MPP-E1180 Lecture 2: Introduction to the R Programming Language

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Objectives for the topic

- Basics of object-oriented programming in R
- Simple R data structures
- Simple descriptive statistics and plotting with Base R

What is R?

Open source programming language, with a particular focus on statistical programming.

History: Originally (in 1993) an implementation of the S programming language (Bell Labs), by **R**oss Ihaka and **R**obert Gentleman (hence **R**) at University of Auckland.

Currently the R Foundation for Statistical Computing is based in Vienna.

RStudio:

RStudio is an Integrated Developer Environment (IDE) that makes using R and other reproducible research tools easier.

Growing popularity

R can be easily expanded by **user created packages** hosted on GitHub and/or CRAN.

How to Cite R

```r
citation()
```

```
##
## To cite R in publications use:
##
##   R Core Team (2015). R: A language and environment for
##   statistical computing. R Foundation for Statistical Co
##   Vienna, Austria. URL https://www.R-project.org/.
##
## A BibTeX entry for LaTeX users is
##
##   @Manual{,
##     title = {R: A Language and Environment for Statistic
##     author = {{R Core Team}},
##     organization = {R Foundation for Statistical Comput
##     address = {Vienna, Austria},
##     year = {2015},
##     url = {https://www.R-project.org/},
```

Fundamentals of the R language

R is **object-oriented**.

Objects are R's nouns. They include (not exhaustive):

- character strings (e.g. words)
- numbers
- vectors of numbers or character strings
- matrices
- data frames
- lists

Assignment

You use the **assignment operator** (<-) to assign character strings, numbers, vectors, etc. to object names

```
## Assign the number 10 to an object called number
number <- 10

number
```

```
## [1] 10
```

```
# Assign Hello World to an object called words
words <- "Hello World"

words
```

```
## [1] "Hello World"
```

Assignment

You can also use the equality sign (=):

```
number = 10

number
```

```
## [1] 10
```

Note: it has a slightly different meaning.

See StackOverflow discussion.

Special values in R

- `NA`: not available, missing
- `NULL`: does not exist, is undefined
- `TRUE`, `T`: logical true. **Logical** is also an object class.
- `FALSE`, `F`: logical false

Finding special values

Function	Meaning
is.na	Is the value NA
is.null	Is the value NULL
isTRUE	Is the value TRUE
!isTRUE	Is the value FALSE

```
absent <- NA
is.na(absent)
```

```
## [1] TRUE
```

Operator	Meaning
<	less than
>	greater than
==	equal to
<=	less than or equal to
>=	greater than or equal to
!=	not equal to
a | b	a or b
a & b	a and b

Classes

Objects have distinct classes.

```r
# Find the class of number
class(number)
```

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

```r
# Find the class of absent
class(absent)
```

```
## [1] "logical"
```

Naming objects

- Object names **cannot have spaces**
  - Use `CamelCase`, `name_underscore`, or `name.period`
- Avoid creating an object with the same name as a function (e.g. `c` and `t`) or special value (`NA`, `NULL`, `TRUE`, `FALSE`).
- Use **descriptive object names**!
  - Not: `obj1`, `obj2`
- Each object name must be **unique** in an environment.
  - Assigning something to an object name that is already in use will **overwrite the object's previous contents**.

Finding objects

```r
# Find objects in your workspace
ls()
```

```
## [1] "absent" "number" "words"
```

Style Guides

As with natural language writing, it is a good idea to stick to one style guide with your R code:

- Google's R Style Guide
- Hadely Wickham's R Style Guide

Vectors

A vector is an **ordered collection** of numbers, characters, etc. of the **same type**.

Vectors can be created with the c (**combine**) function.

```
# Create numeric vector
numeric_vector <- c(1, 2, 3)

# Create character vector
character_vector <- c('Albania', 'Botswana', 'Cambodia')
```

Factor class vector

Categorical variables are called **factors** in R.

```
# Create numeric vector
fruits <- c(1, 1, 2)

# Create character vector for factor labels
fruit_names <- c('apples', 'mangos')

# Convert to labelled factor
fruits_factor <- factor(fruits, labels = fruit_names)

summary(fruits_factor)
```

```
## apples mangos
##      2      1
```

Matrices

Matrices are collections of vectors **with the same length and class**.

```
# Combine numeric_vector and character_vector into a matri
combined <- cbind(numeric_vector, character_vector)

combined
```

```
##      numeric_vector character_vector
## [1,] "1"            "Albania"
## [2,] "2"            "Botswana"
## [3,] "3"            "Cambodia"
```

Note (1): R *coerced* `numeric_vector` into a character vector.

Note (2): You can `rbind` new rows onto a matrix.

Data frames

Data frames are collections of vectors with the same length.

Each column (vector) can be of a **different class**.

```
# Combine numeric_vector and character_vector into a data f
combined_df <- data.frame(numeric_vector, character_vector,
                          stringsAsFactors = FALSE)

combined_df
```

```
##   numeric_vector character_vector
## 1              1          Albania
## 2              2         Botswana
## 3              3         Cambodia
```

Lists

A list is an object containing other objects that can have **different** lengths and classes.

```
# Create a list with three objects of different lengths
test_list <- list(countries = character_vector, not_there =
                  more_numbers = 1:10)
test_list
```

```
## $countries
## [1] "Albania"  "Botswana" "Cambodia"
##
## $not_there
## [1] NA NA
##
## $more_numbers
##  [1]  1  2  3  4  5  6  7  8  9 10
```

Functions

Functions do things to/with objects. Functions are like **R's verbs**.

When using functions to do things to objects, they are always followed by parentheses (). The parentheses contain the **arguments**. Arguments are separated by commas.

```r
# Summarise combined_df
summary(combined_df, digits = 2)
```

```
##  numeric_vector character_vector
##  Min.   :1.0    Length:3
##  1st Qu.:1.5    Class :character
##  Median :2.0    Mode  :character
##  Mean   :2.0
##  3rd Qu.:2.5
##  Max.   :3.0
```

Functions help

Use `?` to find out what arguments a function can take.

```
?summary
```

The help page will also show the function's **default argument values**.

Component selection ($)

The $ is known as the component selector. It selects a component of an object.

```
combined_df$character_vector
```

```
## [1] "Albania"  "Botswana" "Cambodia"
```

Subscripts []

You can use subscripts [] to also select components.

For data frames they have a `[row, column]` pattern.

```r
# Select the second row and first column of combined_df
combined_df[2, 1]
```

```
## [1] 2
```

```r
# Select the first two rows
combined_df[c(1, 2), ]
```

```
##   numeric_vector character_vector
## 1              1          Albania
## 2              2         Botswana
```

Subscripts []

```
# Select the character_vector column
combined_df[, 'character_vector']
```

```
## [1] "Albania"  "Botswana" "Cambodia"
```

Assigment with elements of objects

You can use assigment with parts of objects. For example:

```
combined_df$character_vector[3] <- 'China'
combined_df$character_vector
```

```
## [1] "Albania"  "Botswana" "China"
```

You can even add new variables:

```
combined_df$new_var <- 1:3
combined_df
```

```
##   numeric_vector character_vector new_var
## 1              1          Albania       1
## 2              2         Botswana       2
## 3              3            China       3
```

Packages

You can greatly expand the number of functions by installing and loading user-created packages.

```
# Install dplyr package
install.packages('dplyr')

# Load dplyr package
library(dplyr)
```

You can also call a function directly from a specific package with the double colon operator (`::`).

```
Grouped <- dplyr::group_by(combined_df, character_vector)
```

R's build-in data sets

List internal data sets:

```
data()
```

Load **swiss** data set:

```
data(swiss)
```

Find data description:

```
?swiss
```

R's build-in data sets

Find variable names:

```
names(swiss)
```

```
## [1] "Fertility"        "Agriculture"      "Examination"
## [4] "Education"        "Catholic"         "Infant.Morta
```

See the first three rows and four columns

```
head(swiss[1:3, 1:4])
```

```
##              Fertility Agriculture Examination Educatio
## Courtelary        80.2        17.0          15        1
## Delemont          83.1        45.1           6
## Franches-Mnt      92.5        39.7           5
```

What all the cool kids are doing: piping

Pipe: pass a value forward to a function call.

Why?

- Faster compilation.
- Enhanced code readability.

In R use %>% from the magrittr (or dplyr) package.

%>% passes a value to the **first argument** of the next function call.

Simple piping example

Not piped:

```r
values <- rnorm(1000, mean = 10)
value_mean <- mean(values)
round(value_mean, digits = 2)
```

```
## [1] 10.07
```

Piped:

```r
library(magrittr)

rnorm(1000, mean = 10) %>% mean() %>% round(digits = 2)
```

```
## [1] 9.99
```

Creating Functions

You can create a function to find the sample mean ($\bar{x} = \frac{\sum x}{n}$) of a vector.

```
fun_mean <- function(x){
    sum(x) / length(x)
}

## Find the mean
fun_mean(x = swiss$Examination)
```

```
## [1] 16.48936
```

Why functions?

Functions:

- Simplify your code if you do repeated tasks.
- Lead to fewer mistakes.
- Are easier to understand.
- Save time over the long run–a general solution to problems in different contexts.

Descriptive statistics: review

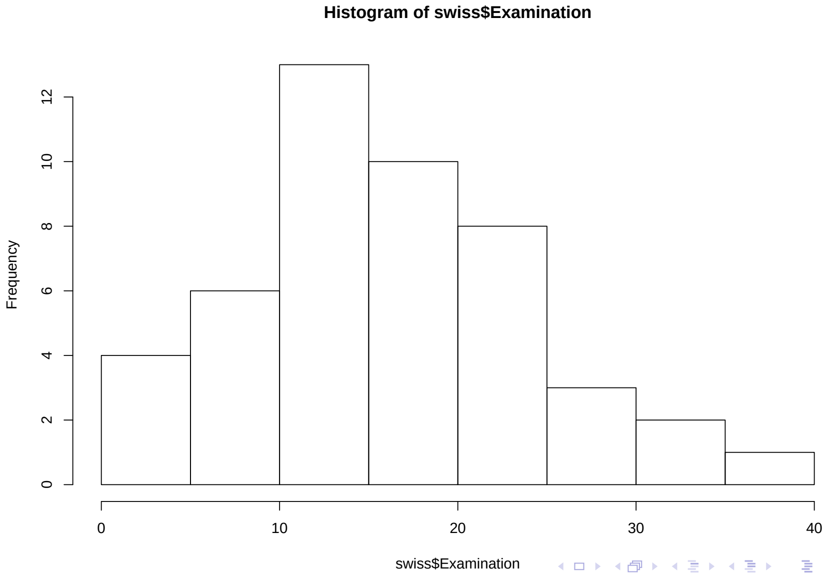
Descriptive Statistics: describe samples

Stats 101: describe samples **distributions** with appropriate measure of

- **central tendancy**
- **variability**

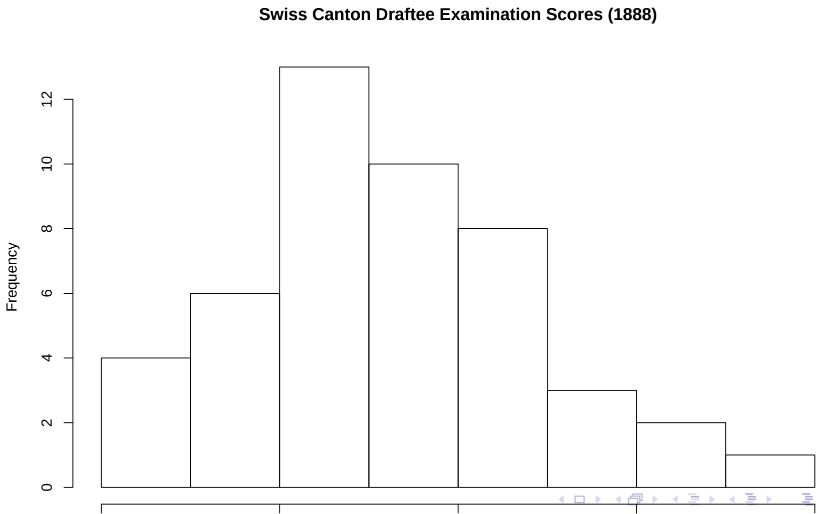
Histograms

```
hist(swiss$Examination)
```



Histograms: styling

```
hist(swiss$Examination,
     main = 'Swiss Canton Draftee Examination Scores (1888)
     xlab = '% receiving highest mark on army exam')
```



Finding means

(or use the mean function in base R)

```r
mean(swiss$Examination)
```

```
## [1] 16.48936
```

If you have missing values (`NA`):

```r
mean(swiss$Examination, na.rm = TRUE)
```

Digression: Loops

You can ‘loop’ through the data set to find the mean for each column

```
for (i in 1:length(names(swiss))) {
    swiss[, i] %>%
    mean() %>%
    round(digits = 1) %>%
    paste(names(swiss)[i], ., '\n') %>%  # the . directs th
    cat()
}
```

```
## Fertility 70.1
## Agriculture 50.7
## Examination 16.5
## Education 11
## Catholic 41.1
## Infant.Mortality 19.9
```

Other functions for central tendency

Median

```r
median(swiss$Examination)
```

```
## [1] 16
```

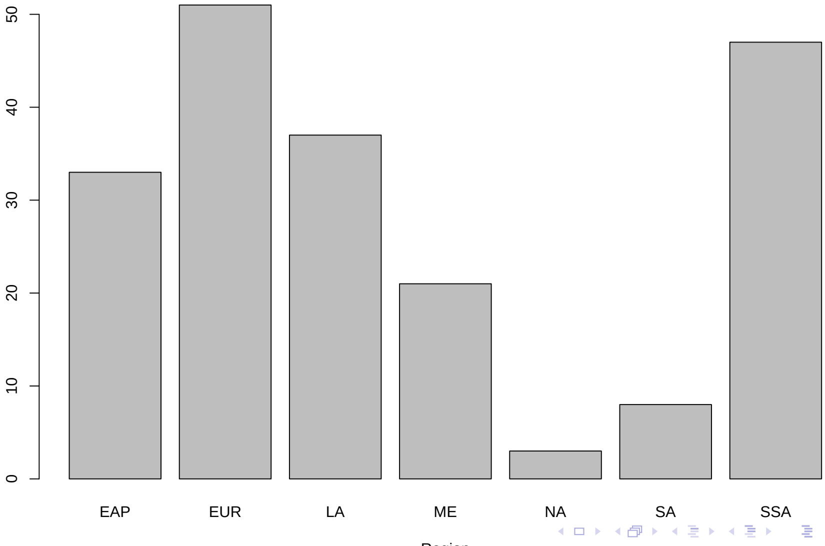
Mode

`mode` is not an R function to find the statistical mode.

Instead use `summary` for factor nominal variables or make a bar chart.

Simple bar chart for nominal

```
devtools::source_url('http://bit.ly/OTWEGS')
plot(MortalityGDP$region, xlab = 'Region')
```



Variation

Range:

```
range(swiss$Examination)
```

```
## [1]  3 37
```

Quartiles:

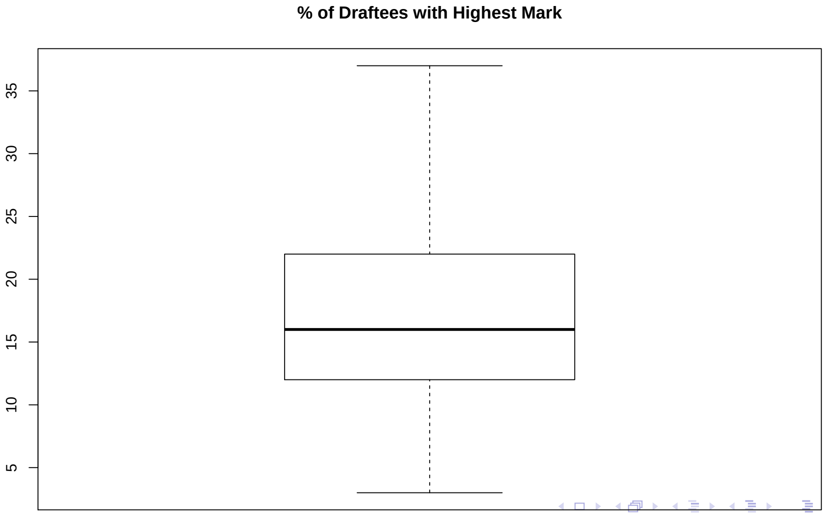
```
summary(swiss$Examination)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    3.00   12.00   16.00   16.49   22.00   37.00
```

Variation

Boxplots:

```
boxplot(swiss$Examination, main = '% of Draftees with Highe
```



Variation

Interquartile Range ($IQR = Q_3 - Q_1$):

```
IQR(swiss$Examination)
```

```
## [1] 10
```

Variation: standard deviation

Sum of squared deviations:

$$\text{Sum of Squares} = \sum (x - \bar{x})^2$$

Degrees of freedom (number of values that are free to vary):

$$\text{df} = n - 1$$

Variance (s^2):

$$s^2 = \frac{\text{Sum of Squares}}{\text{Degrees of Freedom}} = \frac{\sum (x - \bar{x})^2}{n - 1}$$

Standard deviation (s) (in terms of the mean):

$$s = \sqrt{s^2}$$

Variation: Standard Error

The **standard error** of the mean:

If we think of the variation as around a central tendancy as a measure of **unreliability** then we want the measure to **decrease as the sample size goes up**.

$$\mathrm{SE}_{\bar{x}} = \frac{s}{\sqrt{n}}$$

Variation: Variance and Standard Deviation

Variance:

```
var(swiss$Examination)
```

```
## [1] 63.64662
```

Standard Deviation:

```
sd(swiss$Examination)
```

```
## [1] 7.977883
```

Variation: Standard Error

Standard Error:

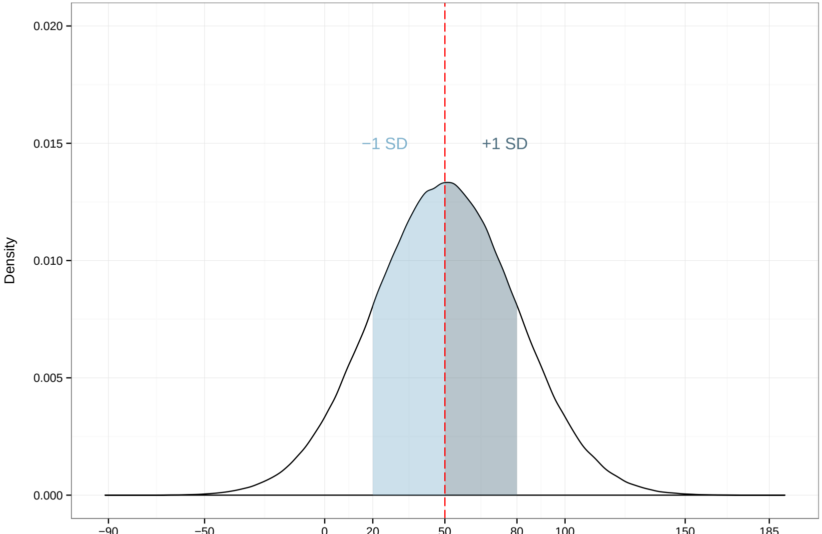
```
sd_error <- function(x) {
    sd(x) / sqrt(length(x))
}

sd_error(swiss$Examination)
```

```
## [1] 1.163694
```

Playing with distributions

Simulated normally distributed data with SD of 30 and mean 50

```
Normal30 <- rnorm(1e+6, mean = 50, sd = 30)
```

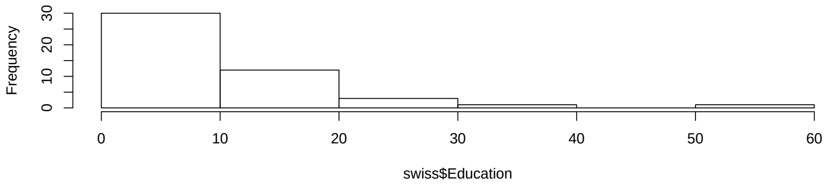


Transform skewed data

Highly skewed data can be transformed to have a normal distribution.

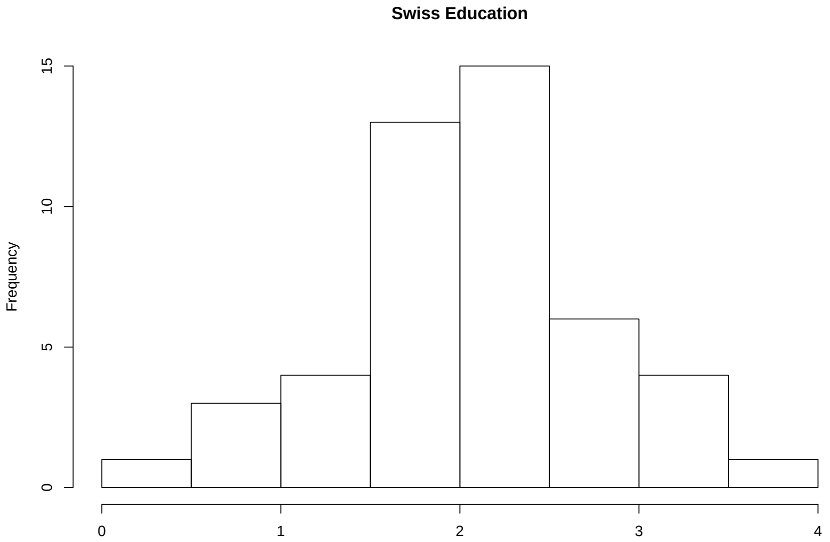
Helps correct two violations of key assumptions: (a) non-linearity and (b) heteroskedasticity.

```
hist(swiss$Education, main = '')
```



Natural log transformed skewed data

```
log(swiss$Education) %>% hist(main = "Swiss Education")
```



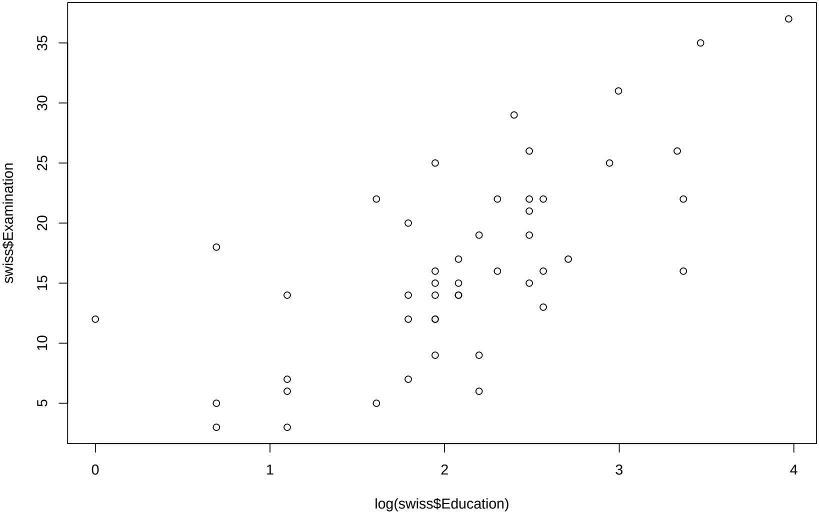
Transformations

The natural log transformation is only useful for data that **does not contain zeros**.

See http://robjhyndman.com/hyndsight/transformations/ for suggestions on other transformations such as Box-Cox and Inverse Hyperbolic Sine.

Joint distributions

```
plot(log(swiss$Education), swiss$Examination)
```



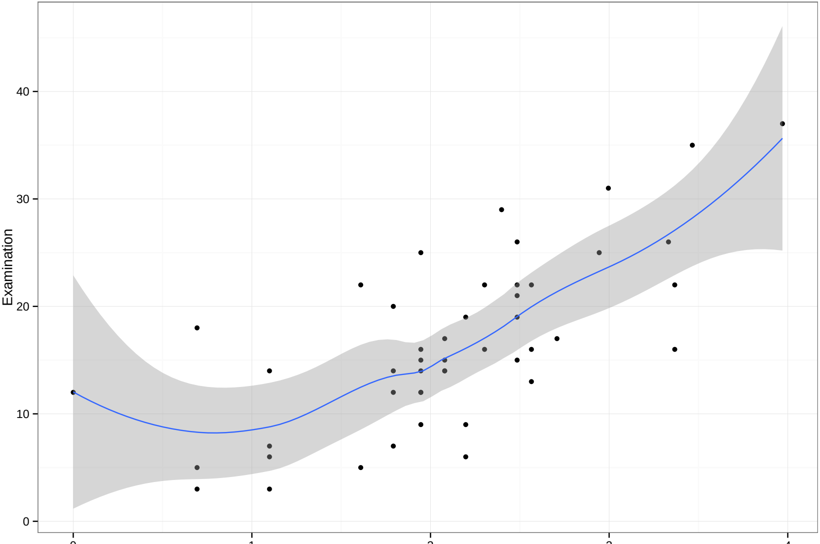
Summarise with correlation coefficients

```
cor.test(log(swiss$Education), swiss$Examination)
```

```
##
##  Pearson's product-moment correlation
##
## data:  log(swiss$Education) and swiss$Examination
## t = 6.4313, df = 45, p-value = 7.133e-08
## alternative hypothesis: true correlation is not equal to
## 95 percent confidence interval:
##  0.5053087 0.8168779
## sample estimates:
##       cor
## 0.6920531
```

Summarise with loess

```
ggplot2::ggplot(swiss, aes(log(Education), Examination)) +
    geom_point() + geom_smooth() + theme_bw()
```



Programming Hint (1)

Always close!

In R this means closing:

- `()`
- `[]`
- `{}`
- `''`
- `""`

Programming Hint (2)

Make your code as **simple as possible**.

- Easier to read.
- Easier to write (ultimately).
- Easier to find mistakes.
- Often computationally more efficient.

One way to do this is to **define things once**–e.g. use variables to contain values and custom functions to contain multiple sequential function calls.

Programming Hint (2)

Bad

```r
mean(rnorm(1000))
```

```
## [1] 0.01963857
```

```r
sd(rnorm(1000))
```

```
## [1] 1.019639
```

Programming Hint (2)

Good

```r
rand_sample <- rnorm(1000)

mean(rand_sample)
```

```
## [1] -0.01687148
```

```r
sd(rand_sample)
```

```
## [1] 0.9936785
```

Seminar: Start using R!

- **Access** R data sets
- Explore the data and find ways to **numerically**/**graphically** describe it.
- Find and use R functions that were **not covered** in the lecture for exploring and transforming your data.
- Create **your own function** (what it does is open to you).