An introduction to programming in R

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[1] https://github.com/sahirbhatnagar/npu

Notice #1

- This is an **introduction** to the R language

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- This is an **introduction** to the R language
- Feel free to ask quesitons

Notice #2

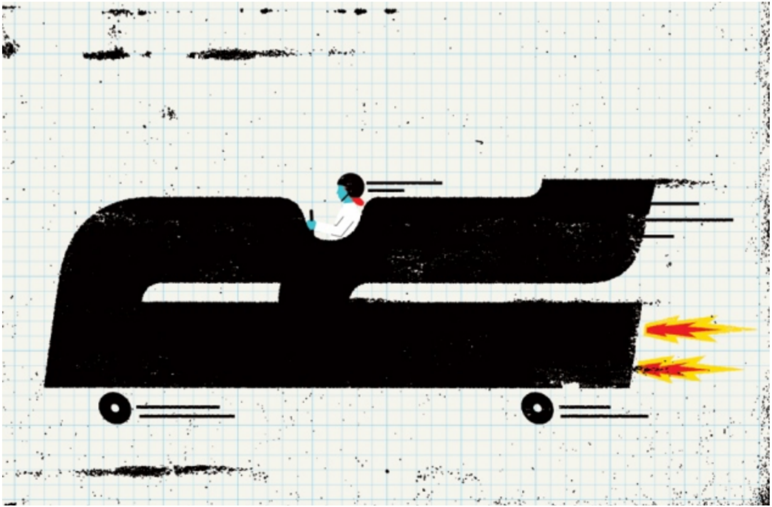
R Studio

R Markdown v2

knitr

We do not have any commercial affiliations with these software

Let's Begin



After this workshop you should be able to:

- Understand, create and modify the 4 main objects in R (`vector`, `data.frame`, `matrix`, `list`)
- Use basic functions
- Import a dataset from an external file
- Create a plot

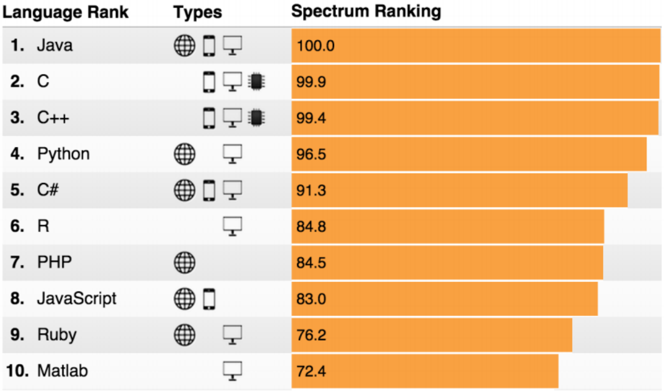
1. Background on the R language

Objectives of this section

1. Understand the advantages of R
2. Know it's characteristics
3. Start an R session and execute some basic commands
4. Create, modify and save an R script

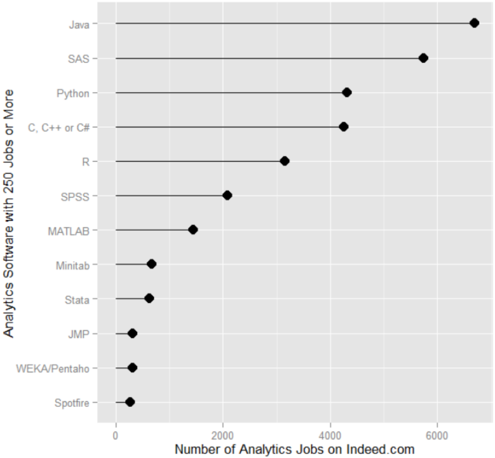
The popularity of R

The rise of popularity



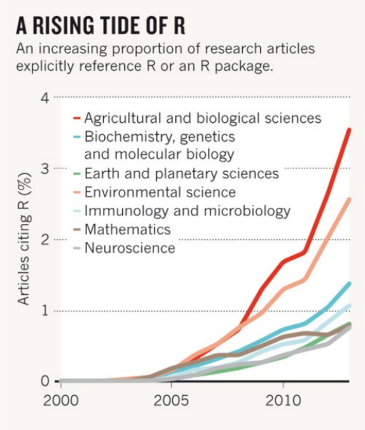
The best programming languages in 2015 according to IEEE Spectrum

Number of Jobs



reference: http://r4stats.com/articles/popularity/

Used in many domains



Published in *Nature*

Powerful tool to analyze data

- Several resources for state-of-the-art statistical computing
- Powerful graphing system
- Integrate your R code into web applications
- Ensure the reproducibility of your analyses

A Brief History

Before R there was S by John M. Chambers

Figure 1: S, is a language developped at Bell Laboratories in the 1970s by a group of researchers led by John M. Chambers

Creators of R

Figure 2: Inspired by S, Ross Ihaka (left) and Robert Gentleman (right) from the University of Auckland in New Zeland launched the first version of R in 1996

Characteristics of R

Object oriented programming language

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- A function can complete several tasks

An interpreted language

- An interpreted language: does not require compiling a program into machine-language instructions
- A compiled language: `C`, `C++`, `JAVA`
- More accessible than a compiled language $\rightarrow$ which allows economists, ecologists, biologists, engineers, statisticians, epidemiologists, etc. to use R

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- This interpreter takes commands in R and it will immediately run
- Another example: code Python

Open Source Software

- Active development for the creation of new tools in several fields
  - https://cran.r-project.org/web/views/
- Easily see other people's code with GitHub
  - http://www.r-pkg.org/
- Well-documented with a lot of free resources available on the internet
  - stackoverflow
  - http://www.rdocumentation.org/
  - http://www.r-bloggers.com/
  - twitter
  - R user groups
  - Google

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R code 1.1

```
c(1,2,3) + c(4,5,6)

## [1] 5 7 9
```

How to find help for a function

- `?name_of_the_function`

How to find help for a function

- `?name_of_the_function`

R code 1.2

```
# find help for linear regression function 'lm'
?lm
```

The help page - 2 main sections

- **Usage:** the name of the function, and all of its arguments and default values

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- **Usage:** the name of the function, and all of its arguments and default values
- **Value:** the type of object returned and its contents

Starting a session

R code 1.3

```r
# Start the interface for documentation
# and navigate the different resources
help.start()

# find help for the rnorm function
?rnorm

# Get the working directory
getwd()
```

R code 1.4

```
# addition
39 + 3

# substraction
58 - 16

# multiplication
6 * 7

# division
8 / 3
```

R code 1.5

```r
# Generate two random vectors of size 50
# from a standard normal distribution
x <- rnorm(50)
y <- rnorm(50)

# Plot the points (x, y)
plot(x, y)

# A histogram of x
hist(x)
```

R code 1.6

```
# to see the contents of the x vector
x

# see the objects in your workspace
ls()

# delete the two vectors x and y
rm(x,y)

# see the contents of x
x

# see the objects in your workspace
ls()
```

R code 1.7

```
# generate a sequence 1, 2, ..., 20.
x <- 1:20

# create another vector as a function of x
y <- 2 * x + 3

# create a data.frame and see its contents
dt <- data.frame(x, y)
dt

# run a linear regression and see the
# results
fit <- lm(y ~ x, data = dt)
summary(fit)
```

R code 1.8

```
# The 'seq' function will generate more gen-
eral sequences
seq(from = -5, to = 10, by = 3)
seq(from = -5, length = 10)

#'rep' repeats values
rep(1, 5) # repeat 1, 5 times
rep(1:5, 5) # repeat the vec-
tor 1,...,5,  five times
rep(1:5, each = 5) # repeat each ele-
ment five times
```

R code 1.9

```r
# vector arithmetic
v <- 1:12  # initialize a vector
v + 2 # add 2 to each element of the vector
v * -12:-1 # element-wise product
v + 1:3 # the shortest vector is recycled

# Generate random uniform(1,10) numbers
v <- runif(12, min = 1, max = 10); v

# You can place the call in parenthe-
ses to see the result
( v <- runif(12, min = 1, max = 10) )
```

R code 1.10

```
# trouver le répertoire où se trouve le
# jeux de données 'morley', qui est inclu avec
# l'installation de R
filepath <- system.file("data", "morley.tab",
            package="datasets")

# importer les données dans un objet appeller 'mm'
mm <- read.table(filepath)

# Graphique
plot(mm$Expt, mm$Speed,
main="Speed of Light Data", xlab="Experiment No.")

# Terminer la session
q()
```

2. Basics of R

Objectives of this section

1. Understand what a function is and how to use it
2. Identify the main objects in R: `vector`, `matrix`, `data frame` and `list`
3. Create and manipulate these objects
4. Import some external datasets `.txt` et `.csv`
5. Install a *package*

Functions

Definition of a Function

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- A function is characterised by two components
  1. It's **name**: this name allows the user to call the function
  2. a **list of arguments**: this is the information the function needs to return a proper result

Function syntax

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```
name_of_the_function(arguments)
```

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- The required arguments between these two parentheses are what the function requires to execute it:

  `name_of_the_function(arguments)`

R code 2.1

```
# look at the help page for square root function
?sqrt

# we see that the sqrt function takes one argument
sqrt(49)
```

Optional arguments

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R code 2.2

```
# look at the help for the logarithm function
?log

# we don't need to specify a value for the 2nd argument
log(2)

# we can specify the second argument if we want
log(2, base = exp(1))
```

R Objects

R Objects

Table 1: The principal R objects and their name

dimension	same type[a]	different type[b]
1d	Atomic vector `c()`	List `list()`
2d	Matrix `matrix()`	Data frame `data.frame()`

[a] all the elements have to be of the same type
[b] the elements can be of different types

Atomic vectors

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R code 2.3

```
c(1, 2, 5)

## [1] 1 2 5
```

Atomic vectors

- Frequently used *atomic vectors*:
  1. *double* (also called *numeric*)
  2. *integer*
  3. *character*
  4. *logical*

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R code 2.4

```
c(1, 2.5, 4.5) # numeric
c(1L, 6L, 10L) # integer
c("these are", "characters") #character
c(TRUE, FALSE, T, F) # logical
```

Test

- `typeof()`: to find out the type of vector
- `is.character()`, `is.double()`, `is.integer()`, `is.logical()`, `is.atomic()`: for case specific types

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R code 2.5

```
int_var <- c(1L, 6L, 10L)
typeof(int_var)

## [1] "integer"

is.integer(int_var)

## [1] TRUE

is.atomic(int_var)

## [1] TRUE
```

Test

R code 2.6

```
dbl_var <- c(1, 2.5, 4.5)
typeof(dbl_var)

## [1] "double"

is.double(dbl_var)

## [1] TRUE

is.atomic(dbl_var)

## [1] TRUE
```

Coercion

- All the elements of an *atomic vector* must be of the same type

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- When you try to combine several types, it will convert everything to the most flexible type

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- All the elements of an *atomic vector* must be of the same type
- When you try to combine several types, it will convert everything to the most flexible type
- From least flexible to most flexible:
  1. *logical*
  2. *integer*
  3. *double*
  4. *character*

R code 2.7

```
# combine a character and an interger will pro-
duce what?
str(c("a", 1))

##  chr [1:2] "a" "1"
```

Coercion

- Most mathematical operations will convert an *atomic vector* into a *double* or *integer*

R code 2.8

```
x <- c(FALSE, FALSE, TRUE)
as.numeric(x)

## [1] 0 0 1

# Number of TRUE
sum(x)

## [1] 1

# Proportion of TRUE
mean(x)

## [1] 0.33
```

List

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- The function to create a *list* is a `list()`

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R code 2.9

```
(x <- list(1:3, "a", c(TRUE, FALSE, TRUE), c(2.3, 5.9)))

## [[1]]
## [1] 1 2 3
##
## [[2]]
## [1] "a"
##
## [[3]]
## [1]  TRUE FALSE  TRUE
##
## [[4]]
## [1] 2.3 5.9
```

Matrix

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R code 2.10

```
# filled by column by defaults
matrix(c(1,2,3,4,5,6), nrow = 2, ncol = 3)

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

Matrix

R code 2.11

```
# automatically converted to same data type
matrix(c(1,2,3,"a","b","c"), nrow = 2, ncol = 3)

##      [,1] [,2] [,3]
## [1,] "1"  "3"  "b"
## [2,] "2"  "a"  "c"
```

Data frame

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R code 2.12

```
# an 'id'  column to identify the individuals
# an 'age' column for their age
data.frame(id = c("yi","yang","zhengzin"),
           age = c(37,34,32))

##          id age
## 1        yi  37
## 2      yang  34
## 3 zhengzin  32
```

The difference between a *data frame* and a *matrix*?

- `matrix`: matrix calculations
- `data.frame`: all other analyses of different data types

R Commands

Expression and Assignment

1. An **expression** is immediately evaluated and the result is posted in the R console:

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R code 2.13

```
2 + 3

## [1] 5

pi

## [1] 3.1

cos(pi/4)

## [1] 0.71
```

Expression and Assignment

2. When performing an **assignment**, an expression is evaluated, but the result is stored in an object and nothing is printed to the console
   - The assignment operator is <-
   - the two characters < and - must be placed one after another (no spaces):

Expression and Assignment

3. When performing an **assignment**, an expression is evaluated, but the result is stored in an object and nothing is printed to the console
   - The assignment operator is <-
   - the two characters < and - must be placed one after another (no spaces):

R code 2.14

```
a <- 5
a

## [1] 5

b <- a - 2
b

## [1] 3
```

Expression and Assignment

4. To create an assignment and simultaneously print its result, you can place the expression in parentheses:

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R code 2.15

```
(a <- 2 + 3)

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```
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```

5. The = is valid, but is not recommended
   - it can cause confusion between the `name = value` in function calls

Naming conventions for objects

- Characters are allowed for naming objects:
  1. lower case letters a–z
  2. upper case letters A–Z
  3. numbers 0–9,
  4. the period .
  5. underscore _

Naming conventions

- R is case-sensitive, which means `foo`, `Foo` and `FOO` are three distinct objects

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- R is case-sensitive, which means `foo`, `Foo` and `FOO` are three distinct objects
- Certain names are reserved for R functions, so its best to avoid them

```
c, q, t, C, D, I, diff, length, mean, pi,
range, var, sd
break, else, for, function, if, in, next,
repeat, return, while
TRUE, FALSE, T, F
Inf, NA, NaN, NULL
```

Indexing a *vector*

- Indexing has two purposes

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  1. extract elements
  2. replace elements

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R code 2.16

```
# create a vectir
x <- c(a = -1, b = 2, c = 8, d = 10)

# extract by position
x[1]

# extract by name
x["c"]

# remplace the second element by 5
x[2] <- 5
```

Indexing a *data frame* and a *matrix*

- Indexing observations by rows and columns for the *data.frame* and *matrix*:

```
df[row, column]
```

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R code 2.17

```
# create a data frame
d <- data.frame(Noms = c("Pierre", "Jean", "Jacques"),
Age = c(42, 34, 19),
Fumeur = c(TRUE, TRUE, FALSE))

d[1, ] # first row

d[ ,1] # first column

d[3,2] # third row, second column
```

Indexing a *list*

R code 2.18

```
# create a list
x <- list(player = c("V", "C"),
                  score = c(10, 12))

# first element of the list
x[[1]]

# 1st element of the 2nd element of the list
x[[2]][1]
```

Import data and code

Table 2: Functions for importing data and code

	files	objects[c]	R script
import	`read.table()`[a] `read.csv()`[b]	`load()`	`source()`
save	`write.table()` `write.csv()`	`save()`	File -> Save As..

[a] value is separated by a space
[b] each value is separated by a comma
[c] objects in your working environment

Import data

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R code 2.19

```
# modify working directory
setwd("~/git_repositories/npu/data")

# import the files
# assign it to the 'lung' and 'admit' objects
lung <- read.csv("lung.csv")

admit <- read.table("admit.txt")
```

Import code from an R Script

R code 2.20

```r
# modify the working directory
setwd("~/git_repositories/npu/script")

# execute the commands of the RScript 'mtcars.R'
# and show the output
source("mtcars.R", echo = TRUE)

# save the results in an RData object
save(df, fit, file = "mtcars.RData")

# delete the R objects
rm(df, fit)

# import the R objects saved in 'mtcars.RData'
load("mtcars.RData")
```

Instal *packages* in R

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R code 2.21

```
# install packages for reproducible code
install.packages(c("knitr","rmarkdown"))

# to get access to those functions
library(knitr)
library(rmarkdown)
```

Summary

Summary of basic R commands

Working Environment

```
sessionInfo() install.packages()
library()
setwd()
getwd()
rm()
ls()
```

Frequently used R objects

```
c()
data.frame()
matrix()
list()
```

Access to external data and scripts

```
read.table()
write.table()
load()
save()
source()
```

3. R Graphics

Objectives of this section

1. Understand the syntax of the`plot` function
2. Create `boxplot, histogram` and `density` plot
3. How to save plots

The `plot` function

Introduction to R graphics

- R offers lots of graphical tools
- To get an idea of what is possible, type the command `demo(graphics)`

The `plot` function

- The `plot` function can take several different inputs

The plot function

- The `plot` function can take several different inputs

R code 3.1

```
# Plot vector values against the index
# equivalent to plot(mtcars[,"mpg"])
plot(mtcars$mpg, xlab = "Index", ylab = "mpg",
    main = "Title")

# Scatterplot (x, y)
plot(mtcars$mpg, mtcars$disp, xlab = "mpg",
ylab = "disp", main = "mpg vs. disp")
```

The `plot` function

- The `plot` function can also take a linear model object as input

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- This is an example of how R is an object oriented language

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R code 3.2

```
# import 'mtcars.RData'
load("~/git_repositories/npu/script/mtcars.RData")

# Diagnostic plots for linear model
# place in 2 rows and 2 columns
par(mfrow=c(2,2))
plot(fit)
```

`histogram` and `boxplot`

The `histogram` function

- Useful for seeing the data distribution
- For continuous univariate variables

The histogram function

- Useful for seeing the data distribution
- For continuous univariate variables

R code 3.3

```
# height for 237 students
# in the 'survey' data of library(MASS)
library(MASS)

# see the names of the columns
names(survey)

# plot histogram of height
hist(survey$Height, labels = TRUE)
```

The `boxplot` function

- Useful for seeing if there's a difference between two groups

The boxplot function

- Useful for seeing if there's a difference between two groups

R code 3.4

```
# height for 237 students by gender
# in the 'survey' data of library(MASS)

boxplot(survey$Height ~ survey$Sex,
        ylab = "Height (cm)",
        col = c("lightpink","lightblue"))
```

Saving graphics

- 2 main functions: `pdf()` and `png()`
- the argument of these functions is the name of the file

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R code 3.5

```
# enregistrer dans le répertoire de tra-
vail courant
pdf("boxplot_survey.pdf")
boxplot(survey$Height ~ survey$Sex,
        ylab = "Height (cm)")
dev.off()
```

Summary

Summary of graphics commands

Functions for creating graphics

```
plot()
hist()        box-
plot()
```

Common arguments for these functions

```
xlab
ylab
main
type
col
```

Function to save these graphics

```
pdf()
png()
dev.off()
```

4. Statistiques

Mean, Standard Deviation

Mean, Standard Deviation, Minimum, Maximum

- main functions: `mean()`, `var()`, `sd()`, `min()`, `max()`

Mean, Standard Deviation, Minimum, Maximum

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- the `summary()` function is useful for calculating statistics for a `data.frame`

Mean, Standard Deviation, Minimum, Maximum

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- the `summary()` function is useful for calculating statistics for a `data.frame`

R code 4.1

```
summary(mtcars)
```

The `apply` function

- To calculate more complicated summaries of a *data frame* (or *matrix*), we can use the `apply` function

The apply function

- The function syntax is as follows:

```
apply(X, MARGIN, FUN)
```

- `X`: a matrix or data frame
- `MARGIN`: 1 for rowwise summary, 2 for column wise summary
- `FUN`: is the function to apply

The apply function

- The function syntax is as follows:

  `apply(X, MARGIN, FUN)`

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- `MARGIN`: 1 for rowwise summary, 2 for column wise summary
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R code 4.2

```r
# variance by row
apply(mtcars, 1, var)
```

The apply function

R code 4.3

```
# variance by column
apply(mtcars, 2, var)

# sd by column
apply(mtcars, 2, sd)

# minimum for each row
apply(mtcars, 1, min)


# maximum for each row
apply(mtcars, 1, max)
```

t-test and ANOVA

t-test

- the function for doing a t-test is `t.test()`

t-test

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R code 4.4

```
# is there a difference in height between
# males and females
t.test(Height ~ Sex, data = survey)
```

Analysis of Variance (ANOVA)

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- Let's take for example the `InsectSprays` data in R
- 6 insecticides were tested 12 times in culture, the response is the number of insects
- The goal is to see if there is an important difference between the 6 insecticides with respect to the number of insects

ANOVA

R code 4.5

```
# boxplot to see the group difference
boxplot(InsectSprays$count ~ InsectSprays$spray)

# Store it in an object called aov.spray
aov.spray <- aov(count ~ spray, data = Insect-
Sprays)

# see results
summary(aov.spray)
```

Linear Regression

Formulas

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1. `y`: est la réponse analysée
2. `model`: est un ensemble de termes pour lesquels les paramètres sont estimés

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  1. `y`: est la réponse analysée
  2. `model`: est un ensemble de termes pour lesquels les paramètres sont estimés

- Ces termes sont séparés par des symboles arithmétiques mais qui ont ici une signification particulière: `a+b`, `a*b`

Linear Model

R code 4.6

```
# import 'admit.txt'
admit <- read.table("admit.txt", header = TRUE)

# are gpa and rank related to gre
fit <- lm(gre ~ gpa+rank, data = admit)

# see the results
summary(fit)
```

GLM

R code 4.7

```
# logistic regression
fit.glm <- glm(admit ~ gre+gpa+rank, data = admit,
               family = binomial(link = "logit"))

# see results
summary(fit.glm)
```

Summary

Summary of Statistics Commands

Functions for descriptive statistics

```
mean()
var()
sd()
min()
max()      me-
dian()      ap-
ply()
```

Statistical Tests

```
aov()
t.test()
chisq.test()
```

Functions for regression models

```
lm()
glm()
```

5. Créer des rapports

Introduction

Introduction

- http://rmarkdown.rstudio.com/
- http://shiny.rstudio.com/gallery/

Session Information

- R version 3.5.0 (2018-04-23), `x86_64-w64-mingw32`
- Running under: `Windows 10 x64 (build 17134)`
- Matrix products: default
- Base packages: base, datasets, graphics, grDevices, methods, stats, utils
- Other packages: data.table 1.11.0, dplyr 0.7.4, ggplot2 2.2.1, knitr 1.20, xtable 1.8-2
- Loaded via a namespace (and not attached): assertthat 0.2.0, bindr 0.1.1, bindrcpp 0.2.2, colorspace 1.3-2, compiler 3.5.0, evaluate 0.10.1, formatR 1.5, glue 1.2.0, grid 3.5.0, gtable 0.2.0, highr 0.6, lazyeval 0.2.1, magrittr 1.5, munsell 0.4.3, pillar 1.2.2, pkgconfig 2.0.1, plyr 1.8.4, R6 2.2.2, Rcpp 0.12.16, rlang 0.2.0, scales 0.5.0, stringi 1.1.7, stringr 1.3.0, tibble 1.4.2, tools 3.5.0