BST02: Using R for Statistics in Medical Research

Part B: Basic use of R

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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 (cont'd)

- 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 http://www.sciviews.org/_rgui/projects/Editors.html

Using R (cont'd)

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

Using R (cont'd)

- 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 (cont'd)

- **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 (cont'd)

- 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 (cont'd)

- 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 (cont'd)

- 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 (cont'd)

- 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 (cont'd)

- 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 (cont'd)

- Common questions
  - What is the average age?
  - What is the average bili?
  - What is the average chol?
  - What is the percentage of females?
  - How many missing values do we have for chol?

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 (cont'd)

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 (cont'd)

- Basic arithmetics

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

- Complicated arithmetics

Basics in R (cont'd)

- 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 (cont'd)

- 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()**
- Not a number
  - is coded as **NaN** (Not a Number). Example:

```
0/0
```

```
[1] NaN
```

Basics in R (cont'd)

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 (cont'd)

- in R Everything (data, results, …) is an object
- In order to list the created variables use objects() or ls()

```
objects()
```

- In order to remove everything:

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

Common R Objects (cont'd)

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

```
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 (cont'd)

The simplest data structures are:

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

To find out what type of vector you have you can use the mode function

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

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

Common R Objects (cont'd)

- Every object in R has a class
  - **Vectors** have the same type of elements
  - **Matrices** have the same type of elements
  - **Data.frames** and lists do not need to have the same type of elements
  - **Lists** may have elements of different length and type

Common R Objects (cont'd)

- Differences between **Vector**, Matrices, Data.frames and Lists

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

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

Common R Objects (cont'd)

- Differences between Vector, **Matrices**, Data.frames and Lists

```
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 (cont'd)

- Differences between Vector, Matrices, **Data.frames** and Lists

```
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 (cont'd)

- Differences between Vector, Matrices, Data.frames and **Lists**

```
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 (cont'd)

Create a vector

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

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

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

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

Common R Objects (cont'd)

Create a matrix

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

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

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

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

Common R Objects (cont'd)

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 (cont'd)

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 (cont'd)

Demos

- Common R Objects R html

Importing Data and Saving your Work

- **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 statistical packages
  - package: **foreign**, function: **read.spss()** , **read.dta()**
  - package: **Hmisc**, function: **sas.get()**
  - package: **readxl**, function: **read_excel()**
  - package: **haven**, functio: **read_spss()**
  - etc

Importing Data and Saving your Work (cont'd)

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 (cont'd)

- **ls()** lists R objects in a session
- **save()**
  - can be used to save a list of R objects
  - a binary file with all the objects available in your last R session
  - platform independent
- 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 importing data from other statistical packages
  - function: **read.csv()**
  - package: **foreign**, function: **write.spss()**, **write.dta()**
  - etc

Importing Data and Saving your Work (cont'd)

- Create a csv, xls or text file from an R object

```
write.csv(mydata, "c:/mydata.txt")
write.table(mydata, "c:/mydata.txt", sep="\t")
library(xlsx)
write.xlsx(mydata, "c:/mydata.xlsx")
```

Importing Data and Saving your Work (cont'd)

Demos

- Importing and Saving R html

Data Transformation

- Round continuous variables
- **numeric** variables to **factors**
- Compute new variables
  - transform variables
- Matrices of wide $\Longleftrightarrow$ long format
- Missing values

Data Transformation (cont'd)

Round continuous variables

```
DF <- format(pbc[,c("id", "time", "status", "trt", "age",
                    "sex", "bili", "chol")], digits = 2)
head(DF)
```

```
  id time status trt age sex bili chol
1  1  400      2   1  59   f 14.5  261
2  2 4500      0   1  56   f  1.1  302
3  3 1012      2   1  70   m  1.4  176
4  4 1925      2   1  55   f  1.8  244
5  5 1504      1   2  38   f  3.4  279
6  6 2503      2   2  66   f  0.8  248
```

Data Transformation (cont'd)

numeric variables to **factors**

```
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 (cont'd)

- 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 (cont'd)

- Matrices of **wide** $\Longleftrightarrow$ long format

```
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 (cont'd)

- Matrices of wide $\Longleftrightarrow$ **long** format

```
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 (cont'd)

- **Missing values**

```
head(pbc[is.na(pbc$chol) == TRUE, c("id", "time", "status",
                                    "trt", "age", "sex",
                                    "bili", "chol")])
```

```
   id time status trt      age sex bili chol
14 14 1217      2   2 56.22177   m  0.8   NA
40 40 4467      0   1 46.66940   f  1.3   NA
41 41 1350      2   1 33.63450   f  6.8   NA
42 42 4453      0   2 33.69473   f  2.1   NA
45 45 4025      0   2 41.79329   f  0.6   NA
49 49  708      2   2 61.15264   f  0.8   NA
```

Data Transformation (cont'd)

Demos

- Data Transformation R html

Data Exploration

- Common questions
  - What is the mean and sd for age?
  - What is the mean and sd 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 sd for age in males?
  - What is the mean and sd for baseline serum bilirubin?

Data Exploration (cont'd)

- Common questions: **Hints**
- Check functions: **mean(...)**, **sd(...)**, **percent(...)**, **median(...)**, **IQR(...)**

Data Exploration (cont'd)

Demos

- Data Exploration R html

Data Visualization

- It is important to investigate each 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 (cont'd)

- 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.

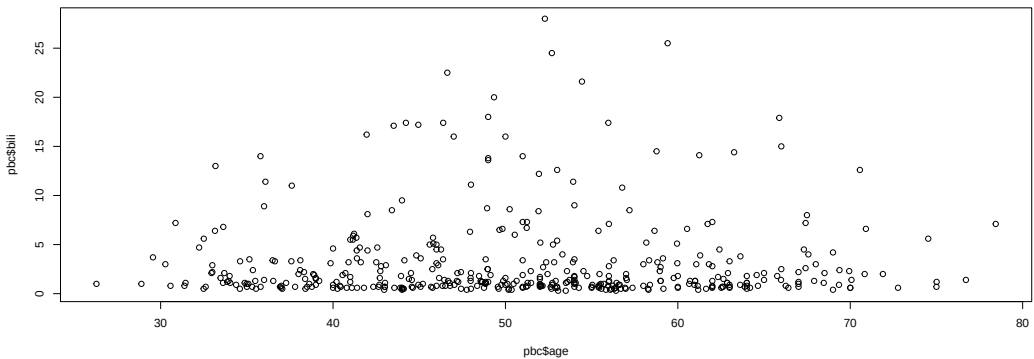
Data Visualization (cont'd)

- 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 (cont'd)

Continuous variables

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



Data Visualization (cont'd)

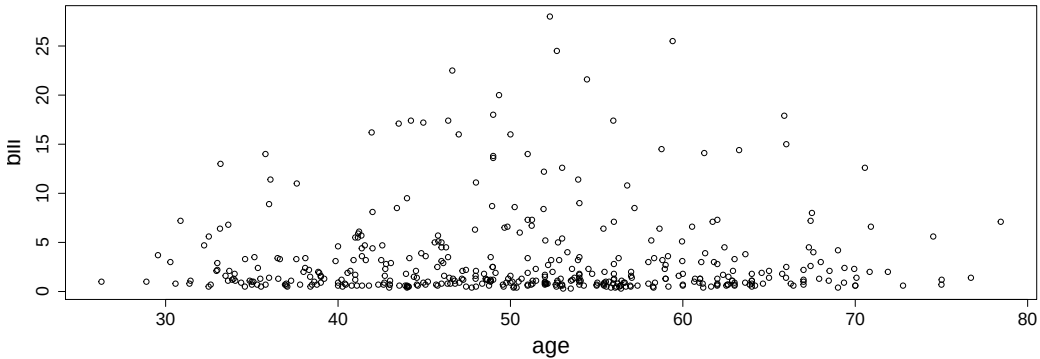
Important plotting functions

- **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 (cont'd)

Continuous variables

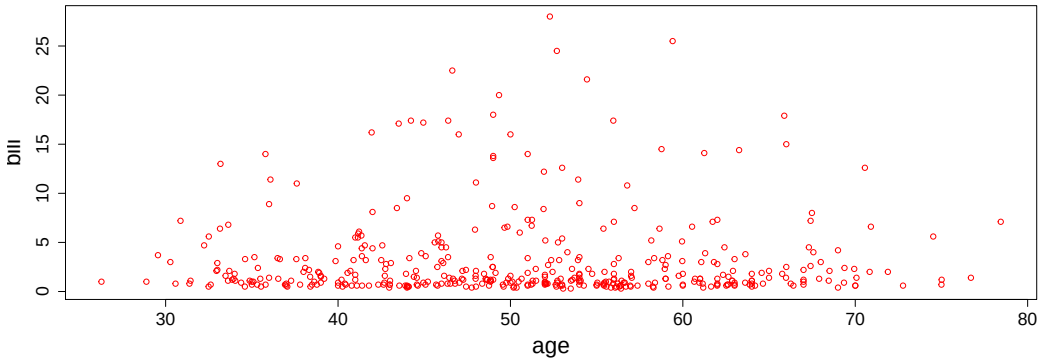
```
plot(pbc$age, pbc$bili, xlab = "age", ylab = "bili",
     cex.lab = 1.9, cex.axis = 1.5)
```



Data Visualization (cont'd)

Continuous variables

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



Data Visualization (cont'd)

Continuous variables per group

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

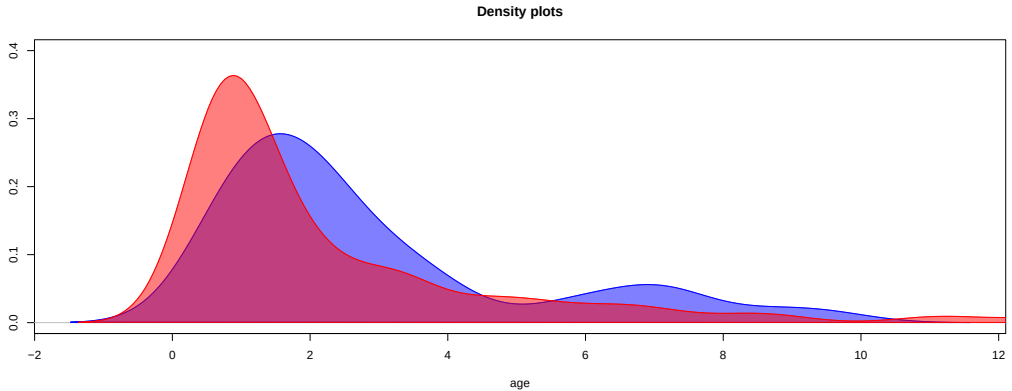
Data Visualization (cont'd)

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 = "age", 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(20,0.03, c("male", "female"),
       col = c(rgb(0,0,1,0.5), rgb(1,0,0,0.5)), lty = 1)
```

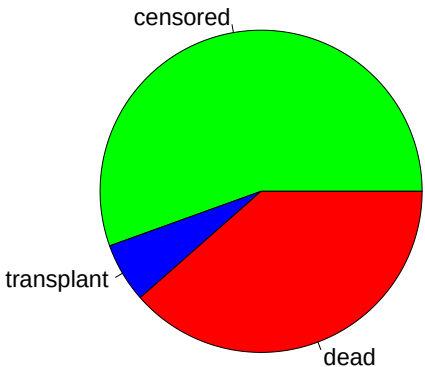
Data Visualization (cont'd)

Continuous variables per group



Data Visualization (cont'd)

Categorical variables



Data Visualization (cont'd)

Demos

- Data Visualization R 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()`
- `par()`
- `xyplot()`
- `ggplot()`

Import/Save/Present

- `head()`
- `save()`, `saveRDS()`
- `load()`, `readRDS()`
- `write.csv()`, `write.xlsx()`, `write.table()`

Other

- `install.packages()`
- `library()`
- `ls()`, `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 (cont'd)

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

Indexing/Subsetting (cont'd)

Position indexing with vectors:

- 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 (cont'd)

Position indexing with vectors:

- 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 (cont'd)

Position indexing with vectors:

- 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 (cont'd)

Logical indexing with vectors:

- 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 (cont'd)

Logical indexing with vectors:

- Logical indexing is often used 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 (cont'd)

Name/character indexing with vectors:

- When a vector has been named the element names can be used as indices

```
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 (cont'd)

Indexing with Matrices:

- Indexing matrices as similar to indexing vectors but with double index
  - The first position denotes the rows
  - The first position denotes the columns

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

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

```
mat[2, 2]
```

```
[1] 5
```

Indexing/Subsetting (cont'd)

Indexing with Matrices:

- When we leave a position blank all elements are selected

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

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

```
mat[2, ]
```

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

Indexing/Subsetting (cont'd)

Indexing with Data Frames:

- When you use a single index the data.frame acts like a list of variables

```
DF <- data.frame(x = 1:4,
                 y = c(35, 23, 14, 45))
DF
```

```
  x  y
1 1 35
2 2 23
3 3 14
4 4 45
```

```
DF <- data.frame(x = 1:4,
                 y = c(35, 23, 14, 45))
DF[2]
```

```
   y
1 35
2 23
3 14
4 45
```

Indexing/Subsetting (cont'd)

Indexing with Data Frames:

- When you using a double index, indexing works like a matrix

```
DF <- data.frame(x = 1:4,
                 y = c(35, 23, 14, 45))
DF
```

```
  x  y
1 1 35
2 2 23
3 3 14
4 4 45
```

```
DF[4, 2]
```

```
[1] 45
```

- When you using a double index, indexing works like a matrix

```
DF <- data.frame(x = 1:4,
                 y = c(35, 23, 14, 45))
DF
```

```
  x  y
1 1 35
2 2 23
3 3 14
4 4 45
```

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

```
  x  y
2 2 23
```

Indexing/Subsetting (cont'd)

Indexing with Data Frames:

- Logical 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 (cont'd)

Indexing with Data Frames:

- Logical 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 (cont'd)

Indexing with Data Frames:

- Logical 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 (cont'd)

Indexing with Lists:

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

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

```
$y
[1] 14 45

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

```
mylist[2]
```

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

Indexing/Subsetting (cont'd)

Indexing with Lists:

- Double square brackets can be also used - 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[[2]]
```

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

Indexing/Subsetting (cont'd)

Indexing with Lists:

- $ 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
```

Useful Summary: Indexing/Subsetting

Vectors

- `[]`
- `[""]`

Matrices

- `[,]`

Data frames

- `[,]`
- `$`
- `[[]]`

Lists

- `[]`
- `[[]]`
- `$`

Useful Summary: Indexing/Subsetting (cont'd)

Demos

- Indexing Subsetting R html

Practicals

- Basic Use R html