BST02: Using R for Statistics in Medical Research

Part B: Basic use of R

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In this Section

- ▶ Using R
- ▶ In practice examples
- ▶ Basics in R
- ▶ Common R objects
- ▶ Importing data and saving your work
- ▶ Data transformation
- ▶ Data exploration
- ▶ Data visualization
- ▶ Indexing/Subsetting
- ▶ Lots of practising

Using R

- ▶ R is a command-based procedural language
  - ▶ write and execute commands
  - ▶ use and define functions
- ▶ You may write the commands in the R console (Windows) or in a shell (Linux)

You will become more familiar with the syntax as you use it

Using R

- ▶ Strongly advisable to use a suitable text editor - Some available options:
    - ▶ RWinEdt (for Windows; you also need WinEdt installed)
    - ▶ Tinn-R (for Windows; http://sciviews.org/Tinn-R/)
    - ▶ Rkward (for Linux)
    - ▶ Emacs (w. ESS, all platforms)
    - ▶ Visual Studio (for Windows)
    - ▶ Rstudio (all major platforms; http://www.rstudio.org/)
    - ▶ for more check https://r-dir.com/blog/2013/01/list-of-r-editors.html

Using R

- ► For this course: Rstudio (http://www.rstudio.org/)
    - ► free
    - ► works fine in Windows, MacOS and Linux
    - ► helpful with errors

Using R

- ► Can I use R without Rstudio?

- ► Can I use Rstudio without R?

Practical Examples

► **Package survival - pbc data set**

id	time	status	trt	age	sex	bili	chol
1	400	2	1	58.76523	f	14.5	261
2	4500	0	1	56.44627	f	1.1	302
3	1012	2	1	70.07255	m	1.4	176
4	1925	2	1	54.74059	f	1.8	244
5	1504	1	2	38.10541	f	3.4	279

Practical Examples

- ▶ **id**: case number
- ▶ **time**: number of days between registration and the earlier of death, transplantation, or study analysis in July, 1986
- ▶ **status**: status at endpoint, 0/1/2 for censored, transplant, dead
- ▶ **trt**: 1/2/NA for D-penicillmain, placebo, not randomised
- ▶ **age**: in years
- ▶ **sex**: m/f
- ▶ **bili**: serum bilirunbin (mg/dl)
- ▶ **chol**: serum cholesterol (mg/dl)

More details:
https://stat.ethz.ch/R-manual/R-devel/library/survival/html/pbc.html

Practical Examples

► What is a **scalar**/vector/matrix

id	time	status	trt	age	sex	bili	chol
1	400	2	1	58.76523	f	14.5	261
2	4500	0	1	56.44627	f	1.1	302
3	1012	2	1	**70.07255**	m	1.4	176
4	1925	2	1	54.74059	f	1.8	244
5	1504	1	2	38.10541	f	3.4	279

Practical Examples

► What is a scalar/**vector**/matrix

id	time	**status**	trt	age	sex	bili	chol
1	400	**2**	1	58.76523	f	14.5	261
2	4500	**0**	1	56.44627	f	1.1	302
3	1012	**2**	1	70.07255	m	1.4	176
4	1925	**2**	1	54.74059	f	1.8	244
5	1504	**1**	2	38.10541	f	3.4	279

Practical Examples

► What is a scalar/**vector**/matrix

id	**time**	status	trt	age	sex	bili	chol
1	**400**	2	1	58.76523	f	14.5	261
2	**4500**	0	1	56.44627	f	1.1	302
3	**1012**	2	1	70.07255	m	1.4	176
4	**1925**	2	1	54.74059	f	1.8	244
5	**1504**	1	2	38.10541	f	3.4	279

Practical Examples

► What is a scalar/vector/**matrix**

id	**time**	**status**	trt	age	sex	bili	chol
1	**400**	**2**	1	58.76523	f	14.5	261
2	**4500**	**0**	1	56.44627	f	1.1	302
3	**1012**	**2**	1	70.07255	m	1.4	176
4	**1925**	**2**	1	54.74059	f	1.8	244
5	**1504**	**1**	2	38.10541	f	3.4	279

Practical Examples

► What is a scalar/vector/**matrix**

id	time	status	trt	age	sex	**bili**	**chol**
1	400	2	1	58.76523	f	**14.5**	**261**
2	4500	0	1	56.44627	f	**1.1**	**302**
3	1012	2	1	70.07255	m	**1.4**	**176**
4	1925	2	1	54.74059	f	**1.8**	**244**
5	1504	1	2	38.10541	f	**3.4**	**279**

Practical Examples

► Common questions
  ► What is the average age?
  ► What is the average serum bilirubin?
  ► What is the average serum cholesterol?
  ► What is the percentage of females?
  ► How many missing values do we have for serum cholesterol?

All these questions can be answered using R!

Basics in R

► Elementary commands: **expressions** and **assignments**
► An **expression** given as command is evaluated printed and discarded
► An **assignment** evaluates an expression and passes the value to a variable - the result is not automatically printed

Basics in R

Expression is given as a command,

```
103473
```

```
[1]  103473
```

► However, it cannot be viewed again unless the command is rerun.

Basics in R

Expression is given as a command,

```
103473
```

```
[1] 103473
```

► However, it cannot be viewed again unless the command is rerun.

In order to store information, the expression should assign the command

```
x <- 103473
x
```

```
[1] 103473
```

Basics in R

You can use R as a calculator!

► Basic arithmetics

```
+, -, *, /, ^
```

```
y <- 103473 + 100000
y
```

```
[1] 203473
```

► Complicated arithmetics

Basics in R

Tips:

- ▶ R is case sensitive, e.g.,
  - ▶ **"sex"** is different than **"Sex"**
- ▶ Commands are separated by a semi-colon or by a newline
- ▶ Comments can be put anywhere, starting with a hashmark **#**: everything to the end of the line is a comment
- ▶ Assign a value to an object by **<-** or **=**

Basics in R

- ► Missing values
  - ► are coded as **NA** (i.e., not available) **is.na()**
- ► Infinity
  - ► is coded as **Inf** (plus infinity) or **-Inf** (minus infinity) **is.finite()**
- ► The Null objects
  - ► are coded as **NULL**
- ► Not a number
  - ► is coded as **NaN** (Not a Number). Example:

```
0/0
```

```
[1] NaN
```

Basics in R

Demos
- Basic R `R` `html`

Common R Objects

▶ There are different kinds of variables

id	time	status	trt	age	sex	bili	chol
1	400	2	1	58.77	f	14.5	261
2	4500	0	1	56.45	f	1.1	302
3	1012	2	1	70.07	m	1.4	176
4	1925	2	1	54.74	f	1.8	244
5	1504	1	2	38.11	f	3.4	279

Common R Objects

- ▶ in R Everything (data, results, …) is an object
- ▶ In order to list the created objects use the following functions

```
objects()
ls()
```

Common R Objects

- ▶ in R Everything (data, results, …) is an object
- ▶ In order to list the created objects use the following functions

```r
objects()
ls()
```

- ▶ In order to remove objects

```r
rm(...)
rm(list=ls(all=TRUE))
```

Common R Objects

► To investigate a specific object (e.g. pbc)

```r
str(pbc[,c("id", "time", "status", "trt", "age", "sex", "bili", "chol")])
```

```
'data.frame':   418 obs. of  8 variables:
 $ id    : int  1 2 3 4 5 6 7 8 9 10 ...
 $ time  : int  400 4500 1012 1925 1504 2503 1832 2466 2400 51 ...
 $ status: int  2 0 2 2 1 2 0 2 2 2 ...
 $ trt   : int  1 1 1 1 2 2 2 2 1 2 ...
 $ age   : num  58.8 56.4 70.1 54.7 38.1 ...
 $ sex   : Factor w/ 2 levels "m","f": 2 2 1 2 2 2 2 2 2 2 ...
 $ bili  : num  14.5 1.1 1.4 1.8 3.4 0.8 1 0.3 3.2 12.6 ...
 $ chol  : int  261 302 176 244 279 248 322 280 562 200 ...
```

Common R Objects

The simplest data structures are:

- ► **numeric** : quantitative data
- ► **character** : qualitative data
- ► **integer** : whole numbers
- ► **logical** : TRUE or FALSE
- ► **factors** : qualitative data (levels)

To find out what type of object you have, you can use the following function

```
mode(pbc$age)
```

```
[1] "numeric"
```

Common R Objects

▶ Data structure:
  - ▶ **Vectors** have the same type of elements
  - ▶ **Matrices** have the same type of elements with the same length
  - ▶ **Data.frames** have elements of different type with the same length
  - ▶ **Lists** have elements of different type and length

Common R Objects

► Differences between **vector**, matrix, data.frame and list

```
pbc[1:6, c("age")]
```

```
[1] 58.76523 56.44627 70.07255 54.74059 38.10541 66.25873
```

Common R Objects

▶ Differences between vector, **matrix**, data.frame and list

```
pbc[1:6, c("age", "bili", "chol")]
```

```
        age bili chol
1 58.76523 14.5  261
2 56.44627  1.1  302
3 70.07255  1.4  176
4 54.74059  1.8  244
5 38.10541  3.4  279
6 66.25873  0.8  248
```

Common R Objects

▶ Differences between vector, matrix, **data.frame** and list

```
pbc[1:6, c("id", "sex", "bili", "chol")]
```

```
  id sex bili chol
1  1   f 14.5  261
2  2   f  1.1  302
3  3   m  1.4  176
4  4   f  1.8  244
5  5   f  3.4  279
6  6   f  0.8  248
```

Common R Objects

▶ Differences between vector, matrix, data.frame and **list**

```
list(pbc[1:6, c("sex")], pbc[1:2, c("sex", "bili")], pbc$age[1:4])
```

```
[[1]]
[1] f f m f f f
Levels: m f

[[2]]
  sex bili
1   f 14.5
2   f  1.1

[[3]]
[1] 58.76523 56.44627 70.07255 54.74059
```

Common R Objects

Create a vector

```r
vec <- c(1, 2, 3, 4, 5)
vec
```

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

```r
vec <- c(1:5)
vec
```

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

Common R Objects

Create a matrix

```
vec <- c(1, 2, 3, 4, 5, 6, 7, 8, 9)
mat <- matrix(vec, 3, 3)
mat
```

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

Common R Objects

Create a matrix

```r
vec <- c(1, 2, 3, 4, 5, 6, 7, 8, 9)
mat <- matrix(vec, 3, 3)
mat
```

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

```r
vec <- c(1, 2, 3, 4, 5, 6, 7, 8, 9)
mat <- matrix(vec, 3, 3,
              byrow = TRUE)
mat
```

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

Common R Objects

Create a data frame

```
dtf <- data.frame(pbc$sex, pbc$age)
dtf[1:3,]
```

```
  pbc.sex  pbc.age
1       f 58.76523
2       f 56.44627
3       m 70.07255
```

Common R Objects

Create a data frame

```
dtf <- data.frame(pbc$sex, pbc$age)
dtf[1:3,]

  pbc.sex  pbc.age
1       f 58.76523
2       f 56.44627
3       m 70.07255
```

```
dtf <- data.frame(Gender = pbc$sex,
                  Age = pbc$age)
dtf[1:3,]

  Gender      Age
1      f 58.76523
2      f 56.44627
3      m 70.07255
```

Common R Objects

Create a list

```
list1 <- list(vec = c(1:5), mat = pbc[1:2, c("age", "sex")])
list1
```

```
$vec
[1] 1 2 3 4 5

$mat
       age sex
1 58.76523   f
2 56.44627   f
```

Common R Objects

Demos

▶ Common R Objects `R` `html`

Practicals

▶ Common R Objects `html`

Importing Data and Saving your Work

- ► function: **read.table()**, **read.csv()** and its variants
  - ► note: use forward slashes or double backward slashes in the file names, e.g.,
    `"C:/Documents and Settings/User/Data/file.txt"` or
    `"C:\\Documents and Settings\\User\\Data\\file.txt"`

- ► Specialized functions for importing data from other programs
  - ► package: **foreign**, function: **read.spss()**, **read.dta()**
  - ► package: **Hmisc**, function: **sas.get()**
  - ► package: **openxlsx**, function: **read.xlsx()**
  - ► package: **readxl**, function: **read_excel()**
  - ► package: **haven**, function: **read_spss()**
  - ► *etc*

Importing Data and Saving your Work

Tips:

- ► Short names are prefered over longer names
- ► Try to avoid using names that contain symbols
- ► Avoid spaces in names
- ► Remove any comments in your data set
- ► Make sure that any missing values in your data set are indicated with the same value (or no value)

Importing Data and Saving your Work

- **save()**
  - can be used to save a list of R objects
  - a binary file with all the objects available in your last R session
- You can load your saved R objects using **load()**
  - be careful about overwriting
- Using **saveRDS** and **readRDS** you can save and read a single R object
  - The result has to be assigned to a variable

- Specialized functions for exporting data to other programs
  - function: **write.table()**, **write.csv()**
  - package: **foreign**, function: **write.spss()**, **write.dta()**
  - package: **openxlsx**, function: **write.xlsx()**
  - *etc*

Importing Data and Saving your Work

Demos
- ► Importing and Saving `R` `html`

Practicals
- ► Importing and Saving `html`

Data Transformation

You will never receive the perfect data set!

- ► **Round** continuous variables
- ► Convert **numeric** variables to **factors**
- ► Compute **new variables**
  - ► transform variables
- ► Data sets of **wide** $\iff$ **long** format

Data Transformation

► **Round** continuous variables

```
pbc[1:3, c("time", "age", "bili", "chol")]
```

```
  time      age bili chol
1  400 58.76523 14.5  261
2 4500 56.44627  1.1  302
3 1012 70.07255  1.4  176
```

```
round(pbc[1:3, c("time", "age", "bili", "chol")], digits = 2)
```

```
  time   age bili chol
1  400 58.77 14.5  261
2 4500 56.45  1.1  302
3 1012 70.07  1.4  176
```

Data Transformation

► Convert **numeric** variables to **factors**

```r
DF <- pbc[,c("id", "time", "status", "trt", "age",
                "sex", "bili", "chol")]
DF$trt <- factor(DF$trt, levels = c(1, 2),
              labels = c("D-penicillmain", "placebo"))
head(DF)
```

```
  id time status             trt      age sex bili chol
1  1  400      2 D-penicillmain 58.76523   f 14.5  261
2  2 4500      0 D-penicillmain 56.44627   f  1.1  302
3  3 1012      2 D-penicillmain 70.07255   m  1.4  176
4  4 1925      2 D-penicillmain 54.74059   f  1.8  244
5  5 1504      1        placebo 38.10541   f  3.4  279
6  6 2503      2        placebo 66.25873   f  0.8  248
```

Data Transformation

- ► Compute **new variables**
  - ► transform variables

```
DF <- pbc[,c("id", "time", "status", "trt", "age",
                "sex", "bili", "chol")]
DF$time <- DF$time/30
DF$time_years <- DF$time/12
head(DF)
```

```
   id       time status trt      age sex bili chol time_years
1  1  13.33333      2   1 58.76523   f 14.5  261   1.111111
2  2 150.00000      0   1 56.44627   f  1.1  302  12.500000
3  3  33.73333      2   1 70.07255   m  1.4  176   2.811111
4  4  64.16667      2   1 54.74059   f  1.8  244   5.347222
5  5  50.13333      1   2 38.10541   f  3.4  279   4.177778
6  6  83.43333      2   2 66.25873   f  0.8  248   6.952778
```

Data Transformation

► Data sets of **wide** $\Longleftrightarrow$ long format

```r
head(pbc[,c("id", "time", "status", "trt", "age",
                    "sex", "bili", "chol")])
```

```
  id time status trt      age sex bili chol
1  1  400      2   1 58.76523   f 14.5  261
2  2 4500      0   1 56.44627   f  1.1  302
3  3 1012      2   1 70.07255   m  1.4  176
4  4 1925      2   1 54.74059   f  1.8  244
5  5 1504      1   2 38.10541   f  3.4  279
6  6 2503      2   2 66.25873   f  0.8  248
```

Data Transformation

▶ Data sets of wide ⟺ **long** format

```r
head(pbcseq[, c("id", "futime", "status", "trt", "age", "day",
                "sex", "bili", "chol")])
```

```
  id futime status trt      age day sex bili chol
1  1    400      2   1 58.76523   0   f 14.5  261
2  1    400      2   1 58.76523 192   f 21.3   NA
3  2   5169      0   1 56.44627   0   f  1.1  302
4  2   5169      0   1 56.44627 182   f  0.8   NA
5  2   5169      0   1 56.44627 365   f  1.0   NA
6  2   5169      0   1 56.44627 768   f  1.9   NA
```

Data Transformation

Demos

► Data Transformation `R` `html`

Data Exploration

▶ Common questions
  ▶ What is the mean and standard deviation for age?
  ▶ What is the mean and standard deviation for time?
  ▶ What is the median and interquartile range for age?
  ▶ What is the percentage of placebo patients?
  ▶ What is the percentage of females?
  ▶ What is the mean and standard deviation for age in males?
  ▶ What is the mean and standard deviation for baseline serum bilirubin?
  ▶ What is the percentage of missings in serum bilirubin?

All these questions can be answered using R!

Data Exploration

► **Hints**

► Check functions: **mean(...)**, **sd(...)**, **percent(...)**, **median(...)**, **IQR(...)**

Data Exploration

► **Hints**

► Check functions: **mean(...)**, **sd(...)**, **percent(...)**, **median(...)**, **IQR(...)**

What is the mean value for age?

```
mean(pbc$age)
```

```
[1] 50.74155
```

Data Exploration

Demos

► Data Exploration `R` `html`

Data Visualization

- ▶ It is important to investigate each variable in our data set using plots
  - ▶ Descriptive statistics for continuous and categorical variables
  - ▶ Distributions of variables
  - ▶ Distributions of variables per group
  - ▶ Extreme values
  - ▶ Linear/nonlinear evolutions

Data Visualization

- ▶ R has very powerful graphics capabilities
- ▶ Some good references are
  - ▶ Murrel, P. (2005) R Graphics. Boca Raton: Chapman & Hall/CRC.
  - ▶ Sarkar, D. (2008) Lattice Multivariate Data Visualization with R. New York: Springer-Verlag.

Data Visualization

- ► Traditional graphics system
  - ► package **graphics**
- ► Trellis graphics system
  - ► package **lattice** (which is based on package grid)
- ► Grammar of Graphics implementation (i.e., Wilkinson, L. (1999) The Grammar of Graphics. New York: Springer-Verlag)
  - ► packages **ggplot** & **ggplot2**

Data Visualization

Important plotting basic functions

- ▶ **plot()**: scatter plot (and others)
- ▶ **barplot()**: bar plots
- ▶ **boxplot()**: box-and-whisker plots
- ▶ **dotchart()**: dot plots
- ▶ **hist()**: histograms
- ▶ **pie()**: pie charts
- ▶ **qqnorm()**, **qqline()**, **qqplot()**: distribution plots
- ▶ **pairs()**: for multivariate data

Data Visualization

Continuous variables

```
plot(pbc$age, pbc$bili)
```

Data Visualization

Continuous variables

```
plot(pbc$age, pbc$bili, xlab = "age", ylab = "bili",
     cex.lab = 1.9, cex.axis = 1.5)
```

Data Visualization

Continuous variables

```r
plot(pbc$age, pbc$bili, xlab = "age", ylab = "bili",
     cex.lab = 1.9, cex.axis = 1.5, col = "red")
```

Data Visualization

► For more options check

```
?plot
```

Data Visualization

Continuous variables per group

```r
plot(pbc$age, pbc$bili, xlab = "age", ylab = "bili",
     cex.lab = 1.9, cex.axis = 1.5, col = pbc$sex)
```

Data Visualization

Continuous variables per group

```
boxplot(pbc$age ~ pbc$sex, xlab = "sex", ylab = "age",
    cex.lab = 1.9, cex.axis = 1.5)
```

Data Visualization

Continuous variables per group

```
pbc_male_bili <- pbc$bili[pbc$sex == "m"]
pbc_female_bili <- pbc$bili[pbc$sex == "f"]
plot(density(pbc_male_bili), col = rgb(0,0,1,0.5),
     main = "Density plots", xlab = "bili", ylab = "")
polygon(density(pbc_male_bili), col = rgb(0,0,1,0.5),
        border = "blue")
lines(density(pbc_female_bili), col = rgb(1,0,0,0.5))
polygon(density(pbc_female_bili), col = rgb(1,0,0,0.5),
        border = "red")
legend(8,0.2, c("male", "female"),
       col = c(rgb(0,0,1,0.5), rgb(1,0,0,0.5)), lty = 1)
```

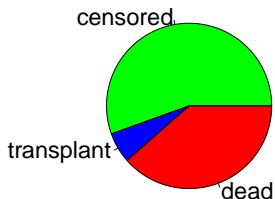# Data Visualization

Continuous variables per group

Density plots
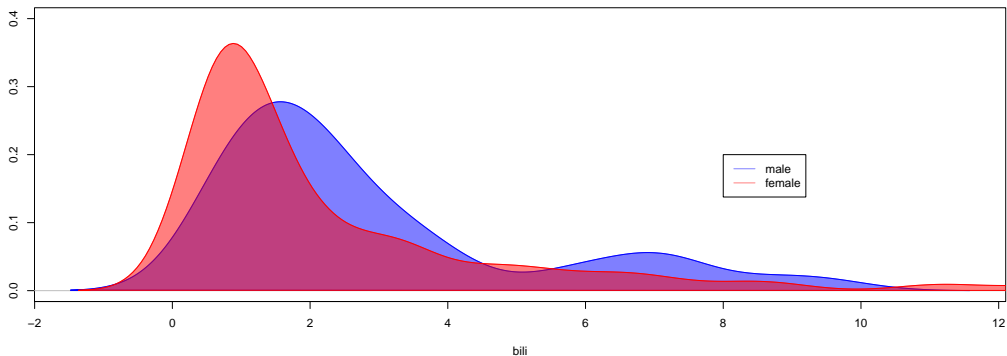
Data Visualization

Categorical variables

```
pbc$status <- factor(pbc$status, levels = c(0, 1, 2),
                     labels = c("censored", "transplant", "dead"))
pie(table(pbc$status), col = c("green", "blue", "red"), cex = 2)
```

Data Visualization

Demos

▶ Data Visualization `R` `html`

Practicals

▶ Data Manipulation `html`

Useful Summary: Data manipulation

Common R objects
- `c()`
- `matrix()`
- `data.frame()`
- `list()`
- `cbind()`, `rbind()`

Transformation
- `factor()`
- `reshape()`
- `order()`
- `complete.cases()`

Exploration
- `is.na()`
- `dim()`
- `mean()`, `sd()`
- `median()`, `IQR()`
- `percent()`

Visualization
- `plot()`, `legend()`
- `hist()`
- `barchart()`
- `boxplot()`
- `xyplot()`, `ggplot()`
- `par()`

Import/Save/Present
- `head()`
- `save()`, `saveRDS()`
- `load()`, `readRDS()`
- `read.csv()`, `write.csv()`, `read.xlsx()`, `write.xlsx()`, `read.table()`, `write.table()`

Other
- `install.packages()`, `library()`
- `ls()`, `objects()`, `getwd()`

Indexing/Subsetting

► When transforming and analyzing data we often need to select specific observations or variables

    ► Examples: Select …

        ► the 3rd element for vector age

        ► the 3rd column of the pbc data set

        ► the sex of the 10th patient

        ► the baseline details of the 5th patient

        ► the serum cholesterol for all males

        ► the age for male patients or patients that have serum bilirubin more than 3

        ► the first measurement per patient

Indexing/Subsetting

▶ This can be done using square bracket (**[ ]**) notation and indices.
▶ Three basic types
    ▶ position indexing
    ▶ logical indexing
    ▶ name indexing

Indexing/Subsetting

Indexing with `vector`

▶ For position indexing, use a **positive** value to select an element

```
x <- c(6:17)
x
```

```
 [1]  6  7  8  9 10 11 12 13 14 15 16 17
```

```
x[2]
```

```
[1] 7
```

▶ Use multiple positive values to select multiple elements

```
x[c(2,3,4)]
```

```
[1] 7 8 9
```

Indexing/Subsetting

Indexing with `vector`

▶ For position indexing, use dublicated **positive** values to select the same elements

```
x <- c(6:17)
x
```

```
 [1]  6  7  8  9 10 11 12 13 14 15 16 17
```

```
x[c(2,2,2)]
```

```
[1] 7 7 7
```

Indexing/Subsetting

Indexing with `vector`

▶ For position indexing, use a **negative** value to remove an element

```
x <- c(6:17)
x
```

```
 [1]  6  7  8  9 10 11 12 13 14 15 16 17
```

```
x[-5]
```

```
 [1]  6  7  8  9 11 12 13 14 15 16 17
```

▶ **Positive and negative indices cannot be combined**

Indexing/Subsetting

Indexing with `vector`

▶ Use logical index of the same length to select elements where the
  value is **TRUE**

```
x <- c(6:10)
y <- c(TRUE, FALSE, FALSE, FALSE, FALSE)
x[y]
```

```
[1] 6
```

Indexing/Subsetting

Indexing with `vector`

► Use logical indexing in combination with conditions

```
x <- c(6:10)
x[x > 7]
```

```
[1]   8   9  10
```

```
x[x > 7 & x > 9]
```

```
[1] 10
```

```
x[x > 7 | x > 9]
```

```
[1]   8   9  10
```

Indexing/Subsetting

Indexing with `vector`

▶ For name/character indexing, use the name of the element

```
x <- c(foo=5, bar=4, one=7, two=12, three=2)
x[c('foo', 'one')]
```

```
foo one
  5   7
```

▶ Use the function `names` to obtain the names

Indexing/Subsetting

Indexing with `matrix`

► Indexing matrices are similar to indexing vectors but with double index
  ► The first position denotes the rows **["index",]**
  ► The first position denotes the columns **[, "index"]**

Indexing/Subsetting

Indexing with `matrix`

- ► Indexing matrices are similar to indexing vectors but with double index
  - ► The first position denotes the rows **["index",]**
  - ► The first position denotes the columns **[, "index"]**

```
mat <- matrix(1:4, 2, 2)
mat
```

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

► Use position indexing as:

```
mat <- matrix(1:4, 2, 2)
mat[2, 2]
```

```
[1] 4
```

Indexing/Subsetting

Indexing with `matrix`

▶ Be cautious, it also works with a single index. In this case, it selects the particular element of the vector that will be included in the matrix

```
mat <- matrix(1:4, 2, 2)
mat[[2]]
```

```
[1] 2
```

```
mat[2]
```

```
[1] 2
```

Indexing/Subsetting

Indexing with `matrix`

► When we leave a position blank all elements are selected

```
mat <- matrix(1:4, 2, 2)
mat
```

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

```
mat[2, ]
```

```
[1] 2 4
```

Indexing/Subsetting

Indexing with `data.frame`

▶ Works with single and double index

```
DF <- data.frame(x = 1:3,
          y = c(35, 23, 14))
DF
```

```
  x  y
1 1 35
2 2 23
3 3 14
```

Indexing/Subsetting

Indexing with `data.frame`

► Works with single and double index

```
DF <- data.frame(x = 1:3,
         y = c(35, 23, 14))
DF
```

```
  x  y
1 1 35
2 2 23
3 3 14
```

► Use position indexing as:

```
DF[2]
```

```
   y
1 35
2 23
3 14
```

```
DF[[2]]
```

```
[1] 35 23 14
```

Indexing/Subsetting

Indexing with `data.frame`

▶ $ provides a convinient notation to extract an element by name

```
head(pbc$time)
```

```
[1]   400 4500 1012 1925 1504 2503
```

Indexing/Subsetting

Indexing with `data.frame`

▶ When using a double index,
  indexing works like a matrix

```
DF <- data.frame(x = 1:3,
          y = c(35, 23, 14))
DF
```

```
  x  y
1 1 35
2 2 23
3 3 14
```

Indexing/Subsetting

Indexing with `data.frame`

▶ When using a double index, indexing works like a matrix

```
DF <- data.frame(x = 1:3,
         y = c(35, 23, 14))
DF
```

```
  x  y
1 1 35
2 2 23
3 3 14
```

▶ Use position indexing

```
DF[2, ]
```

```
  x  y
2 2 23
```

▶ Use logical indexing

```
DF[DF$y < 30, ]
```

```
  x  y
2 2 23
3 3 14
```

Indexing/Subsetting

Indexing with `data.frame`

► Combine logical and position indexing in data frame

```
pbcDF <- data.frame(pbc)
head(pbc[pbc$sex == "m", 1:7])
```

```
   id time    status trt      age sex ascites
3   3 1012      dead   1 70.07255   m       0
14 14 1217      dead   2 56.22177   m       1
21 21 3445  censored   2 64.18891   m       0
24 24 4079      dead   1 44.52019   m       0
48 48 4427  censored   2 49.13621   m       0
52 52 2386      dead   1 50.54073   m       0
```

Indexing/Subsetting

Indexing with `data.frame`

► Combine logical and position indexing in data frame

```
pbcDF <- data.frame(pbc)
head(pbc[pbc$age > 30 | pbc$sex == "f", 1:7])
```

```
  id time    status    trt      age sex ascites
1  1  400      dead      1 58.76523   f       1
2  2 4500  censored      1 56.44627   f       0
3  3 1012      dead      1 70.07255   m       0
4  4 1925      dead      1 54.74059   f       0
5  5 1504 transplant     2 38.10541   f       0
6  6 2503      dead      2 66.25873   f       0
```

Indexing/Subsetting

Indexing with `data.frame`

► Combine logical and position indexing in data frame

```
pbcDF <- data.frame(pbc)
head(pbc[pbc$age > 30 & pbc$sex == "f", 1:7])
```

```
  id time      status trt      age sex ascites
1  1  400        dead   1 58.76523   f       1
2  2 4500    censored   1 56.44627   f       0
4  4 1925        dead   1 54.74059   f       0
5  5 1504  transplant   2 38.10541   f       0
6  6 2503        dead   2 66.25873   f       0
7  7 1832    censored   2 55.53457   f       0
```

Indexing/Subsetting

Indexing with `list`

► Lists can be subsetted in the same way as vectors using single brackets - Note that the output is a list

► Use position indexing

```
mylist <- list(y = c(14, 45), z = c("m", "f", "f"))
mylist[2]
```

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

Indexing/Subsetting

Indexing with `list`

▶ Double square brackets can be also used - Note that the output is a vector

▶ Use position indexing

```
mylist <- list(y = c(14, 45), z = c("m", "f", "f"))
mylist[[2]]
```

```
[1] "m" "f" "f"
```

Indexing/Subsetting

Indexing with `list`

► `$` provides a convinient notation to extract an element by name - Note that the output is a vector

```
mylist <- list(y = c(14, 45), z = c("m", "f", "f"))
mylist
```

```
$y
[1] 14 45

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

```
mylist$y
```

```
[1] 14 45
```

Indexing/Subsetting

▶ Use the following webpage to further investigate indexing and subsetting
https://emcbiostatistics.shinyapps.io/indexing/

> **Demos**
>
> ▶ Shiny app indexing subsetting **R**

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

▶ `survival`
▶ `shiny`

Useful Summary: Indexing/Subsetting

Demos
- ▶ Indexing/Subsetting `R` `html`

Practicals
- ▶ Indexing/Subsetting `html`

Useful Summary: Indexing/Subsetting

Vectors
- ► []
- ► [""] - for categorical variables

Matrices
- ► [,]
- ► [[]], []

Data frames
- ► [,]
- ► [[]], []
- ► $

Lists
- ► []
- ► [[]]
- ► $