, I can easily call one command and re-run the analysis so it is updated with the new samples included!



Ruby the Researcher



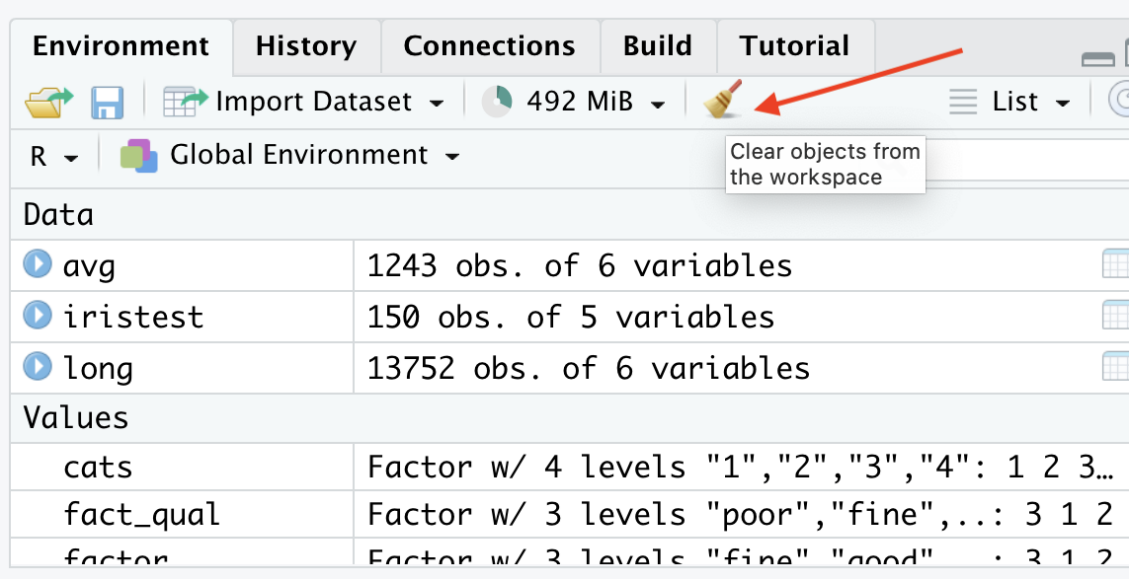
RMarkdown is handy for creating updateable reports!

Image created by Candace Savonen using Avataars.

Clean your environment

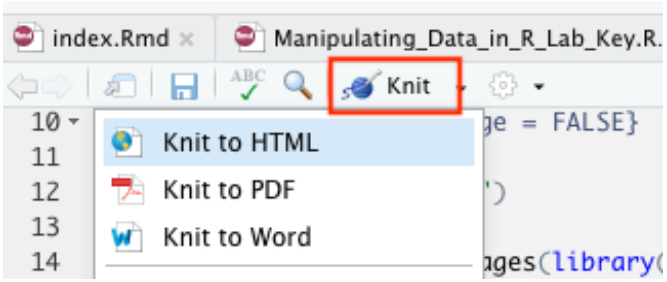
Regularly cleaning your environment and trying your code again, can help ensure that your code is running as expected.

Occasionally we might forget to save a step of our code in our R Markdown file that we ran only in the console. This will help us figure that out.



Check if your file knits regularly

Regularly checking if your file knits will help you spot a missing step or error earlier when you have less code to try to identify where your code might have gone wrong.



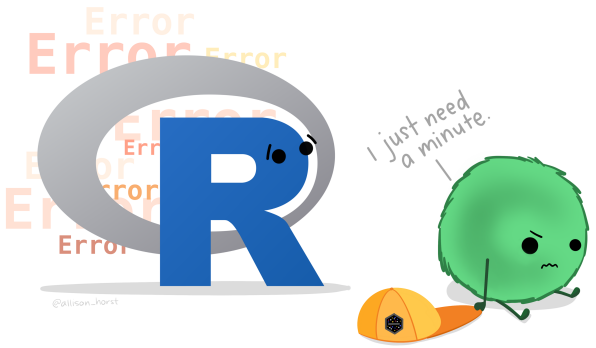


Image by Allison Horst.

Tell your future self and others what you did!

Provide sufficient detail so that you can understand what you did and why.

```
# Taking a random sample of 100 individuals from the population
# WITHOUT replacement
samp_pop <- sample(100, replace = FALSE)

# Then split them into two groups of 50
# a[x:xx] is the syntax for indexing a vector
samp_pop1 <- samp_pop[1:50]
samp_pop2 <- samp_pop[51:100]
```

Image by Allison Horst.

Need random numbers to stay consistent?

Use `set.seed()`: sets the starting state for the random number generator.

```
set.seed(123)
sample(10)
```

```
 [1]  3 10  2  8  6  9  1  7  5  4
```

```
set.seed(123)
sample(10)
```

```
 [1]  3 10  2  8  6  9  1  7  5  4
```

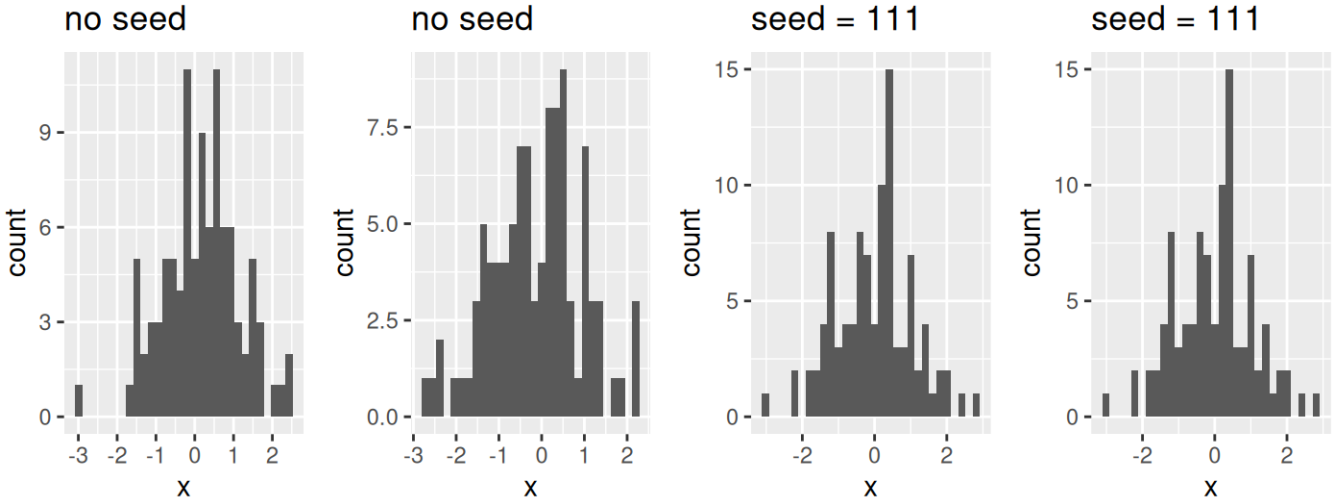
```
set.seed(456)
sample(10)
```

```
 [1]  5  3  6 10  4  9  1  2  8  7
```

Note that these are only pseudo random and the values are created doing calculations based on the given seed. Thus the same "random" values will be reproduced by everyone using the same seed with `set.seed`.

set.seed() visualization

```
Aset <- data.frame(x = rnorm(100)) # no seed
Bset <- data.frame(x = rnorm(100)) # no seed
set.seed(111); Cset <- data.frame(x = rnorm(100)) # set seed = 111
set.seed(111); Dset <- data.frame(x = rnorm(100)) # set seed = 111
randomA <- ggplot(Aset) + geom_histogram(aes(x = x)) + ggtitle("no seed")
randomB <- ggplot(Bset) + geom_histogram(aes(x = x)) + ggtitle("no seed")
randomC <- ggplot(Cset) + geom_histogram(aes(x = x)) + ggtitle("seed = 111")
randomD <- ggplot(Dset) + geom_histogram(aes(x = x)) + ggtitle("seed = 111")
randomA + randomB + randomC + randomD + plot_layout(ncol = 4) # combine plots with patchwork
```



Very helpful for bootstrapping

https://rsample.tidymodels.org/reference/bootstraps.html

R Markdown syntax

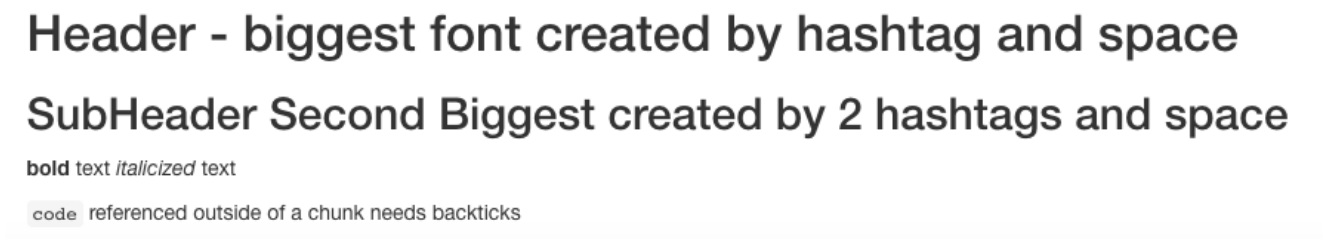
Before:

```
# Header - biggest font created by hashtag and space
## SubHeader Second Biggest created by 2 hashtags and space

**bold** text
*italicized* text

`code` referenced outside of a chunk needs backticks
```

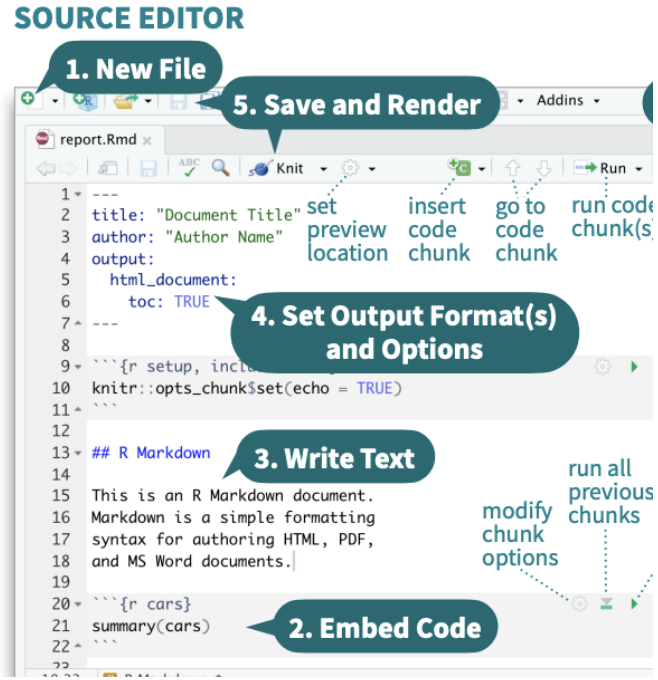
After knit:



R Markdown syntax

Go to the RStudio toolbar: Help > Cheat Sheets > R Markdown Cheat Sheet (which will download it)

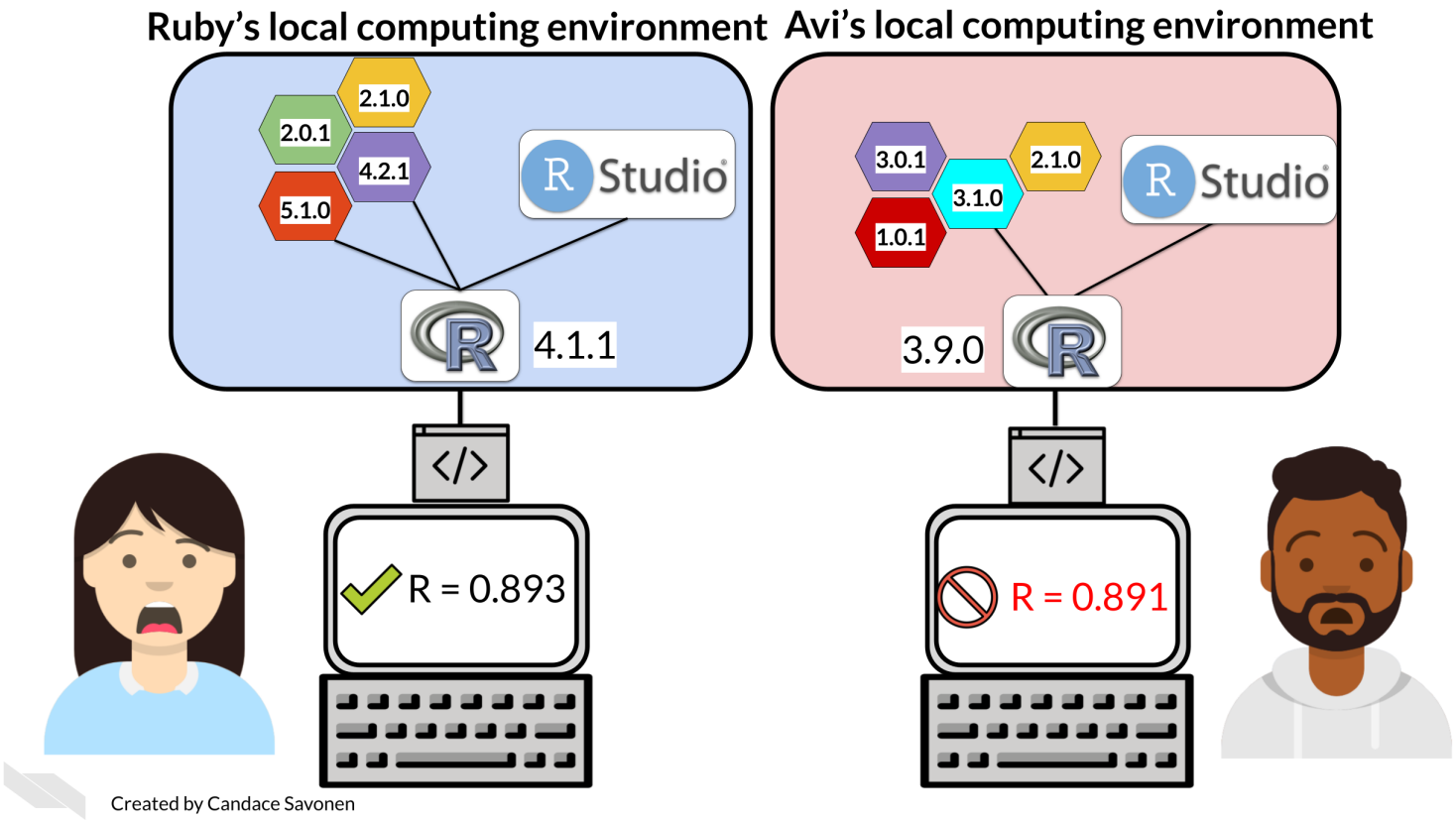
Or Help > Cheat Sheets > R Markdown Reference Guide



Additional references

Or check out the Class Website! The Resources page has links to additional helpful cheat sheets.

Versions matter



Session info can help

Ruby's session info print out

```
R version 4.0.2 (2020-06-22)
Platform: x86_64-pc-linux-gnu (64-bit)
Running under: Ubuntu 20.04.2 LTS

Matrix products: default
BLAS/LAPACK: /usr/lib/x86_64-linux-gnu/openblas-pthread/libopenblasp-r0.3.8.so

locale:
 [1] LC_CTYPE=en_US.UTF-8       LC_NUMERIC=C               LC_TIME=en_US.UTF-8
 [4] LC_COLLATE=en_US.UTF-8     LC_MONE
 [7] LC_PAPER=en_US.UTF-8       LC_NAME
[10] LC_TELEPHONE=C             LC_MEAS

attached base packages:
[1] stats     graphics  grDevices utils     datasets  methods   base

other attached packages:
[1] rmarkdown_2.4

loaded via a namespace (and not attached):
 [1] rstudioapi_0.11   knitr_1.30        magrittr_1.5      hms_0.5.3         tidyselect_1.
 [6] R6_2.4.1          rlang_0.4.7       fansi_0.4.1       dplyr_1.0.2       tools_4.0.2
[11] xfun_0.18         sessioninfo_1.1.1 tinytex_0.26      cli_2.0.2         withr_2.3.0
[16] htmltools_0.5.0   ellipsis_0.3.1    assertthat_0.2.1  yaml_2.2.1        digest_0.6.25
[21] tibble_3.0.3      lifecycle_0.2.0   crayon_1.3
[26] vctrs_0.3.4       glue_1.4.2        evaluate_0
[31] generics_0.0.2    jsonlite_1.7.1    pkgconfig_2.0.3
```

R version 4.0.2 vs 4.0.5

Different operating systems!

rmarkdown 2.4 vs 2.10

Avi's session info print out

```
R version 4.0.5 (2021-03-31)
Platform: x86_64-apple-darwin17.0 (64-bit)
Running under: macOS Big Sur 10.16

Matrix products: default
LAPACK: /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRlapack.dyli

locale:
[1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8

attached base packages:
[1] stats     graphics  grDevices utils     datasets  methods   base

other attached packages:
[1] rmarkdown_2.10

loaded via a namespace (and not attached):
 [1] leanbuild_0.1.2     BiocManager_1.30.16 compiler_4.0.5      magrittr_2.0.1
 [5] fastmap_1.1.0       htmltools_0.5.2     tools_4.0.5         yaml_2.2.1
 [9] tinytex_0.33        knitr_1.33          digest_0.6.27       xfun_0.25
[13] rlang_0.4.11        evaluate_0.14
```

If Avi and Ruby have discrepancies in their results, the session info print out gives a record which may have clues to why that might be!

Image by Candace Savonen

GUT CHECK

Why is reproducibility so important?

A. It helps to ensure that your code is working consistently and it helps others understand what you did

B. It ensures that your code is correct

GUT CHECK

What is NOT a practice to improve the reproducibility of our work?

A. Using R Markdown files to describe what your code is doing

B. Using scripts instead of R Markdown files

C. Testing your code with R Markdown files or the run previous button

D. Regularly cleaning the environment

More resources

These are just some quick tips, for more information:

- Reproducibility in Cancer Informatics course
- Advanced Reproducibility in Cancer Informatics course
- The RMarkdown book
- Jenny Bryan's organizational strategies.
- Write efficient R code for science.

Summary

To help make your work more reproducible:

- Use RMarkdown
- Clean your environment regularly
- Check the knit of your RMarkdown regularly
- Tell your future self and others what you did!
- Print session info!

Resources & Lab

- Class Website
- Lab
- Day 1 Cheatsheet
- RStudio Cheatsheet

Image by Gerd Altmann from Pixabay