

# 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](mailto:n.erler@erasmusmc.nl)   ✉ [e.andrinopoulou@erasmusmc.nl](mailto:e.andrinopoulou@erasmusmc.nl)

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# Recap Part B

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## Objects

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

## Data Structures

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

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- ▶ NA
- ▶ NaN
- ▶ Inf, -Inf

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

## Data Visualizations

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

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## 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

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# Functions

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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 Data [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] -0.9083366
```

```
random()
```

```
[1] -0.6466098
```

```
random()
```

```
[1] 1.019912
```

# 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

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```

```
[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()

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To do this we can use an **if** statement

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```

For example:

```
x <- rnorm(n = 10)
if (length(x) > 5) {mean(x)}
```

```
[1] 0.4139608
```

## Control-flow Constructs: `if()`

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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}
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For example:

```
x <- rnorm(n = 10)
if (length(x) > 5) {mean(x)}
```

```
[1] 0.4139608
x <- rnorm(n = 5)
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 (cond) {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 (cond) {expression} else {alternative expression}
```

For example:

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

```
[1] -1.06784990  0.13495206 -0.83880872 -1.16866248  0.07765486
```

## Conditional Element Selection: `ifelse()`

---

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

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

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

For example:

```
(x <- round(rnorm(n = 6), 2))
```

```
[1] 0.53 0.62 0.45 -2.32 -0.88 0.65
```

```
ifelse(x > 0, ">0", "<0")
```

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

## Conditional Element Selection: `ifelse()`

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

```
ifelse(test, yes, no)
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For example:

```
(x <- round(rnorm(n = 6), 2))
```

```
[1] 0.53 0.62 0.45 -2.32 -0.88 0.65
```

```
ifelse(x > 0, ">0", "<0")
```

```
[1] ">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 <- 0
while (s < 7) {
  x <- rnorm(n = 1, mean = 0, sd = 2)
  s <- s + abs(x)
  print(s)
}
```

[1] 2.414131

[1] 2.96899

[1] 5.137872

[1] 9.829268

# Control-flow Constructs

---

## Demo

- ▶ Control Flow **R** **html**

## Practical

- ▶ Control Flow and Functions  
**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 'test's
- ▶ `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 (cont'd)

---

`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 (cont'd)

- ▶ 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 (cont'd)

- ▶ 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 (cont'd)

- ▶ You can also apply your own functions

- ▶ Rv 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 (cont'd)

- ▶ 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 (cont'd)

---

```
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 (cont'd)

```
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 (cont'd)

```
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 (cont'd)

- ▶ 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	ascite
418	418	418	418	418	418	4
edema	bili	chol	albumin	copper	alk.phos	a
418	418	418	418	418	418	4
protime	stage	stage_ord	stage_rev	stage_ref4		
418	418	418	418	418		



## How To Use `mapply()` in R (cont'd)

---

- 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 (cont'd)

### ► 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/](https://emcbiostatistics.shinyapps.io/the_apply_family/)
- ▶ The **R** code for the shiny app is also available:

### Demos

- ▶ Shiny app apply family 

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

- ▶ `survival`
- ▶ `shiny`

## Useful Summary: Apply Family (cont'd)

---

### Demos

- ▶ The Apply Family [R](#) [html](#)

### Practicals

- ▶ The Apply Family [html](#)