

BST02: Using R for Statistics in Medical Research

Part C: Functions and Programming

Nicole Erler Eleni-Rosalina Andrinopoulou

Department of Biostatistics, Erasmus Medical Center

✉ n.erler@erasmusmc.nl ✉ e.andrinopoulou@erasmusmc.nl

24 - 28 February 2020

Recap Part B

Objects

- ▶ `vector`
- ▶ `matrix`
- ▶ `data.frame`
- ▶ `list`

Data Structures

- ▶ `numeric`
- ▶ `character`
- ▶ `integer`
- ▶ `logical`
- ▶ `factor`

Recap Part B

Objects

- ▶ vector
- ▶ matrix
- ▶ data.frame
- ▶ list

Data Structures

- ▶ numeric
- ▶ character
- ▶ integer
- ▶ logical
- ▶ factor

Operators

- ▶ +, -, *, /
- ▶ <-, =
- ▶ <, >, ==

Special Values

- ▶ NA
- ▶ NaN
- ▶ Inf, -Inf

Recap Part B

Objects

- ▶ vector
- ▶ matrix
- ▶ data.frame
- ▶ list

Data Structures

- ▶ numeric
- ▶ character
- ▶ integer
- ▶ logical
- ▶ factor

Data Transformations

- ▶ rounding (format())
- ▶ convert to factor (factor())

Operators

- ▶ +, -, *, /
- ▶ <-, =
- ▶ <, >, ==

Special Values

- ▶ NA
- ▶ NaN
- ▶ Inf, -Inf

Recap Part B

Objects

- ▶ vector
- ▶ matrix
- ▶ data.frame
- ▶ list

Operators

- ▶ +, -, *, /
- ▶ <-, =
- ▶ <, >, ==

Data Structures

- ▶ numeric
- ▶ character
- ▶ integer
- ▶ logical
- ▶ factor

Special Values

- ▶ NA
- ▶ NaN
- ▶ Inf, -Inf

Data Transformations

- ▶ rounding (format())
- ▶ convert to factor (factor())

Data Exploration

- ▶ mean(), median(), sd(), IQR(), ...

Data Visualizations

- ▶ plotting packages
- ▶ plot types (plot(), barplot(), ...)

Recap Part B

Objects

- ▶ vector
- ▶ matrix
- ▶ data.frame
- ▶ list

Operators

- ▶ +, -, *, /
- ▶ <-, =
- ▶ <, >, ==

Data Structures

- ▶ numeric
- ▶ character
- ▶ integer
- ▶ logical
- ▶ factor

Special Values

- ▶ NA
- ▶ NaN
- ▶ Inf, -Inf

Data Transformations

- ▶ rounding (format())
- ▶ convert to factor (factor())

Data Exploration

- ▶ mean(), median(), sd(), IQR(), ...

Data Visualizations

- ▶ plotting packages
- ▶ plot types (plot(), barplot(), ...)

Subsetting

- ▶ [[...]], [...], \$, ...

In this Section

- ▶ What are functions?
- ▶ Useful functions for data exploration
- ▶ Useful functions for data manipulations
- ▶ Writing functions
- ▶ Control-flow constructs
- ▶ The `apply` family
- ▶ Lots of practising

Functions

Sometimes we want to perform the same action / manipulation on several objects.

- ▶ Option 1: copy & paste
 - ▶ a lot of work
 - ▶ susceptible to mistakes

Functions

Sometimes we want to perform the same action / manipulation on several objects.

- ▶ Option 1: copy & paste
 - ▶ a lot of work
 - ▶ susceptible to mistakes
- ▶ Option 2: **functions**

Functions

Sometimes we want to perform the same action / manipulation on several objects.

- ▶ Option 1: copy & paste
 - ▶ a lot of work
 - ▶ susceptible to mistakes
- ▶ Option 2: **functions**

What are functions?

- ▶ a group of (organized) R commands
- ▶ a (small) program with flexible (= not pre-specified) input

Almost all commands in R are functions!

Functions

Some examples:

- ▶ `mean()`
- ▶ `sum()`
- ▶ `plot()`
- ▶ ...

```
class(mean)
## [1] "function"
class(sum)
## [1] "function"
class(plot)
## [1] "function"
```

Functions

Some examples:

- ▶ `mean()`
- ▶ `sum()`
- ▶ `plot()`
- ▶ ...

```
class(mean)
## [1] "function"
class(sum)
## [1] "function"
class(plot)
## [1] "function"
```

Even `class()` is a function:

```
class(class)
```

```
## [1] "function"
```

Useful Functions for Data Exploration

Demos

- ▶ Functions for Data Exploration [R](#) [html](#)

Practicals

- ▶ Exploring and Summarizing Data [html](#)

Useful Functions for Data Exploration

Dimension

- ▶ `dim()`
- ▶ `nrow(), ncol()`
- ▶ `length()`

Data Structure

- ▶ `str()`
- ▶ `names()`,
- ▶ `head(), tail()`
- ▶ `is.data.frame(),`
`is.list(),`
`is.matrix()`
`is.numeric(),`
`is.ordered(), ...`

Descriptives for Continuous Variables

- ▶ `summary()`
- ▶ `min(), max(),`
`range()`
- ▶ `mean(), median(),`
`quantile(), IQR()`
- ▶ `sd(), var()`
- ▶ `ave()`

Tables

- ▶ `table(),`
`prop.table()`
- ▶ `addmargins(),`
`ftable()`

for `matrix` & `data.frame`

- ▶ `summary()`
- ▶ `var(), cor(), cov2cor()`
- ▶ `colSums(), colMeans(),`
`rowSums(), rowMeans()`

Duplicates & Comparison

- ▶ `duplicated()`
- ▶ `unique()`

Useful functions for Data Manipulation

Demo

- ▶ Functions for Data Manipulation [R](#) [html](#)

Practicals

- ▶ Merging Datasets [html](#)

Useful functions for Data Manipulation

Transformations

- ▶ `log()`, `log2()`, `log10()`
- ▶ `exp()`, `sqrt()`, `plogis()`

Splitting & Combining

- ▶ `split()`, `cut()`
- ▶ `cbind()`, `rbind()`
- ▶ `merge()`
- ▶ `subset()`
- ▶ `c()`
- ▶ `paste()`

Sorting

- ▶ `sort()`, `order()`, `rev()`, `rank()`

Repetition & Sequence

- ▶ `rep()`, `seq()`
- ▶ `expand.grid()`

Converting Objects

- ▶ `t()`
- ▶ `unlist()`, `unname()`
- ▶ `as.numeric()`, `as.matrix()`,
`as.data.frame()`

Writing Functions

To write your own function:

```
myfun <- function(arguments) {  
  syntax  
}
```

Writing Functions

To write your own function:

```
myfun <- function(arguments) {  
  syntax  
}
```

For example:

```
square <- function(x) {  
  x^2  
}
```

```
square(3)
```

```
## [1] 9
```

Writing Functions

Functions do not always need an argument:

```
random <- function() {  
  rnorm(n = 1)  
}
```

```
random()  
## [1] 0.7388628  
random()  
## [1] 0.6527227  
random()  
## [1] 1.295957
```

Writing Functions

Functions can use **multiple arguments**:

```
subtract <- function(x, y) {  
  x - y  
}
```

```
subtract(x = 5.2, y = 3.3)
```

```
## [1] 1.9
```

Writing Functions

Multiple arguments are interpreted in the **pre-defined order**, unless they are named:

```
subtract(5.2, 1.2)
```

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

is equivalent to

```
subtract(x = 5.2, y = 1.2)
```

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

Writing Functions

Multiple arguments are interpreted in the **pre-defined order**, unless they are named:

```
subtract(5.2, 1.2)
```

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

is equivalent to

```
subtract(x = 5.2, y = 1.2)
```

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

But this is different:

```
subtract(y = 5.2, x = 1.2)
```

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

Writing Functions

We can also define **default values** for arguments.

```
multiply <- function(x, y = 2) {  
  x * y  
}
```

The default value is used when the user does not specify a value for that argument:

```
multiply(x = 3, y = 3)
```

```
## [1] 9
```

```
multiply(x = 3)
```

```
## [1] 6
```

Writing Functions

Practical

- ▶ Rolling the Dice [html](#)

Control-flow Constructs: `if()`

Sometimes, we may want to execute code only **if a certain condition is fulfilled**.

To do this, we can use an `if` statement

```
if (condition) {expression}
```

Control-flow Constructs: `if()`

Sometimes, we may want to execute code only **if a certain condition is fulfilled**.

To do this, we can use an `if` statement

```
if (condition) {expression}
```

For example:

```
x <- c(0.3, -1.2, 0.8, 1.7, 0.7, -0.1, -0.4, -0.1, -0.2, 0.6)
if (length(x) > 5) {mean(x)}
```

```
## [1] 0.21
```

Control-flow Constructs: `if()`

Sometimes, we may want to execute code only **if a certain condition is fulfilled**.

To do this, we can use an `if` statement

```
if (condition) {expression}
```

For example:

```
x <- c(0.3, -1.2, 0.8, 1.7, 0.7, -0.1, -0.4, -0.1, -0.2, 0.6)
if (length(x) > 5) {mean(x)}
```

```
## [1] 0.21
```

```
x <- c(0.7, -0.1, -0.4, -0.1)
if (length(x) > 5) {mean(x)}
```

If the condition is not fulfilled, `NULL` is returned.

Control-flow Constructs: `if()` and `else`

We can also specify an expression that is evaluated **if the condition is not fulfilled**:

```
if (condition) {expression} else {alternative expression}
```

Control-flow Constructs: `if()` and `else`

We can also specify an expression that is evaluated **if the condition is not fulfilled**:

```
if (condition) {expression} else {alternative expression}
```

For example:

```
if (length(x) > 5) {  
  mean(x)  
} else {  
  x  
}
```

```
## [1] 0.7 -0.1 -0.4 -0.1
```

Conditional Element Selection: `ifelse()`

A similar function is `ifelse()`, which performs **conditional element selection**:

```
ifelse(test, yes, no)
```

Conditional Element Selection: `ifelse()`

A similar function is `ifelse()`, which performs **conditional element selection**:

```
ifelse(test, yes, no)
```

For example:

```
x <- c(0.3, -1.2, 0.8, 1.7, 0.7, -0.1, -0.4, -0.1, -0.2, 0.6)
ifelse(x > 0, ">0", "<0")
```

```
## [1] ">0" "<0" ">0" ">0" ">0" "<0" "<0" "<0" "<0" ">0"
```

Conditional Element Selection: `ifelse()`

A similar function is `ifelse()`, which performs **conditional element selection**:

```
ifelse(test, yes, no)
```

For example:

```
x <- c(0.3, -1.2, 0.8, 1.7, 0.7, -0.1, -0.4, -0.1, -0.2, 0.6)
ifelse(x > 0, ">0", "<0")
```

```
## [1] ">0" "<0" ">0" ">0" ">0" "<0" "<0" "<0" "<0" ">0"
```

Note:

- ▶ `if()` expects **one** condition
- ▶ `ifelse()` expects a **vector of conditions**

Control-flow Constructs: for()-loop

To perform an operation multiple times, we can use a **for-loop**

```
for (variable in sequence) {expression}
```

For example:

```
for (i in 1:5) {  
  print(2 * i)  
}
```

```
## [1] 2  
## [1] 4  
## [1] 6  
## [1] 8  
## [1] 10
```

Control-flow Constructs: for()-loop

In a **for-loop**, the variable does not need to be used in the expression:

```
for (i in 1:5) {  
  print('test')  
}
```

```
## [1] "test"  
## [1] "test"  
## [1] "test"  
## [1] "test"  
## [1] "test"
```

Note that when using `for()`, always the full sequence is used, i.e., we cannot skip iterations.

Control-flow Constructs: `while()`-loop

The function `while()` repeatedly evaluates an expression as long as a condition is fulfilled:

```
while (condition) {expression}
```

Careful:

If your condition is never `FALSE` this will run forever!!!
(or until you stop it manually)

Note:

`for()` and `while()` loops will not print output, unless we specifically use the function `print()`.

Control-flow Constructs: while()-loop

For example:

```
s <- 1
while (s < 5) {
  s <- s + s/2
  print(s)
}
```

```
## [1] 1.5
## [1] 2.25
## [1] 3.375
## [1] 5.0625
```

Control-flow Constructs

Demo

- ▶ Control Flow [R](#) [html](#)

Practicals

- ▶ Control Flow and Functions [html](#)
- ▶ Custom Subset Function [html](#)

Summary: Writing Functions

```
function_name <- function(arguments) {  
  "function body"  
}
```

- ▶ can have 0, 1, 2, ...arguments
- ▶ arguments are interpreted in the **pre-specified order**, unless the **names are used**
- ▶ we can specify **default values**

Summary: Control-flow Constructs

- ▶ `if (condition) expression:`
evaluates the expression only if the condition is TRUE
- ▶ `if (condition) expression1 else expression2:`
evaluates expression1 if the condition is TRUE and expression2 if the condition is FALSE
- ▶ `ifelse(test, yes, no):`
expects a vector of tests
- ▶ `for()` and `while()` loops:
can be used to repeatedly perform the same action
- ▶ to print output from within `for()` and `while()` we need to use `print()`

What is the apply Family

Manipulate **vectors** or slices of data from **matrices**, **data frames** and **lists** in a repetitive way avoiding explicit use of loop-constructs

- ▶ An aggregating function, like for example the mean, or the sum
- ▶ Other transforming or subsetting functions
- ▶ Other vectorized functions, which return more complex structures like lists, vectors and matrices

What is the apply Family

`apply()`, `lapply()` , `sapply()`, `tapply()`, `mapply()`

But how and when should we use these?

How To Use `apply()` in R

- ▶ Operates on `matrix` and `data.frame`
- ▶ By column

```
mat <- matrix(1:6, 3, 3)
mat
```

| | [,1] | [,2] | [,3] |
|------|------|------|------|
| [1,] | 1 | 4 | 1 |
| [2,] | 2 | 5 | 2 |
| [3,] | 3 | 6 | 3 |

```
apply(mat, 2, sum)
```

```
[1] 6 15 6
```

How To Use `apply()` in R

- ▶ Operates on `matrix` and `data.frame`

- ▶ By column

```
mat <- matrix(1:6, 3, 3)
mat
```

```
      [,1] [,2] [,3]
[1,]     1     4     1
[2,]     2     5     2
[3,]     3     6     3
```

```
apply(mat, 2, sum)
```

```
[1]  6 15  6
```

- ▶ By row

```
apply(mat, 1, sum)
```

```
[1]  6  9 12
```

How To Use `apply()` in R

- ▶ Operates on `matrix` and `data.frame`
- ▶ By column

```
mat <- matrix(1:6, 3, 3)
mat
```

| | [,1] | [,2] | [,3] |
|------|------|------|------|
| [1,] | 1 | 4 | 1 |
| [2,] | 2 | 5 | 2 |
| [3,] | 3 | 6 | 3 |

```
apply(mat, 2, mean)
```

```
[1] 2 5 2
```

How To Use `apply()` in R

- ▶ Operates on `matrix` and `data.frame`

- ▶ By column

```
mat <- matrix(1:6, 3, 3)
mat
```

| | [,1] | [,2] | [,3] |
|------|------|------|------|
| [1,] | 1 | 4 | 1 |
| [2,] | 2 | 5 | 2 |
| [3,] | 3 | 6 | 3 |

```
apply(mat, 2, mean)
```

```
[1] 2 5 2
```

- ▶ By row

```
apply(mat, 1, mean)
```

```
[1] 2 3 4
```

How To Use `apply()` in R

- ▶ You can also apply your own functions
- ▶ By column

```
mat <- matrix(1:6, 3, 3)
mat
```

| | [,1] | [,2] | [,3] |
|------|------|------|------|
| [1,] | 1 | 4 | 1 |
| [2,] | 2 | 5 | 2 |
| [3,] | 3 | 6 | 3 |

```
apply(mat, 2, function(x)
      sum(x)/(length(x)-1))
```

```
[1] 3.0 7.5 3.0
```

How To Use `apply()` in R

► You can also apply your own functions

► By column

```
mat <- matrix(1:6, 3, 3)
mat
```

```
      [,1] [,2] [,3]
[1,]     1     4     1
[2,]     2     5     2
[3,]     3     6     3
```

```
apply(mat, 2, function(x)
      sum(x)/(length(x)-1))
```

```
[1] 3.0 7.5 3.0
```

► By row

```
apply(mat, 1, function(x)
      sum(x)/(length(x)-1))
```

```
[1] 3.0 4.5 6.0
```

How To Use `lapply()` in R

- ▶ Apply a given function to every element of a `list` and return a `list`
- ▶ The difference with `apply()`:
 - ▶ It can be used for other objects like `vector`, `data.frame` or `list`
 - ▶ The output returned is a list

How To Use lapply() in R

```
myList <- list(x = c(1:6),  
              y = c("m", "f"),  
              z = c(30, 4, 23))
```

myList

\$x

[1] 1 2 3 4 5 6

\$y

[1] "m" "f"

\$z

[1] 30 4 23

How To Use lapply() in R

```
myList <- list(x = c(1:6),  
              y = c("m", "f"),  
              z = c(30, 4, 23))
```

myList

\$x

[1] 1 2 3 4 5 6

\$y

[1] "m" "f"

\$z

[1] 30 4 23

► Use pre-specified functions

```
lapply(myList, length)
```

\$x

[1] 6

\$y

[1] 2

\$z

[1] 3

How To Use lapply() in R

```
myList <- list(x = c(1:6),  
              y = c("m", "f"),  
              z = c(30, 4, 23))
```

myList

\$x

[1] 1 2 3 4 5 6

\$y

[1] "m" "f"

\$z

[1] 30 4 23

- Use pre-specified functions

```
lapply(myList, median)
```

\$x

[1] 3.5

\$y

[1] NA

\$z

[1] 23

- You can also apply your own functions!

How To Use `sapply()` in R

- ▶ `sapply()` is similar to `lapply()`, but it tries to simplify the output

```
myList <- list(x = c(1:6),  
              y = c("m", "f"),  
              z = c(30, 4, 23))  
myList
```

```
$x  
[1] 1 2 3 4 5 6
```

```
$y  
[1] "m" "f"
```

```
$z  
[1] 30  4 23
```

How To Use `sapply()` in R

- ▶ `sapply()` is similar to `lapply()`, but it tries to simplify the output

```
myList <- list(x = c(1:6),  
              y = c("m", "f"),  
              z = c(30, 4, 23))
```

myList

\$x

[1] 1 2 3 4 5 6

\$y

[1] "m" "f"

\$z

[1] 30 4 23

- ▶ Use pre-specified functions

```
sapply(myList, length)
```

x y z

6 2 3

```
sapply(myList, median)
```

| x | y | z |
|-----|----|------|
| 3.5 | NA | 23.0 |

- ▶ You can also apply your own functions!

How To Use `tapply()` in R

- ▶ Apply a function to subsets of a **vector** - The subsets are defined by some other **vector**, usually a factor

```
tapply(pbc$bili, pbc$sex, mean)
```

```
      m      f  
2.865909 3.262567
```

```
tapply(pbc$age, pbc$sex, median)
```

```
      m      f  
54.00137 50.19302
```

How To Use `tapply()` in R

- ▶ You can also apply your own functions

```
tapply(pbc$bili, pbc$sex, function(x) sum(x)/(length(x)-1))
```

| m | f |
|----------|----------|
| 2.932558 | 3.271314 |

How To Use `mapply()` in R

- ▶ Multivariate apply
- ▶ Its purpose is to be able to vectorize arguments to a function that is not usually accepting **vectors** as arguments
- ▶ `mapply()` applies a function to multiple **list** or multiple **vector** arguments

```
mapply(length, pbc)
```

| | | | | | | |
|----------|---------|--------|----------|---------|---------|---------|
| id | time | status | trt | age | sex | ascites |
| 418 | 418 | 418 | 418 | 418 | 418 | 418 |
| hepato | spiders | edema | bili | chol | albumin | copper |
| 418 | 418 | 418 | 418 | 418 | 418 | 418 |
| alk.phos | ast | trig | platelet | protime | stage | |
| 418 | 418 | 418 | 418 | 418 | 418 | |

How To Use `mapply()` in R

- Overlapping between functions

```
myList <- list(x = c(1:6),  
              y = c("m", "f"),  
              z = c(30, 4, 23))  
mapply(length, myList,  
        SIMPLIFY = FALSE)
```

```
$x  
[1] 6
```

```
$y  
[1] 2
```

```
$z  
[1] 3
```

How To Use `mapply()` in R

► Overlapping between functions

```
myList <- list(x = c(1:6),  
              y = c("m", "f"),  
              z = c(30, 4, 23))  
mapply(length, myList,  
        SIMPLIFY = FALSE)
```

```
$x  
[1] 6
```

```
$y  
[1] 2
```

```
$z  
[1] 3
```

```
lapply(myList, length)
```

```
$x  
[1] 6
```

```
$y  
[1] 2
```

```
$z  
[1] 3
```

- You can also apply your own functions!

Useful Summary: Apply Family

Vectors

- ▶ `tapply()`
- ▶ `mapply()`

Matrices

- ▶ `apply()`
- ▶ `tapply()`
- ▶ `lapply()`
- ▶ `sapply()`
- ▶ `mapply()`

Data frames

- ▶ `apply()`
- ▶ `tapply()`
- ▶ `lapply()`
- ▶ `sapply()`
- ▶ `mapply()`

Lists

- ▶ `lapply()`
- ▶ `sapply()`
- ▶ `mapply()`

Useful Summary: Apply Family

- ▶ Use the following webpage to further investigate the apply family https://emcbiostatistics.shinyapps.io/the_apply_family/
- ▶ The **R** code for the shiny app is also available:

Demos

- ▶ Shiny app apply family **R**

In order to run the app you will need to install the packages:

- ▶ `survival`
- ▶ `shiny`

Useful Summary: Apply Family

Demos

- ▶ The Apply Family [R](#) [html](#)

Practicals

- ▶ The Apply Family [html](#)