TESTS IN R

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PRELUDE

CONFIDENCE INTERVALS

- it is an interval estimate;
- we construct an interval following a procedure that, if applied in a large number of replications of the experiment, gives intervals which contain the true value $1 - \alpha$ of the time;
- $1 - \alpha$ is called confidence level;
- usual values are 0.90, 0.95 and 0.99.

EXAMPLES OF CONFIDENCE INTERVALS

- true mean, gaussian distribution, known variance:

```
x <- rnorm(100,mean=1,sd=2)
mean.x <- mean(x)
low <- mean.x - qnorm(0.975)*2/sqrt(100)
up <- mean.x + qnorm(0.975)*2/sqrt(100)
c(low,up)
```

```
[1] 0.9227046 1.7066902
```

- true mean, gaussian distribution, unknown variance:

```
sd.x <- sd(x)
low <- mean.x - qt(0.975, df=99)*sd.x/sqrt(100)
up <- mean.x + qt(0.975, df=99)*sd.x/sqrt(100)
c(low,up)
```

```
[1] 0.8881171 1.7412777
```

EXCERCISE 4 TASK 3

STUDENT'S ONE-SAMPLE TEST

- $H_0 : \mu = \mu_0$
- $H_1 : \mu \neq \mu_0$

t.test(x, mu=μ_0, alternative='two-sided')

t.test(x, mu=μ_0, alternative='greater')

t.test(x, mu=μ_0, alternative='less')

- default alternative is 'two-sided'

```
x <- rnorm(100, mean=3, sd=1)
t.test(x, mu=1)
```

```
    One Sample t-test

data:  x
t = 19.63, df = 99, p-value < 2.2e-16
alternative hypothesis: true mean is not equal to 1
95 percent confidence interval:
 2.841634 3.255800
```

```
sample estimates:
mean of x
 3.048717
```

FURTHER EXAMPLES

Further examples: greater, less

```r
t.test(x, mu=1, alternative="greater")
```

```
    One Sample t-test

data:  x
t = 19.63, df = 99, p-value < 2.2e-16
alternative hypothesis: true mean is greater than 1
95 percent confidence interval:
 2.87543     Inf
sample estimates:
mean of x
 3.048717
```

```r
t.test(x, mu=1, alternative="less")
```

```
    One Sample t-test

data:  x
t = 19.63, df = 99, p-value = 1
alternative hypothesis: true mean is less than 1
95 percent confidence interval:
     -Inf 3.222003
sample estimates:
mean of x
 3.048717
```

TWO-SAMPLE T-TEST (UNEQUAL VARIANCE)

- $Var[X] \neq Var[Y]$
- $H_0 : \mu_X = \mu_Y$

```
t.test(x, y, alternative=c('two.sided', 'less','greater'))
```

Example:

```
x <- rnorm(100, mean=4, sd=5)
y <- rnorm(100, mean=2, sd=2)
t.test(x, y)
```

```
	Welch Two Sample t-test

data:  x and y
t = 4.493, df = 129.9, p-value = 1.536e-05
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 1.237719 3.185308
sample estimates:
mean of x mean of y
 4.379350  2.167836
```

TWO-SAMPLE T-TEST (EQUAL VARIANCE)

- $Var[X] = Var[Y]$
- $H_0 : \mu_X = \mu_Y$

```
t.test(x, y, var.equal=T,alternative=c('two.sided', 'less',
'greater'))
```

Example:

```r
x <- rnorm(100, mean=4, sd=1)
y <- rnorm(100, mean=2, sd=1)
t.test(x, y, var.equal=T)
```

```
	Two Sample t-test

data:  x and y
t = 15.037, df = 198, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 1.752869 2.282017
sample estimates:
mean of x mean of y
 4.082856  2.065413
```

F-TEST FOR COMPARING VARIANCES

- $H_0 : \sigma_X^2 = \sigma_Y^2$
- $H_1 : \sigma_X^2 \neq \sigma_Y^2$

```
var.test(x, y, ratio = 1,alternative=c('two.sided', 'less',
'greater'),conf.level = 0.95)
```

Example:

```r
x <- rnorm(80, mean=4, sd=5)
y <- rnorm(20, mean=2, sd=2)
var.test(x, y)
```

```
    F test to compare two variances

data:  x and y
F = 5.7545, num df = 79, denom df = 19, p-value = 8.826e-05
alternative hypothesis: true ratio of variances is not equal to 1
95 percent confidence interval:
  2.571244 10.968061
sample estimates:
ratio of variances
```

5.754537

PROPORTION TEST 1

- $H_0 : p = p_0$
- $H_1 : p \neq p_0$

```
prop.test(x, n, p)
```

- x: number of successes
- n: total number of trials
- p: proportion to be tested.
- Example:

```
# Load preprocessed version of the data saved as .RData file
load(file="myNhanes.RData")
prop.test(sum(mydata$male), length(mydata$male), p=0.5)
```

```

	1-sample proportions test with continuity correction

data:  sum(mydata$male) out of length(mydata$male), null probability 0.5
```

```
X-squared = 0.2738, df = 1, p-value = 0.6008
alternative hypothesis: true p is not equal to 0.5
95 percent confidence interval:
 0.4898438 0.5177503
sample estimates:
     p
0.5038
```

PROPORTION TEST 2

- $H_0 : p_1 = p_2$
- $H_1 : p_1 \neq p_2$

```
prop.test(table(x, y))
```

- x: first (categorical) variable
- y second (binary) variable
- Example:

```r
# prop.test(table(educ, male))
tbl <- table(mydata$educ, mydata$male)
prop.test(tbl)
```

```
    5-sample test for equality of proportions without continuity correction

data:  tbl
X-squared = 13.481, df = 4, p-value = 0.00915
alternative hypothesis: two.sided
sample estimates:
```

```
   prop 1    prop 2    prop 3    prop 4    prop 5 
0.5218295 0.5082707 0.5292929 0.4605078 0.4881356 
```

QUICK SUMMARY

```
t.test(height[male==T],height[male==F])

var.test(height[male==T],height[male==F])
```

- and a Z-test, testing the equality of proportions:

```
table(male,heartdis_ever,dnn=c("Male","Heart disease"))
prop.table(table(male,!heartdis_ever,dnn=c("Male","Heart disease")),1)
prop.test(table(male,!heartdis_ever))
```

CHI-SQUARE TEST

- $H_0 : \pi_1 = \pi_2 = \pi$

```r
chisq.test(x, y = NULL, correct = TRUE, p =rep(1/length(x), length(x)), rescale.p = FALSE,
           simulate.p.value = FALSE, B = 2000)
```

- you can pass to the function:
  - a contingency table;
  - directly two categorical vectors.

Examples:

```r
x <- c("M","F","M","F","M","M","F","F","M")
y <- c("Y","N","N","N","Y","Y","N","Y","N")
chisq.test(x,y)
```

```
	Pearson's Chi-squared test with Yates' continuity correction

data:  x and y
X-squared = 0.14062, df = 1, p-value = 0.7077
```

or, with a contingency table,

```r
tab <- table(x,y)
chisq.test(tab)
```

```
	Pearson's Chi-squared test with Yates' continuity correction

data:  tab
X-squared = 0.14062, df = 1, p-value = 0.7077
```

FISHER TEST

- exact test

```
fisher.test(x, y = NULL, workspace = 200000,
    hybrid = FALSE, control = list(), or = 1,
    alternative = "two.sided", conf.int = TRUE,
    conf.level = 0.95, simulate.p.value = FALSE, B =
    2000)
```

- you can pass to the function two factor vectors

Examples:

```
fisher.test(x,y)
```

```
	Fisher's Exact Test for Count Data

data:  x and y
p-value = 0.5238
alternative hypothesis: true odds ratio is not equal to 1
95 percent confidence interval:
   0.1497998 312.5621395
sample estimates:
odds ratio
```

```
  3.764195
```

. . . or a contingency table

```
tab <- table(x,y)
fisher.test(tab)
```

```

	Fisher's Exact Test for Count Data

data:  tab
p-value = 0.5238
alternative hypothesis: true odds ratio is not equal to 1
95 percent confidence interval:
   0.1497998 312.5621395
sample estimates:
odds ratio
  3.764195
```

MCNEMAR TEST

- symmetry of rows and columns;

```
mcnemar.test(x, y = NULL, correct = TRUE)
```

- you can pass to the function two factor vectors

Examples:

```
mcnemar.test(x,y)
```

```
	McNemar's Chi-squared test with continuity correction

data:  x and y
McNemar's chi-squared = 0, df = 1, p-value = 1
```

. . . or a contingency table

```
tab <- table(x,y)
mcnemar.test(tab)
```

```
	McNemar's Chi-squared test with continuity correction

data:  tab
```

EXCERCISE 4 TASK 4

NON-PARAMETRIC TESTS

SIGN TEST

- $H_0 : median = md_0$
- we need the package BSDA

```r
SIGN.test(x, y = NULL, md = 0, alternative = "two.sided", conf.level = 0.95)
```

Example:

```r
library(BSDA)
x <- rpois(100,5)
SIGN.test(x, md=5)
```

```
    One-sample Sign-Test

data:  x
s = 39, p-value = 0.3374
alternative hypothesis: true median is not equal to 5
95 percent confidence interval:
 4 5
sample estimates:
median of x
          5

Achieved and Interpolated Confidence Intervals:
```

```
                  Conf.Level L.E.pt U.E.pt
Lower Achieved CI     0.9431      4      5
```

WILCOXON TEST

- $H_0 : median = md_0$
- test based on ranks

```
wilcox.test(x, y = NULL, alternative = c("two.sided", "less", "greater"), mu = 0,
            paired = FALSE, exact = NULL, correct = TRUE, conf.int = FALSE,
            conf.level = 0.95, ...)
```

Example:

```
x <- rpois(100,5)
wilcox.test(x,mu=5)
```

```
	Wilcoxon signed rank test with continuity correction

data:  x
V = 1551.5, p-value = 0.7999
alternative hypothesis: true location is not equal to 5
```

RECALL: SIGN TEST VS. WILCOXON TEST VS. T-TEST PART 1

Sign test:

- Applicable for ordinal or higher scale level
- No distributional assumptions
- Low power

Wilcoxon test:

- Applicable for discrete or continuous quantitative data
- Symmetrical distribution required
- Intermediate power

T-test:

- Normal distribution required
- Highest power

COMPARE ALL TESTS ON THE SAME DATA (WE ASSUME NORMAL DISTRIBUTED DATA!)

```r
set.seed(123)
x <- rnorm(20,0.5)
c(
  signTest = BSDA::SIGN.test(x, md = 0)$p.value,
  wilcoxonTest =wilcox.test(x,mu=0)$p.value,
  tTest = t.test(x, mu = 0)$p.value
)
```

```
  signTest wilcoxonTest        tTest 
0.04138947   0.01068878   0.00822065 
```

MANN-WHITNEY U TEST

- $H_0 : median_1 = median_2$
- non-parametric test for independent samples
- package coin (Why extra package and not using `wilcox.test`? -> https://stats.stackexchange.com/questions/31417/what-is-the-difference-between-wilcox-test-and-coinwilcox-test-in-r)

```
wilcox_test(formula, data, subset = NULL, weights= NULL, ...)
```

- needs a formula, e.g. y~x.

Example hdl in NHANES data (not normal):

```
hist(mydata$hdl[mydata$male == T], breaks = 40, col = "steelblue", freq = F, ylim=c(0,1.5))
hist(mydata$hdl[mydata$male == F], breaks = 40, col = "coral", add = T, freq = F)
```

```
coin::wilcox_test(hdl ~ as.factor(male), data = mydata)
```

```
	Asymptotic Wilcoxon-Mann-Whitney Test
```

```
data:  hdl by as.factor(male) (FALSE, TRUE)
Z = -21.838, p-value < 2.2e-16
alternative hypothesis: true mu is not equal to 0
```

```r
wilcox.test(hdl ~ as.factor(male), data = mydata)
```

```
	Wilcoxon rank sum test with continuity correction

data:  hdl by as.factor(male)
W = 1520720, p-value < 2.2e-16
alternative hypothesis: true location shift is not equal to 0
```

CORRELATION

```r
cor(X,Y)

cor(x, y = NULL, use = "everything", method =c("pearson", "kendall", "spearman"))
```

- correlation between x and y
- with incomplete observations, we may want to set use =“complete.obs”
- based on the argument method, the function cor() computes
  - Pearson’s r (default)
  - Kendall’s τ (rank based)
  - Spearman’s ρ (rank based)

Example:

```r
x<-rnorm(10)
y<-rnorm(10)
cor(x,y)
```

CORRELATION TEST

- test for correlation between paired samples

```
cor.test(x, y, alternative = c("two.sided","less", "greater"), method = c("pearson","kendall", "spe
```

- H_1 is defined through the argument alternative
- the argument `method` sets the correlation coefficient

Example:

```
cor.test(x,y)
```

```
    Pearson's product-moment correlation

data:  x and y
t = -1.3752, df = 8, p-value = 0.2063
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.8365717  0.2654408
sample estimates:
       cor
-0.4372649
```

EXCERCISE 4 TASK 5