

Part 3.

Numerical variables

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Outline

1. Measures of central tendency
2. Measures of dispersion
3. Graphical representations
4. Testing normality

Data frame ldt

- > `library(Rling)` # loads a package that has been installed
- > `data(ldt)` # loads the data
- > `head(ldt)` # returns the first 6 rows

	Length	Freq	Mean_RT
marveled	8	131	819.19
persuaders	10	82	977.63
midmost	7	0	908.22
crutch	6	592	766.30
resuspension	12	2	1125.42
efflorescent	12	9	948.33

Data frame structure

```
> str(ldt) # displays the structure
```

```
'data.frame': 100 obs. of 3 variables:
```

```
$ Length : int 8 10 7 6 12 12 3 11 11 5 ...
```

```
$ Freq : int 131 82 0 592 2 9 14013 15 48 290 ...
```

```
$ Mean_RT: num 819 978 908 766 1125 ...
```

Attach a data frame

```
> head(Idt$Length)
```

```
[1] 8 10 7 6 12 12
```

```
> head(Length)
```

```
Error in head(Length) : object 'Length' not found
```

```
> attach(Idt)
```

```
> head(Length) #now you can access all variables  
directly
```

```
[1] 8 10 7 6 12 12
```

Mean, median and mode

```
> mean(ldt$Length)
```

```
[1] 8.23
```

```
> median(ldt$Length)
```

```
[1] 8
```

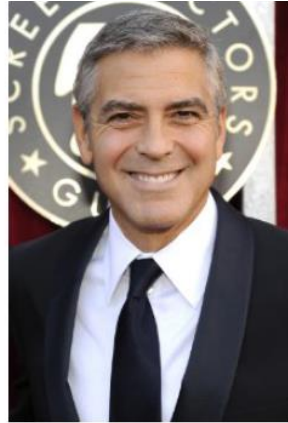
```
> table(ldt$Length) #shows how many times every  
value occurs; the most popular value is the mode
```

```
3 4 5 6 7 8 9 10 11 12 13 14 15
```

```
2 5 7 13 12 16 11 16 11 3 1 2 1
```

Understanding the median

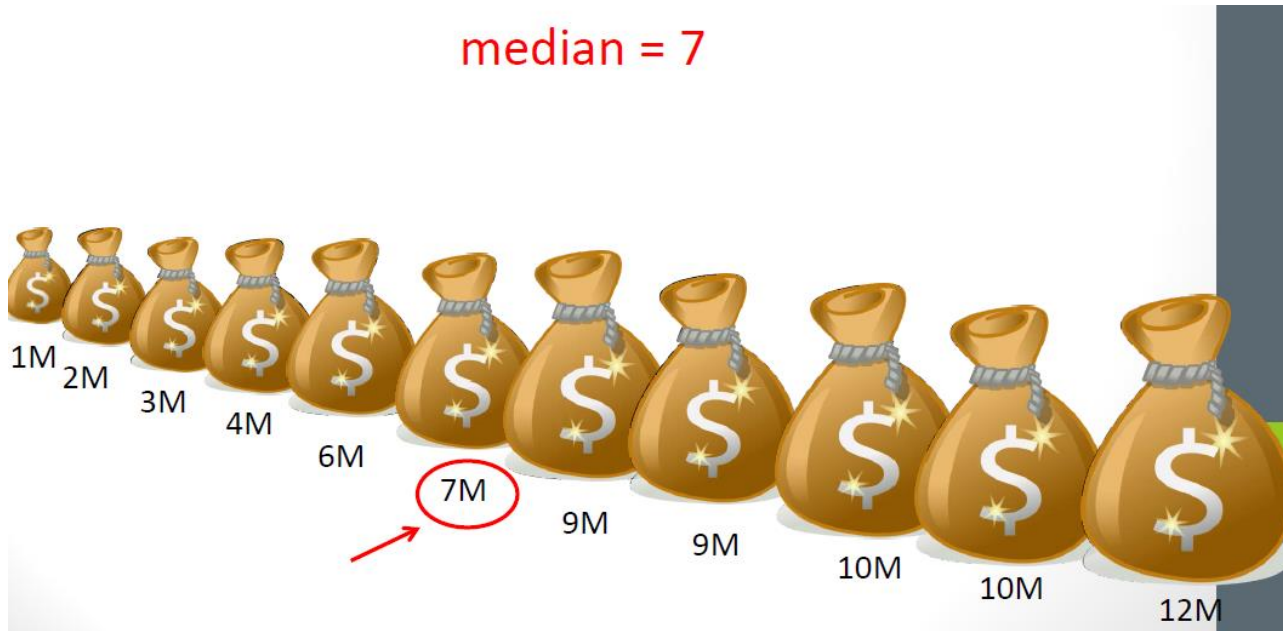
- Ocean's Eleven



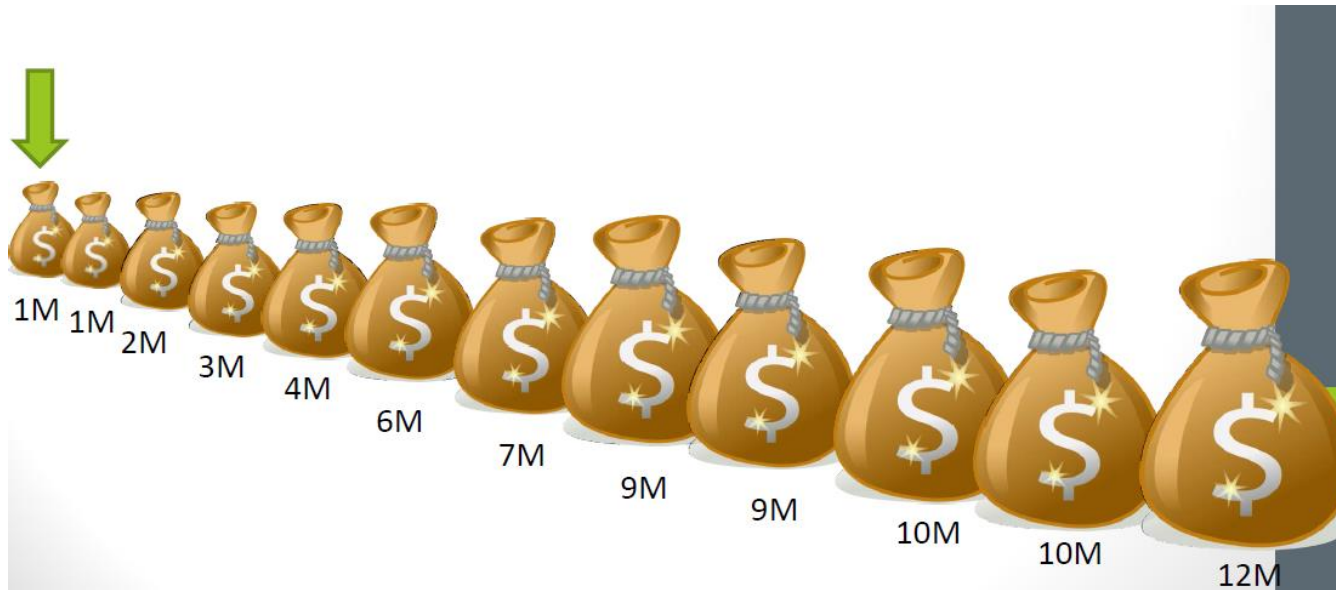
Danny Ocean



Ocean's 11: the median



Ocean's twelve



Ocean's twelve: the median

$$\text{median} = (6 + 7)/2 = 6.5$$



Mean vs. median

- In some situations the median gives a better idea of the most typical value than the mean. The problem with the latter is that it is easily influenced by outliers, i.e. scores with unusually high or low values.
- For example, if twenty employees in a company have net salaries of €2000 a month, and the CEO's salary is €50000, the mean salary will be €4286, and the median will be €2000. The median gives a more realistic idea of the salaries in the company than the mean because the CEO's salary is exceptional.

Exercise

- Find the mean and the median of the reaction times in ldt.

A very useful function `summary()`

```
> summary(Mean_RT)
```

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
564.2	713.1	784.9	808.3	905.2	1458.8

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Measures of dispersion

> `range(Length)` # the minimum and the maximum

[1] 3 15

> `var(Length)` #variance = sum of squared deviations
[1] 6.259697 from the mean, divided by
the number of observations
- 1

> `sd(Length)` # standard deviation = the squared root
[1] 2.501939 of variance

Why care about the dispersion?

- Consider two countries with a similar average income per capita. In one country the variance and standard deviation are relatively small because the finances are distributed fairly, whereas in the other they are very large because of several billionaires and many extremely poor people. Although the means are identical, life in the two countries will differ dramatically.

Statisticians make jokes, too 😊

- If your head is in the oven, and your feet are in the fridge, on average you're quite comfortable.



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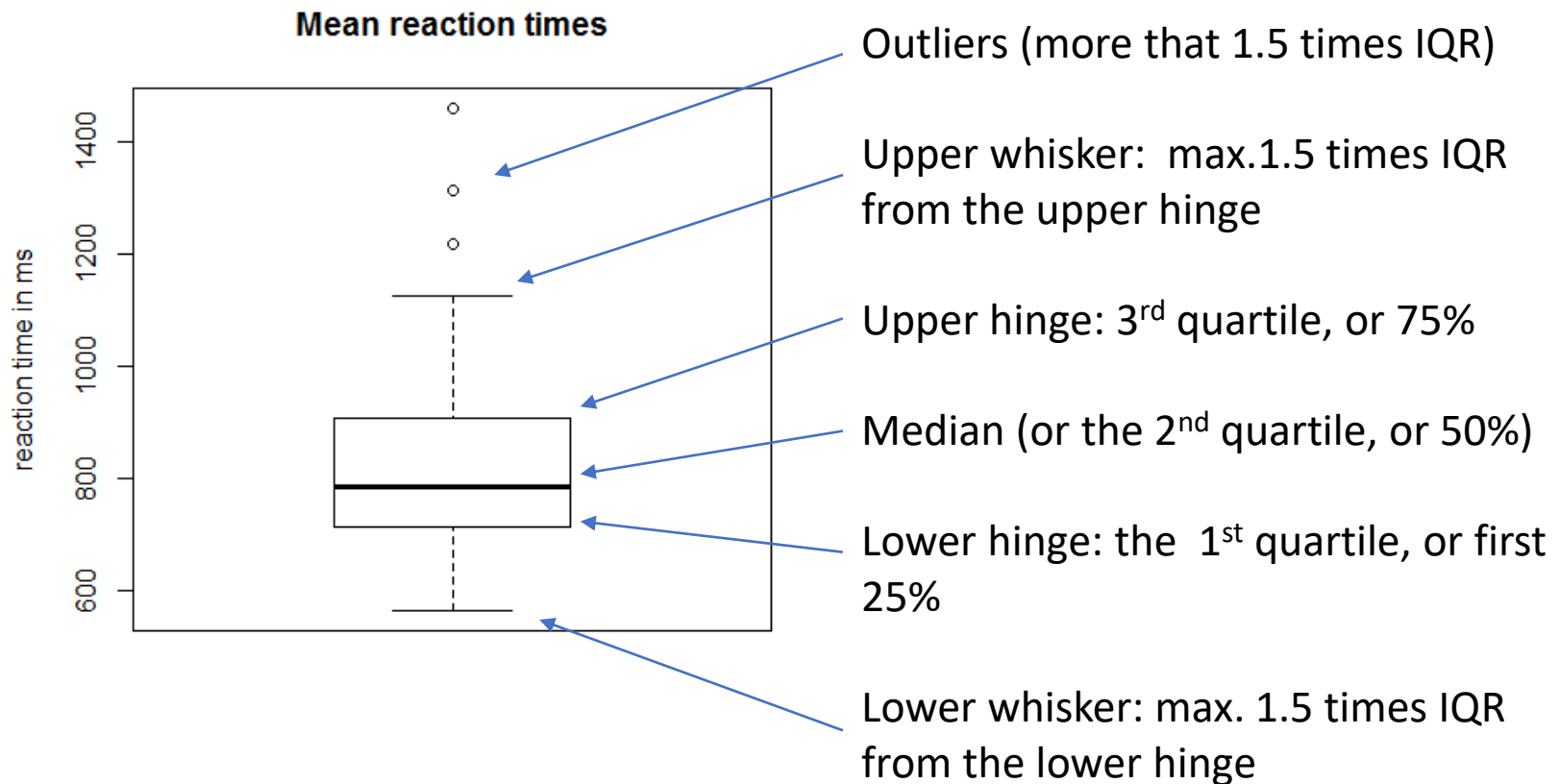
Boxplot

```
> boxplot(Mean_RT)
```

A bit more sophisticated:

```
> boxplot(Mean_RT, main = "Mean reaction times",  
ylab = "reaction time in ms")
```

Box-and-whisker plot



Boxplot stats

```
> boxplot.stats(Mean_RT)
```

```
$stats # l. whisker, l. notch, median, u. notch, u. whisker
```

```
[1] 564.180 712.285 784.940 905.930 1125.420
```

```
$n #number of observations
```

```
[1] 100
```

```
$conf # ignore for the time being
```

```
[1] 754.3441 815.5359
```

```
$out # outliers
```

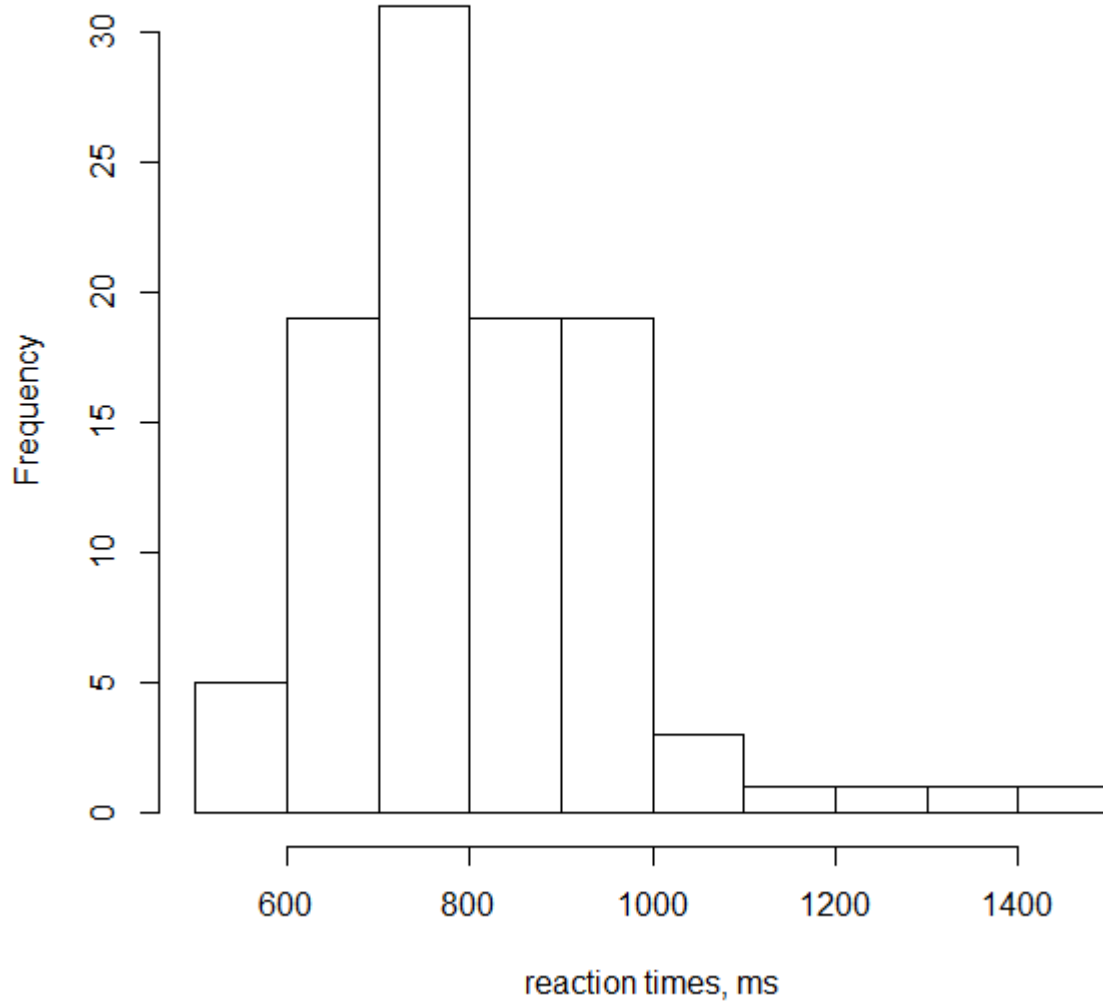
```
[1] 1314.33 1216.81 1458.75
```

Histogram

```
> hist(Mean_RT, main = "Histogram of mean reaction  
times", xlab = "reaction times, ms")
```

A histogram shows the frequencies of different values aggregated in bins.

Histogram of mean reaction times



Exercise

	Subj 1	Subj 2	Subj 3	Subj 4	Subj 5	Subj 6	Subj 7	Subj 8	Subj 9	Subj 10
Reaction time, ms	583	667	1149	827	488	452	NA	739	455	572

Task:

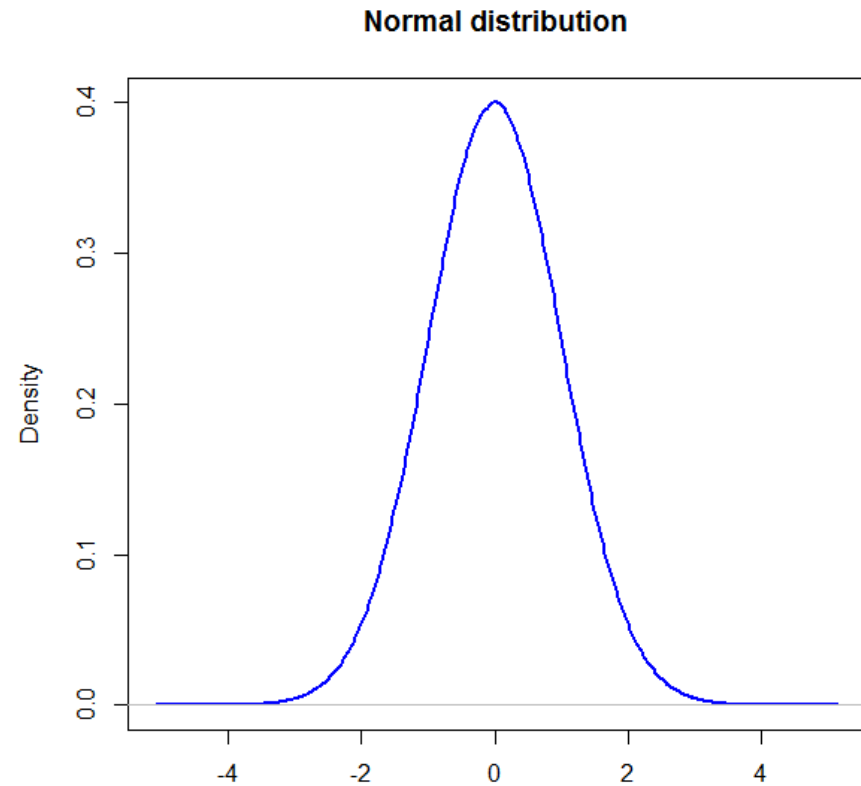
1. Create a numeric vector with the reaction times from the table
2. Compute the mean and the median (add `na.rm = TRUE` to exclude the missing value)
3. Compute the range, the deviance and the standard deviation
4. Create a box plot and a histogram.

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Normal distribution

- A bell-shaped curve
- Mean = median = mode



Why is it important?

- Some tests require that the data should be normally distributed.
- This is why one should learn how to test if the data are normally distributed.

Shapiro test

```
> shapiro.test(Mean_RT)
```

Shapiro-Wilk normality test

data: Mean_RT

$W = 0.92006$, $p\text{-value} = 1.418e-05$

A small p -value (less than 0.05) means that the assumption that the data are normally distributed can be rejected.

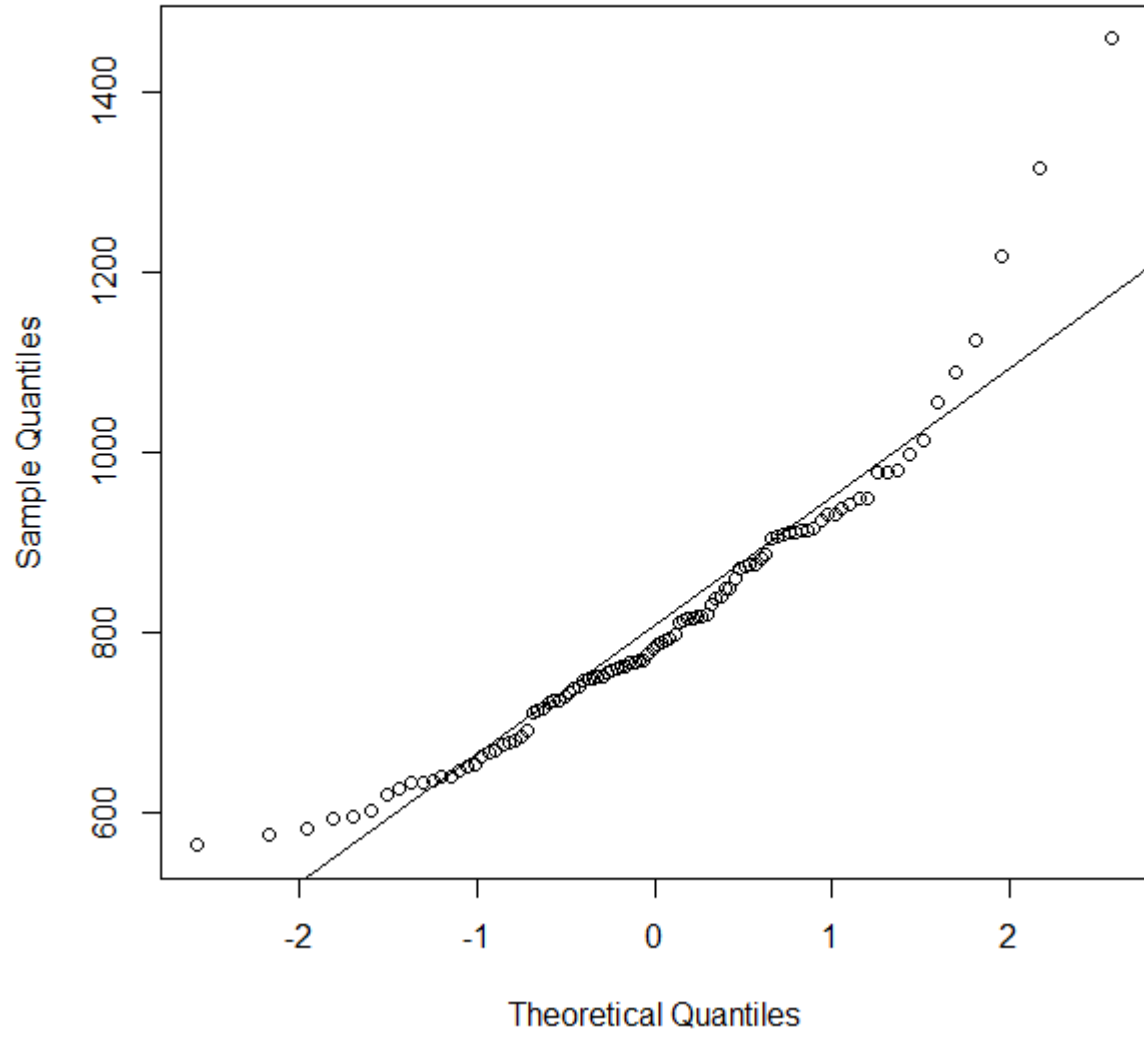
QQ-plot

```
> qqnorm(Mean_RT)
```

```
> qqline(Mean_RT)
```

The points should lie close to the line, which is not the case.

Normal Q-Q Plot

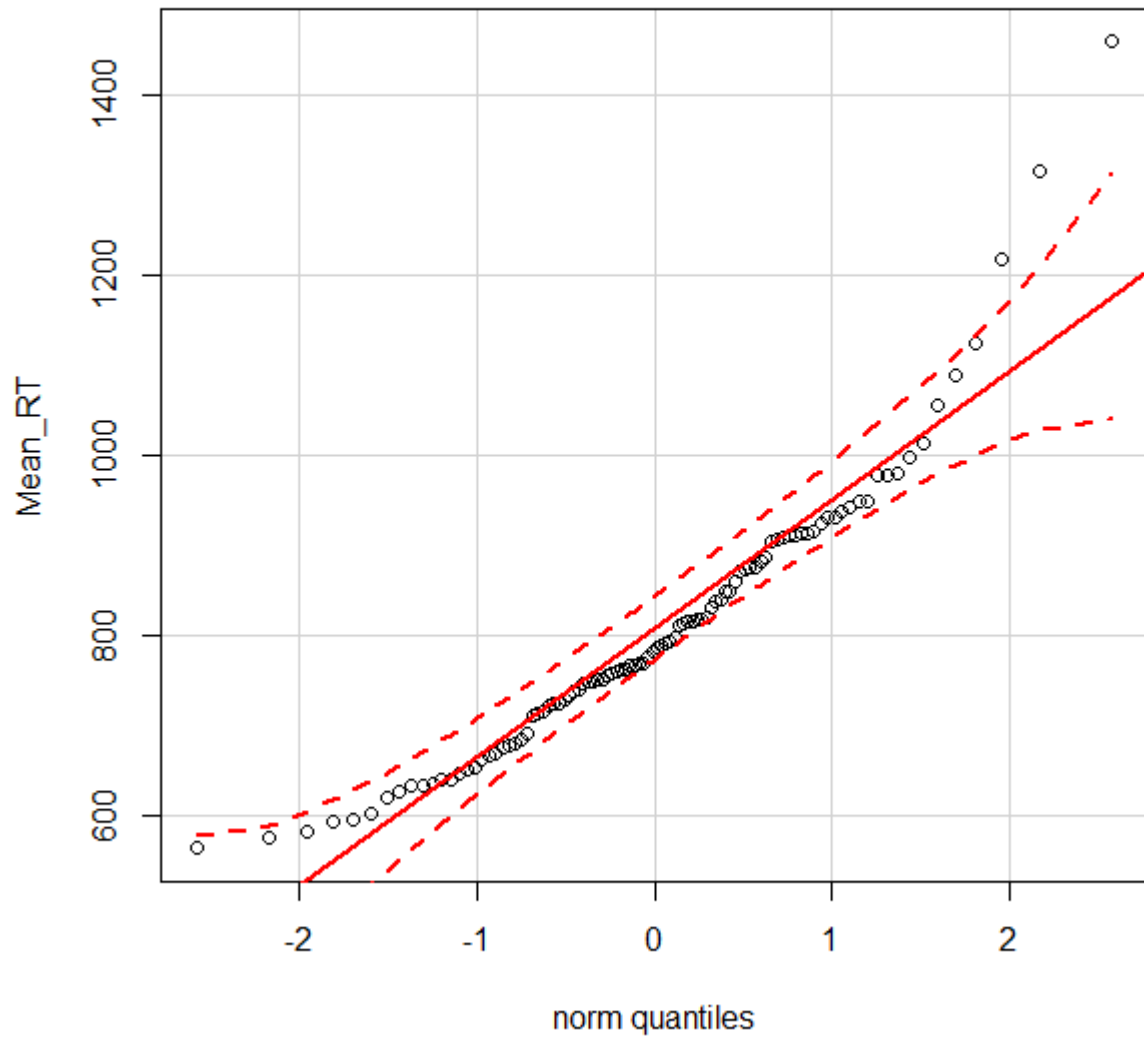


Another convenient function

```
> library(car)
```

```
> qqPlot(Mean_RT)
```

The plot displays a 95% confidence ‘envelope’ around the distribution. The points should be inside the envelope. If not, there’s a problem. The plot clearly shows that the three outliers with high scores are problematic.



What to do with outliers?

- If they represent errors, remove them.
- If there are correct, one has several options:
 - Use a test which does not have a normality assumption (e.g. a non-parametric test)
 - Transform the variable (e.g. taking a logarithm)
 - Assign smaller values, e.g. based on the number of standard deviations from the mean.

Exercise

- Remove the outliers:

```
> Mean_RT_new <- Mean_RT[Mean_RT < 1200]
```

```
> Length(Mean_RT_new)
```

```
[1] 97
```

- Perform diagnostics: does the new sample look more normally distributed?