

# MRI-Together 2021-<https://mritogether.github.io/>

## A White Hat's Guide to p-Hacking

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Imagine, we have two data distributions, one the **controls** and one a distribution that we want to compare to the controls. This could be the quantitative values of a volunteers' group (controls="ctrl"), let's call them **qmr** and the respective values of a different group e.g. patients ("pat") with a certain condition.

Let's assume for now that the distributions are **normal** Gaussian distributions. So let's assume we checked the distributions and that BEFORE starting our analysis, we have a **hypothesis** that in disease presence qmr values are increased. And let's imagine we have estimated that we should measure and we measured under identical and ideal conditions **nr\_s healthy controls** and **nr\_s patients**. We consider these independent measurements.

### Let's agree on some definitions first

$\alpha$ : Significance level.

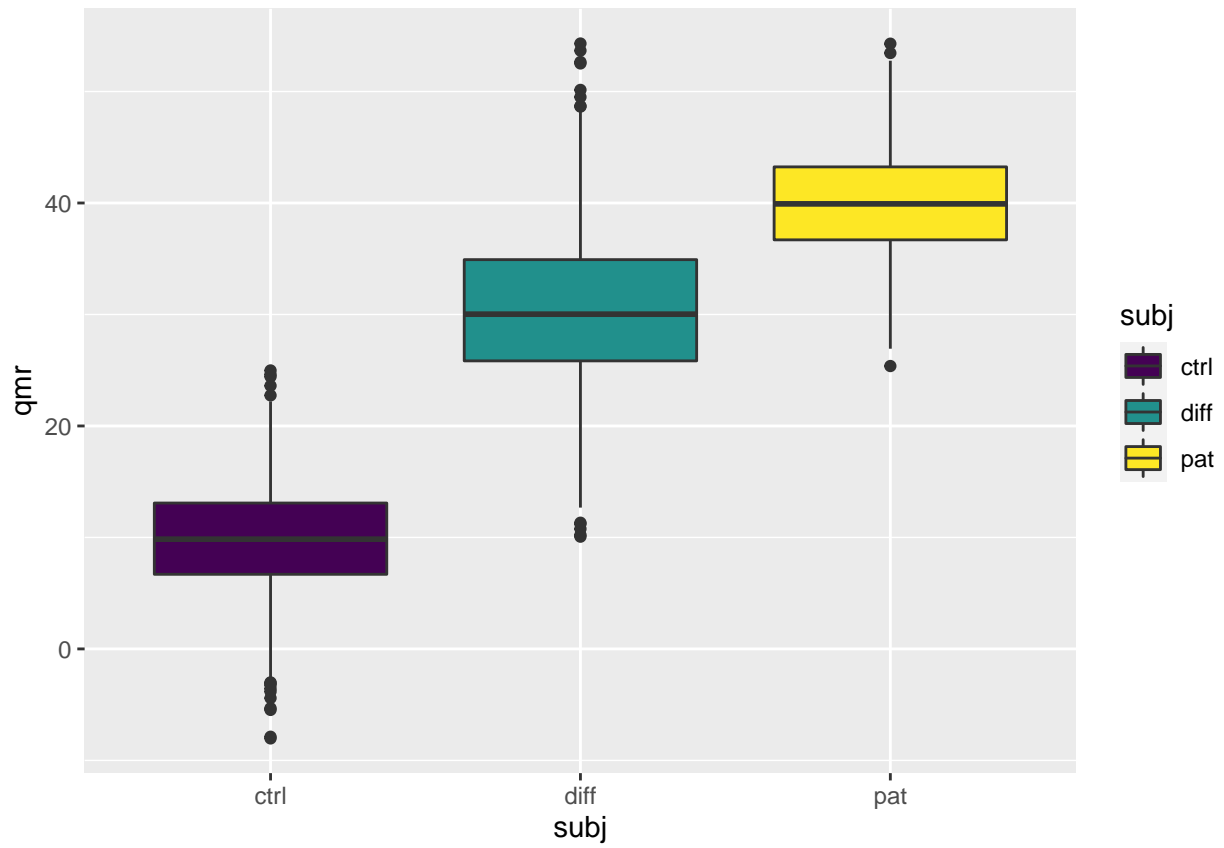
**p-value**: the probability of obtaining the observed difference, or one more extreme, if the null hypothesis is true. A p-value below  $\alpha$  will lead to the null hypothesis being rejected.

### Ready? Let's create some fictional data.

Let's create two perfectly **normal distributions**. One with **mean** 40 and **standard deviation** (sd) 5 and one with mean 10 and standard deviation 2. And let's visualize at their distributions, as well as the distribution of their difference. We start with 1000 samples for each distribution.

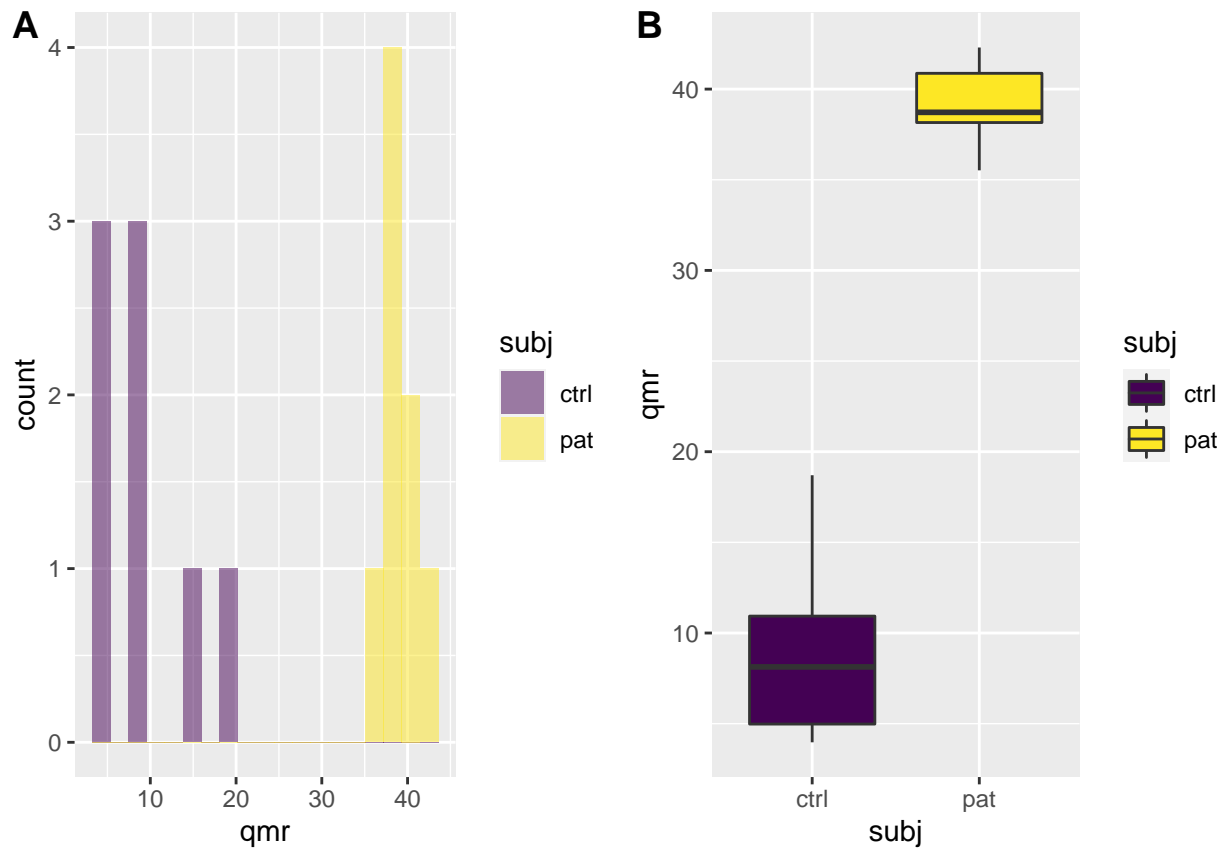


That looks clear. Doesn't it? Let's also look at the boxplot visualization.



So what's next?

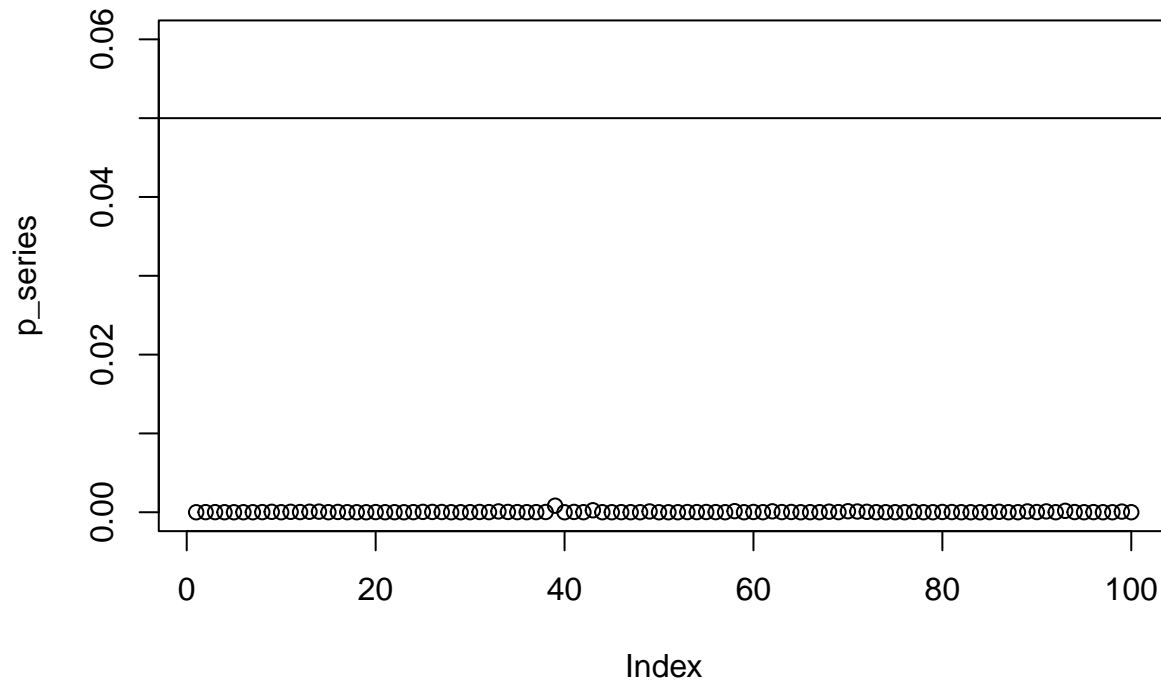
Let's look at one of the subdatasets with 8 samples per distribution



```
## [1] "p-value" "7.63043791725118e-10"
```

##What result would we get from a t-test?

What would we get by testing whether there is a difference in these 2 distributions and if the difference is different than zero. And let's see what would happen if we wouldn't have 1000 samples for each distribution, but less. Try to change the `nr_s` and plot.



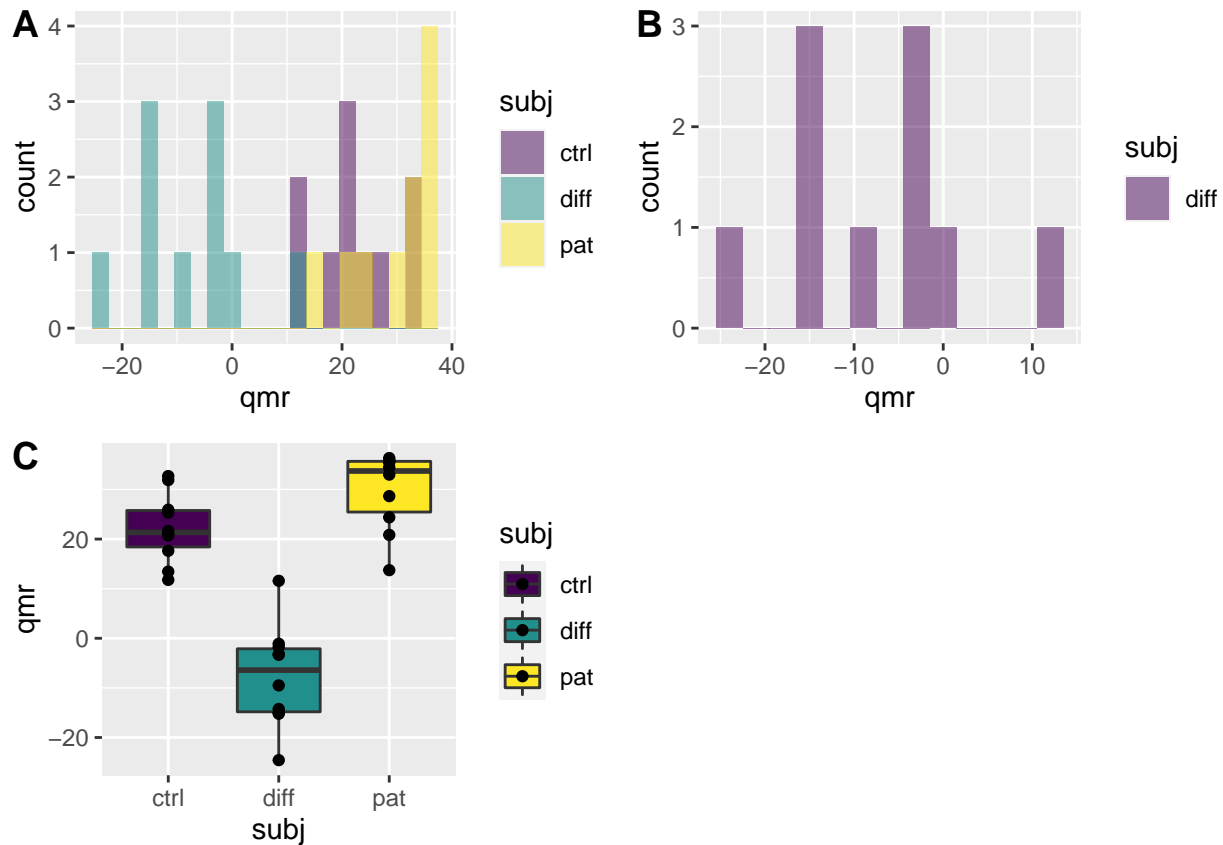
But what if the differences were less clear?

### Trap Nr. 1: Numbers count!

Topic 1: The **number of samples** is important. What if we have 15 samples of some less different data. Let's get them & repeat the steps.

So, let's change distributions, bring the **mean values** closer and increase the **standard deviation**. Keeping the assumptions for t-test, we keep standard deviation the same.

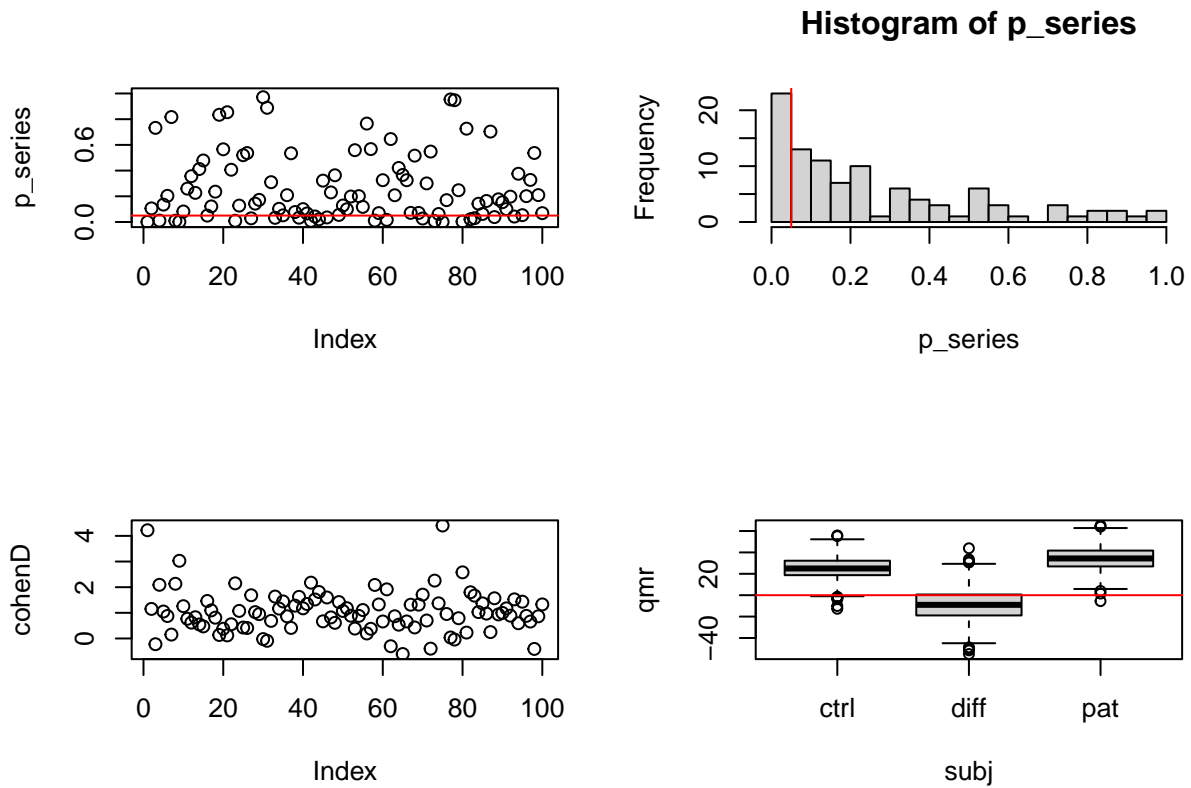
Here, you can try again to change the number of samples (nr\_s) of each distribution and observe the effect: 1) on the distributions, 2) on the t-test performed once. TO DO: Change the nr\_s and observe.



```
## [1] "res.tt" "0.0331340916011829"
```

```
## [1] "estimate cohend" "1.0318599741014"
```

So let's draw different number of samples `nr_s` (from the bigger normal distribution) and let's look at the `p_value`. Let's also look how the test result change, if we draw again `nr_s` new samples! TO DO: change the `nr_s` and observe.



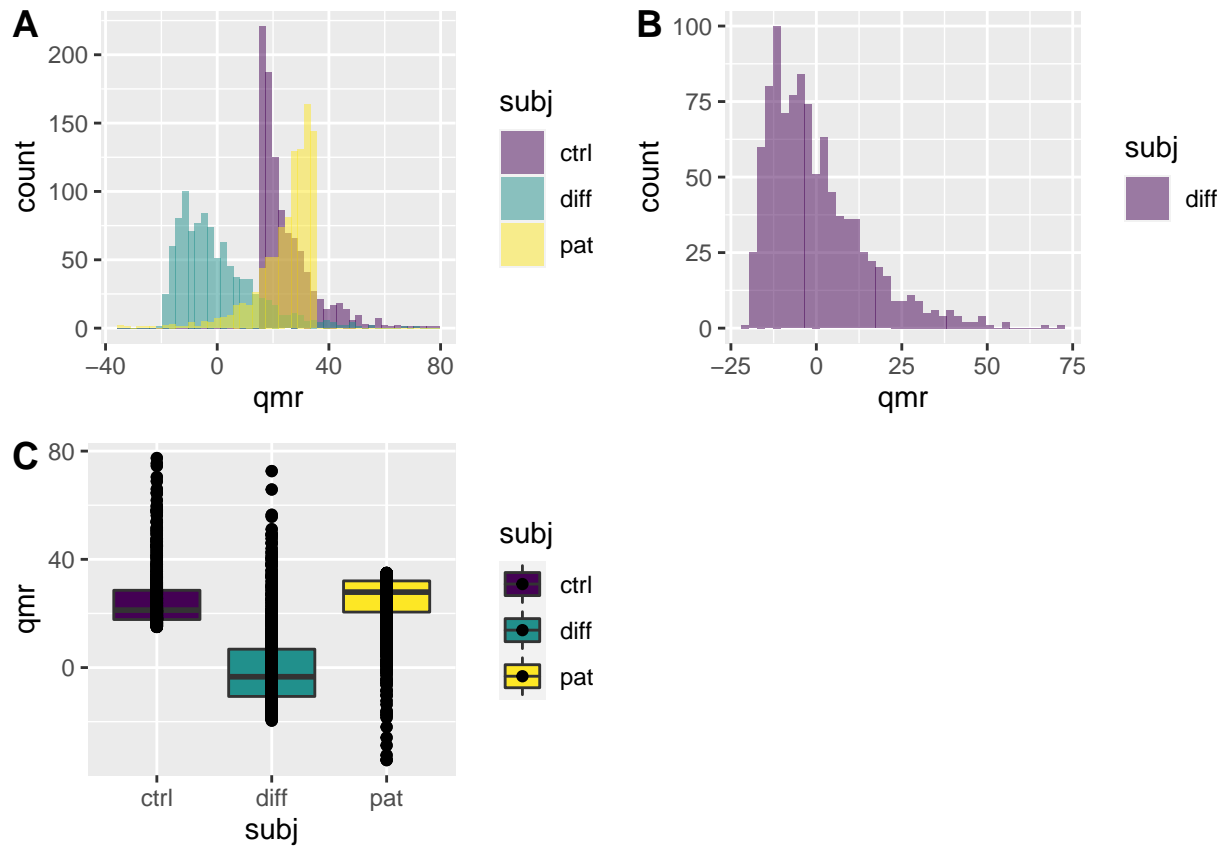
### What can we do?

Decide in advance the sample size we need! If we don't know maybe it is an exploratory analysis after all. Use more than the p-value! As a minimum use **confidence intervals**, not only point estimates!

## Trap Nr. 2: Step 1: Look at your data

**Not all datasets are normal, t-test is not for everything!**

The same way as mean is not always the proper statistic. Let's now look at some different distributions. Let's start with 1000 samples and try to reduce it! TO DO: change the nr\_s and observe.

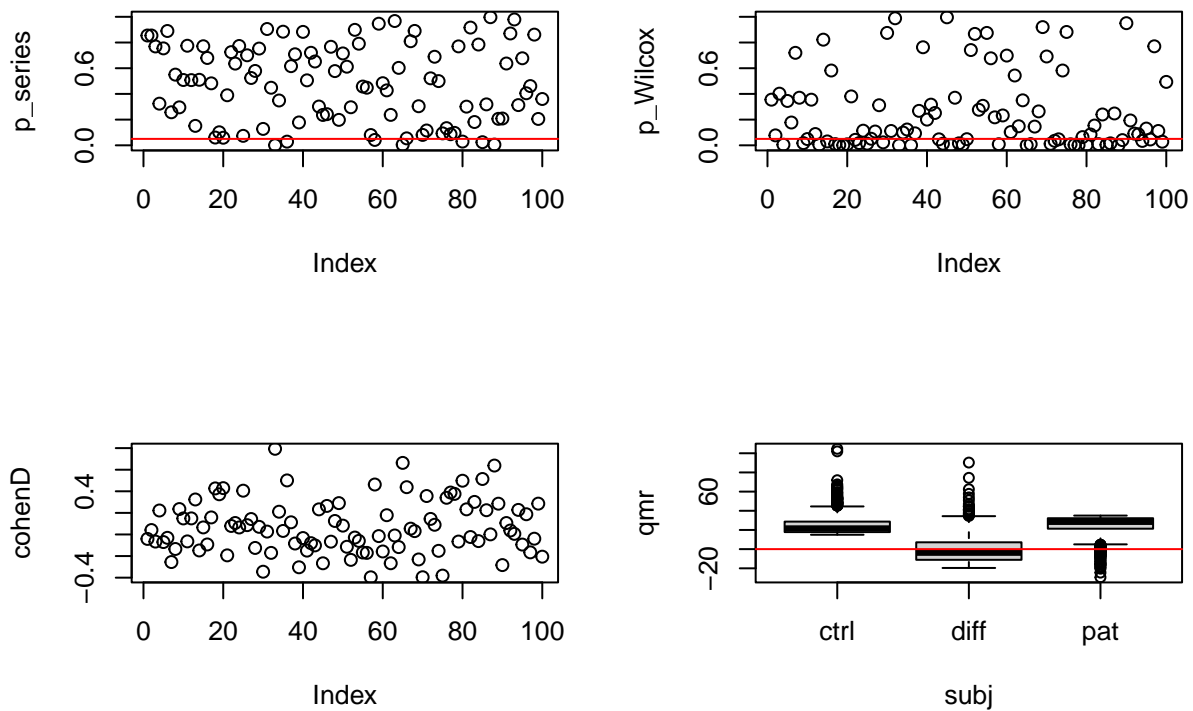


```
## [1] "ttest pvalue"      "0.887758824537744"
```

```
## [1] "res.wt"             "2.51232159581579e-14"
```

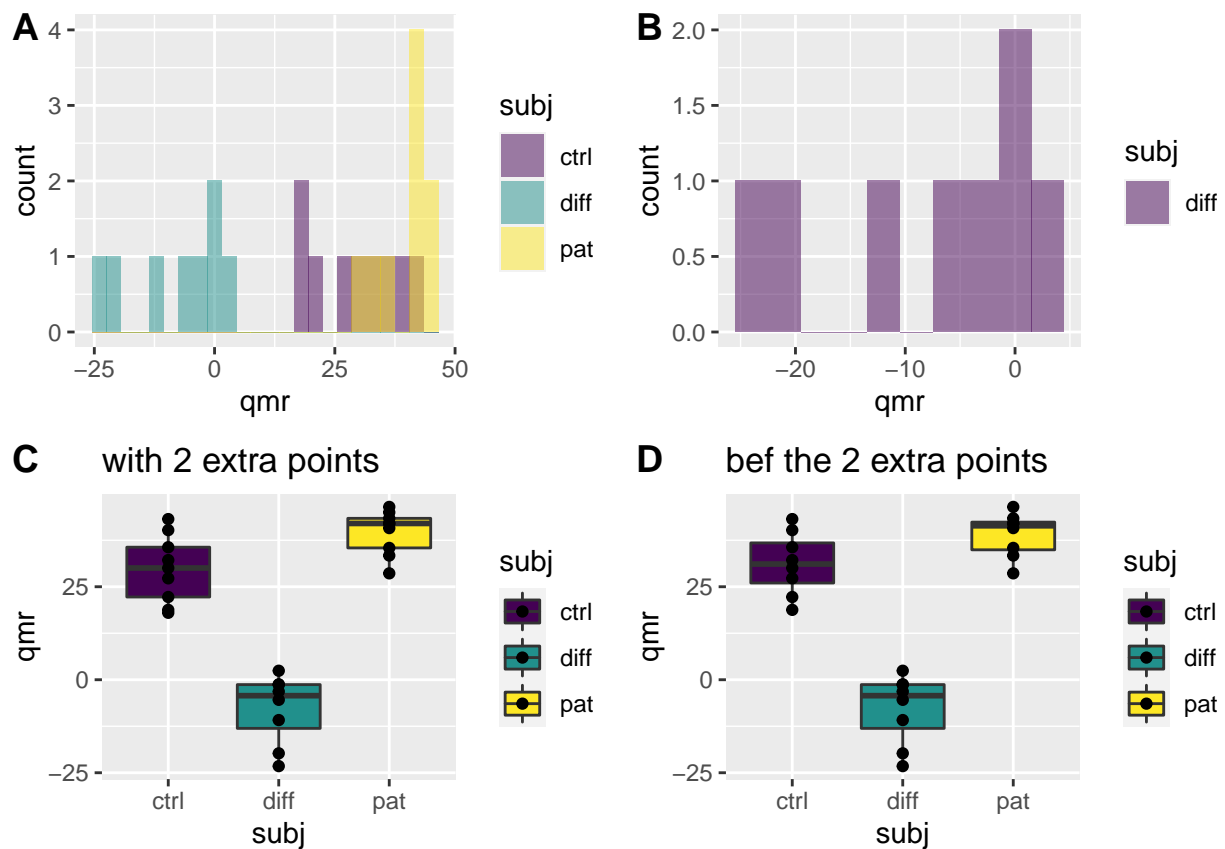
Let's load an example of these distributions, and experiment with taking samples `nr_s` and observe the effect. TO DO: Change the "nr\_s" and observe the plots





**Trap Nr. 3a:** Just one more experiment then! It almost looks good. Let's repeat it. Trap of adding data on marginal distributions. ##

## [1] "nr of ctrls" "8"



```
## [1] "p-value with 2 extra points" "0.0137866343690589"
```

```
## [1] "p-value without points" "0.0501597788149334"
```

**Trap Nr. 3b: This one looks wrong. Let's remove it**

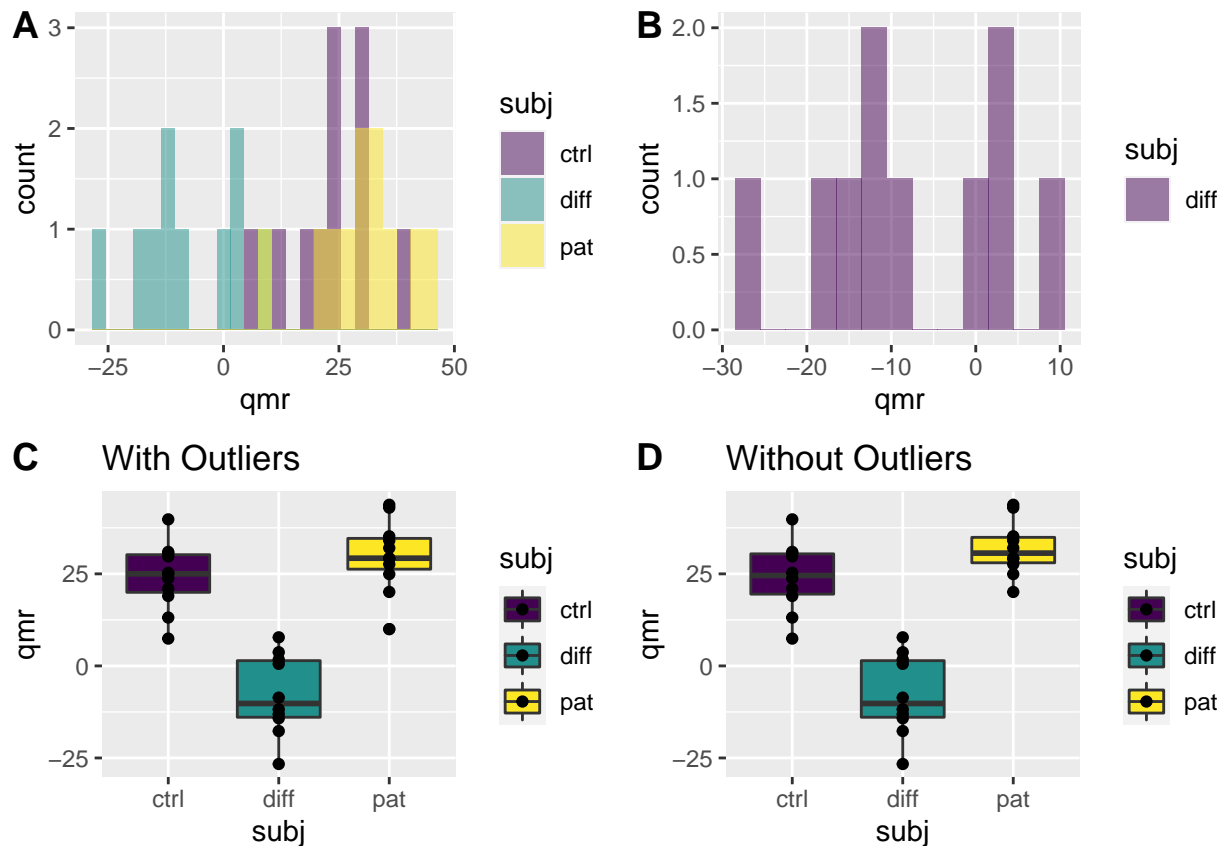
##Topic: post-hoc data selection, Keep adjusting the data collection removing outliers, 1) use different threshold, 2) remove outliers and test till you get you result

```
## [1] "nr of ctrls wOutl" "11"
```

```
## [1] "nr of ctrls wo Outl" "10"
```

```
## [1] "nr of pats wOutl" "11"
```

```
## [1] "nr of pats wo Outl" "10"
```



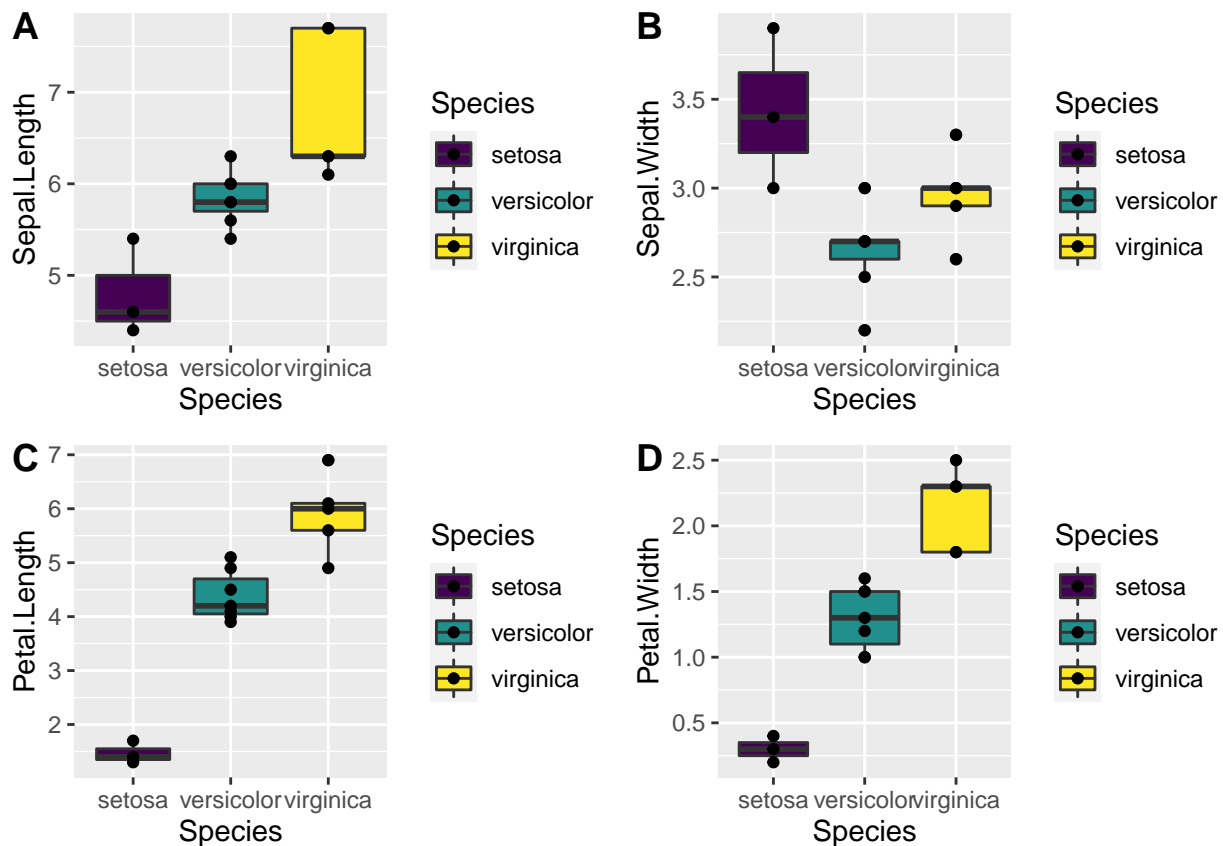
```
## [1] "p-value wo Outliers:" "0.0544741516793329"
```

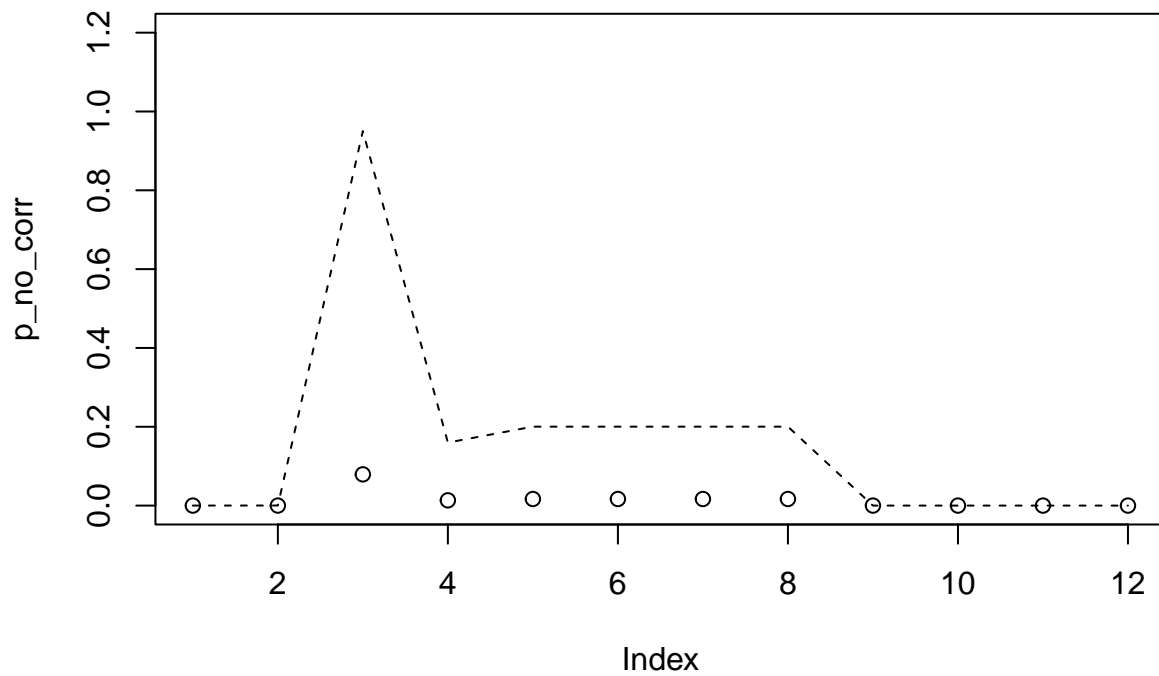
```
## [1] "p-value with Outliers:" "0.163547659953177"
```

## Trap Nr. 4: Problem of repeated sequential testing

### Bonferroni and other corrections

```
## Sepal.Length Sepal.Width Petal.Length Petal.Width
## Min. :4.300 Min. :2.000 Min. :1.000 Min. :0.100
## 1st Qu.:5.100 1st Qu.:2.800 1st Qu.:1.600 1st Qu.:0.300
## Median :5.800 Median :3.000 Median :4.350 Median :1.300
## Mean :5.843 Mean :3.057 Mean :3.758 Mean :1.199
## 3rd Qu.:6.400 3rd Qu.:3.300 3rd Qu.:5.100 3rd Qu.:1.800
## Max. :7.900 Max. :4.400 Max. :6.900 Max. :2.500
## Species
## setosa :50
## versicolor:50
## virginica :50
##
##
##
```

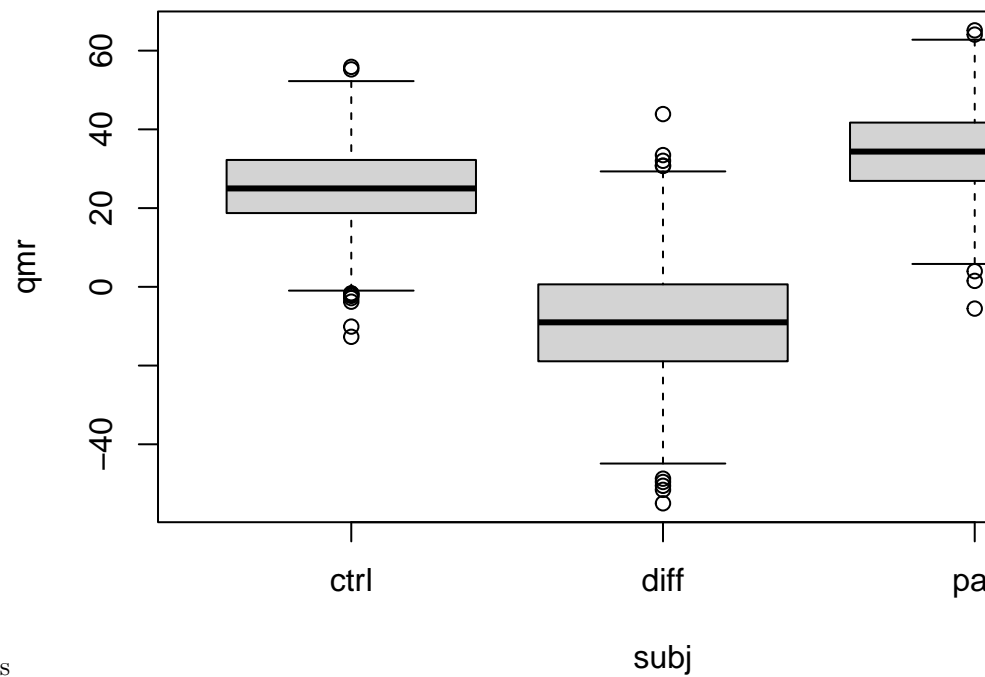




### Trap Nr. 5: POST HOC hypothesis

Be ware of one-sided tests,

Check the assumptions: (different variation, reaching normality)



TO DO: alternate between the 2 datasets

```
## [1] 1.622123e-78 1.000000e+00 8.110617e-79
```

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