```
knitr::opts_chunk$set(echo = TRUE)
nsims <- 100000 #set number of simulations
library(mvtnorm, quietly = TRUE)
library(MASS, quietly = TRUE)
library(afex, quietly = TRUE)
library(emmeans, quietly = TRUE)
library(ggplot2, quietly = TRUE)
library(gridExtra, quietly = TRUE)
library(reshape2, quietly = TRUE)
library(pwr, quietly = TRUE)

# Install functions from GitHub by running the code below:
source("https://raw.githubusercontent.com/Lakens/ANOVA_power_simulation/master/ANOVA_design.R")
source("https://raw.githubusercontent.com/Lakens/ANOVA_power_simulation/master/ANOVA_power.R")
source("https://raw.githubusercontent.com/Lakens/ANOVA_power_simulation/master/helper_functions/power_or
source("https://raw.githubusercontent.com/Lakens/ANOVA_power_simulation/master/helper_functions/power_or
source("https://raw.githubusercontent.com/Lakens/ANOVA_power_simulation/master/helper_functions/power_tw
source("https://raw.githubusercontent.com/Lakens/ANOVA_power_simulation/master/helper_functions/power_2x
source("https://raw.githubusercontent.com/Lakens/ANOVA_power_simulation/master/helper_functions/plot_pow
source("https://raw.githubusercontent.com/Lakens/ANOVA_power_simulation/master/helper_functions/plot_pow
source("https://raw.githubusercontent.com/Lakens/ANOVA_power_simulation/master/helper_functions/plot_pow
source("https://raw.githubusercontent.com/Lakens/ANOVA_power_simulation/master/helper_functions/plot_pow
```

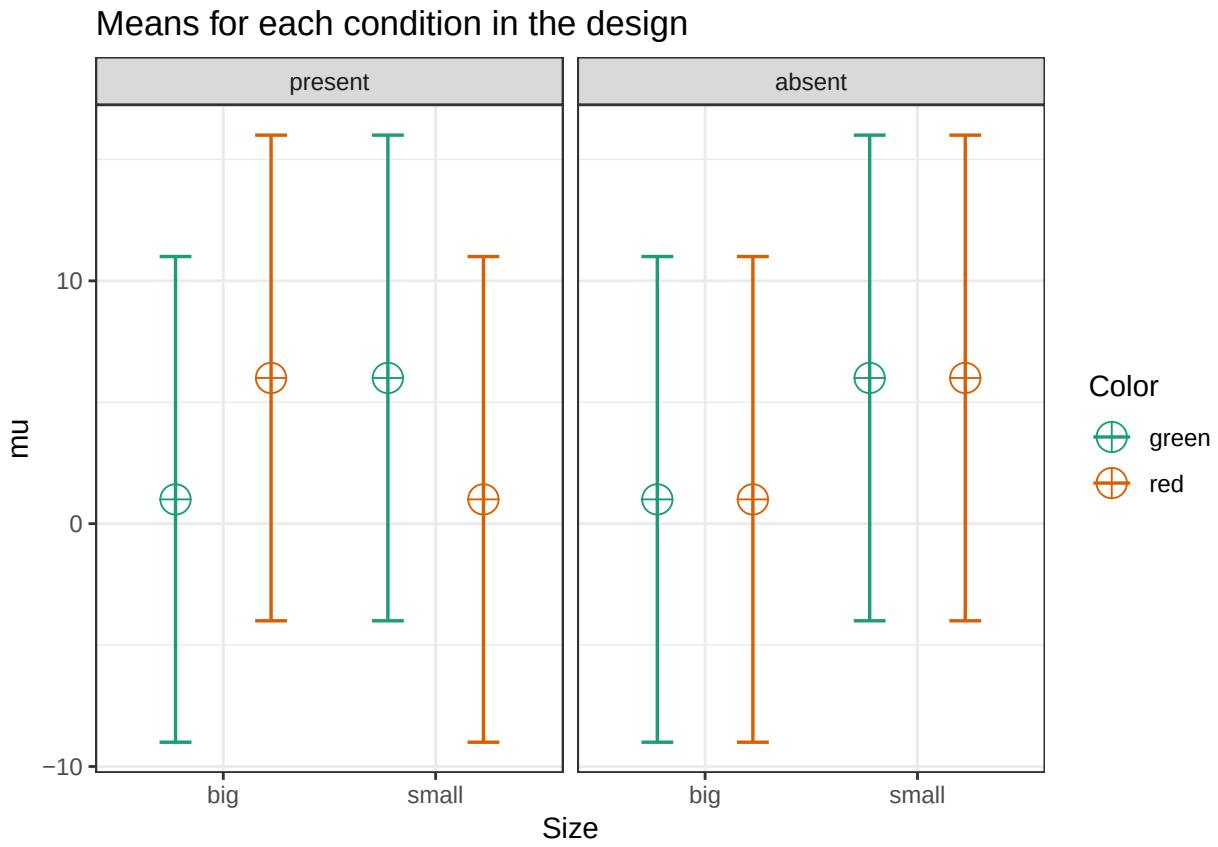
Power for Three-way Interactions

There are almost no software solutions that allow researchers to perform power anaysis for more complex designs. Through simulation, it is relatively straightforward to examine the power for designs with multiple factors with many levels.

Let's start with a 2x2x2 between subjects design. We collect 50 participants in each between participant condition (so 400 participants in total - 50x2x2x2).

```
string <- "2b*2b*2b"
n <- 50
mu <- c(1, 1, 6, 1, 6, 6, 1, 6)
sd <- 10
r <- 0.0
labelnames <- c("Size", "big", "small", "Color", "green", "red",
                "CognitiveLoad", "present", "absent") #

design_result <- ANOVA_design(string = string,
                   n = n,
                   mu = mu,
                   sd = sd,
                   labelnames = labelnames)
```




```
# Power for the given N in the design_result
ANOVA_power(design_result, nsims = nsims)
```

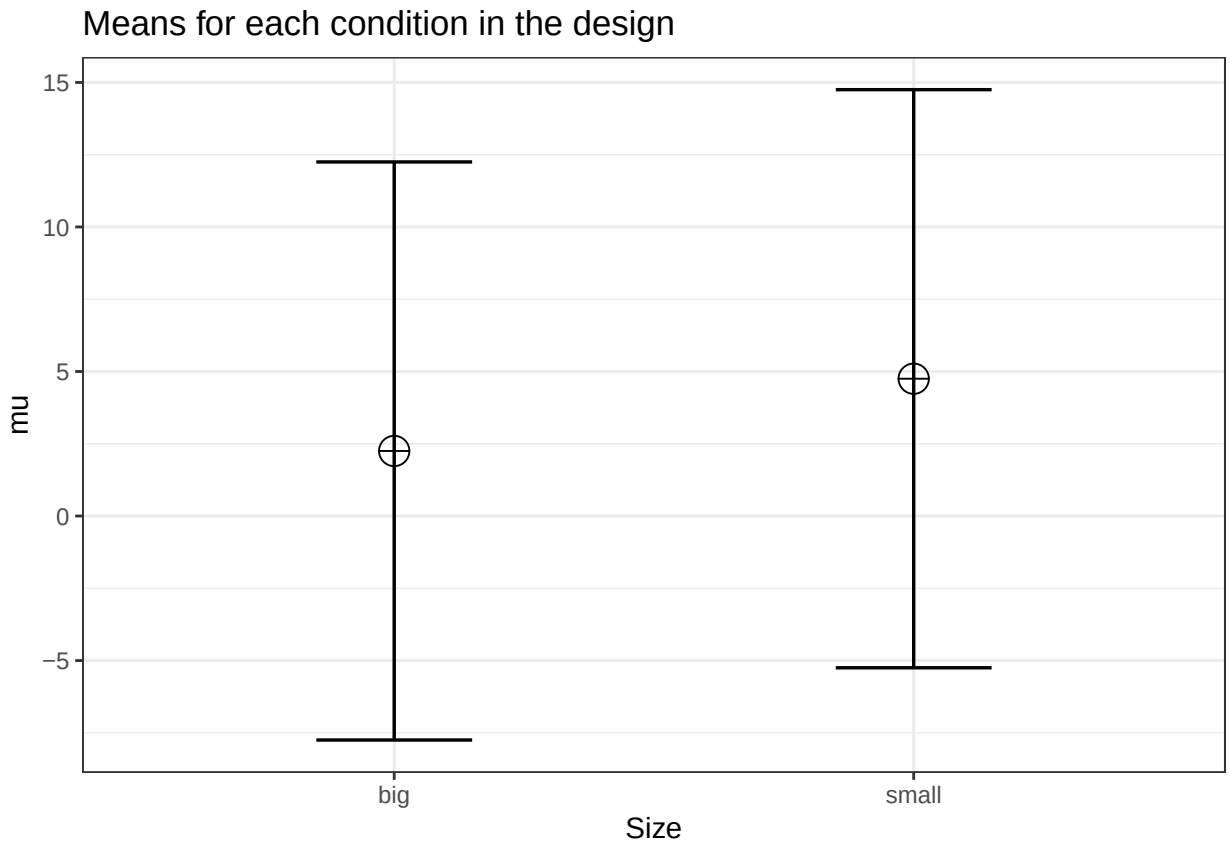
```
## Power and Effect sizes for ANOVA tests
##                                 power effect size
## anova_Size                     70.179      0.0156
## anova_Color                     4.969      0.0012
## anova_CognitiveLoad             4.948      0.0012
## anova_Size:Color               70.192      0.0157
## anova_Size:CognitiveLoad       70.369      0.0157
## anova_Color:CognitiveLoad       5.036      0.0012
## anova_Size:Color:CognitiveLoad 70.605      0.0158
##
## Power and Effect sizes for contrasts
##                                                                                                 power ef
## p_Size_big_Color_green_CognitiveLoad_present_Size_big_Color_green_CognitiveLoad_absent           4.963
## p_Size_big_Color_green_CognitiveLoad_present_Size_big_Color_red_CognitiveLoad_present           69.630
## p_Size_big_Color_green_CognitiveLoad_present_Size_big_Color_red_CognitiveLoad_absent            4.960
## p_Size_big_Color_green_CognitiveLoad_present_Size_small_Color_green_CognitiveLoad_present      69.727
## p_Size_big_Color_green_CognitiveLoad_present_Size_small_Color_green_CognitiveLoad_absent       69.399
## p_Size_big_Color_green_CognitiveLoad_present_Size_small_Color_red_CognitiveLoad_present         5.022
## p_Size_big_Color_green_CognitiveLoad_present_Size_small_Color_red_CognitiveLoad_absent         69.697
## p_Size_big_Color_green_CognitiveLoad_absent_Size_big_Color_red_CognitiveLoad_present           69.661
## p_Size_big_Color_green_CognitiveLoad_absent_Size_big_Color_red_CognitiveLoad_absent            4.906
## p_Size_big_Color_green_CognitiveLoad_absent_Size_small_Color_green_CognitiveLoad_present      69.715
## p_Size_big_Color_green_CognitiveLoad_absent_Size_small_Color_green_CognitiveLoad_absent       69.442
```

```
## p_Size_big_Color_green_CognitiveLoad_absent_Size_small_Color_red_CognitiveLoad_present      4.855
## p_Size_big_Color_green_CognitiveLoad_absent_Size_small_Color_red_CognitiveLoad_absent      69.644
## p_Size_big_Color_red_CognitiveLoad_present_Size_big_Color_red_CognitiveLoad_absent         69.719
## p_Size_big_Color_red_CognitiveLoad_present_Size_small_Color_green_CognitiveLoad_present     5.103
## p_Size_big_Color_red_CognitiveLoad_present_Size_small_Color_green_CognitiveLoad_absent      4.987
## p_Size_big_Color_red_CognitiveLoad_present_Size_small_Color_red_CognitiveLoad_present      69.737
## p_Size_big_Color_red_CognitiveLoad_present_Size_small_Color_red_CognitiveLoad_absent        4.930
## p_Size_big_Color_red_CognitiveLoad_absent_Size_small_Color_green_CognitiveLoad_present     69.864
## p_Size_big_Color_red_CognitiveLoad_absent_Size_small_Color_green_CognitiveLoad_absent      69.432
## p_Size_big_Color_red_CognitiveLoad_absent_Size_small_Color_red_CognitiveLoad_present        4.886
## p_Size_big_Color_red_CognitiveLoad_absent_Size_small_Color_red_CognitiveLoad_absent        69.711
## p_Size_small_Color_green_CognitiveLoad_present_Size_small_Color_green_CognitiveLoad_absent  5.115
## p_Size_small_Color_green_CognitiveLoad_present_Size_small_Color_red_CognitiveLoad_present  69.814
## p_Size_small_Color_green_CognitiveLoad_present_Size_small_Color_red_CognitiveLoad_absent    5.018
## p_Size_small_Color_green_CognitiveLoad_absent_Size_small_Color_red_CognitiveLoad_present   69.716
## p_Size_small_Color_green_CognitiveLoad_absent_Size_small_Color_red_CognitiveLoad_absent     5.099
## p_Size_small_Color_red_CognitiveLoad_present_Size_small_Color_red_CognitiveLoad_absent     69.641
```

A Three-Way ANOVA builds on the same principles as a One_Way ANOVA. We look at whether the differences between groups are large, compared to the standard deviation. For the main effects we simply have 2 groups of 200 participants, and 2 means. If the population standard deviations are identical across groups, this is not in any way different from a One-Way ANOVA. Indeed, we can show this by simulating a One-Way ANOVA, where instead of 8 conditions, we have two conditions, and we average over the 4 groups of the other two factors. For example, for the main effect of size above:

```
string <- "2b"
n <- 200
mu <- c(mean(c(1, 1, 6, 1)), mean(c(6, 6, 1, 6)))
sd <- 10
labelnames <- c("Size", "big", "small")

design_result <- ANOVA_design(string = string,
                   n = n,
                   mu = mu,
                   sd = sd,
                   labelnames = labelnames)
```




```
# Power based on simulations
ANOVA_power(design_result, nsims = nsims)
```

```
## Power and Effect sizes for ANOVA tests
##             power effect size
## anova_Size 70.655      0.0156
##
## Power and Effect sizes for contrasts
##                         power effect size
## p_Size_big_Size_small 70.655      0.2513
```

```
# Power based on analytical solution
power_oneway_between(design_result)$power #using default alpha level of .05
```

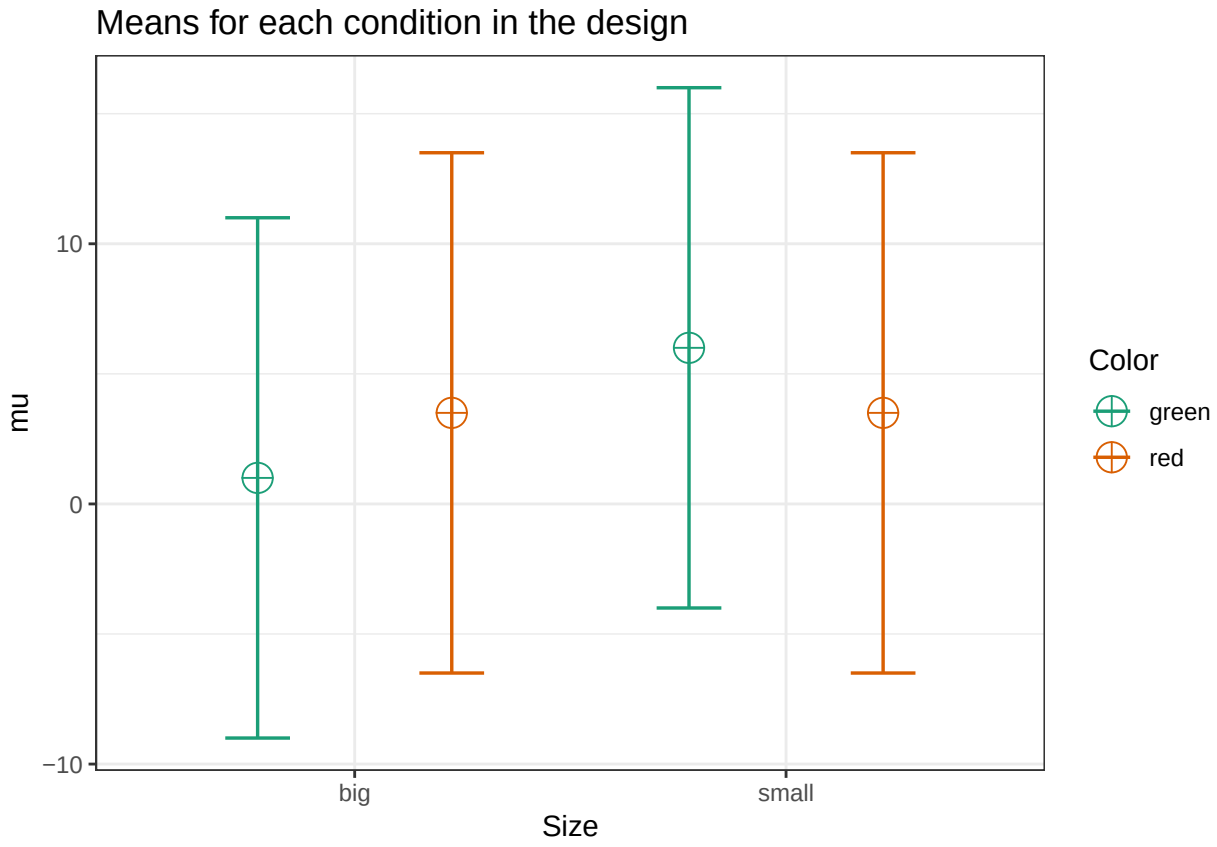
```
## [1] 0.7033333
```

Similarly, we can create a 2 factor design where we average over the third factor, and recreate the power analysis for the Two-Way interaction. For example, we can group over the Cognitive Load condition, and look at the Size by Color Interaction:

```
string <- "2b*2b"
n <- 100
mu <- c(mean(c(1, 1)), mean(c(6, 1)), mean(c(6, 6)), mean(c(1, 6)))
sd <- 10
```

```
labelnames <- c("Size", "big", "small", "Color", "green", "red")

design_result <- ANOVA_design(string = string,
                    n = n,
                    mu = mu,
                    sd = sd,
                    labelnames = labelnames)
```




```
# Power based on simulations
ANOVA_power(design_result, nsims = nsims)
```

```
## Power and Effect sizes for ANOVA tests
##                   power effect size
## anova_Size       70.326      0.0156
## anova_Color       5.047      0.0012
## anova_Size:Color 70.518      0.0157
##
## Power and Effect sizes for contrasts
##                                                  power effect size
## p_Size_big_Color_green_Size_big_Color_red     42.250      0.2516
## p_Size_big_Color_green_Size_small_Color_green 93.984      0.5025
## p_Size_big_Color_green_Size_small_Color_red   42.146      0.2511
## p_Size_big_Color_red_Size_small_Color_green   41.951      0.2509
## p_Size_big_Color_red_Size_small_Color_red      5.102     -0.0006
## p_Size_small_Color_green_Size_small_Color_red 42.146     -0.2514
```

```r
# Power based on analytical solution
power_res <- power_twoway_between(design_result) #using default alpha level of .05

power_res$power_A
```

```
## [1] 0.7033228
```

```r
power_res$power_B
```

```
## [1] 0.05
```

```r
power_res$power_AB
```

```
## [1] 0.7033228
```