

Share your knowledge week 2023

Writing scientific reports in
RMarkdown

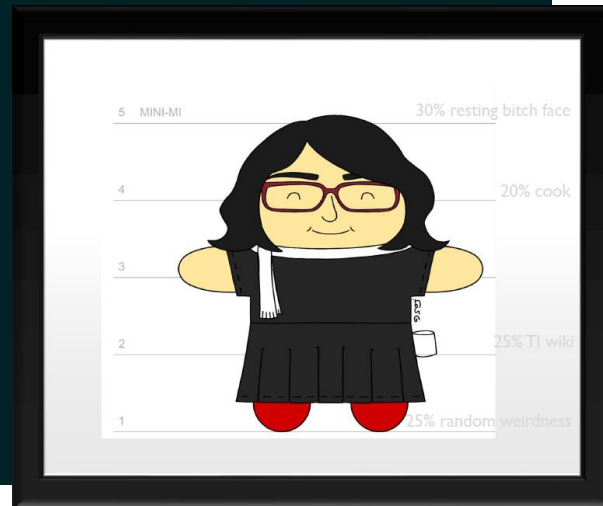
A. Schmidt



Write scientific reports in R Markdown:

Meet your instructor

- PhD Candidate in Econometrics (DNB + TI+ ESE) since 2021
- Previous:
 - Bsc in Statistics (2010),
 - Bsc in Economics (2019),
 - Msc in Economics (2019),
 - Mphil in Econometrics (2022)
- R user since 2008 (but not a developer)
- Available at venesschmidt@ese.eur.nl



Erasmus

Goal of this tutorial:

Write scientific reports in R Markdown

- To introduce R Markdown:
 - Motivation
 - How to get started
 - Markdown writing
 - Inserting LaTeX
 - Inserting chunks with R code
 - Calling R functions along Markdown text

RMarkdown: what?



- RMarkdown was introduced in 2012 along the knitr package for R (and became a package in 2014)
- The idea is to have code together with text, written with Markdown
- Can create reports in different formats: pdf, html, word or slides in power point, beamer, html
- Compiled from R, it can insert output from code directly in your file

Erasmus

RMarkdown: what changes from standard R code?

```
1 #####
2 # RMarkdown introduction
3 # Author: A. Schmidt
4 # Last update: 05/09/2021
5 #
6 # Description: This is an example of an R script for the lecture from week 2 at the
7 # FEM11149 Introduction to Data Science Course at Erasmus University.
8 #
9 # Dependencies: None
10 #
11 # Version:
12 # * 05/09/2021: Initialization
13 #####
14
15 #####
16 # Load packages
17 #####
18 if (!require("ggplot2")) install.packages("ggplot2")
19
20 #####
21 # Functions
22 #####
23
24 # Creates a data frame with n rows and 3 group values
25 # Input:
26 ## n number of observations
27 # Output:
28 ## data a data frame with 2 columns and n*3 rows
29
30
31 fcreateData <- function(n = 100){
32   data <- data.frame(values = c(rnorm(n, 5, 3),
33                                 rnorm(n, 7, 2),
34                                 runif(n, 8, 11)),
35                       group = c(rep("A", n),
36                                 rep("B", n),
37                                 rep("C", n)))
38   return(data)
39 }
40
41 # Computes the average of individual columns in a data frame
42 # Input:
43 ## data a data frame with 2 columns named values (continuous) and group (categorical)
44 # Output:
45 ## average a table with the mean of each group
46
47 fcomputeAverage <- function(data = data){
48
49   if (!is.data.frame(data)){
50     stop("Please use a data.frame object!")
51   }
52
53   average <- tapply(data$values, data$group, mean)
54   return(average)
55 }
```

```
56 #####
57 # Magic numbers
58 #####
59
60 n <- 200
61
62
63 #####
64 # Initialization
65 #####
66
67 dx <- fcreateData(n)
68
69 #####
70 # Main
71 #####
72
73 head(dx)
74 tail(dx)
75 fcomputeAverage(dx)
76
77
78 g1 <- ggplot(dx, aes(x = values, fill = group)) +
79   geom_histogram(position = "identity", alpha = 0.3, bins = 50) +
80   theme_bw() +
81   xlab("values") + ylab("Frequencies")
82
83 g1
```

I have some documentation for my functions, but they are displayed as comments

The plot g1 will not be displayed in my *.R code, to see the graph it you have to run the code yourself.



RMarkdown: what changes from standard R code?

Does not appear anywhere
in the report!

```
1 title: "Example RMarkdown file"
2 author: |
3   | A. Schmidt | (https://sites.google.com/view/alshameriane)
4 date: "September, 2021"
5 output:
6   pdf_document:
7     subtitle: FEM11149 - Introduction to Data Science
8   editor_options:
9     chunk_output_type: inline
10    urlcolor: blue
11    linkcolor: red
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```

Example RMarkdown file
FEM11149 - Introduction to Data Science

A. Schmidt

September, 2021

Introduction

This is an example of an R script for the lecture from Week 2 from the FEM11149 Introduction to Data Science Course at Erasmus University.

Declaring functions

fCreateData

fCreateData(n) creates a data frame with n observations and 3 groups, where the observations are generated from a normal distribution. Group A observations come from $N(5, 3)$, group B comes from $N(7, 2)$ and group C is generated using $N(8, 11)$.

Inputs

- n: number of rows

Output

- data: a data frame with 2 columns and n * 3 rows.

```
fCreateData = function(n = 100) {
  data <- data.frame(values = c(rnorm(n, 5, 3), rnorm(n,
    7, 2), runif(n, 8, 11)), group = c(rep("A",
    n), rep("B", n), rep("C", n)))
  return(data)
}
```

fComputeAverage

fComputeAverage(data) calculates the average of a quantitative variable according to groups defined in another variable.

Now I can have a proper
space for documenting my
function

RMarkdown: what changes from standard R code?

Initialization

```
n <- 200  
dX <- fCreateData(n)
```

Main

We first check the first and last observations from dX, to see what information is there.

Table 1: First and last values of dX

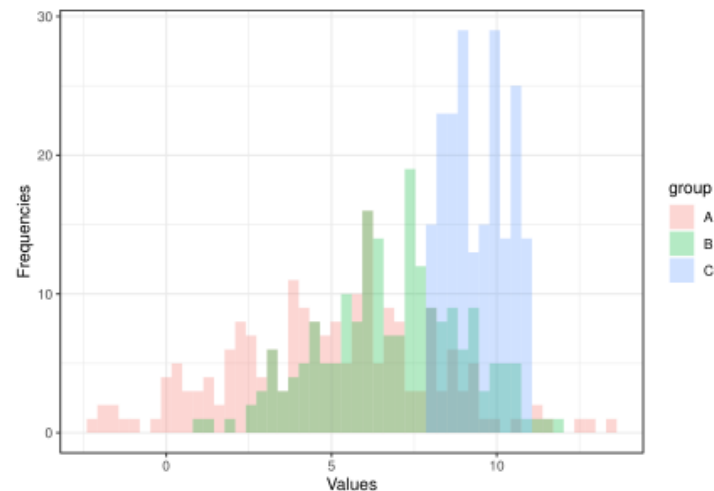
Value	Group	Variable	Group
0.2034385	A	8.413659	C
6.3201182	A	8.877690	C
6.2419738	A	9.129007	C
0.0055206	A	10.370745	C
6.9101949	A	10.568385	C
8.8625207	A	10.458294	C

Now we take a look of the average value for each group.

Table 2: Average values per group from dX

	x
A	4.924333
B	6.853090
C	9.430250

And we take a look on the histogram.



RMarkdown: why?

- Improves scientific communication: you can use text to explain parts of the code to others (including your future self!)
- Makes it easier to update dynamic

When it might not be so helpful?

- Writing packages
- Doing heavy simulations (better run separately in a regular R file and call in the Rmarkdown document later)



Erasmus

So what are we doing, in practice?

- Instead of starting an R code file, we start an Rmarkdown file
- In it, **we include code using chunks**, that might or might not appear in the final document
- We can use results from the code to **display tables, graphs, coding results**
- We can also **insert text using Markdown** and **equations using LaTeX**



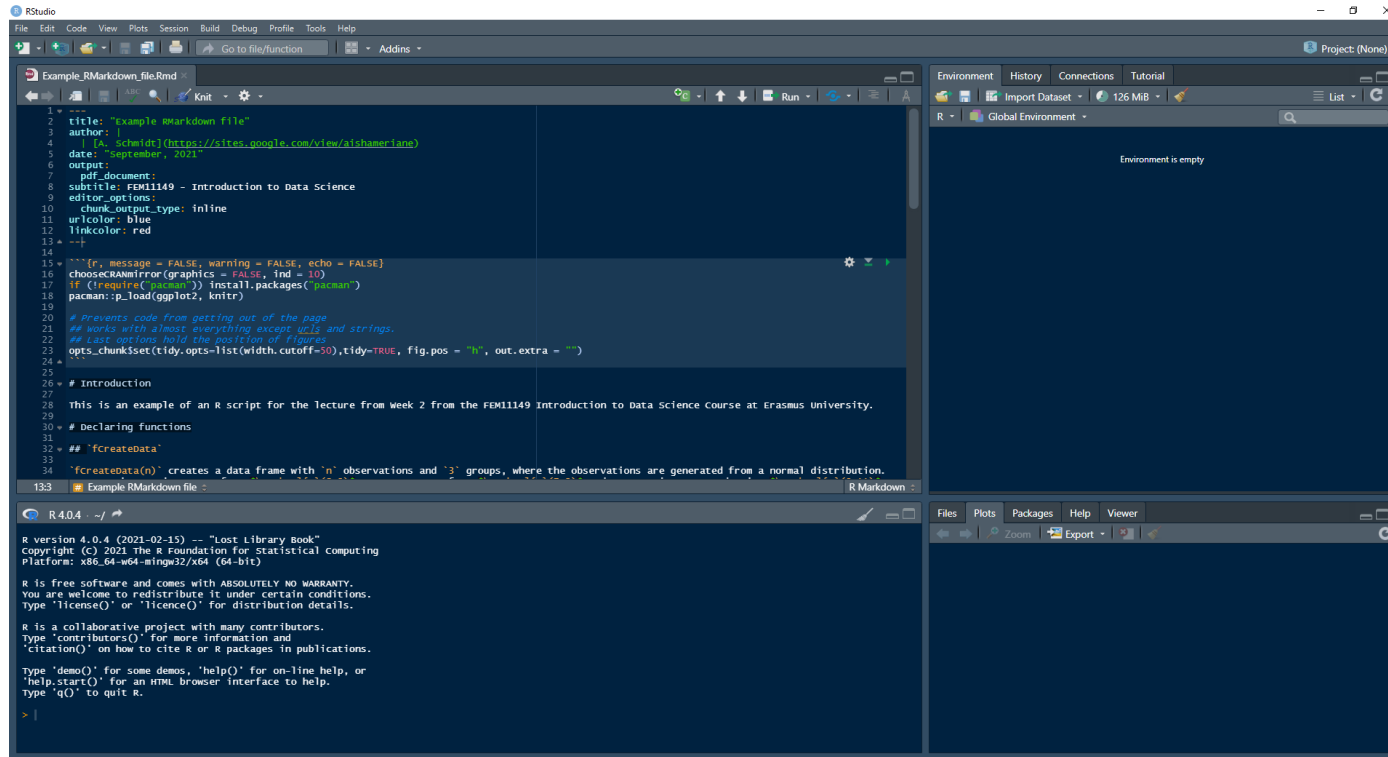
Goal of this tutorial:

Write scientific reports in R Markdown

- To introduce R Markdown:
 - ~~Motivation~~
 - **How to get started**
 - **Markdown writing**
 - Inserting LaTeX
 - Inserting chunks with R code
 - Calling R functions along Markdown text

← *We are here!*

RMarkdown: first steps



```
1 #---
2 title: "Example RMarkdown file"
3 author: |
4   [r, schmid](https://sites.google.com/view/aihammerlane)
5 date: "September, 2021"
6 output:
7   pdf_document:
8     subtitle: FEM11149 - Introduction to Data Science
9 editor_options:
10   chunk_output_type: inline
11   uricolor: blue
12   linkcolor: red
13 #--
14
15 # [r, message = FALSE, warning = FALSE, echo = FALSE]
16 chooseRANmirror(graphics = FALSE, ind = 10)
17 if (requireNamespace("pacman")) install.packages("pacman")
18 pacman::p_load(ggplot2, knitr)
19
20 # Prevents code from getting out of the page
21 ## works with almost everything except urls and strings.
22 ## Last options hold the position of figures
23 opts_chunk$set(tidy.opts=list(width.cutoff=30),tidy=TRUE, fig.pos = "N", out.extra = "")
24
25 # Introduction
26
27 This is an example of an R script for the lecture from week 2 from the FEM11149 Introduction to Data Science Course at Erasmus University.
28
29 # Declaring functions
30
31 ## 'fcreateData'
32
33 'fcreateData(n)' creates a data frame with 'n' observations and '3' groups, where the observations are generated from a normal distribution.
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```

```
R version 4.0.4 (2021-02-15) -- "Lost Library Book"
Copyright (c) 2021 The R Foundation for Statistical Computing
Platform: x86_64-w64-mingw32/x64 (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

> |
```

At this point you should know how to start an Rmarkdown file based on the preparation slides.



RMarkdown: the anatomy of a file (1)



```
1 ---
2 title: "Example RMarkdown file"
3 author: |
4   [A. Schmidt](https://sites.google.com/view/aishameriane)
5 date: "September, 2021"
6 output:
7   pdf_document:
8     subtitle: FEM1149 - Introduction to Data Science
9   editor_options:
10     chunk_output_type: inline
11     urlcolor: blue
12     linkcolor: red
13 ---
14
15 ```{r, message = FALSE, warning = FALSE, echo = FALSE}
16 chooseCRANmirror(graphics = FALSE, ind = 10)
17 if (!require("pacman")) install.packages("pacman")
18 pacman::p_load(ggplot2, knitr)
19
20 # Prevents code from getting out of the page
21 ## Works with almost everything except urls and strings.
22 ## Last options hold the position of figures
23 opts_chunk$set(tidy.opts=list(width.cutoff=50),tidy=TRUE, fig.pos = "h", out.extra = "")
24 ```
25
26 # Introduction
27
28 This is an example of an R script for the lecture from Week 2 from the FEM1149 Introduction to Data Science Course at Erasmus University.
29
30 # Declaring functions
31
32 ## `fCreateData`
33
34 `fCreateData(n)` creates a data frame with `n` observations and `3` groups, where the observations are generated from a normal distribution.
```

This is called YAML header

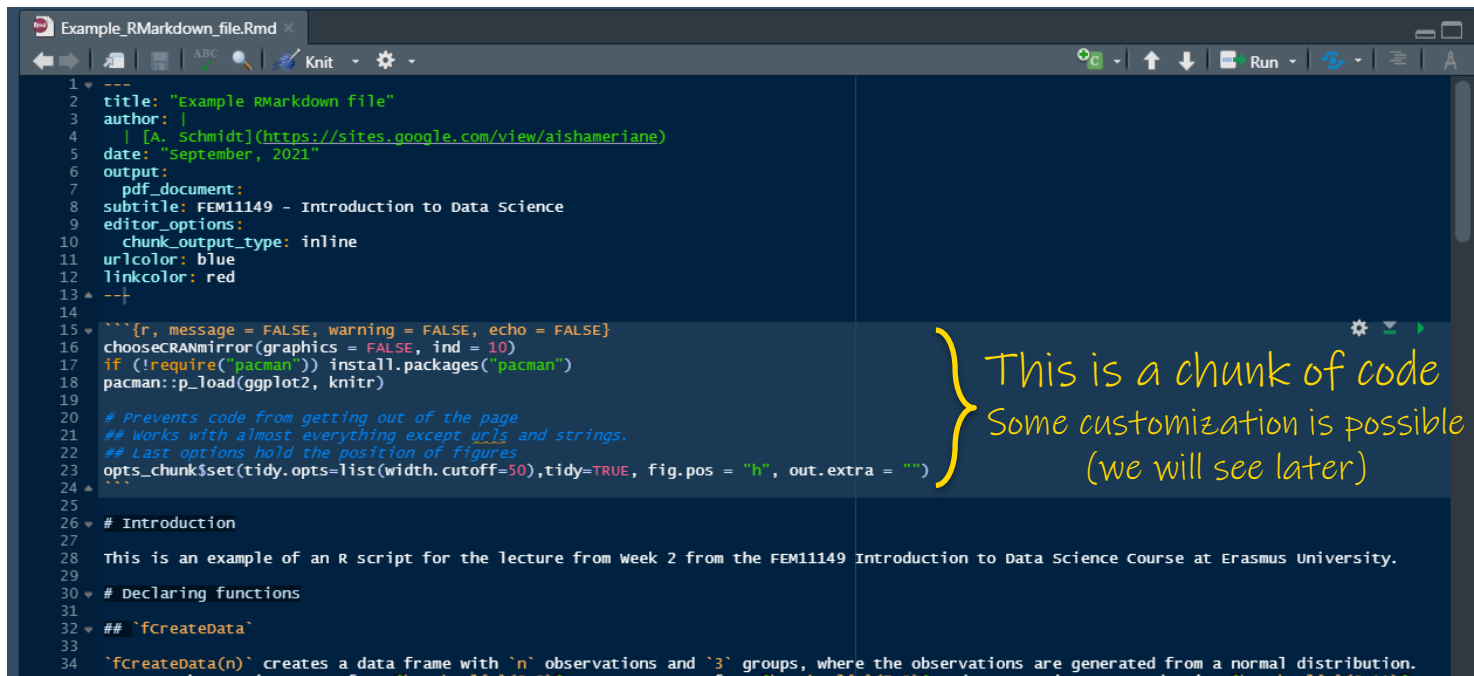
There are many options that can be added here (as you can see I already modified the 'simple' header)

You can check here for some more options for pdf file:

<https://bookdown.org/yihui/rmarkdown/pdf-document.html>



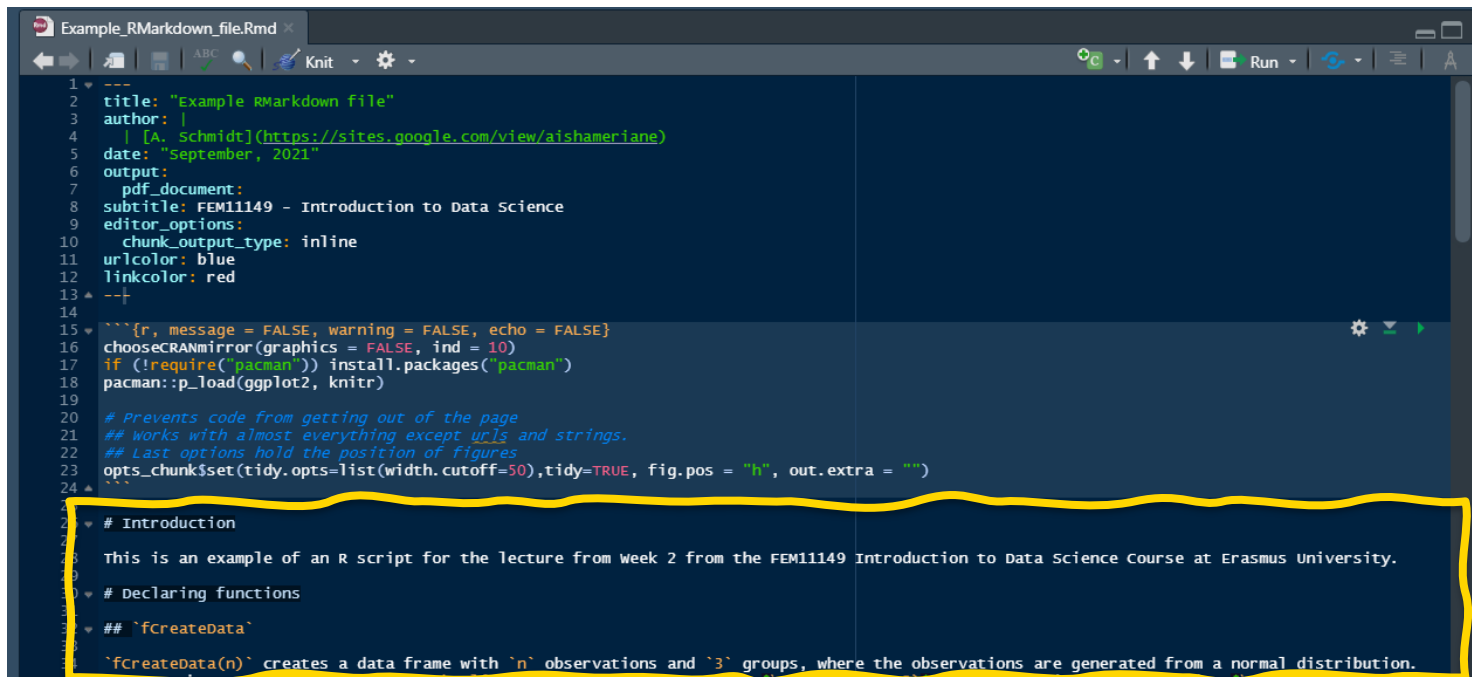
RMarkdown: the anatomy of a file (2)



```
1 ---
2 title: "Example RMarkdown file"
3 author: |
4   | [A. Schmidt](https://sites.google.com/view/aishameriane)
5 date: "September, 2021"
6 output:
7   pdf_document:
8     subtitle: FEM1149 - Introduction to Data Science
9 editor_options:
10   chunk_output_type: inline
11 urlcolor: blue
12 linkcolor: red
13 ---
14
15 ```{r, message = FALSE, warning = FALSE, echo = FALSE}
16 chooseCRANmirror(graphics = FALSE, ind = 10)
17 if (!require("pacman")) install.packages("pacman")
18 pacman::p_load(ggplot2, knitr)
19
20 # Prevents code from getting out of the page
21 ## Works with almost everything except urls and strings.
22 ## Last options hold the position of figures
23 opts_chunk$set(tidy.opts=list(width.cutoff=50),tidy=TRUE, fig.pos = "h", out.extra = "")
24 ```
25
26 # Introduction
27
28 This is an example of an R script for the lecture from Week 2 from the FEM1149 Introduction to Data Science Course at Erasmus University.
29
30 # Declaring functions
31
32 ## `fCreateData`
33
34 `fCreateData(n)` creates a data frame with `n` observations and `3` groups, where the observations are generated from a normal distribution.
```

This is a chunk of code
Some customization is possible
(we will see later)

RMarkdown: the anatomy of a file (2)



```
1 ---
2 title: "Example RMarkdown file"
3 author: |
4   | [A. Schmidt](https://sites.google.com/view/aishameriane)
5 date: "September, 2021"
6 output:
7   pdf_document:
8     subtitle: FEM1149 - Introduction to Data Science
9 editor_options:
10   chunk_output_type: inline
11 urlcolor: blue
12 linkcolor: red
13 ---
14
15 ```{r, message = FALSE, warning = FALSE, echo = FALSE}
16 chooseCRANmirror(graphics = FALSE, ind = 10)
17 if (!require("pacman")) install.packages("pacman")
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23 opts_chunk$set(tidy.opts=list(width.cutoff=50),tidy=TRUE, fig.pos = "h", out.extra = "")
24 ```
25
26 # Introduction
27
28 This is an example of an R script for the lecture from Week 2 from the FEM1149 Introduction to Data Science Course at Erasmus University.
29
30 # Declaring functions
31
32 ## `fCreateData`
33
34 `fCreateData(n)` creates a data frame with `n` observations and `3` groups, where the observations are generated from a normal distribution.
```

This is plain text
Written in Markdown

Erasmus

Markdown (1)

- **Markdown is intended to be an accessible syntax to write text that can be converted to html or other format types**
- **It is different from writing in MS Word where 'what you see is what you get' (WYSIWYG):**
 - **in Markdown, you have some basic syntax that needs to be interpreted in order to show its final form**
- **Still, it is simpler than a programming language**

A handwritten signature in black ink, appearing to read 'Erasmus', is located in the bottom right corner of the slide.

Markdown (2)

Say you want to make a webpage that displays this:

Today's shopping list:

- Milk
- Eggs
- Cereal
- Fruit

This is the html
code

```
<body>
  <h3>Today's shopping list:</h3>
  <ul>
    <li>Milk</li>
    <li>Eggs</li>
    <li>Cereal</li>
    <li>Fruit</li>
  </ul>
</body>
```

This is the
markdown code

```
### Today's shopping list:

* Milk
* Eggs
* Cereal
* Fruit
```


Markdown syntax

- To delimit sections, you use # to make headers

Time to learn some markdown!
Time to learn some markdown!
Time to learn some markdown!
Time to learn some markdown!



Time to learn some markdown!

Time to learn some markdown!

Time to learn some markdown!

Time to learn some markdown!



Markdown syntax

- Plain text can be bold, italic, strikethrough

This is **bold** text

This is *italic* text

This is ~~crossed out~~ text



This is **bold** text

This is *italic* text

This is ~~crossed out~~ text

Erasmus

Markdown syntax

- You can make numbered or bullet lists

Bullet list

- * a bullet point
- a bullet point
- + still a bullet point



Bullet list

- a bullet point
- a bullet point
- still a bullet point

Numbered list

1. First item on our numbered list
2. Second item on our numbered list



Numbered list

1. First item on our numbered list
2. Second item on our numbered list



Markdown syntax

- You can mix elements in lists

Mixing things

1. First item on our numbered list

- * a bullet point
- a bullet point
- + still a bullet point

2. Second item on our numbered list

- * a bullet point:
 - * Now with a sub-list to our sub-list
 - * still with a sub-list to our sub-list
- a bullet point
- + still a bullet point

Mixing things

1. First item on our numbered list

- a bullet point
- a bullet point
- still a bullet point

2. Second item on our numbered list

- a bullet point:
 - Now with a sub-list to our sub-list
 - still with a sub-list to our sub-list
- a bullet point
- still a bullet point

Erasmus

Practice a bit!

Go to <https://dillinger.io/>
and edit the file in there

A stylized, handwritten-style logo for Erasmus, featuring a large, flowing 'E' followed by the word 'Erasmus' in a cursive script.

Goal of this tutorial:

Write scientific reports in R Markdown

- To introduce R Markdown:
 - ~~Motivation~~
 - ~~How to get started~~
 - ~~Markdown writing~~
 - **Inserting LaTeX** ← *We are here!*
 - Inserting chunks with R code
 - Calling R functions along Markdown text

LaTeX (1)

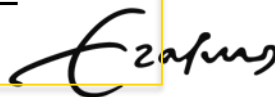
- It is a software system intended for document preparation
- Outside RMarkdown you can use LaTeX to make whole documents (papers, thesis, books, etc)
 - In Rmarkdown we will use to write math expressions

LaTeX raw code

```
x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}
```

How it looks after
compiling

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$



LaTeX (2)

- Inside Rmarkdown, we insert LaTeX code inline using `$equation$` or in a new line using `$$equation$$`

Inline LaTeX equations can be written in a pair of dollar signs using the LaTeX syntax, e.g., `$f(k) = \{n \choose k\} p^k (1-p)^{n-k}$` (actual output: $f(k) = \binom{n}{k} p^k (1-p)^{n-k}$); math expressions of the display style can be written in a pair of double dollar signs, e.g., `$$f(k) = \{n \choose k\} p^k (1-p)^{n-k}$$`, and the output looks like this:

$$f(k) = \binom{n}{k} p^k (1-p)^{n-k}$$

LaTeX (3)



- Check [here](#) + [here](#) for some LaTeX tips;
- Be careful that not all LaTeX packages will be available, so some commands could not work on your document;
- Equation labeling and referencing is also not equal to what you do in 'plain' LaTeX
- Like any other software/language, it is the type of thing you learn by doing
 - And on Google

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LaTeX (4)

- Try to write in a Markdown document what is written in the example for reports (link on chat)

```
39
40- ## Writing what is in the instructions_report.pdf file
41
42 Equations and mathematical symbols can be easily added to a Markdown file.
43 be written as  $\frac{2}{3}$ . Other expressions are, e.g.,  $\hat{\lambda}$  =
44 (...)
45
46 An  $n \times m$  matrix can be shown as
47
48 \begin{equation}
49   n\mathbb{A}m =
50   \begin{pmatrix}
51     a_{11} & a_{12} & \dots & a_{1m} \\
52     a_{21} & a_{22} & \dots & a_{2m} \\
53     \vdots & \vdots & \ddots & \vdots \\
54     a_{n1} & a_{n2} & \dots & a_{nm}
55   \end{pmatrix}
56 \end{equation}
```

Writing what is in the instructions_report.pdf file

Equations and mathematical symbols can be easily added to a Markdown file. A fraction of two-thirds can be written as $\frac{2}{3}$. Other expressions are, e.g., $\hat{\lambda} = 1.02$ and $\sqrt{4}$.
(...)

An $n \times m$ matrix can be shown as

$$nAm = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1m} \\ a_{21} & a_{22} & \dots & a_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nm} \end{pmatrix} \quad (1)$$

You can use [Mathpix Snip](#) to crop images, pdf files and other type of files and generate a LaTeX code. There are good tutorials on how to write equations in LaTeX (just be aware that in RMarkdown your possibilities with packages are a bit more limited than in a *.tex document). Some references can be found [here](#) or in the report instructions on Canvas.

Check out this software: <https://mathpix.com/>

You can take 'snips' of text and it makes the LaTeX code.

If you register with your Erasmus e-mail you get some extra benefits.



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Inserting chunks of R code into RMarkdown files (1)

- The biggest advantage of RMarkdown is to be able to use R code
- A 'chunk' is a piece of the document that will work exactly as an R file (so you cannot put text inside unless in commented lines)
- You can insert a chunk via menu or using the shortcut **Ctrl+Alt+I**
- There are many options for a chunk, for example size of figures that will display, hide the code (and display only results), etc

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Inserting chunks of R code into RMarkdown files (2)

```
142 # Inserting R code
143
144 ```{r}
145 # This is the most basic R code chunk
146
147 x <- 1+1
148 x
149 ```
```

Click here to run everything that is
inside the chunk
(without having to compile the
whole file)

Inserting chunks of R code into RMarkdown files (3)

```
142 ▾ # Inserting R code
143
144 ▾ ```{r}
145   # This is the most basic R code chunk
146
147   x <- 1+1
148   x
149 ▴ ```
```

Click here to compile all chunks that
come before this one

Inserting chunks of R code into RMarkdown files (4)

```
142 ▾ # Inserting R code
143
144 ▾ ```{r}
145   # This is the most basic R code chunk
146
147   x <- 1+1
148   x
149 ▴ ```
```

Click here for some shortcuts for the chunk options

Inserting chunks of R code into RMarkdown files (5)

```
142 ▾ # Inserting R code
143
144 ▾ ```{r}
145   # This is the most basic R code chunk
146
147   x <- 1+1
148   x
149 ▴ |
```

You can also position the cursor
(or select a few lines) and press
ctrl + enter

Inserting chunks of R code into RMarkdown files (6)

```
142 # Inserting R code
143
144 ```{r}
145 # This is the most basic R code chunk
146
147 x <- 1+1
148 x
149 ```
```

And this is how it looks when compiled

Inserting R code

```
# This is the most basic R code chunk
```

```
x <- 1 + 1
x
```

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

A stylized, handwritten-style logo of the word "Erasmus" in a dark grey color.

Inserting chunks of R code into RMarkdown files (7)

```
142 ▾ # Inserting R code
143
144 ▾ ```{r}
145   # This is the most basic R code chunk
146
147   x <- 1
148   x
149 ▴ ```
```

Here is where you insert chunk options

Chunk options (1)

- `eval = TRUE` **evaluate a code chunk (or FALSE to skip it)**
- `echo = TRUE` **to make the code appear in the final document (or FALSE to omit it)**
- `message = TRUE, warning = TRUE` **to allow for messages and warnings from the code**
- **Example:**

```
```{r, eval = TRUE, echo = FALSE, warning = FALSE}  
This is the most basic R code chunk

x <- 1+1
x
```
```

- **Check here for more:**
<https://bookdown.org/yihui/rmarkdown/r-code.html>
and <https://yihui.org/knitr/options/>

Goal of this tutorial: Write scientific reports in R Markdown

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 - **Calling R functions along Markdown text** ← *We are here!*

Calling R functions inside Rmarkdown text (in line)

▼ ## Adding inline R code

To use R code inline, you need to type ``r 3+1``. Besides doing simple math operations, you can call objects that are already saved in the memory. Recall that the value of `x` is ``r x``.

Alternatively, you can use functions, such as ``r mean(c(1,2,3,4))``. But for tables, figures and more elaborate code, you have to use a chunk.

Calling R functions inside Rmarkdown text (in line)

Adding inline R code

To use R code inline, you need to type ``r 3+1``. Besides doing simple math operations, you can call objects that are already saved in the memory. Recall that the value of `x` is ``r x``.
Alternatively, you can use functions, such as ``r mean(c(1,2,3,4))``. But for tables, figures and more elaborate code, you have to use a chunk.

Adding inline R code

To use R code inline, you need to type ``r 4``. Besides doing simple math operations, you can call objects that are already saved in the memory. Recall that the value of `x` is 2.

Alternatively, you can use functions, such as ``r 2.5``. But for tables, figures and more elaborate code, you have to use a chunk.

Goal of this lecture: write scientific reports in R Markdown

- To introduce R Markdown:
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Final remarks

- You can find plenty of material online
- Best way to learn is starting your projects in RMarkdown
- Remember that programming can be unexpected

debugging



1.
I got this.



2.
Huh. Really
thought that
was it.



3.
(...)



4.
Fine. Restarting.



5.
OH WTF.



6.
Zombie
meltdown



7.



8.
A NEW HOPE!

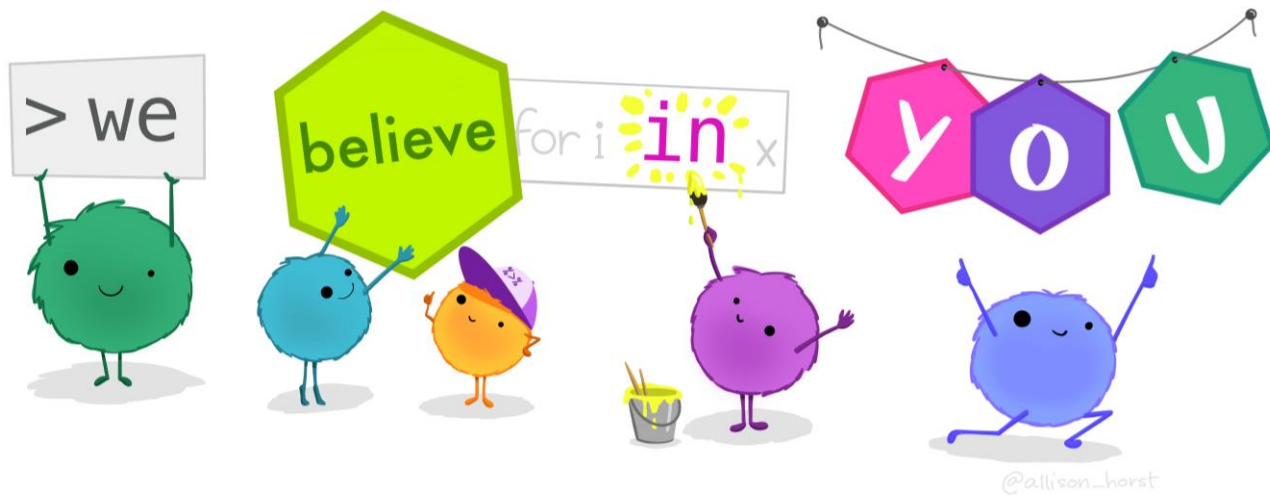


9.
[insert awesome
theme song]



10.
I ♥ CODING!

Remember to have fun!



Useful links

- https://rmarkdown.rstudio.com/authoring_quick_tour.html
- <https://rmarkdown.rstudio.com/docs/>
- <https://bookdown.org/yihui/rmarkdown/installation.html>

Acknowledgements

- Drawings by Alisson Horst. Check her other awesome images here: <https://github.com/allisonhorst/stats-illustrations>

Bedankt Thank you

You can reach me at venesschmidt@ese.eur.nl

The Erasmus logo, featuring a stylized, handwritten-style script of the word "Erasmus" in a dark color.