

# Collaborative 3DUI Data Analysis

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## Data analysis

This is a on going analysis of the data collected in the user experiment performed...

## Comparisons between groups

### Hypothesis

- Groups with more than one member perform the tasks with less errors.
- Groups with two and three members perform the tasks with less errors than with one and four.
- Groups with more than one member perform the tasks faster.
- Groups with two and three members perform the tasks faster than with one and four.
- Task one and two are easier than three and four.

## Data Summary

```
errorXGroups <- read.csv("ErrorXGroups.csv",header = FALSE)
errorXGroups
```

##	V1	V2	V3	V4
## 1	4.280380	1.923633	0.867342	1.554914
## 2	16.953010	11.753480	3.243309	3.538198
## 3	9.070060	3.251326	2.972291	2.389965
## 4	8.529819	3.595758	3.701374	2.110792
## 5	3.869670	3.004579	2.359320	1.402203
## 6	6.642847	4.069859	4.060901	4.501410
## 7	7.381541	4.849439	3.978512	3.337539
## 8	5.705525	4.512303	3.053629	2.288988
## 9	1.317529	2.192855	2.259253	3.145458
## 10	9.220284	5.547572	3.317118	6.065219
## 11	6.207668	6.037892	4.150805	3.023767
## 12	5.088869	4.339551	4.628316	3.257560
## 13	4.024921	2.576868	1.300738	1.623129
## 14	8.576299	8.645294	3.357939	2.768127
## 15	3.341505	4.726371	3.179116	1.776181
## 16	3.299659	3.707839	4.247869	1.903549
## 17	4.456124	4.601643	2.329338	NA
## 18	9.002918	8.891509	4.309965	NA
## 19	6.817599	4.380987	2.652203	NA
## 20	8.455383	5.540681	2.953497	NA
## 21	NA	1.390942	2.187007	NA
## 22	NA	4.142436	8.903512	NA
## 23	NA	4.699787	4.778647	NA

```
## 24      NA  4.160006 4.583976      NA
```

```
timeXGroups <- read.csv("TimeXGroups.csv", header = FALSE)
timeXGroups
```

```
##      V1      V2      V3      V4
## 1  44.6010 19.92100 58.66863 47.19800
## 2  27.7300 23.75830 16.39880 21.40800
## 3  44.5060 86.01300 127.23090 162.96200
## 4  56.6990 90.59442 82.56380 87.06737
## 5  86.2698 13.64980 29.00930 22.00295
## 6  26.6007 15.95330 49.16030 16.25100
## 7 129.5357 87.26190 120.67140 74.45340
## 8  88.6565 113.11968 91.11170 71.80547
## 9  37.2235 16.45030 36.21300 21.09751
## 10 32.5000 14.49990 22.41350 16.95763
## 11 130.7602 69.36490 76.82150 56.40480
## 12 63.4430 58.41970 55.29020 63.90760
## 13 71.4288 17.20950 21.44110 54.20073
## 14 55.8885 29.62760 17.18680 37.12230
## 15 281.5956 139.37750 86.81320 127.17520
## 16 225.2061 111.04040 61.24430 60.76750
## 17 32.6565 59.33450 20.20286      NA
## 18 41.4964 16.48410 25.70100      NA
## 19 105.6555 109.53340 283.41380      NA
## 20 139.6341 83.16500 192.72400      NA
## 21      NA 35.49839 24.40880      NA
## 22      NA 34.55538 42.26010      NA
## 23      NA 99.48090 41.29660      NA
## 24      NA 93.11320 38.11630      NA
```

Below the data is summarized:

```
describe(errorXGroups)
```

```
##      vars  n mean   sd median trimmed  mad  min   max range skew kurtosis
## V1      1 20 6.61 3.36   6.43   6.34 3.18 1.32 16.95 15.64 1.17    2.02
## V2      2 24 4.69 2.32   4.36   4.43 1.39 1.39 11.75 10.36 1.33    1.73
## V3      3 24 3.47 1.55   3.28   3.38 1.33 0.87  8.90  8.04 1.48    3.97
## V4      4 16 2.79 1.22   2.58   2.66 1.07 1.40  6.07  4.66 1.11    0.74
##      se
## V1 0.75
## V2 0.47
## V3 0.32
## V4 0.31
```

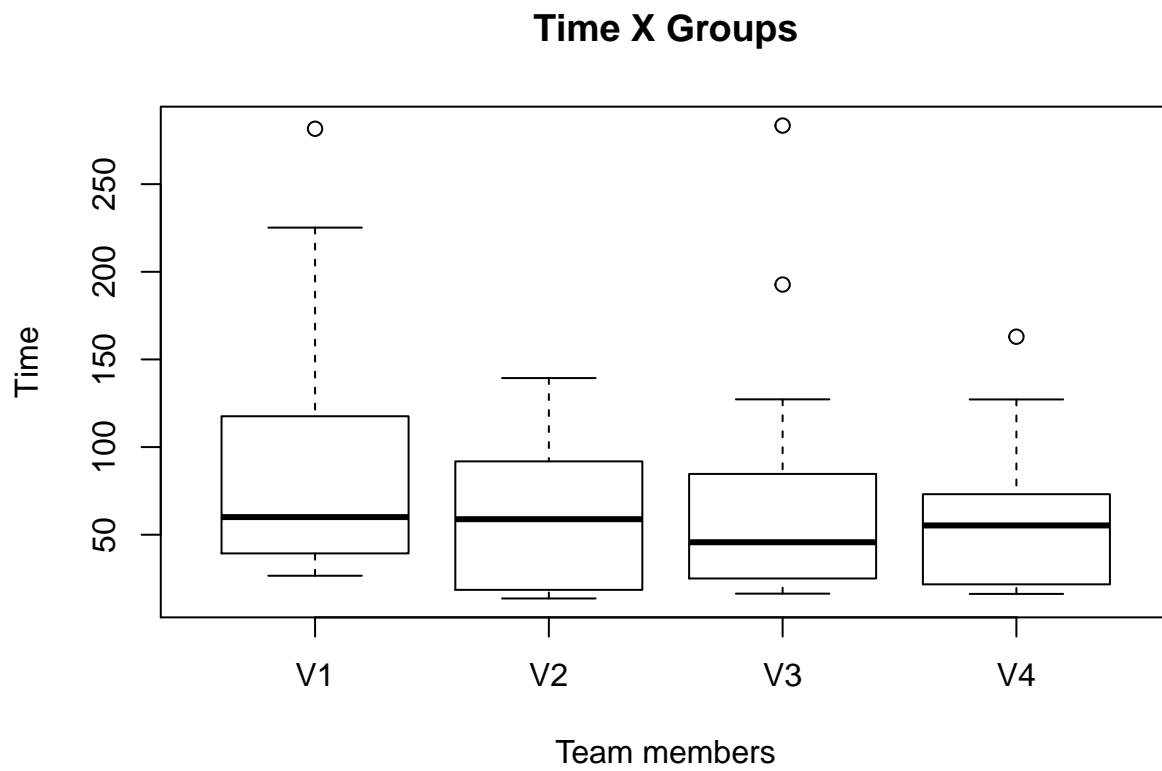
```
describe(timeXGroups)
```

```
##      vars  n mean   sd median trimmed  mad  min   max range skew
## V1      1 20 86.10 67.95  60.07   72.56 40.76 26.60 281.60 254.99 1.49
## V2      2 24 59.89 39.94  58.88   57.84 54.91 13.65 139.38 125.73 0.26
## V3      3 24 67.52 62.67  45.71   55.53 35.26 16.40 283.41 267.01 1.96
## V4      4 16 58.80 40.93  55.30   54.40 37.74 16.25 162.96 146.71 1.06
##      kurtosis      se
## V1      1.48 15.19
## V2     -1.43  8.15
## V3      3.69 12.79
```

```
## V4      0.40 10.23
```

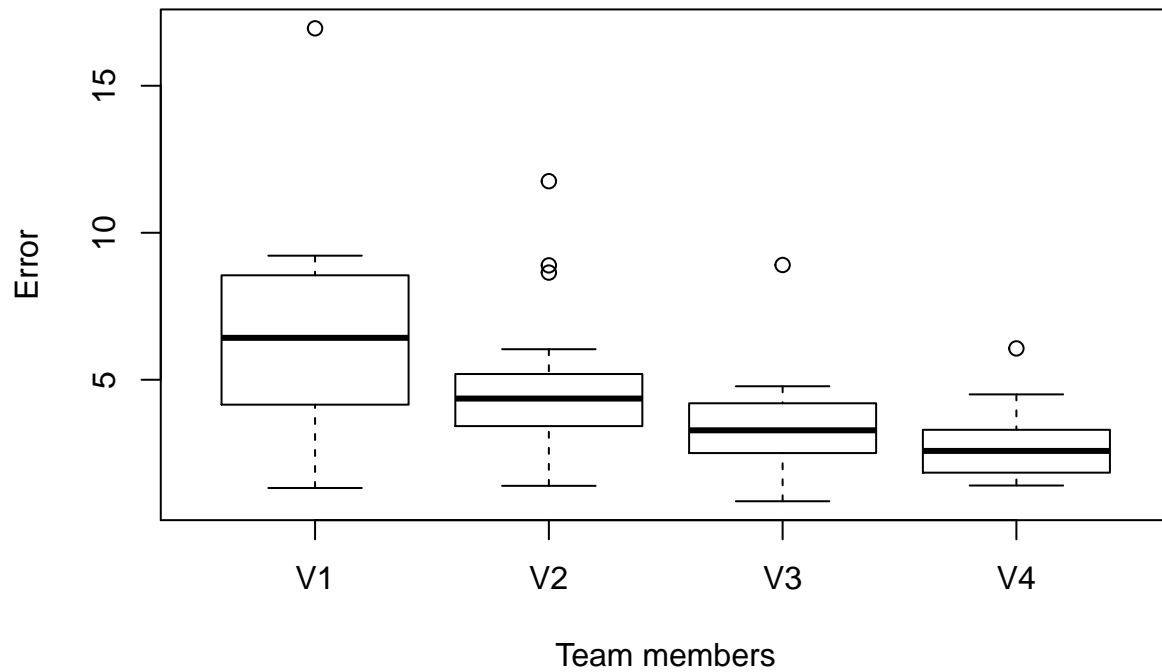
And plotted:

```
boxplot(timeXGroups,xlab="Team members",ylab="Time",main="Time X Groups")
```



```
boxplot(errorXGroups,xlab="Team members",ylab="Error",main="Error X Groups")
```

## Error X Groups



## Correlation Analysis

The Pearson product-moment correlation coefficient is a measure of the linear correlation between two variables X and Y, giving a value between +1 and -1 inclusive, where 1 is total positive correlation, 0 is no correlation, and -1 is total negative correlation. It is widely used in the sciences as a measure of the degree of linear dependence between two variables.

Correlacao Qtd de Pessoas – Tempo Medio	
Pearson	
	Colunas 1 e 10
n (pares) =	23
r (Pearson) =	-0,3321
IC 95% =	-0,65 a 0,09
IC 99% =	-0,73 a 0,23
R2 =	0,1103
t =	-1,6137
GL =	21
(p) =	0,1214
Poder 0.05 =	0,4598
Poder 0.01 =	0,2168

Correlacao Qtd de Pessoas – Erro Medio	
Pearson	
	Colunas 1 e 11
n (pares) =	23
r (Pearson) =	-0,7719
IC 95% =	-0,90 a -0,53
IC 99% =	-0,92 a -0,42
R2 =	0,5959
t =	-5,5649
GL =	21
(p) =	< 0.0001
Poder 0.05 =	0,9984
Poder 0.01 =	0,9880

#### Kruskal-Wallis

A collection of data samples are independent if they come from unrelated populations and the samples do not affect each other. Using the Kruskal-Wallis Test, we can decide whether the population distributions are identical without assuming them to follow the normal distribution.

### Erro por Qnt de Pessoas

Kruskal-Wallis				
H =	25.9856			
Graus de liberdade =	3			
(p) Kruskal-Wallis =	< 0.0001			
R 1 =	1227			
R 2 =	1157			
R 3 =	808			
R 4 =	378			
R 1 (posto médio) =	61.35			
R 2 (posto médio) =	48.2083			
R 3 (posto médio) =	33.6667			
R 4 (posto médio) =	23.625			
Comparações (método)	Dif. Postos	z calculado	z crítico	p
Postos médios 1 e 2	13.1417	1.7795	2.635	ns
Postos médios 1 e 3	27.6833	3.7485	2.635	< 0.05
Postos médios 1 e 4	37.725	4.611	2.635	< 0.05
Postos médios 2 e 3	14.5417	2.0651	2.635	ns
Postos médios 2 e 4	24.5833	3.1226	2.635	< 0.05
Postos médios 3 e 4	10.0417	1.2755	2.635	ns

Análise de Erro em cada checkpoint por Qtd de Pessoas				
Shapiro				
Kruskal-Wallis				
	Resultados			
H =	90,0959			
Graus de liberdade =	3			
(p) Kruskal-Wallis =	< 0.0001			
R 1 =	27466,0000			
R 2 =	27680,0000			
R 3 =	23579,0000			
R 4 =	8846,0000			
R 1 (posto médio) =	289,1158			
R 2 (posto médio) =	225,0407			
R 3 (posto médio) =	188,6320			
R 4 (posto médio) =	117,9467			
Dunn (posHoc)				
Comparações (método de	Dif. Postos	z calculado	z crítico	p
Postos médios E1 e E2	64,0751	3,8830	2635	< 0.05
Postos médios E1 e E3	100,4838	6,1108	2635	< 0.05
Postos médios E1 e E4	171,1691	9,1725	2635	< 0.05
Postos médios E2 e E3	36,4087	2,3729	2635	ns
Postos médios E2 e E4	107,0940	6,0508	2635	< 0.05
Postos médios E3 e E4	70,6853	4,0059	2635	< 0.05

Comparações Student-Newman-Keuls	Dif. Postos	p-valor
Grupos ( 1 e 2) =	13.1417	0.0752
Grupos ( 1 e 3) =	27.6833	0.0002
Grupos ( 1 e 4) =	37.725	< 0.0001
Grupos ( 2 e 3) =	14.5417	0.0389
Grupos ( 2 e 4) =	24.5833	0.0018
Grupos ( 3 e 4) =	10.0417	0.2021

## Comparisons between tasks

### Hypotesis

- Task 1 and 2 are easier than 3 and 4;
- Task 4 is performed better than task 3

### Summary

First we set the environment, load and show the raw data.



```
setwd("/home/jeronimo/Documents/DataAnalysis3DController/Analysis/R")
dAvgPerTask <- read.csv("SummaryToR.csv")
dAvgPerTask
```

##	Members	T1	T2	T3	T4	E1	E2
## 1	1	44.60100	27.73000	44.5060	56.69900	4.280380	16.953010
## 2	1	86.26980	26.60070	129.5357	88.65650	3.869670	6.642847
## 3	1	37.22350	32.50000	130.7602	63.44300	1.317529	9.220284
## 4	1	71.42880	55.88850	281.5956	225.20610	4.024921	8.576299
## 5	1	32.65650	41.49640	105.6555	139.63410	4.456124	9.002918
## 6	2	19.92100	23.75830	86.0130	90.59442	1.923633	11.753480
## 7	2	13.64980	15.95330	87.2619	113.11968	3.004579	4.069859
## 8	2	16.45030	14.49990	69.3649	58.41970	2.192855	5.547572
## 9	2	17.20950	29.62760	139.3775	111.04040	2.576868	8.645294
## 10	2	59.33450	16.48410	109.5334	83.16500	4.601643	8.891509
## 11	2	35.49839	34.55538	99.4809	93.11320	1.390942	4.142436
## 12	3	58.66863	16.39880	127.2309	82.56380	0.867342	3.243309
## 13	3	29.00930	49.16030	120.6714	91.11170	2.359320	4.060901
## 14	3	36.21300	22.41350	76.8215	55.29020	2.259253	3.317118
## 15	3	21.44110	17.18680	86.8132	61.24430	1.300738	3.357939
## 16	3	20.20286	25.70100	283.4138	192.72400	2.329338	4.309965
## 17	3	24.40880	42.26010	41.2966	38.11630	2.187007	8.903512
## 18	4	47.19800	21.40800	162.9620	87.06737	1.554914	3.538198
## 19	4	22.00295	16.25100	74.4534	71.80547	1.402203	4.501410
## 20	4	21.09751	16.95763	56.4048	63.90760	3.145458	6.065219
## 21	4	54.20073	37.12230	127.1752	60.76750	1.623129	2.768127
##	E3	E4					
## 1	9.070060	8.529819					
## 2	7.381541	5.705525					
## 3	6.207668	5.088869					
## 4	3.341505	3.299659					
## 5	6.817599	8.455383					
## 6	3.251326	3.595758					
## 7	4.849439	4.512303					
## 8	6.037892	4.339551					
## 9	4.726371	3.707839					
## 10	4.380987	5.540681					
## 11	4.699787	4.160006					
## 12	2.972291	3.701374					
## 13	3.978512	3.053629					
## 14	4.150805	4.628316					
## 15	3.179116	4.247869					
## 16	2.652203	2.953497					
## 17	4.778647	4.583976					
## 18	2.389965	2.110792					
## 19	3.337539	2.288988					
## 20	3.023767	3.257560					
## 21	1.776181	1.903549					

The data is arranged by Task vs. Team members. Columns are organized as follows:

- Members: Number of users in the team;
- T1, T2, T3, T4: Time to complete task 1 to 4;

- E1, E2, E3, E4: Errors in task 1 to 4.

We split the data for better manipulation:

```
dAvgTime <- subset(dAvgPerTask, select = c(2,3,4,5))
dAvgError <- subset(dAvgPerTask, select = c(6,7,8,9))
```

Below the data is summarized:

```
describe(dAvgTime)
```

```
##      vars  n   mean    sd median trimmed  mad   min    max  range skew
## T1     1 21  36.60 19.92  32.66   34.17 18.46 13.65  86.27  72.62 0.87
## T2     2 21  27.81 11.90  25.70   26.38 13.13 14.50  55.89  41.39 0.77
## T3     3 21 116.21 63.86 105.66  105.27 37.22 41.30 283.41 242.12 1.46
## T4     4 21  91.79 45.68  83.17   83.31 32.50 38.12 225.21 187.09 1.57
##      kurtosis    se
## T1    -0.25   4.35
## T2    -0.50   2.60
## T3     1.64  13.93
## T4     1.84   9.97
```

```
describe(dAvgError)
```

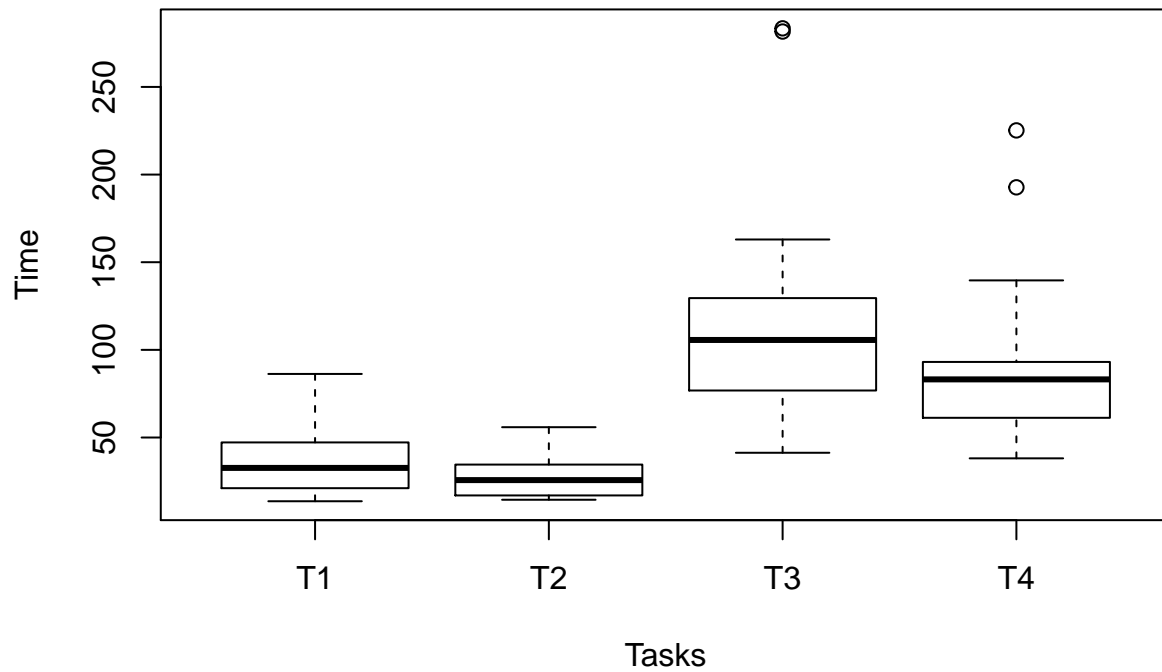
```
##      vars  n mean    sd median trimmed  mad   min    max range skew kurtosis
## E1     1 21  2.51  1.15   2.26   2.44 1.27 0.87   4.60  3.73 0.50   -1.15
## E2     2 21  6.55  3.55   5.55   6.05 3.31 2.77 16.95 14.18 1.17    1.04
## E3     3 21  4.43  1.82   4.15   4.26 1.44 1.78   9.07  7.29 0.83   -0.04
## E4     4 21  4.27  1.74   4.16   4.04 1.34 1.90   8.53  6.63 1.07    0.71
##      se
## E1 0.25
## E2 0.77
## E3 0.40
## E4 0.38
```

## Plots

Time of task completion vs. Task for all combinations of teams: The code used to generate the charts is:

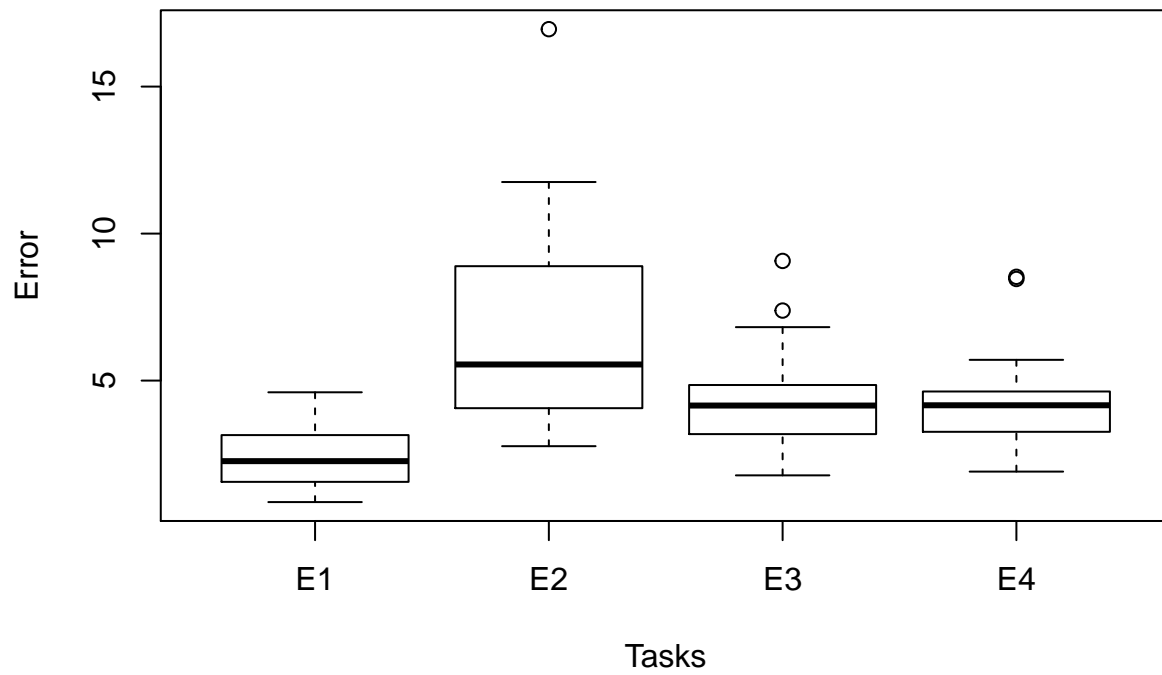
```
boxplot(dAvgTime,xlab="Tasks",ylab="Time",main="Time to complete the tasks")
```

### Time to complete the tasks



```
boxplot(dAvgError,xlab="Tasks",ylab="Error",main="Error perfered in the tasks")
```

### Error perfered in the tasks



## Analysis of time of completion per task

### Shapiro

First, we perform the Shapiro normality test. This test determine if the data is normally distributed. It is important to determine if the data is normally distributed to conduce posterior tests.

```
shap_dT <- lapply(dAvgTime, shapiro.test)
shap_dE <- lapply(dAvgError, shapiro.test)
res_shap_dT <- sapply(shap_dT, `[,`, c("statistic", "p.value"))
res_shap_dE <- sapply(shap_dE, `[,`, c("statistic", "p.value"))
```

```
res_shap_dT
```

##	T1	T2	T3	T4
## statistic	0.8974621	0.9017898	0.812624	0.8037059
## p.value	0.03125427	0.0379083	0.001029792	0.0007478811

```
res_shap_dE
```

##	E1	E2	E3	E4
## statistic	0.9139373	0.8525865	0.9313148	0.8860365
## p.value	0.06570504	0.004708184	0.1462635	0.0189353

As we can see, the  $p$  - *value* of most Shapiro tests reveled that the data are not normally distributed. Since in this test the comparisons are made with the same subjects and we are varying the tasks, the next step is to perform a Friedman analysis.

### Friedman

Friedman test is a non-parametric randomized block analysis of variance. Which is to say it is a non-parametric version of a one way ANOVA with repeated measures. That means that while a simple ANOVA test requires the assumptions of a normal distribution and equal variances (of the residuals), the Friedman test is free from those restriction. The price of this parametric freedom is the loss of power (of Friedman's test compared to the parametric ANOVA versions).

The hypotheses for the comparison across repeated measures are:

- H0: The distributions (whatever they are) are the same across repeated measures
- H1: The distributions across repeated measures are different

The test statistic for the Friedman's test is a Chi-square with [(number of repeated measures)-1] degrees of freedom. A detailed explanation of the method for computing the Friedman test is available on Wikipedia.

Friedman				
	T1	T2	T3	T4
Soma dos R	40,0000	32,0000	84,0000	74,0000
Mediana =	35,4984	25,7010	127,1752	88,6565
Média dos R	1,7391	1,3913	3,6522	3,2174
Média dos v	37,0001	27,8165	131,2051	100,7838
Desvio padr	19,0349	11,3654	67,6085	46,0546
Friedman (F)	50,3739			
Graus de libe	3			
(p) =	< 0.0001			
PostHoc				
Comparação	Diferença	(p)		
Ranks T1 e	8	ns		
Ranks T1 e	44	< 0.05		
Ranks T1 e	34	< 0.05		
Ranks T2 e	52	< 0.05		
Ranks T2 e	42	< 0.05		
Ranks T3 e	10	ns		

Friedman				
	E1	E2	E3	E4
Soma dos Ranks	28,0000	79,0000	62,0000	61,0000
Mediana =	2,2593	5,5476	4,0136	4,0136
Média dos Ranks	1,2174	3,4348	2,6957	2,6522
Média dos valores	2,4973	6,3589	4,3564	4,2113
Desvio padrão	1,1008	3,5407	1,7560	1,6780
Friedman (F)	35,6087			
Graus de liberdade	3			
(p) =	< 0.0001			
PostHoc				
Comparações	Diferença	(p)		
Ranks E1 e E2	51	< 0.05		
Ranks E1 e E3	34	< 0.05		
Ranks E1 e E4	33	< 0.05		
Ranks E2 e E3	17	ns		
Ranks E2 e E4	18	ns		
Ranks E3 e E4	1	ns		

### Analysis of learning between tasks 3 and 4

As the data is not normally distributed and the comparison is between tasks (instead of groups) we performed a Friedman analysis.

### Análise de erro entre tarefas 3 e 4

#### Friedman

Soma dos Ranks =	36	33
Mediana =	4.0136	4.0136
Média dos Ranks =	1.5652	1.4348
Média dos valores =	4.3564	4.2113
Desvio padrão =	1.756	1.678
Friedman (Fr) =	0.3913	
Graus de liberdade =	1	
(p) =	0.5316	

### Análise de tempo entre tarefas 3 e 4

#### Friedman

Soma dos Ranks =	40	29
Mediana =	127.1752	88.6565
Média dos Ranks =	1.7391	1.2609
Média dos valores =	131.2051	100.7838
Desvio padrão =	67.6085	46.0546
Friedman (Fr) =	5.2609	
Graus de liberdade =	1	
(p) =	0.0218	
Comparações:	Diferença	(p)
Ranks 1 e 2 =	11	< 0.05

# Analysis Correlation between Errors and Work division

	Colunas 1 e 2
n (pares) =	76
r (Pearson) =	-0.4877
IC 95% =	-0.64 a -0.29
IC 99% =	-0.68 a -0.23
R2 =	0.2379
t =	-4.8060
GL =	74
(p) =	< 0.0001
Poder 0.05 =	0.9982
Poder 0.01 =	0.9871



### Teste de Regressão Linear

