```
knitr::opts_chunk$set(echo = TRUE)
nsims <- 10000 #set number of simulations
library(mvtnorm)
library(afex)
```

```
## Loading required package: lme4
```

```
## Warning: package 'lme4' was built under R version 3.5.2
```

```
## Loading required package: Matrix
```

```
## ************
## Welcome to afex. For support visit: http://afex.singmann.science/
```

```
## - Functions for ANOVAs: aov_car(), aov_ez(), and aov_4()
## - Methods for calculating p-values with mixed(): 'KR', 'S', 'LRT', and 'PB'
## - 'afex_aov' and 'mixed' objects can be passed to emmeans() for follow-up tests
## - NEWS: library('emmeans') now needs to be called explicitly!
## - Get and set global package options with: afex_options()
## - Set orthogonal sum-to-zero contrasts globally: set_sum_contrasts()
## - For example analyses see: browseVignettes("afex")
## ************
```

```
##
## Attaching package: 'afex'
```

```
## The following object is masked from 'package:lme4':
##
##     lmer
```

```
library(emmeans)
```

```
## Warning: package 'emmeans' was built under R version 3.5.2
```

```
library(ggplot2)
```

```
## Warning: package 'ggplot2' was built under R version 3.5.2
```

```
library(gridExtra)
library(reshape2)
```

Validation of Power in Mixed ANOVA

We install the functions:

```
# Install the two 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")
```

Two by two ANOVA, within-between design

We can simulate a Two-Way ANOVA with a specific alpha, sample size and effect size, to achieve a specified statistical power. We wil try to reproduce the power analysis by g*power for an F-test, ANOVA: Repeated

measures, within-between interaction.

For the 2-way interaction, the result should be a power of 91.25% is we have a total samplesize of 46. Since we have 2 groups in the between factor that means the sample size per group is 2 (and both these groups collect 2 repeated measures).

```
mu <- c(-0.25, 0.25, 0.25, -0.25)
n <- 23
sd <- 1
r <- 0.5
string = "2w*2b"
alpha_level <- 0.05
p_adjust = "none"
labelnames = c("age", "old", "young", "color", "blue", "red")
design_result <- ANOVA_design(string = string,
                              n = n,
                              mu = mu,
                              sd = sd,
                              r = r,
                              p_adjust = p_adjust,
                              labelnames = labelnames)
```

```
simulation_result <- ANOVA_power(design_result, alpha = 0.05, nsims = nsims)
```

```
## Power and Effect sizes for ANOVA tests
##                 power effect size
## anova_color      5.39      0.0104
## anova_age        5.18      0.0101
## anova_color:age 91.30      0.2096
##
## Power and Effect sizes for contrasts
##                                                 power effect size
## p_age_old_color_blue_age_old_color_red          38.17      0.5066
## p_age_old_color_blue_age_young_color_blue       62.69      0.5179
## p_age_old_color_blue_age_young_color_red         5.30     -0.0056
## p_age_old_color_red_age_young_color_blue         5.21      0.0020
## p_age_old_color_red_age_young_color_red         63.76     -0.5199
## p_age_young_color_blue_age_young_color_red      38.73     -0.5145
```

Two by two ANOVA, within-between design Variation 1

We can simulate the same Two-Way ANOVA increasing the correlation to 0.7.

```
mu <- c(-0.25, 0.25, 0.25, -0.25)
n <- 23
sd <- 1
r <- 0.7
string = "2w*2b"
alpha_level <- 0.05
p_adjust = "none"
labelnames = c("age", "old", "young", "color", "blue", "red")
design_result <- ANOVA_design(string = string,
                              n = n,
                              mu = mu,
                              sd = sd,
```

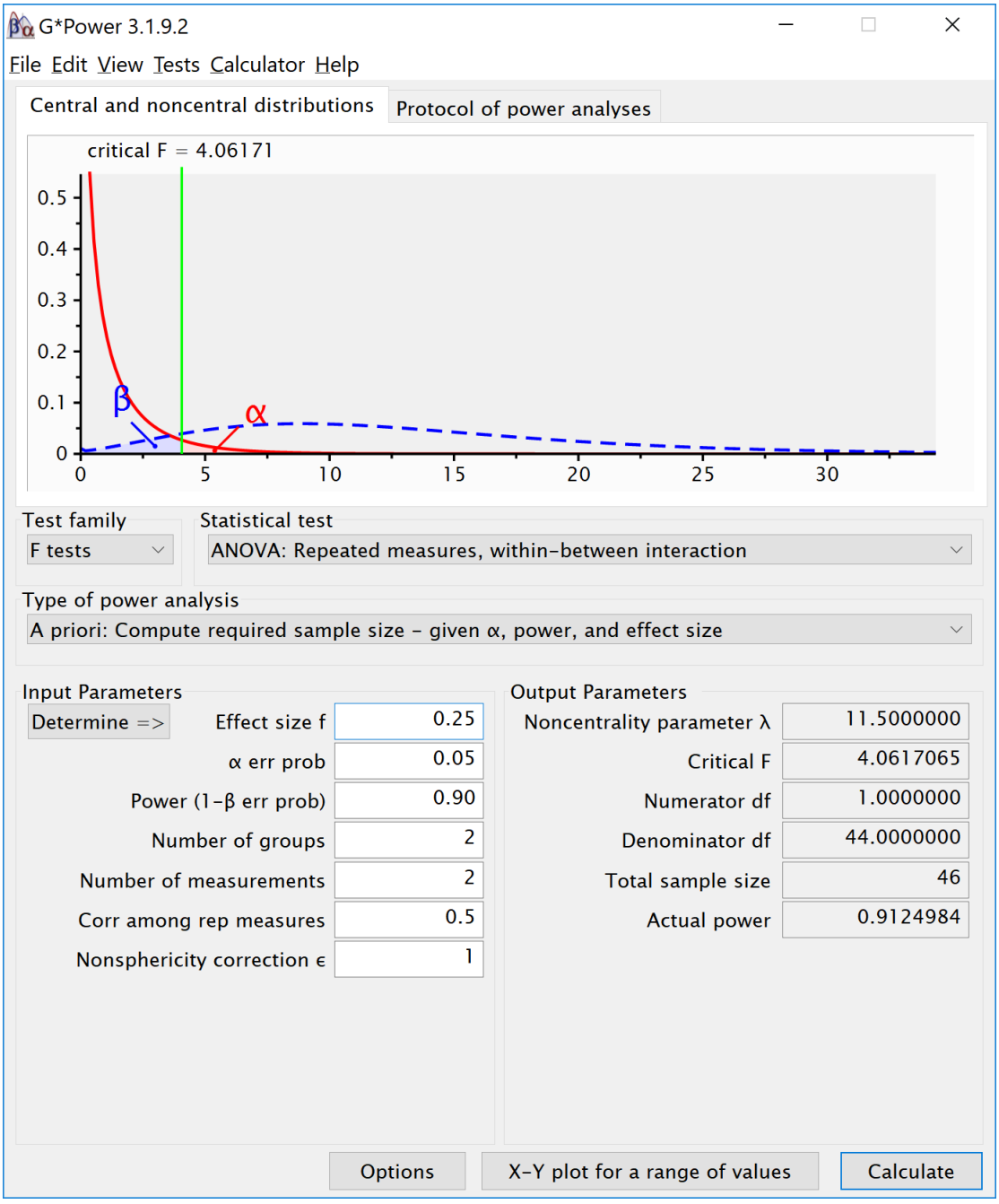
G*Power 3.1.9.2
File Edit View Tests Calculator Help
Central and noncentral distributions
Protocol of power analyses
critical F = 4.06171
0.5
0.4
0.3
0.2
0.1
0
β
α
0
5
10
15
20
25
30
Test family
F tests
Statistical test
ANOVA: Repeated measures, within-between interaction
Type of power analysis
A priori: Compute required sample size – given α, power, and effect size
Input Parameters
Determine =>
Effect size f
0.25
α err prob
0.05
Power (1-β err prob)
0.90
Number of groups
2
Number of measurements
2
Corr among rep measures
0.5
Nonsphericity correction ε
1
Output Parameters
Noncentrality parameter λ
11.5000000
Critical F
4.0617065
Numerator df
1.0000000
Denominator df
44.0000000
Total sample size
46
Actual power
0.9124984
Options
X-Y plot for a range of values
Calculate

Figure 1:

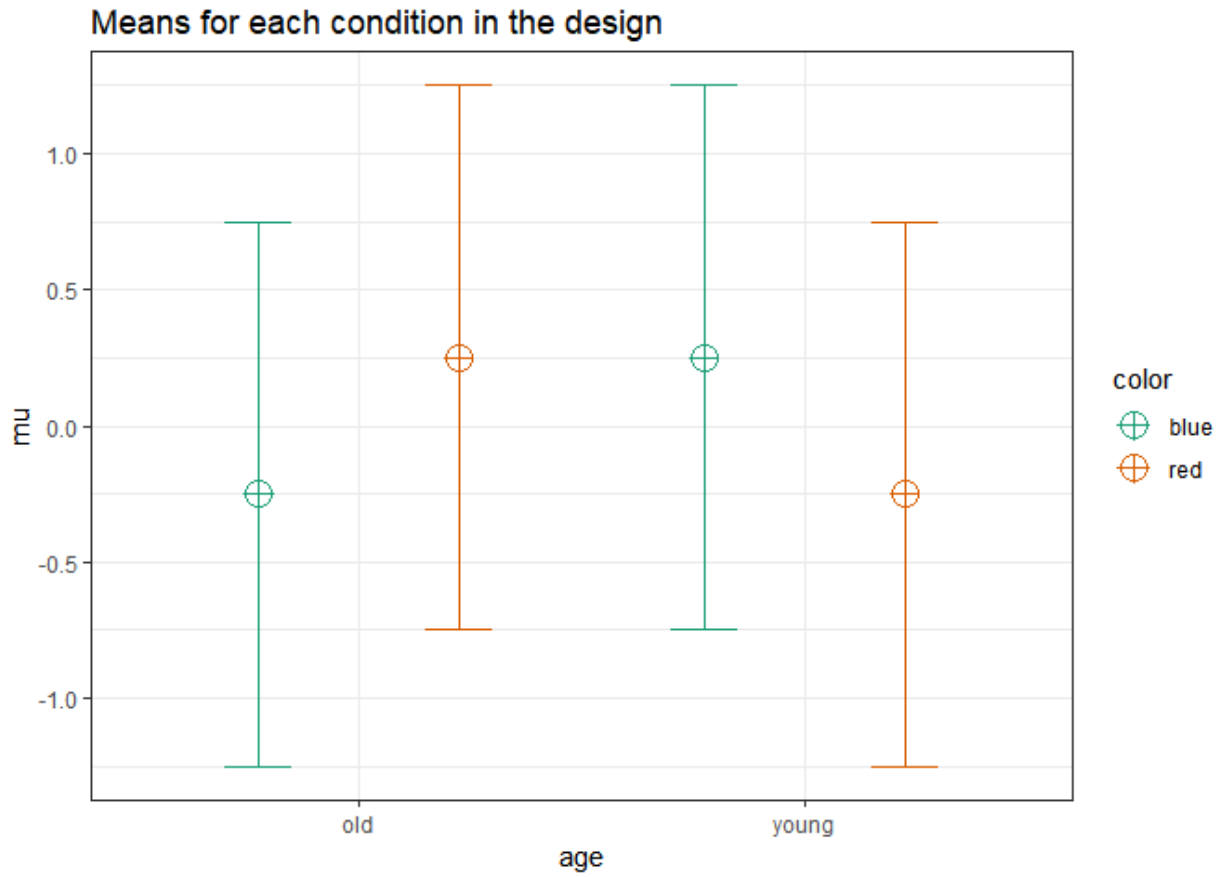
Means for each condition in the design
mu
1.0
0.5
0.0
-0.5
-1.0
old
young
age
color
blue
red

Figure 2:

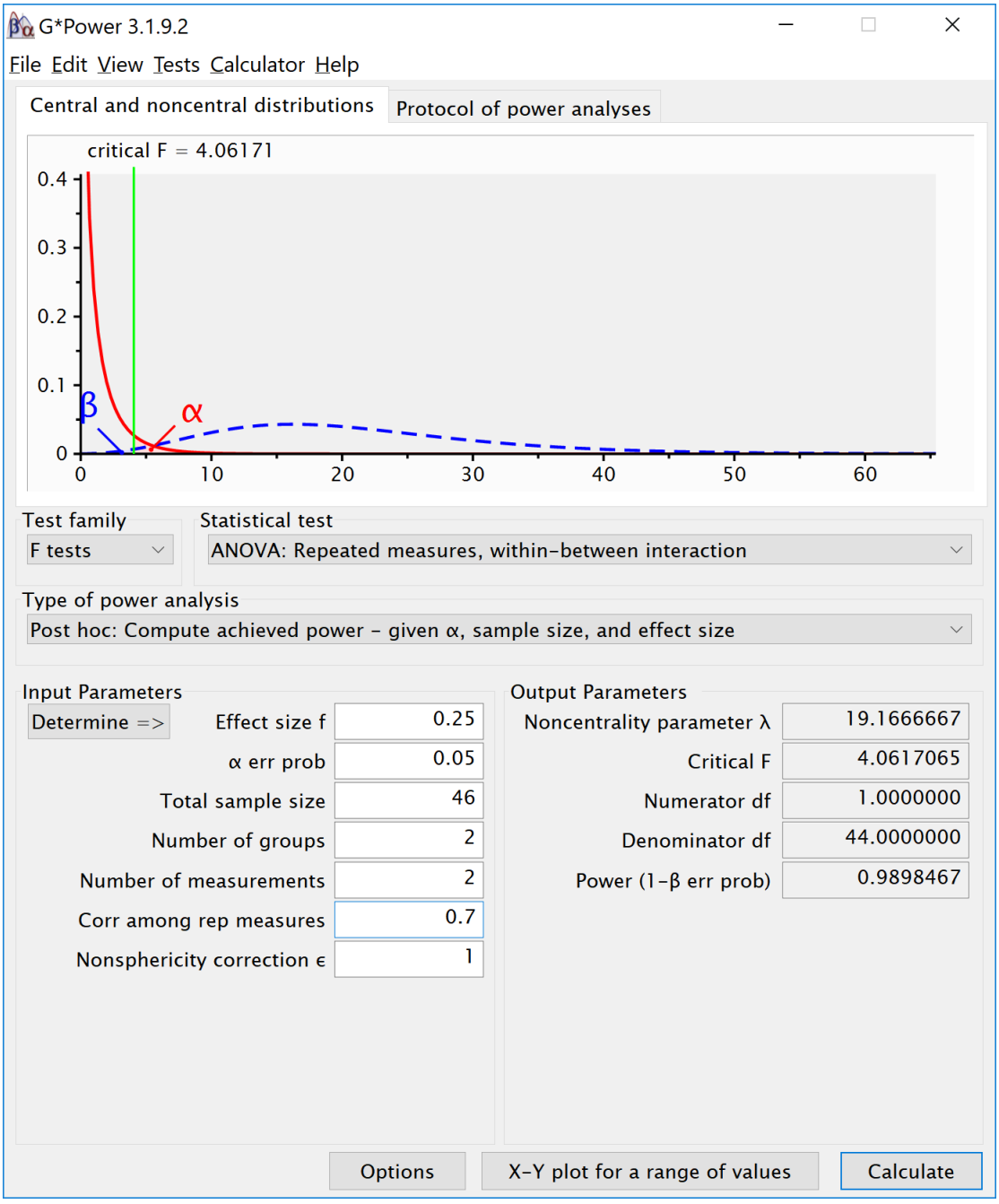
G*Power 3.1.9.2
File Edit View Tests Calculator Help
Central and noncentral distributions
Protocol of power analyses
critical F = 4.06171
0.4
0.3
0.2
0.1
0
β
α
0
10
20
30
40
50
60
Test family
F tests
Statistical test
ANOVA: Repeated measures, within-between interaction
Type of power analysis
Post hoc: Compute achieved power – given α, sample size, and effect size
Input Parameters
Determine =>
Effect size f
0.25
α err prob
0.05
Total sample size
46
Number of groups
2
Number of measurements
2
Corr among rep measures
0.7
Nonsphericity correction ε
1
Output Parameters
Noncentrality parameter λ
19.1666667
Critical F
4.0617065
Numerator df
1.0000000
Denominator df
44.0000000
Power (1-β err prob)
0.9898467
Options
X-Y plot for a range of values
Calculate

Figure 3:

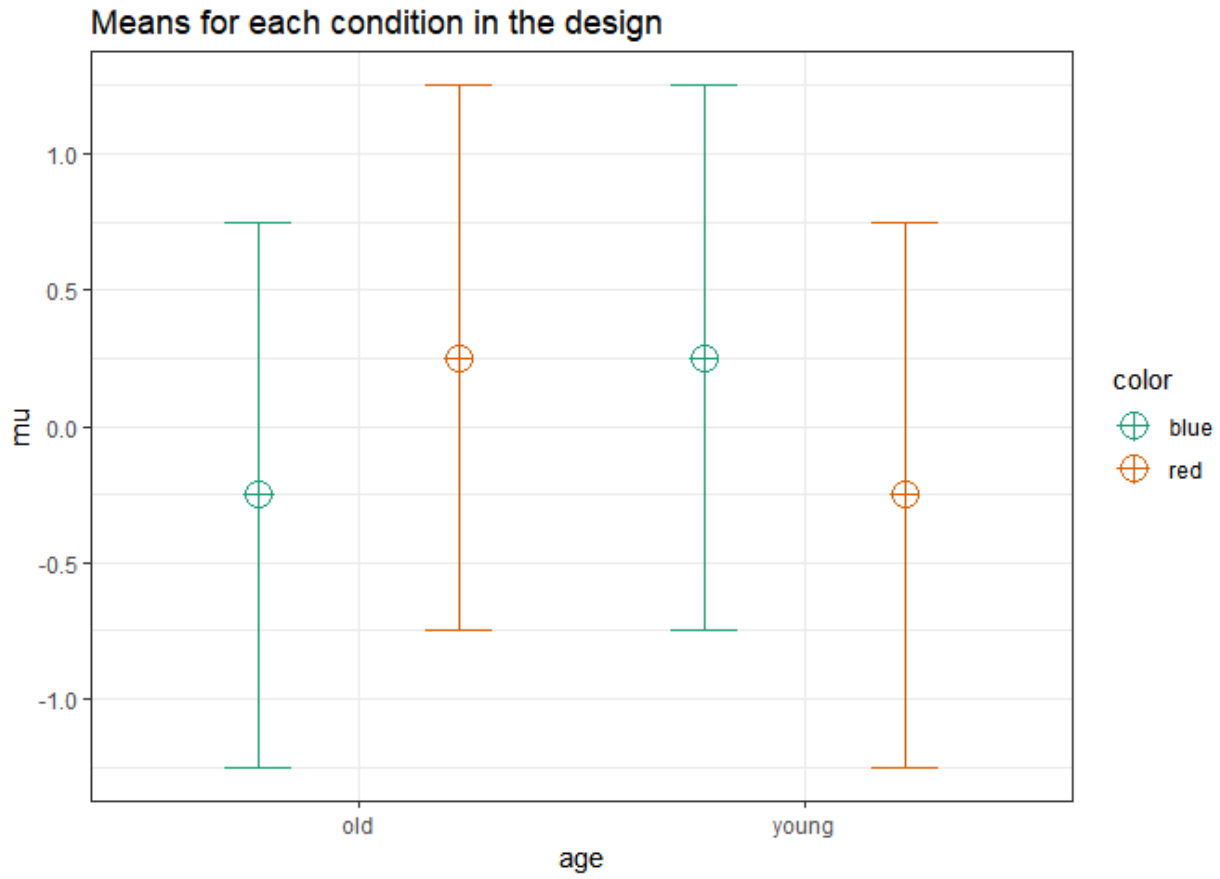

Figure 4:

```
                              r = r,
                              p_adjust = p_adjust,
                              labelnames = labelnames)
```

```
simulation_result <- ANOVA_power(design_result, alpha = 0.05, nsims = nsims)
```

```
## Power and Effect sizes for ANOVA tests
##                 power effect size
## anova_color      4.97      0.0103
## anova_age        4.84      0.0103
## anova_color:age 99.08      0.3056
##
## Power and Effect sizes for contrasts
##                                                power effect size
## p_age_old_color_blue_age_old_color_red         38.28      0.5104
## p_age_old_color_blue_age_young_color_blue      84.37      0.6686
## p_age_old_color_blue_age_young_color_red        5.16      0.0020
## p_age_old_color_red_age_young_color_blue        5.06     -0.0027
## p_age_old_color_red_age_young_color_red        84.10     -0.6673
## p_age_young_color_blue_age_young_color_red     37.87     -0.5067
```