Testing difference of means in R

Let’s see how can we test the null hypothesis of equality of means in R. We can distinguish two cases:

* **paired data** we test for equality of means of two measurements of the same variable in the same sample. In this sample, we can track both measures for the same individual. An example of paired data is taking some measurement (e.g., blood pressure) on a set of individuals before and after tracking a drug.
* **non-paired data** we test for equality of means of two independent samples. An example of non-paired data are the scores on student’s scores on two different school groups.

## Paired data

Let’s simulate a situation of **paired data**: the heart rate on a set of individuals before and after a short run. Before running heart rate is between 50 and 70, and after running is between 60 and 90.

set.seed(1212)  
before <- runif(100, 50, 70)  
after <- runif(100, 60, 90)

We pack the observations in a data frame. The measurement variable is the value of heart rate for each observation, and moment is a variable indicating when the measurement has taken place. Both variables are listed in the same order, as indicated by the id variable.

measure <- c(before, after)  
moment <- c(rep("before", 100), rep("after", 100))  
id <- rep(1:100, 2)  
  
sample <- data.frame(id, measure, moment)  
head(sample) #first observations

## id measure moment  
## 1 1 55.29293 before  
## 2 2 52.17097 before  
## 3 3 69.33852 before  
## 4 4 57.02047 before  
## 5 5 62.68914 before  
## 6 6 50.66329 before

tail(sample) #last observations

## id measure moment  
## 195 95 89.65357 after  
## 196 96 72.26234 after  
## 197 97 71.82468 after  
## 198 98 70.33387 after  
## 199 99 69.88640 after  
## 200 100 64.95407 after

With data structured in this way, we can proceed to perform the test doing:

t.test(sample$measure ~ sample$moment, paired=TRUE)

##   
## Paired t-test  
##   
## data: sample$measure by sample$moment  
## t = 12.816, df = 99, p-value < 2.2e-16  
## alternative hypothesis: true difference in means is not equal to 0  
## 95 percent confidence interval:  
## 11.55838 15.79321  
## sample estimates:  
## mean of the differences   
## 13.6758

The results show that we can discard the mull hypothesis, and conclude with a reasonable level of certainty that heart rate increases after running.

## Non-paired data

Let’s simulate student’s scores in two classes: class 1 and class 2:

set.seed(1313)  
class1 <- runif(80, 4, 6)  
class2 <- runif(60, 3, 9)  
  
print(class1, digits=2)

## [1] 5.8 4.8 5.4 5.0 5.3 5.3 4.5 4.2 5.1 4.7 4.7 4.2 4.8 5.9 5.4 5.8 5.9  
## [18] 4.9 5.7 4.2 4.7 4.5 5.6 5.9 4.6 5.9 4.6 5.9 5.0 6.0 4.8 4.3 5.8 4.5  
## [35] 4.4 4.7 4.8 5.4 5.7 5.5 5.7 4.9 4.5 5.5 4.9 5.0 5.5 5.9 4.7 5.1 5.0  
## [52] 5.1 4.8 4.6 5.9 5.6 4.6 4.5 4.3 4.6 5.2 5.7 4.4 4.1 4.5 4.5 4.5 5.6  
## [69] 4.0 5.2 4.6 4.6 5.3 4.6 5.4 4.9 5.7 4.0 4.1 5.1

print(class2, digits=2)

## [1] 4.2 3.5 3.4 4.3 7.0 6.5 8.8 8.5 7.7 7.6 4.6 6.9 4.3 3.6 6.5 7.1 3.6  
## [18] 8.5 7.7 3.3 3.5 7.4 4.3 3.7 8.0 3.8 7.3 3.9 7.3 3.9 4.2 7.0 3.0 5.5  
## [35] 3.7 3.9 6.4 3.8 4.5 7.2 3.9 7.3 7.6 5.2 4.9 8.2 3.1 3.2 5.8 8.9 5.4  
## [52] 7.7 7.7 9.0 6.8 5.2 5.6 8.8 4.7 3.0

We want to test the difference of means for **non-paired data**, as students are different in each class. Note that now we have entered both samples independently, and that the paired variable is set to its default value, which is FALSE.

t.test(class1, class2)

##   
## Welch Two Sample t-test  
##   
## data: class1 and class2  
## t = -2.683, df = 66.689, p-value = 0.009191  
## alternative hypothesis: true difference in means is not equal to 0  
## 95 percent confidence interval:  
## -1.1866794 -0.1741909  
## sample estimates:  
## mean of x mean of y   
## 5.012298 5.692733

In this case, we can see that **we can reject the null hypothesis**, as the p-value is inferior to 0.05.

Let’s see now two other classes:

class3 <- runif(90, 4, 7)  
class4 <- runif(70, 4, 7)  
  
print(class3, digits=2)

## [1] 6.4 6.1 4.6 6.5 4.6 4.7 5.2 6.7 6.0 5.7 4.9 5.4 4.4 6.7 6.6 5.5 4.5  
## [18] 4.7 6.6 5.0 5.3 4.4 5.6 4.2 5.4 6.1 5.1 5.9 7.0 6.4 4.6 5.7 6.2 6.6  
## [35] 6.0 6.9 5.0 4.8 5.5 5.7 5.0 4.2 5.1 6.8 6.6 5.0 5.4 4.6 5.7 4.8 6.6  
## [52] 5.6 6.6 5.1 4.7 6.2 6.0 5.5 6.3 4.8 4.4 6.3 5.6 5.6 6.8 5.4 5.9 6.3  
## [69] 5.0 5.2 4.5 4.7 6.5 6.2 4.9 4.9 5.6 6.0 5.2 6.6 4.3 5.4 5.3 5.8 6.3  
## [86] 5.7 5.2 6.1 5.8 5.2

print(class4, digits=2)

## [1] 6.1 4.8 5.0 5.7 6.6 4.4 4.7 4.2 6.5 5.0 5.6 5.0 5.4 4.0 5.2 5.9 6.3  
## [18] 7.0 4.4 7.0 4.4 5.8 6.8 4.9 4.9 4.3 5.0 5.7 4.1 5.3 6.8 4.4 4.4 5.0  
## [35] 5.3 4.4 4.7 6.7 6.3 6.1 4.7 5.9 7.0 6.6 4.3 4.8 4.0 6.8 5.9 4.4 5.7  
## [52] 5.5 5.5 6.3 6.6 4.3 4.6 4.9 4.7 6.8 5.7 4.8 6.4 4.5 6.0 5.9 5.3 5.3  
## [69] 6.3 6.1

We can procded now to make the hypothesis testing:

t.test(class3, class4)

##   
## Welch Two Sample t-test  
##   
## data: class3 and class4  
## t = 1.0455, df = 135.57, p-value = 0.2977  
## alternative hypothesis: true difference in means is not equal to 0  
## 95 percent confidence interval:  
## -0.1227791 0.3982092  
## sample estimates:  
## mean of x mean of y   
## 5.564304 5.426588

In this case, as the p-value is above 0.05, **we cannot discard the null hypothesis** of equality of means. In this particular case, as we have performed a simulation, we know that poblational means for class3 and class4 are equal.