Detailed analyses ADHD data

Fernando Marmolejo-Ramos

2021-03-17

Table of Contents

Key for variables

Key for variables used in the ADHD manuscript:

A-TIME = a-time = a-wave time to peak

A-AMP = a-amp = a-wave amplitude

B-TIME = b-time = b-wave time to peak

B-AMP = b-amp = b-wave amplitude

TMIN = Tmin = Time of Photopic Negative Response (PhNR) at a minimal amplitude occurred within the 55-95ms window

P72 = p72 = PhNR amplitude at 72ms post stimulus onset

BT = PhNRmin = PhNR amplitude measured as the most negative point from the baseline

P-RATIO =p-ratio

W-RATIO = w-ratio

GENDER = s = sex

Loading and exploring the data set[1]

Be weary of the R packages required at different stages in the analyses

Primary analyses

The following code allows to read off the data contained in the file 'ADHD_data_v._2_3_21.xlsx'. Note this file has three tabs and data is contained in the tab called 'ADHD'.

```
# DATA CAN BE EASILY UPLOADED VIA THE 'IMPORT DATASET' TAB IN R STUDIO...
LIBRARY(READXL)
ADHD <- READ_EXCEL(FILE.CHOOSE(), SHEET = "ADHD")
```

Selecting the columns of interest. The variables of interest are the following:

Covariates (names in data set in brackets):

- Eye (categorical variable with 2 levels: left and right) [EYE],
- Gender (categorial variable with 2 levels: male and female) [GENDER],
- Age (continuous variable) [AGE],
- Electrode height (categorical with 4 levels referring to positions below the eye. This variable has levels from 0-4 with 2 as reference level; i.e. 2mm below the eye which is recommended. So 3 or 4 amplitudes are expected to be lower and 0 or 1 then higher than the '2' reference) [VERT],
- Iris colour (continuous variable) [IRIS],
- CNS medication (categorical variable with 2 levels: on-medication vs off-medication) [CNS_MED],
- Ethnicity (categorical variable with five levels) [ETHNIC]
- Group (categorical variable with the following levels: ASD, CONTROL, and ADHD) [GROUP] and
- Flash intensity (categorical as it has 10 levels: -0.367, -0.119, 0.114, 0.398, 0.477, 0.602, 0.799, 0.949, 1.114, and 1.204) [STRENGTH]

The *dependent* (all continous) variables are (names in data set in brackets):

- a-time,
- a-amp,
- b-time,
- b-wave,
- bdiva_amp,
- p72,
- Tmin,
- BT,
- p_ratio, and
- w_ratio

[1] useful examples **HERE**

a_time, b_time and Tmin are in milliseconds (ms), a_amp, b_amp, p72, and BT are in microvolts (μV). No units for the ratio metrics (p_ratio, w_ratio and bdiva_amp).

Each participant has repeated measures in each eye according to the flash intensity but there was variability in the number of measurements per eye and per participant.

```
adhd2 <- subset(adhd, select=c(
# independent variables
  `ID entered in RETeval device`,age,gender,group,VERT,
  Ethnic,eye,iris,
  Strength,CNS_MED,
# dependent variables
  a_time,  a_amp, b_time,  b_amp, bdiva_amp,   p72, Tmin, BT,
  p_ratio,  w_ratio))

# checking the data's structure...
str(adhd2)
```

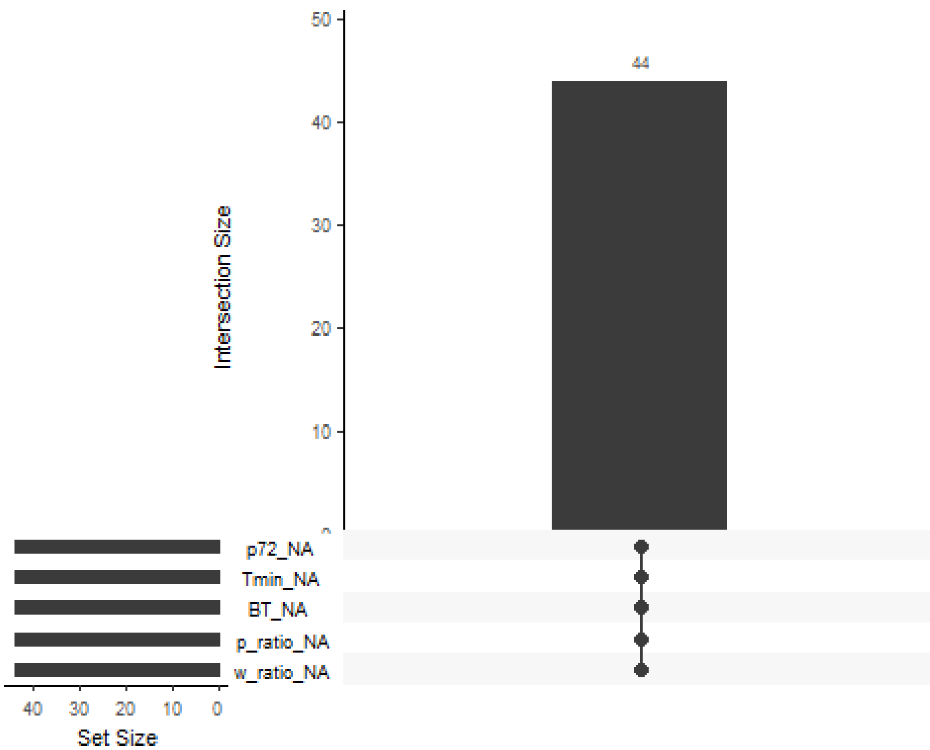
```
## tibble [3,838 x 20] (S3: tbl_df/tbl/data.frame)
##  $ ID entered in RETeval device: chr [1:3838] "a10" "a10" "a10" "a10" ...
##  $ age                         : num [1:3838] 10.9 10.9 10.9 10.9 10.9 10.9 10
.9 10.9 10.9 10.9 ...
##  $ gender                      : num [1:3838] 0 0 0 0 0 0 0 0 0 0 ...
##  $ group                       : num [1:3838] 0 0 0 0 0 0 0 0 0 0 ...
##  $ VERT                        : num [1:3838] 4 4 4 4 4 4 4 4 4 4 ...
##  $ Ethnic                      : num [1:3838] 1 1 1 1 1 1 1 1 1 1 ...
##  $ eye                         : num [1:3838] 0 0 0 0 0 0 0 0 0 0 ...
##  $ iris                        : num [1:3838] 1.12 1.12 1.12 1.12 1.12 ...
##  $ Strength                    : num [1:3838] -0.367 -0.119 0.114 0.398 0.477
 ...
##  $ CNS_MED                     : num [1:3838] 1 1 1 1 1 1 1 1 1 1 ...
##  $ a_time                      : num [1:3838] 14.14 12.26 13.13 12.72 9.91 ..
.
##  $ a_amp                       : num [1:3838] -3.49 -1.64 -6.46 -4.32 -2.36 .
..
##  $ b_time                      : num [1:3838] 21.3 21.8 24.1 24.4 27.3 ...
##  $ b_amp                       : num [1:3838] 10.1 8.4 19.8 22.1 12.9 ...
##  $ bdiva_amp                   : num [1:3838] 2.88 5.12 3.06 5.11 5.47 ...
##  $ p72                         : num [1:3838] 1.75 -11.65 -5.02 -0.66 4.69 ..
.
##  $ Tmin                        : num [1:3838] 55.1 95.7 70.7 55.2 95.2 ...
##  $ BT                          : num [1:3838] -1.55 -18.01 -5.13 -1.27 1.43 .
..
##  $ p_ratio                     : num [1:3838] -0.2664 1.7248 0.3777 0.0371 -0
.4438 ...
##  $ w_ratio                     : num [1:3838] 0.807 2.95 0.933 0.862 0.707 ..
.
```

```r
dim(adhd2)
```

```
## [1] 3838   20
```

```r
# rendering variables into their right type
adhd2$`ID entered in RETeval device` <- as.factor(adhd2$`ID entered in RETeval devic
e`)
adhd2$gender <- as.factor(adhd2$gender)
adhd2$group <- as.factor(adhd2$group)
adhd2$VERT <- as.factor(adhd2$VERT)
   adhd2$VERT<-relevel(adhd2$VERT, ref='2') # ref level in this variable
adhd2$Ethnic <- as.factor(adhd2$Ethnic)
adhd2$eye <- as.factor(adhd2$eye)
adhd2$Strength <- as.factor(adhd2$Strength)
adhd2$CNS_MED <- as.factor(adhd2$CNS_MED)


# changing the name of the columns
colnames(adhd2) <- c('Participant','Age','Gender','Group','Vert',
                'Ethnicity','Eye','Iris','Strength','Medication',
                'a_time', 'a_amp',  'b_time',   'b_amp','bdiva_amp',
                'p72',  'Tmin', 'BT',   'p_ratio',  'w_ratio')


# relabeling some of the variables' levels
library(plyr)
adhd2$Gender <-
mapvalues(adhd2$Gender,
  from = c('0','1'),
  to = c('Male','Female'))

adhd2$Group <-
mapvalues(adhd2$Group,
  from = c('0','1', '3'),
  to = c('ASD','Control','ADHD'))

adhd2$Ethnicity <-
mapvalues(adhd2$Ethnicity,
  from = c('1','2','3','4','5'),
  to = c('Caucasian','Asian','Afro-Caribbean','Latino','Mixed'))

adhd2$Eye <-
mapvalues(adhd2$Eye,
  from = c('0','1'),
  to = c('Right','Left'))

adhd2$Medication <-
```

```
MAPVALUES(ADHD2$MEDICATION,
  FROM = C('0','1'),
  TO = C('NOT TAKEN','TAKEN'))


# CHECKING IF THERE ARE MISSING VALUES...
# SEE HTTPS://CRAN.R-PROJECT.ORG/WEB/PACKAGES/NANIAR/VIGNETTES/NANIAR-VISUALISATION.HT
ML
# FOR MORE VISUALISATIONS
LIBRARY(NANIAR)
GG_MISS_UPSET(ADHD2)
```



Only complete cases could be retained at this stage, but this step would require removing entire rows. So the data is retained as it is. IFF NAs give problems during the model fitting, then only a data set without NAs will be used.

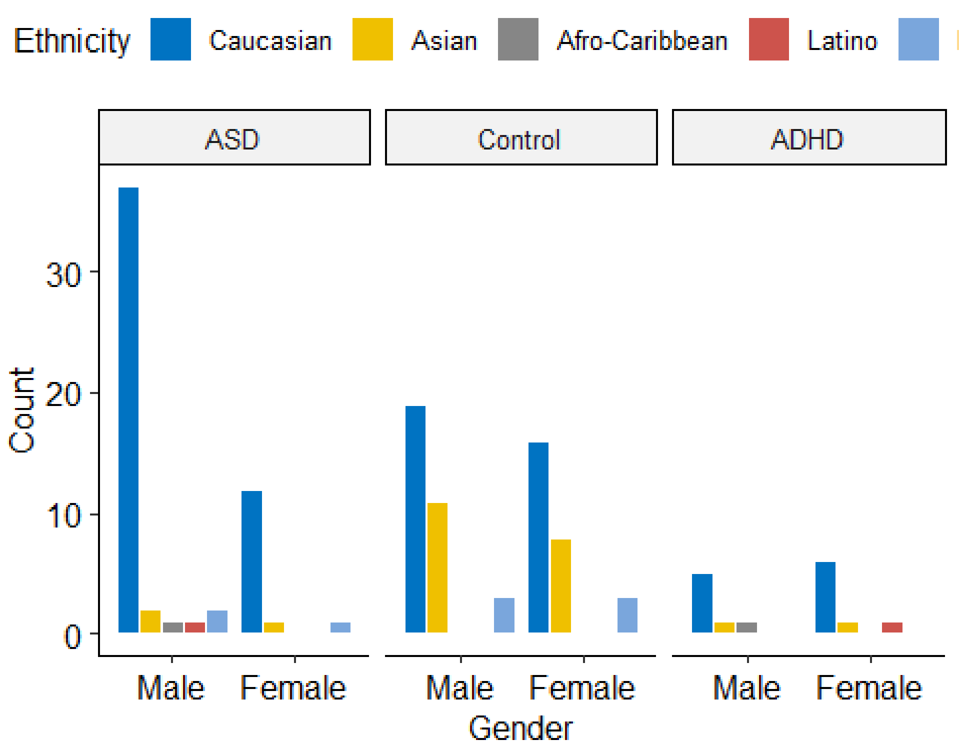
Descriptive statistics

This section shows some descriptive statistics along with robust estimations of location (median) and scale (MAD = median absolute deviations) for both all dependent variables regardless of STRENGTH and EYE.

```
LIBRARY(TIDYVERSE)

# NOTE 'EYE' IS LEFT OUT IN ORDER TO AVOID DUPLICATES
# VERT AND STRENGTH ARE ALSO NOT INCLUDED
```

```
SOME_STATS_BY_PARTICIPANTS <- ADHD2 %>%
  GROUP_BY(PARTICIPANT, AGE, GENDER, ETHNICITY, MEDICATION, GROUP) %>%
  SUMMARIZE(MEDIAN.A.TIME = MEDIAN(A_TIME),
            MAD.A.TIME=MAD(A_TIME),
            CV.A.TIME = MAD(A_TIME)/MEDIAN(A_TIME),

            MEDIAN.A.AMP = MEDIAN(A_AMP),
            MAD.A.AMP=MAD(A_AMP),
            CV.A.AMP = MAD(A_AMP)/MEDIAN(A_AMP),

            MEDIAN.B.TIME = MEDIAN(B_TIME),
            MAD.B.TIME=MAD(B_TIME),
            CV.B.TIME = MAD(B_TIME)/MEDIAN(B_TIME),

            MEDIAN.B.AMP = MEDIAN(B_AMP),
            MAD.B.AMP=MAD(B_AMP),
            CV.B.AMP = MAD(B_AMP)/MEDIAN(B_AMP),

            MEDIAN.BDIVA_AMP = MEDIAN(BDIVA_AMP),
            MAD.BDIVA_AMP=MAD(BDIVA_AMP),
            CV.BDIVA_AMP = MAD(BDIVA_AMP)/MEDIAN(BDIVA_AMP),

            MEDIAN.P72 = MEDIAN(P72),
            MAD.P72 =MAD(P72),
            CV.P72 = MAD(P72)/MEDIAN(P72),

            MEDIAN.TMIN = MEDIAN(TMIN),
            MAD.TMIN =MAD(TMIN),
            CV.TMIN = MAD(TMIN)/MEDIAN(TMIN),

             MEDIAN.BT = MEDIAN(BT),
            MAD.BT=MAD(BT),
            CV.BT = MAD(BT)/MEDIAN(BT),

            MEDIAN.P_RATIO = MEDIAN(P_RATIO),
            MAD.P_RATIO =MAD(P_RATIO),
            CV.P_RATIO = MAD(P_RATIO)/MEDIAN(P_RATIO),

            MEDIAN.W_RATIO = MEDIAN(W_RATIO),
            MAD.W_RATIO =MAD(W_RATIO),
            CV.W_RATIO = MAD(W_RATIO)/MEDIAN(W_RATIO))

# FILTERING THE DATA FOR DEMOGRAPHICS ONLY
DEMOGRAPHICS <- SOME_STATS_BY_PARTICIPANTS[ , C(1:6)]
```

```r
# number of observations per gender, ethnicity and group
# note: observations can come from the same participant
library(ggplot2)
library(ggpubr)
theme_set(theme_pubr())

count.data.1<-with(demographics , ftable(Gender, Group, Ethnicity))
count.data<-as.data.frame(count.data.1)
names(count.data)[4] <- c('Count')

ggplot(count.data, aes(x = Gender, y = Count))+
  geom_bar(
    aes(fill = Ethnicity), stat = "identity", color = "white",
    position = position_dodge(0.9)
  )+
  facet_wrap(~Group) +
  fill_palette("jco")
```



Notice participants a25b and c66 have missing values in p72, Tmin, BT, p_ratio and w_ratio metrics.

How many taking and not taking medication by group:

```r
with(demographics , ftable(Medication, Group))
```

```
##            Group ASD Control ADHD
## Medication
```

```
## not taken          49      60   14
## taken               8       0    1
```

Other summary statistics

```
summary(demographics)
```

```
##   Participant        Age            Gender            Ethnicity       Medication
##  C010   :  2   Min.   : 5.40   Male  :83   Caucasian     :95   not taken:123
##  a10    :  1   1st Qu.:10.25   Female:49   Asian         :24   taken    :  9
##  a100   :  1   Median :13.30              Afro-Caribbean: 2
##  a20    :  1   Mean   :13.62              Latino        : 2
##  a21    :  1   3rd Qu.:15.97              Mixed         : 9
##  a22    :  1   Max.   :27.30
##  (Other):125
##      Group
##  ASD    :57
##  Control:60
##  ADHD   :15
##
##
##
##
```

```
# For the numeric variable 'Age'...
library(psych)
describeBy(demographics$Age)
```

```
##    vars   n  mean  sd median trimmed  mad min  max range skew kurtosis   se
## X1    1 132 13.62 4.6   13.3   13.33 4.45 5.4 27.3  21.9 0.58     0.16 0.4
```

```
# Age per group ::::::::::::::::::::::::::::::::::
# A library to get nice colour combinations
library(paletteer)
# Checking the colour codes from a selected package and colour range
# All colours are here: https://github.com/EmilHvitfeldt/r-color-palettes
paletteer_d("ggsci::lanonc_lancet")
```

```
## <colors>
## #00468BFF #ED0000FF #42B540FF #0099B4FF #925E9FFF #FDAF91FF #AD002AFF #A
DB6B6FF #1B1919FF
```

```
picked.colours <-c('#925E9FFF', '#ADB6B6FF', '#ED0000FF')

boxplot(Age ~ interaction(Group,Gender),
        main='Ages by group and gender',
        notch=T, xlab='Gender',
        ylab='Age', xaxt='n',
        col=picked.colours,lwd=1, pch=22, data = demographics)
# line showing the grand median age
```

```r
abline(h=median(demographics$Age), col='grey',lty=2)


# Changing x axis so that the labels for gender are shown
# underneath the second group in each gender group
xtick<-c(2,5)
axis(side=1, at=xtick, labels = FALSE)
text(x=xtick,  y=1, # tick location on the y axis
     labels = levels(demographics$Gender), srt = 0, pos = 1, xpd = TRUE)

# a legend
legend('topleft', border='black', bty='n',
       legend=levels(demographics$Group),
       fill=picked.colours,
       cex=1)
```

Missing values in the PhNR-related metrics (i.e. p72 to w_ratio) don't enable estimations. Hence, those participants with missing data will be removed when analyses are performed.

```r
# The NAs can be appreciated in the HTML version of this report
some_stats_by_participants
```

```
## # A tibble: 132 x 36
## # Groups:   Participant, Age, Gender, Ethnicity, Medication [132]
##    Participant   Age Gender Ethnicity Medication Group median.A.time MAD.A.time
##    <fct>       <dbl> <fct>  <fct>     <fct>      <fct>         <dbl>      <dbl>
```

```
##  1 a10          10.9 Male   Caucasian taken      ASD            11.6      1.52
##  2 a100         15.3 Male   Caucasian not taken  ASD            12.4      1.19
##  3 a20           8.2 Male   Caucasian not taken  ASD            11.1      1.10
##  4 a21          10.3 Male   Caucasian not taken  ASD            11.2      0.854
##  5 a22           8.3 Male   Caucasian not taken  ASD            11.3      0.992
##  6 a23b          6   Male   Caucasian not taken  ASD            11.3      0.917
##  7 a25b         14.8 Male   Caucasian not taken  ASD            11.8      1.38
##  8 a27          16.5 Male   Caucasian not taken  ASD            11.3      0.708
##  9 a28          15.5 Male   Caucasian not taken  ASD            11.4      1.71
## 10 a29           9.5 Male   Caucasian not taken  ASD            11.8      1.29
## # ... with 122 more rows, and 28 more variables: CV.A.time <dbl>,
## #   median.A.amp <dbl>, MAD.A.amp <dbl>, CV.A.amp <dbl>, median.B.time <dbl>,
## #   MAD.B.time <dbl>, CV.B.time <dbl>, median.B.amp <dbl>, MAD.B.amp <dbl>,
## #   CV.B.amp <dbl>, median.bdiva_amp <dbl>, MAD.bdiva_amp <dbl>,
## #   CV.bdiva_amp <dbl>, median.P72 <dbl>, MAD.P72 <dbl>, CV.P72 <dbl>,
## #   median.Tmin <dbl>, MAD.Tmin <dbl>, CV.Tmin <dbl>, median.BT <dbl>,
## #   MAD.BT <dbl>, CV.BT <dbl>, median.p_ratio <dbl>, MAD.p_ratio <dbl>,
## #   CV.p_ratio <dbl>, median.w_ratio <dbl>, MAD.w_ratio <dbl>, CV.w_ratio <dbl>
```

Statistical analyses

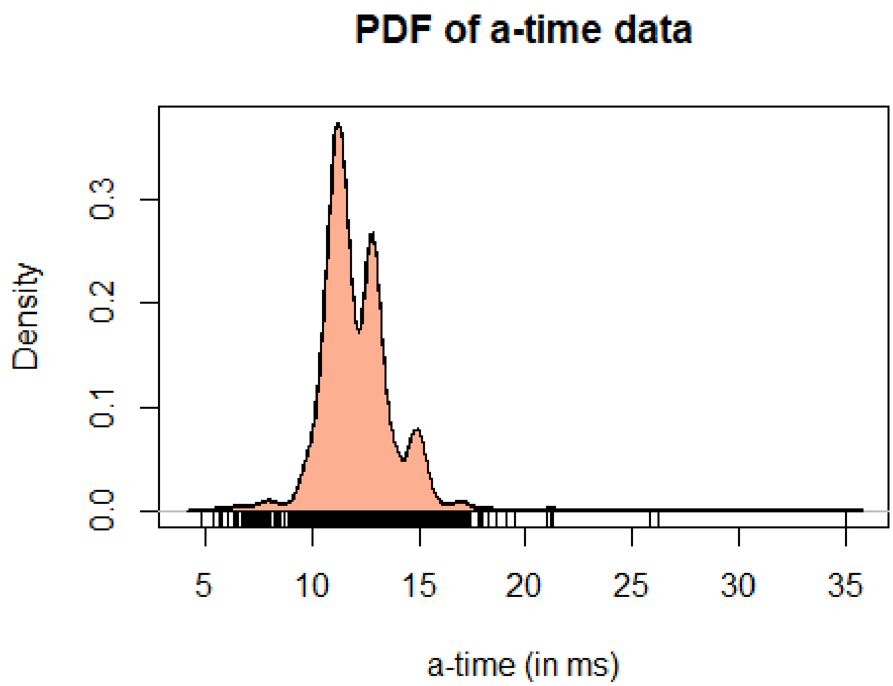
The analyses encompass two stages: EDA and CDA.

Exploratory data analyses

Continuous variables are visualized.

a-time

```
# Raw distributions of the dependent variable
# i.e. all observations per participant across all conditions
plot(density(ADHD2$a_time),lwd=2, main='PDF of a-time data',
     xlab='a-time (in ms)')
polygon(density(ADHD2$a_time), col='#FDAF91FF')
rug(ADHD2$a_time)
```

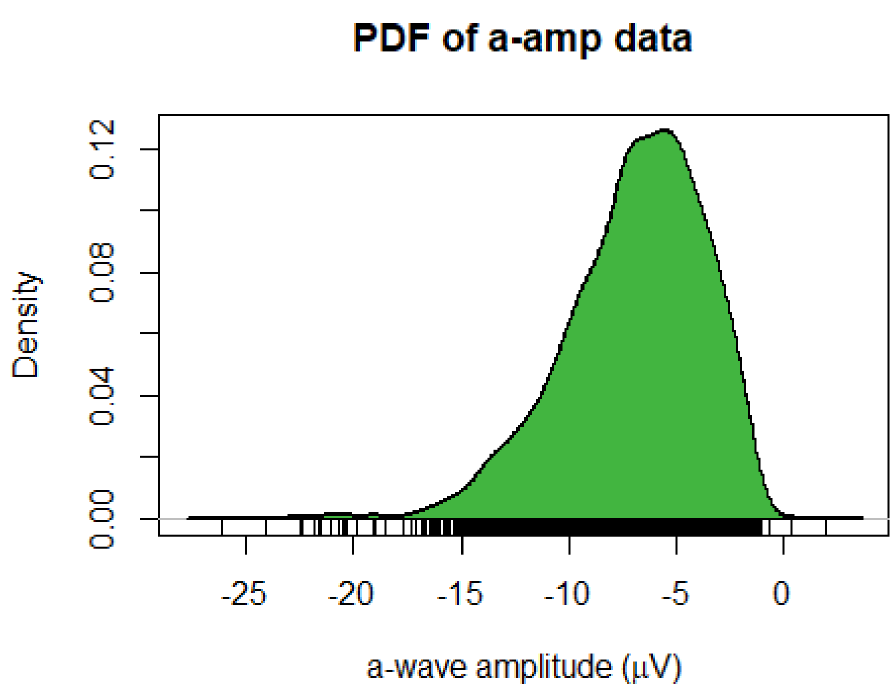



```
# BOXPLOT STATS....
BOXPLOT.STATS(ADHD2$A_TIME)

## $STATS
## [1]  8.31416 11.07760 11.75430 12.92690 15.68090
##
## $N
## [1] 3838
##
## $CONF
## [1] 11.70714 11.80146
##
## $OUT
##   [1] 16.34730 17.35030  7.72588  8.19002  6.04885  6.67709  7.69348 16.7
1290
##   [9] 35.03710 26.20260 15.77560 17.04080  6.81153 17.01520  5.36272  7.7
4499
##  [17]  5.70220  7.74491  8.19972  8.23649  6.44397 17.84690 16.19100 16.4
8540
##  [25] 17.12540 16.12300  7.13935  7.45241 16.73910  5.74908 17.18520 17.
82900
##  [33] 16.88500  7.93828 17.78510 16.52800 17.05930  6.96250 18.21870 16.
92840
##  [41]  6.47867 15.91560 17.16830  6.44499  8.27566 25.87900 16.95830 16.
32170
```

```
##  [49] 15.81990 15.72280 15.98890 20.96060 16.89680  7.20853 16.61930 16.
03090
##  [57]  7.54315 21.23880  7.86395  7.79417  7.39360 15.88950 16.19910 17.0
1730
##  [65]  7.94488  7.45065  8.00396 17.28440  7.18458  7.91044 18.60950  7.2
4791
##  [73]  7.85205  8.03560  7.95510  7.89865 17.94340 19.49130 16.88280 16.7
1490
##  [81]  4.83707 16.91530  6.90330  7.43813 15.90000  8.21021 16.75270 17.3
9080
##  [89] 17.17520 15.81880 16.05040  7.08374  6.79633  6.55052 21.29300  6.5
0126
##  [97]  7.84634  7.88943  8.07939  6.57316 15.94890 19.10490 16.78030 16.2
4130
## [105] 17.86250 16.95510  7.86070 17.21890  6.35874
```

a-amp

```
# RAW DISTRIBUTIONS OF THE DEPENDENT VARIABLE
# I.E. ALL OBSERVATIONS PER PARTICIPANT ACROSS ALL CONDITIONS
PLOT(DENSITY(ADHD2$A_AMP, NA.RM = T),LWD=2,
     MAIN='PDF OF A-AMP DATA',
     XLAB=EXPRESSION(PASTE('A-WAVE AMPLITUDE (',MU,'V)')))
POLYGON(DENSITY(ADHD2$A_AMP, NA.RM = T), COL='#42B540FF')
RUG(ADHD2$A_AMP)
```

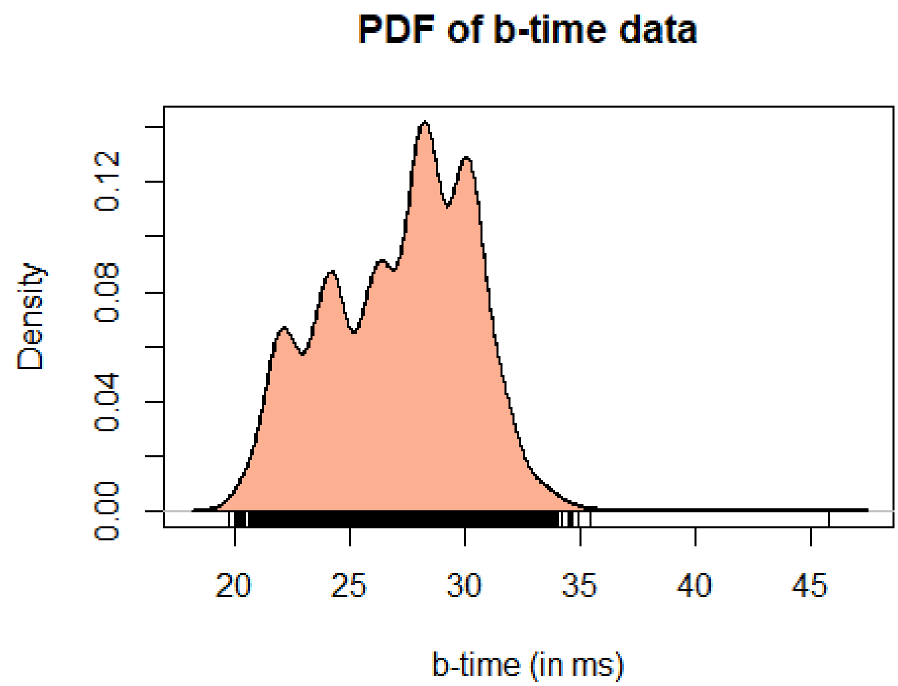


```
# boxplot-rule estimations
boxplot.stats(adhd2$a_amp)
```

```
## $stats
## [1] -15.29680  -8.82384  -6.50713  -4.49062   2.00000
##
## $n
## [1] 3838
##
## $conf
## [1] -6.617644 -6.396616
##
## $out
##  [1] -20.3727 -21.7918 -20.5013 -19.0641 -16.8458 -24.1295 -19.1400 -21.
6277
##  [9] -21.5294 -16.3795 -19.8317 -15.5705 -15.6357 -16.3216 -22.5304 -16.
1605
## [17] -16.7642 -16.0310 -15.7090 -18.9625 -15.8351 -26.1324 -17.6493 -16.
0902
## [25] -15.5376 -16.0069 -16.2286 -16.0215 -15.5302 -16.6732 -15.5893 -17.
2738
## [33] -21.0658 -15.4994 -16.8612 -15.5427 -15.6789 -17.1680 -22.4206 -18.
9974
## [41] -15.6394 -18.5080 -16.1770 -16.7873 -16.4373 -16.8114 -15.8140 -20.
6849
## [49] -20.3770
```

b-time

```
# Raw distributions of the dependent variable
# i.e. all observations per participant across all conditions
plot(density(adhd2$b_time),lwd=2, main='PDF of b-time data',
     xlab='b-time (in ms)')
polygon(density(adhd2$b_time), col='#FDAF91FF')
rug(adhd2$b_time)
```

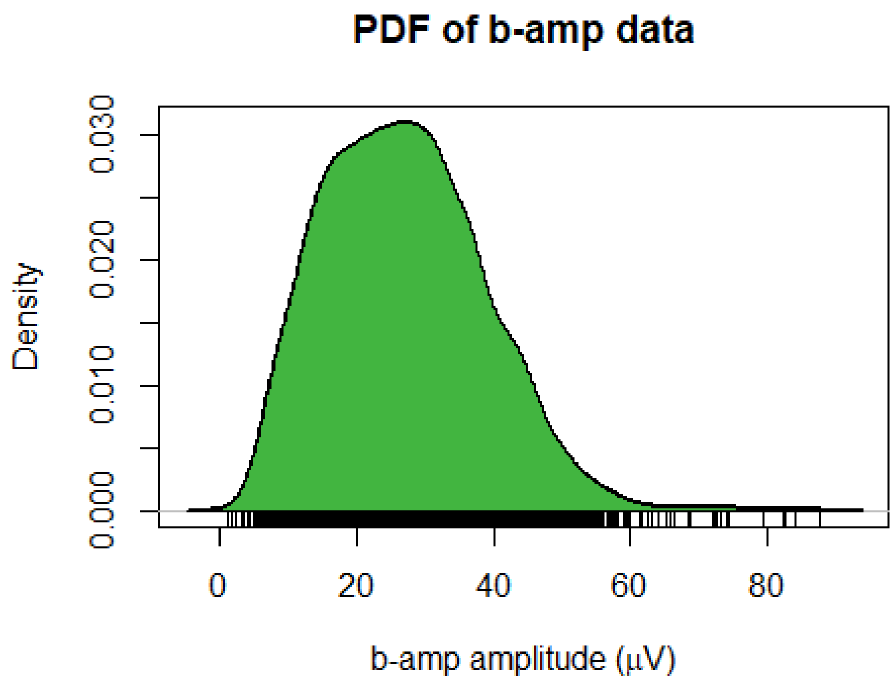



```
# Boxplot stats....
boxplot.stats(adhd2$b_time)
```

```
## $stats
## [1] 19.7365 24.4940 27.7566 29.7330 35.3851
##
## $n
## [1] 3838
##
## $conf
## [1] 27.62299 27.89021
##
## $out
## [1] 45.7958
```

b-amp

```
# Raw distributions of the dependent variable
# i.e. all observations per participant across all conditions
plot(density(adhd2$b_amp),lwd=2, main='PDF of b-amp data',
     xlab=expression(paste('b-amp amplitude (',mu,'V)')))
polygon(density(adhd2$b_amp), col='#42B540FF')
rug(adhd2$b_amp)
```



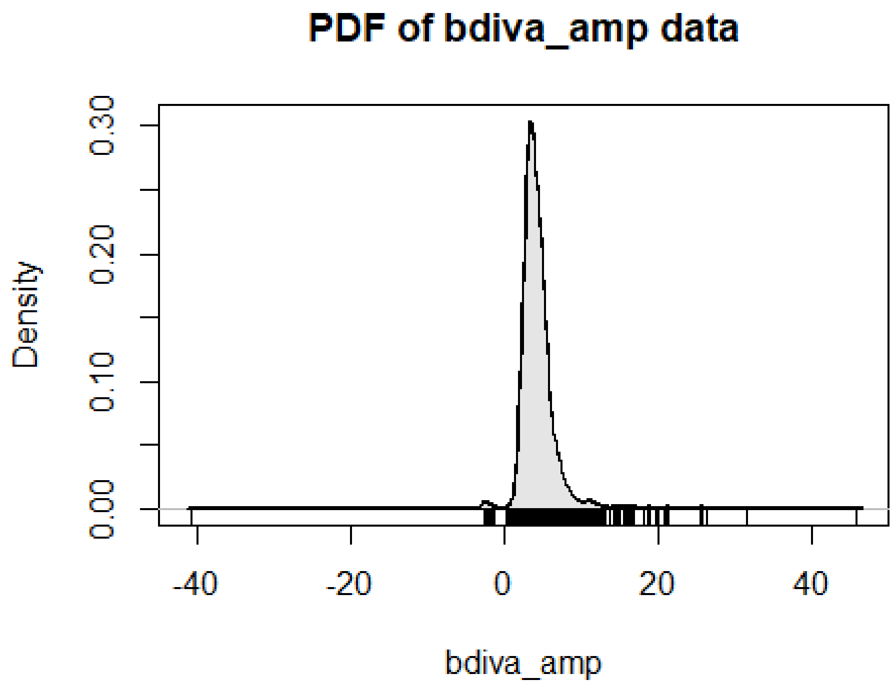

```
# BOXPLOT STATS....
BOXPLOT.STATS(ADHD2$B_AMP)
```

```
## $STATS
## [1]  1.14624 17.88850 26.29640 34.65750 59.78970
##
## $N
## [1] 3838
##
## $CONF
## [1] 25.86873 26.72407
##
## $OUT
##  [1] 61.8612 72.0574 72.5994 87.8044 84.1636 74.5560 74.3620 71.9850 68.
5063
## [10] 64.1651 72.3103 82.4112 82.6290 79.4384 65.7154 68.6895 74.2887 73.
1941
## [19] 63.2368 61.5642 66.3653 65.1453 68.5959 62.4865 59.8585
```

bdiva_amp

```
# RAW DISTRIBUTIONS OF THE DEPENDENT VARIABLE
# I.E. ALL OBSERVATIONS PER PARTICIPANT ACROSS ALL CONDITIONS
PLOT(DENSITY(ADHD2$BDIVA_AMP),LWD=2, MAIN='PDF OF BDIVA_AMP DATA',
     XLAB='BDIVA_AMP')
```

```
POLYGON(DENSITY(ADHD2$BDIVA_AMP), COL='GREY90')
RUG(ADHD2$BDIVA_AMP)
```



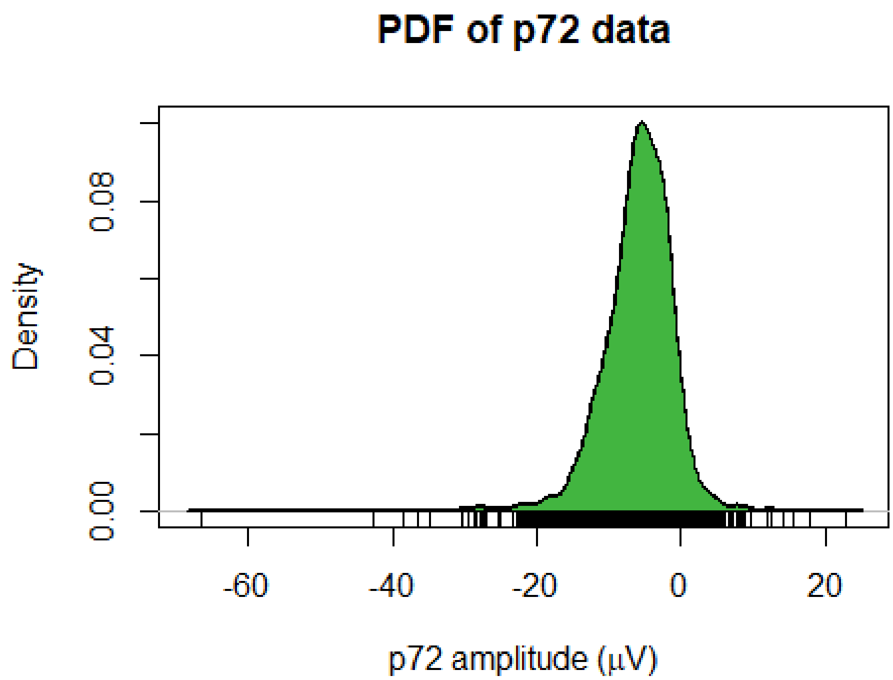

```
# BOXPLOT STATS....
BOXPLOT.STATS(ADHD2$BDIVA_AMP)
```

```
## $STATS
## [1] 0.2630554 3.0969657 3.9269973 5.0022624 7.8536998
##
## $N
## [1] 3838
##
## $CONF
## [1] 3.878405 3.975590
##
## $OUT
##   [1]   8.344445  13.105729   9.910406   8.290847  -1.475795  -1.484971
##   [7]  -1.827431  -1.973582  -2.536376  -2.475432  -2.692258  -2.711497
##  [13]  -2.443083  -2.603154  -2.593637  -2.673757  -2.602079  -1.322047
##  [19]  -1.609389  -1.781186  -1.971798  -2.421666  -2.536065  -2.204415
##  [25]  -2.673305  -2.352577  -2.478081  -2.546698  13.771486   8.339462
##  [31]   8.224896   9.861995   9.888424   8.146019  15.668213   8.981235
##  [37]  11.182878  11.270445  14.188338   9.533721  26.302844   9.701805
##  [43]  12.136206  10.092195   9.813344  10.774509   7.975043  11.595360
##  [49]   8.795578   8.058174   9.228760  15.542119   8.824429   8.045289
```

```
## [55] 10.096211  8.202686  8.748828  8.363867  8.463773  8.405367
## [61]  8.914833  8.884487  9.734645  8.527386 13.022970 20.710088
## [67]  9.311557 25.534725  8.444708  8.651538 10.994024 19.618008
## [73] 31.446570 25.637763 11.142915 45.794767  9.050932 12.167646
## [79] 19.942657  9.243011  8.493424 -40.792284 11.954673 11.970318
## [85] 11.818766  8.109406  8.992740 10.047147 12.138112  8.014937
## [91]  9.300075  8.131839  8.176640  9.664472 15.924797  8.568712
## [97] 10.539528 10.906971 12.819848 18.131489  9.028865 14.555717
## [103] 18.802741 21.166694  9.629908  8.341635  9.917897  9.422353
## [109] 16.884715 16.311067  8.607804  8.855555 11.335768 18.943271
## [115]  8.375963  8.055415 11.556046  8.224439  8.527969  7.938424
## [121]  8.589055 10.995756 10.468718 12.318324 12.313601 16.646822
## [127] 10.856420 15.603894 18.549315 10.697048  8.440234  9.268201
## [133] 14.233209 12.901368 15.892117 11.126049  8.314616  9.899181
## [139] 12.831278  8.730829 10.734934  8.016218 14.774633 15.093218
## [145] 11.603903 10.745367  7.918063 11.295493  9.203931  8.622709
## [151]  8.562779  8.349513  8.049494 10.402947  7.934517  7.922826
## [157]  8.385213  9.037880 10.340742 10.799923  8.226945 12.464081
## [163] 11.345154 11.536198 10.247243 10.932139  7.881607  9.173397
## [169]  8.123582  9.196469  8.790085  8.284236 10.449788 11.711720
## [175] 25.533743 21.063667 11.388739 11.280199  8.916109 14.388024
## [181]  9.780421 10.627865 16.784580  8.160172  8.138586 10.560510
## [187]  7.862929
```

p72

```
# RAW DISTRIBUTIONS OF THE DEPENDENT VARIABLE
# I.E. ALL OBSERVATIONS PER PARTICIPANT ACROSS ALL CONDITIONS
PLOT(DENSITY(ADHD2$P72, NA.RM = T),LWD=2, MAIN='PDF OF P72 DATA',
     XLAB=EXPRESSION(PASTE('P72 AMPLITUDE (',MU,'V)')))
POLYGON(DENSITY(ADHD2$P72, NA.RM=T), COL='#42B540FF')
RUG(ADHD2$P72)
```

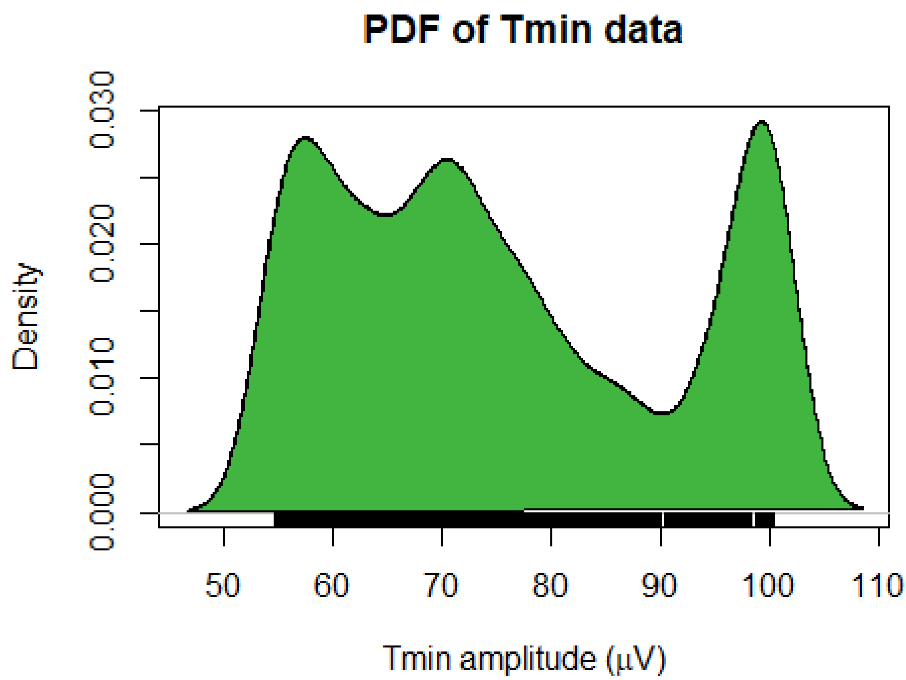



```
# BOXPLOT STATS....
BOXPLOT.STATS(ADHD2$P72)

## $STATS
## [1] -16.42910  -8.36482  -5.51289  -2.91996   5.17969
##
## $N
## [1] 3794
##
## $CONF
## [1] -5.652557 -5.373223
##
## $OUT
##   [1]   8.73921   5.95380   8.30402   5.25591 -17.64910   7.74753 -17.1674
0
##   [8] -18.66650 -16.54970 -16.60580 -17.93670 -22.48460 -18.16820   5.61
047
##  [15] -19.76740 -18.51570 -27.13430 -19.41600 -21.94580 -27.18210 -29.59
100
##  [22]   7.19230 -19.14660  14.11800   7.08100 -30.44900 -22.80790 -27.855
10
##  [29] -16.55570 -16.82230 -25.25660 -28.81600 -66.43920 -24.97240 -22.21
500
##  [36]  15.40810 -18.10890 -18.37430 -34.78170 -17.19040 -17.60790 -18.35
570
```

```
## [43]   9.78696   5.47272 -16.84330  22.89380  17.83660 -18.38550 -19.213
90
## [50]   7.19238 -18.52350 -38.60860 -21.24640   8.48391 -21.32900 -18.36
440
## [57] -36.64640 -18.71670 -23.44180 -28.42480 -19.99840 -21.78520 -27.62
630
## [64] -19.50020  12.41950 -20.96030   7.89408   6.83922 -19.44760 -29.659
40
## [71] -17.07740 -23.25620 -19.59210 -17.43220 -20.29040 -27.04270 -18.15
450
## [78] -42.73080   8.90494   8.35028 -28.76170   5.56143 -22.52440 -18.923
10
## [85] -21.78910 -16.76830 -17.47950   6.59860   5.25481  11.91390 -18.495
50
## [92] -16.91060 -20.49610 -22.57400 -18.75240 -21.38620 -21.26750 -20.25
190
## [99] -17.50400   7.69633 -18.13150 -17.39380 -17.72660 -17.36000 -16.99
750
```

Tmin

```
# Raw distributions of the dependent variable
# i.e. all observations per participant across all conditions
plot(density(adhd2$Tmin, na.rm = T),lwd=2, main='PDF of Tmin data',
     xlab=expression(paste('Tmin amplitude (',mu,'V)')))
polygon(density(adhd2$Tmin, na.rm=T), col='#42B540FF')
rug(adhd2$Tmin)
```

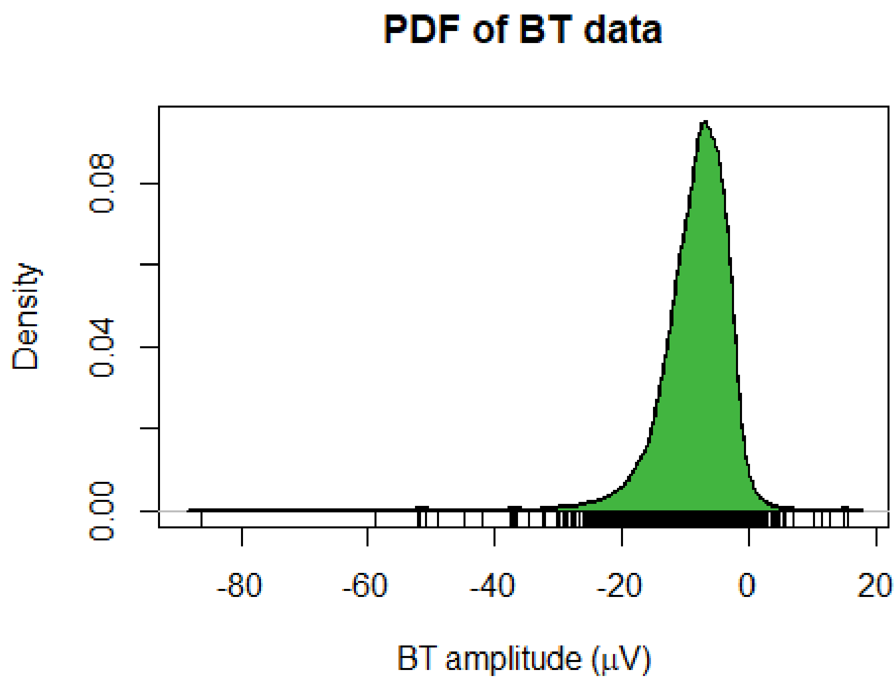



```
# boxplot stats....
boxplot.stats(ADHD2$Tmin)
```

```
## $stats
## [1]  54.62660  62.09700  72.20255  91.38910 100.37300
##
## $n
## [1] 3794
##
## $conf
## [1] 71.45117 72.95393
##
## $out
## numeric(0)
```

BT

```
# Raw distributions of the dependent variable
# i.e. all observations per participant across all conditions
plot(density(ADHD2$BT, na.rm = T),lwd=2, main='PDF of BT data',
     xlab=expression(paste('BT amplitude (',mu,'V)')))
polygon(density(ADHD2$BT, na.rm=T), col='#42B540FF')
rug(ADHD2$BT)
```

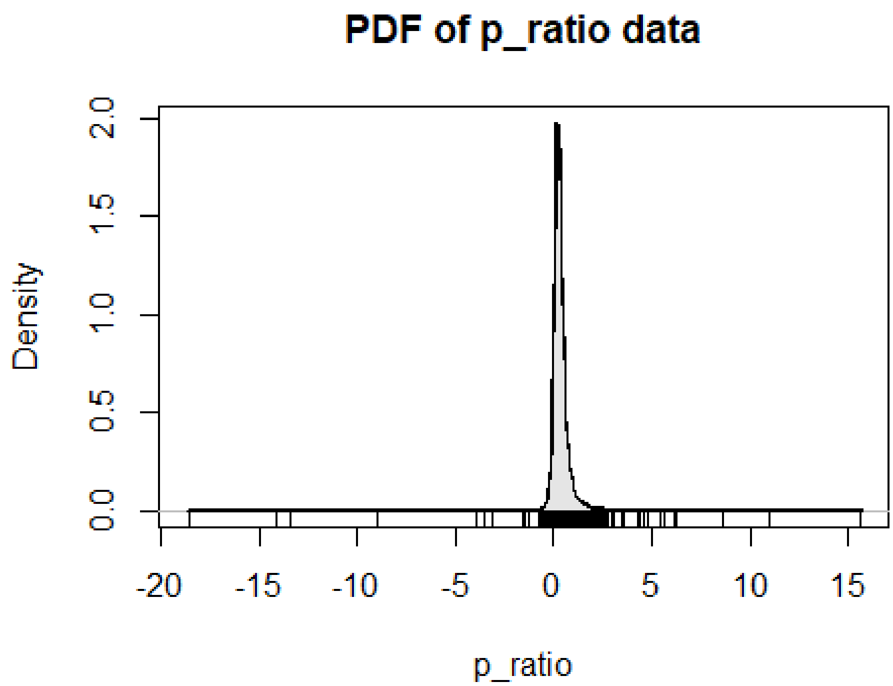



```
# BOXPLOT STATS....
BOXPLOT.STATS(ADHD2$BT)

## $STATS
## [1] -19.64500 -10.81890  -7.56148  -4.92633   3.89584
##
## $N
## [1] 3794
##
## $CONF
## [1] -7.712632 -7.410328
##
## $OUT
##   [1]   5.82591 -21.74970 -21.66850   3.98969 -21.41900 -19.94930 -19.695
70
##   [8]   4.69270 -25.13350 -21.44230 -20.82950 -25.60860 -22.35230 -20.73
970
##  [15] -25.67300 -26.03060 -25.28880 -19.77250 -24.90990 -23.60480 -27.71
880
##  [22] -27.55370 -27.49130 -30.35490 -22.22620 -42.12620 -19.96090 -23.69
860
##  [29]  11.48300 -37.00110 -21.37390 -23.90190 -37.07050 -25.46680 -51.97
550
##  [36] -24.14910 -86.28970 -27.20650 -28.99250  12.77690 -37.49390 -29.81
650
```

```
##  [43] -20.87640 -52.08530 -32.34960 -20.07730 -21.13400 -22.23450 -21.81
930
##  [50] -20.70730 -24.39710 -21.00050 -20.62200  14.91560  15.47190 -25.00
080
##  [57] -28.97370 -20.73860 -32.00610 -58.88300 -26.01050 -28.08830 -24.27
930
##  [64] -44.83850 -24.03430 -25.39000 -28.79250 -20.40610 -22.19690 -34.71
870
##  [71] -19.78570  10.04500 -22.54600 -20.54460 -21.01580 -24.78210 -27.23
170
##  [78] -22.44470 -30.16490 -25.80600 -36.67950 -28.75180 -22.51280 -24.58
210
##  [85] -30.21250 -21.54230 -23.10040 -22.96790 -20.18340 -23.80050 -22.82
980
##  [92] -27.29150 -20.33320 -29.17140 -21.13470 -20.65050 -49.07240   4.55
148
##  [99] -50.85400 -22.07170 -19.81430 -23.14340 -21.76760 -21.84900 -21.46
670
## [106] -21.23020   5.30965 -19.81410 -20.10820 -24.11160 -22.88860 -22.67
910
## [113] -20.66400 -20.13750 -22.54370 -23.30030 -26.65500   7.12090 -20.15
990
## [120] -20.20600 -21.21860 -19.70350
```

p_ratio

```
# RAW DISTRIBUTIONS OF THE DEPENDENT VARIABLE
# I.E. ALL OBSERVATIONS PER PARTICIPANT ACROSS ALL CONDITIONS
PLOT(DENSITY(ADHD2$P_RATIO, NA.RM = T),LWD=2, MAIN='PDF OF P_RATIO DATA',
     XLAB='P_RATIO')
POLYGON(DENSITY(ADHD2$P_RATIO, NA.RM = T), COL='GREY90')
RUG(ADHD2$P_RATIO)
```



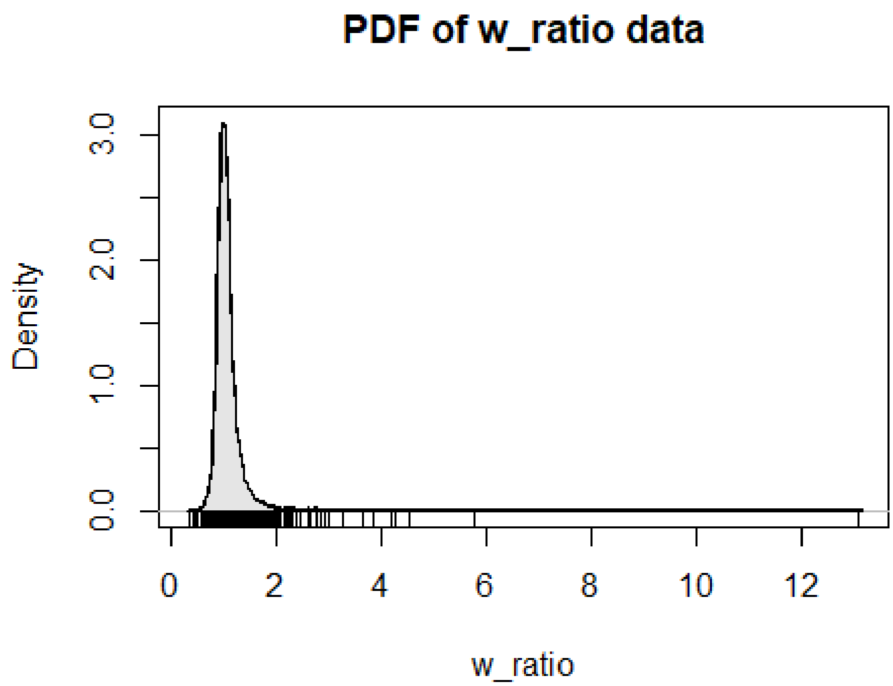

```
# BOXPLOT STATS....
BOXPLOT.STATS(ADHD2$P_RATIO)

## $STATS
## [1] -0.2767636  0.1571389  0.2820967  0.4548281  0.9012893
##
## $N
## [1] 3794
##
## $CONF
## [1] 0.2744606 0.2897328
##
## $OUT
##   [1]   1.7247565  -0.4437742  -0.5341654   1.9799010   1.6760014   3.0124
290
##   [7]   1.2069070   1.4933720   1.1605916   0.9379418   0.9434972   0.9641
728
##  [13]   1.5529642   0.9978250   1.2679353   1.4568411   1.3603506  -1.5864
629
##  [19]   1.2238907   4.2432203   2.9284341  -0.5753933  -0.3963504   1.093
4775
##  [25]   1.7716773  -0.7217340   1.1110015   1.2591330   2.2536852  -0.557
3453
##  [31]  -0.3418572  -0.5017965   1.5015005   3.5714047   0.9263062   2.301
2168
```

```
## [37]  1.3979990 -0.3065955 -0.2927620  2.5188589  1.0813155  4.551
2571
## [43]  1.5226964  2.3782213  0.9017886  1.0703176  1.6462121  1.3608
028
## [49]  1.2132733  1.2315938  1.1609888  2.6229765 -14.1660328  1.280
7127
## [55]  1.0291953 -1.4369175  1.0366672  1.1979092  -0.3812411  0.916
5193
## [61]  1.6448271  1.4659768 -0.3548900  1.0688094  1.8213991 -3.141
4635
## [67]  2.1977746  6.2649026 -0.3115042  6.1393666  0.9887230  0.9365
568
## [73]  1.3411641  1.7280345  1.1778259  1.8979182  8.5950413  1.2511
939
## [79]  1.8234007  1.3917117  1.3171254 -0.3032779  2.1418855  1.1142
365
## [85]  1.5482118  1.1422998  1.0174212  0.9920536  0.9063886  0.9644
310
## [91]  1.1709116  0.9828745  1.0640925  0.9405834  1.0866058  1.1554
035
## [97]  2.2862680  1.3499304  2.0071735  0.9448263  0.9071401  1.2816
558
## [103]  1.4330775  1.5466510  1.0450655  1.1031325  1.1783841  0.9710
912
## [109]  0.9479896  0.9435359 -0.6722544  1.2855902 -0.5893365  1.348
0954
## [115] -0.3870351  1.4917675  1.2934052  1.1403180  0.9323548  1.954
7962
## [121]  1.0581328  1.1889312  1.5368451  2.2324495  5.4153152  1.6596
061
## [127]  0.9820749  1.0350571  1.0345395 -0.3756292  2.1786439  1.081
8869
## [133]  1.3274609 -8.9358492  4.2911301  0.9074793 10.9437904  1.215
1337
## [139]  1.1311566  1.1793298  1.5031186  4.3956041  1.1056154  1.3736
427
## [145]  1.2335240  1.8785449  0.9142429  2.4870651  1.6236804  1.2972
873
## [151]  1.4872854  0.9453967  0.9250734 -0.6346120  0.9804219  1.361
3696
## [157]  1.4311236  0.9948655  0.9728363  1.1948761  1.2859056  1.8306
082
## [163]  1.2080711  1.0616264  0.9174181  0.9671122  1.2973467  1.4080
563
## [169]  2.7894585  0.9752969  3.4343507 -0.3018030  1.0774831  1.088
```

```
2846
## [175]   0.9790237  -0.4570580   1.1826260   1.6246707   1.3526071   1.307
3274
## [181]   2.0508363   0.9532999   1.1013153   1.3958769   1.0223899   1.2949
530
## [187]   1.5399523   2.4765828   1.5262674   1.0704653 -13.4553194  -3.574
1770
## [193]   4.8196554  15.5748739   1.0794698   2.1729786   1.6990633   0.990
8352
## [199]   0.9071897   1.0726362   1.4032482   1.7627167   0.9602426   0.9113
201
## [205]   0.9890760   1.2951483   0.9664804  -3.9532893  -0.4749303  -0.407
8935
## [211]   1.5587133  -0.3311976   0.9344515 -18.5831394   1.0499662   1.614
2374
## [217]   1.1279618   0.9778589   1.1739634   1.3352505   1.8792540   0.9234
144
## [223]  -0.5197540   0.9826844   1.6211706   1.0010139  -0.3104669  -1.248
9616
## [229]   1.6555948   0.9105136   1.5088527   1.9137678   0.9458219   1.5740
491
## [235]   1.5143375   0.9660182   1.0248535   1.2601521   1.4056718   0.9437
737
## [241]   0.9923837   2.1133161   1.3414265   0.9347077   1.0113457   0.9275
907
## [247]   1.4550277   1.7071835   1.0308467   1.0485873   0.9830213   2.0478
902
## [253]   1.2051088   1.0414071   1.0250123   1.2091171   1.3794203   1.0673
357
## [259]   1.5153335   1.7185737   0.9700752   0.9635893   1.0231063   0.9176
647
## [265]   1.3086052   1.0492818   0.9620767   5.5897779  -0.3549825   1.115
6973
## [271]   0.9452140   1.7850130   0.9210202   1.1115220   0.9239115   1.6596
202
## [277]   0.9771122   1.2473131   1.8024320   1.4357540
```

w_ratio

```
# RAW DISTRIBUTIONS OF THE DEPENDENT VARIABLE
# I.E. ALL OBSERVATIONS PER PARTICIPANT ACROSS ALL CONDITIONS
PLOT(DENSITY(ADHD2$W_RATIO, NA.RM = T),LWD=2, MAIN='PDF OF W_RATIO DATA',
     XLAB='W_RATIO')
POLYGON(DENSITY(ADHD2$W_RATIO, NA.RM = T), COL='GREY90')
RUG(ADHD2$W_RATIO)
```



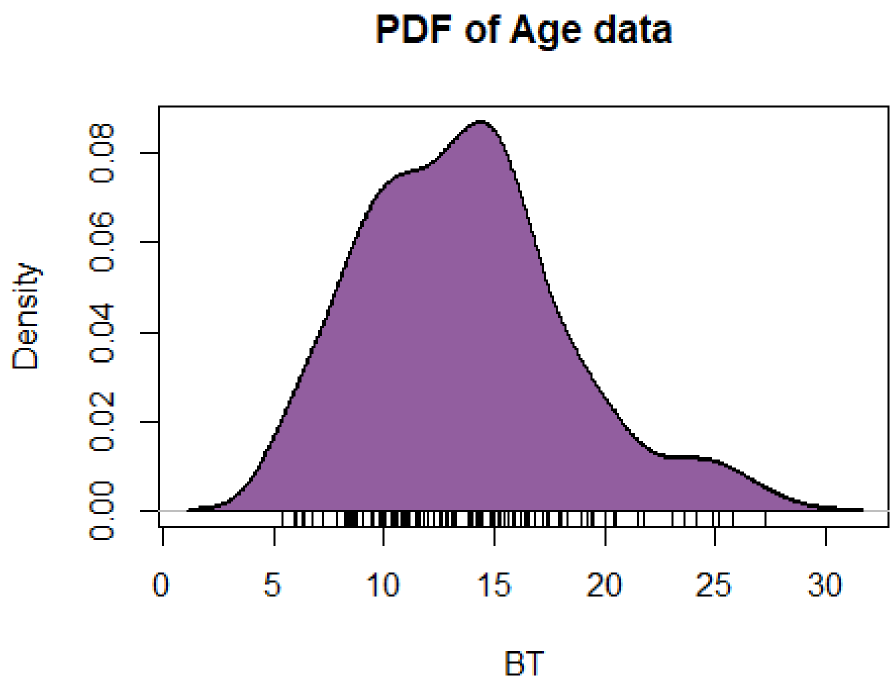

```
# BOXPLOT STATS....
BOXPLOT.STATS(ADHD2$W_RATIO)

## $STATS
## [1] 0.6840084 0.9559827 1.0371374 1.1401144 1.4155090
##
## $N
## [1] 3794
##
## $CONF
## [1] 1.032414 1.041861
##
## $OUT
##   [1]  2.9498000  0.5947723  1.5585282  1.4447824  1.5941221  1.4452467
##   [7]  4.5547881  1.5282221  1.4471924  0.6601689  1.7990608  1.5048442
##  [13]  2.2272191  1.6717196  1.4280497  2.0644524  0.3734299  1.5596570
##  [19]  1.7765058  1.5985264  1.4777364  1.4768921  1.7340012  1.5692552
##  [25]  1.4371694  1.7971402  1.4946373  0.5780306  0.6387066  1.9371622
##  [31]  1.4786880  1.5649234  1.5365224  1.6834344  1.4677513  1.6617597
##  [37]  0.6052530  1.6537390  1.4714724  1.5513666  1.4895351  2.7634497
##  [43]  1.5515090  1.6652274  1.4692929  1.4863349  1.4500705  2.4757831
##  [49]  1.7695715  1.4388305  1.4486547  1.6190431  1.5817671  1.4686652
##  [55]  5.7748775  1.6672450  1.4259591  1.8105340  1.5455927  1.5176361
##  [61]  1.6070715  1.7299253  2.0199041  1.4272962 13.0725241  2.2329483
##  [67]  2.6374953  0.6592145  1.6581326  3.8693888  2.3237131  1.4624696
```

```
## [73] 1.5484217 1.9795568 2.2037606 1.5168601 2.1655045 1.7464511
## [79] 1.8086711 3.6483107 2.6066809 1.6154199 1.4692268 1.5079281
## [85] 1.4323351 1.4568534 1.5019120 0.6700841 1.9136771 1.5360742
## [91] 1.5398055 1.5814410 1.8395510 1.4486215 1.4608388 1.7033226
## [97] 1.5432978 1.7339574 1.4201015 0.5234070 1.4902703 0.4628005
## [103] 1.5012165 1.4528497 1.4580152 1.5610175 1.5912229 1.5101830
## [109] 1.4625705 1.7450490 4.2122755 1.7424823 4.2666459 2.0517650
## [115] 1.5234847 2.2374122 1.4385163 1.4658389 1.4611228 1.5205473
## [121] 1.5245960 1.7385124 0.4254077 1.5821879 1.6463171 1.5640515
## [127] 1.6578172 1.4916284 1.9130807 1.8015157 2.1669996 1.9419523
## [133] 1.5812186 1.7413528 2.7586091 2.7756193 1.4300693 1.4709607
## [139] 1.7624357 1.8294380 2.2039378 2.0874238 1.7946895 1.8947845
## [145] 1.4722739 1.7408631 1.6144869 1.4643295 0.5944954 2.6433663
## [151] 1.5633334 1.4312847 1.4358023 1.4506325 1.6439725 1.9499772
## [157] 1.7292582 1.9478583 1.5606037 1.6152626 1.6742016 1.4928120
## [163] 1.4942188 1.4781873 1.7126104 2.3189685 1.5892657 1.9138397
## [169] 2.8386498 2.9993708 1.8676202 2.3925436 1.5027896 1.6145862
## [175] 1.6434776 1.5381806 1.4476124 3.2952535 1.5833011 1.8506526
## [181] 1.8820583 1.6190965 1.5121349 1.4237516 1.4704959 1.6524225
## [187] 2.2653458 0.6761301 1.8533379 1.4406344 1.5063165 1.6465999
## [193] 1.4924421 1.4278371 1.6957706 1.8552680 1.8405026 1.4862300
## [199] 1.6468178 1.5035063 2.2312024 1.4949732 1.5840220 1.8920289
## [205] 1.9716419 1.5826485 1.8456389 1.5115713 1.5573132 1.7581235
## [211] 1.4532487 1.5592442 1.7907000 1.9256904 1.5117003 1.7679474
## [217] 1.6850637 1.4417354 1.5520211 1.9288052 1.4537648 1.5455754
## [223] 1.4469548 0.6439744 0.6741737 1.7222304 0.6771486 0.6713772
## [229] 1.5625970 1.7026988 1.4579725 1.6226918 1.4799496 1.4682342
## [235] 1.5288303 1.9604940 1.5342600 1.4797400 1.5423900
```

Looking at some of the covariates...

This is the distribution of age.

```
PLOT(DENSITY(SOME_STATS_BY_PARTICIPANTS$AGE),
     LWD=2, MAIN='PDF OF AGE DATA',
     XLAB='BT')
POLYGON(DENSITY(SOME_STATS_BY_PARTICIPANTS$AGE), COL='#925E9FFF')
RUG(SOME_STATS_BY_PARTICIPANTS$AGE)
```




```
# SOME BOXPLOT-RULE INSPECTIONS...
BOXPLOT.STATS(SOME_STATS_BY_PARTICIPANTS$AGE)

## $STATS
## [1]  5.40 10.20 13.30 16.05 24.20
##
## $N
## [1] 132
##
## $CONF
## [1] 12.4955 14.1045
##
## $OUT
## [1] 25.2 25.8 24.9 27.3
```

Age doesn't distribute normally; it's rather, positively skewed. Particularly, one participant is clearly an outlier (age=47.3).

Checking for incomplete data and sticking to a complete data set

Some extra examination of the data set...

```
# THE FIRST IS TO CHECK THE SUMMARY DATA FRAME DOESN'T HAVE NAS (I.E. PARTICIPANTS
# WITH INCOMPLETE DATA)
SUM(!COMPLETE.CASES(SOME_STATS_BY_PARTICIPANTS))

## [1] 2
```

```r
# which are those participants?
some_stats_by_participants[rowSums(is.na(some_stats_by_participants)) > 0,]
```

```
## # A tibble: 2 x 36
## # Groups:   Participant, Age, Gender, Ethnicity, Medication [2]
##   Participant   Age Gender Ethnicity Medication Group median.A.time MAD.A.time
##   <fct>       <dbl> <fct>  <fct>     <fct>      <fct>         <dbl>      <dbl>
## 1 a25b         14.8 Male   Caucasian not taken  ASD            11.8      1.38
## 2 c66           6.3 Female Caucasian not taken  Cont~          11.4      0.618
## # ... with 28 more variables: CV.A.time <dbl>, median.A.amp <dbl>,
## #   MAD.A.amp <dbl>, CV.A.amp <dbl>, median.B.time <dbl>, MAD.B.time <dbl>,
## #   CV.B.time <dbl>, median.B.amp <dbl>, MAD.B.amp <dbl>, CV.B.amp <dbl>,
## #   median.bdiva_amp <dbl>, MAD.bdiva_amp <dbl>, CV.bdiva_amp <dbl>,
## #   median.p72 <dbl>, MAD.p72 <dbl>, CV.p72 <dbl>, median.Tmin <dbl>,
## #   MAD.Tmin <dbl>, CV.Tmin <dbl>, median.BT <dbl>, MAD.BT <dbl>, CV.BT <dbl>
,
## #   median.p_ratio <dbl>, MAD.p_ratio <dbl>, CV.p_ratio <dbl>,
## #   median.w_ratio <dbl>, MAD.w_ratio <dbl>, CV.w_ratio <dbl>
```

```r
incomp <- some_stats_by_participants[rowSums(is.na(some_stats_by_participants)) > 0,]

incomp.part<-as.character(incomp$Participant)
```

Two participants need to be culled as they have incomplete data.

So let's work with a complete data set that excludes those participants.

```r
# complete data set
adhd.complete<-adhd2[!(adhd2$Participant %in% incomp.part), ]
```

The following tables show the number of observations per participant, per eye and per flash strength (note that the excluded participants appear in the following tables and their counts are 0; but they don't show up in the actual analyses):

```r
with(adhd.complete, ftable(Participant, Eye, Strength))
```

```
##                      Strength -0.367 -0.119 0.114 0.398 0.477 0.602 0.799 0.949
 1.114 1.204
## Participant Eye

## a10         Right                  1      1     1     1     1     1     1     1
    1
##             Left                  1      1     1     1     1     1     1     1     1
    1
## a100        Right                  1      1     1     1     1     1     1     1     1
    1
##             Left                  1      1     1     1     1     1     1     1     1
    1
## a20         Right                  1      1     1     1     1     1     1     1     1
    1
```

```
##            Left            2    1    1    1    1    1    1    1    1
   1
## a21         Right           2    1    2    2    2    1    2    1    2
   1
##            Left            2    1    1    1    2    1    1    1    2
   1
## a22         Right           1    1    1    1    1    1    1    1    1
   1
##            Left            1    1    1    1    1    1    1    1    1
   1
## a23b        Right           0    1    1    0    0    1    1    1    1
   1
##            Left            0    0    0    0    0    0    0    0    0
   0
## a25b        Right           0    0    0    0    0    0    0    0    0
   0
##            Left            0    0    0    0    0    0    0    0    0
   0
## a27         Right           0    1    1    0    1    1    1    1    1
   0
##            Left            1    1    0    1    1    1    1    1    1
   1
## a28         Right           1    1    1    1    1    1    1    1    1
   1
##            Left            1    1    1    1    1    1    1    1    1
   1
## a29         Right           1    1    1    1    1    1    1    1    1
   1
##            Left            1    1    1    1    1    1    1    1    1
   1
## a3          Right           1    2    1    1    1    1    1    1    1
   1
##            Left            2    0    1    1    2    1    1    1    1
   1
## a31         Right           1    1    0    1    0    1    1    1    1
   1
##            Left            0    1    1    0    0    0    2    1    2
   0
## a32         Right           1    1    0    1    0    1    1    1    1
   1
##            Left            1    1    0    0    0    1    0    1    0
   2
## a33         Right           1    1    1    1    1    1    1    1    1
   1
##            Left            1    1    1    1    1    1    1    1    1
```

```
   1
## A34        RIGHT              1     2     1     1     1     1     1     0     1
   1
##            LEFT               2     1     1     1     1     1     1     1     1
   1
## A36        RIGHT              1     1     1     1     1     1     1     1     1
   1
##            LEFT               0     1     1     1     1     1     1     1     1
   1
## A37        RIGHT              1     0     1     1     1     1     1     1     1
   1
##            LEFT               1     1     1     1     0     1     1     1     1
   1
## A43        RIGHT              0     1     1     1     1     1     1     1     1
   1
##            LEFT               0     0     1     1     0     1     1     1     1
   1
## A46        RIGHT              1     0     1     1     1     1     1     0     1
   1
##            LEFT               1     1     0     1     1     1     1     1     1
   1
## A47        RIGHT              1     1     1     1     1     1     0     1     1
   1
##            LEFT               1     1     1     1     1     1     1     1     1
   1
## A48        RIGHT              1     1     1     1     1     1     1     1     1
   1
##            LEFT               1     1     1     1     1     1     1     1     1
   1
## A5         RIGHT              1     1     1     1     1     1     1     1     1
   1
##            LEFT               1     1     1     1     1     1     1     1     1
   1
## A52        RIGHT              1     1     1     1     1     1     1     1     1
   1
##            LEFT               1     1     1     1     1     1     1     1     1
   1
## A6         RIGHT              1     1     1     1     1     1     1     1     1
   1
##            LEFT               1     1     1     1     1     1     1     1     1
   1
## A60        RIGHT              1     1     1     1     1     1     1     1     1
   1
##            LEFT               1     1     1     1     1     1     1     1     1
   1
```

```
## A61       RIGHT          0    1    1    1    0    1    1    1    1
   1
##           LEFT           1    1    1    1    0    0    1    1    1
   1
## A7        RIGHT          2    1    1    1    1    1    1    1    1
   1
##           LEFT           1    1    1    1    1    1    1    1    1
   1
## A8        RIGHT          1    0    1    1    1    1    1    1    1
   1
##           LEFT           0    1    1    1    1    1    1    1    1
   1
## A9        RIGHT          1    1    1    1    1    1    1    1    0
   1
##           LEFT           1    1    1    1    1    1    1    1    1
   1
## AD01       RIGHT          2    2    2    2    2    2    2    2    2
    2
##           LEFT           2    1    1    2    2    2    1    1    1
   2
## AD03       RIGHT          1    2    2    2    2    2    2    2    2
    2
##           LEFT           1    2    2    1    3    2    2    2    2
   2
## AD04       RIGHT          2    2    2    2    2    2    2    2    2
    2
##           LEFT           2    2    2    2    1    2    2    2    2
   2
## AD05       RIGHT          2    2    2    2    2    2    2    2    2
    2
##           LEFT           1    2    2    1    2    1    2    1    1
   2
## AD06       RIGHT          2    1    2    2    2    2    2    2    2
    2
##           LEFT           2    2    3    1    2    2    3    1    2
   2
## AD07       RIGHT          2    2    2    2    2    2    2    3    2
    2
##           LEFT           2    2    1    2    1    1    1    1    3
   2
## AD08       RIGHT          2    3    2    2    2    2    2    3    2
    2
##           LEFT           2    2    2    2    2    2    2    2    2
   2
## AD08S1     RIGHT          0    0    0    0    0    0    0    0    0
```

```
    0
##          Left            1    1    3    2    1    2    2    2    1
   2
## AD09      Right           2    2    2    2    2    2    2    2    2
    2
##          Left            2    3    3    3    2    2    2    2    2
   2
## AD1      Right           1    2    1    1    2    1    2    2    2
   1
##          Left            2    1    2    1    2    1    1    2    2
   1
## AD10      Right           3    2    2    2    2    2    2    2    2
    2
##          Left            2    2    2    2    1    2    2    4    2
   2
## AD13      Right           2    2    2    2    2    2    2    2    2
    2
##          Left            1    2    3    2    2    2    2    2    2
   2
## AD14      Right           2    1    2    2    2    2    2    2    2
    2
##          Left            3    3    2    2    2    2    2    2    2
   2
## AD15      Right           2    2    2    2    2    2    2    2    2
    2
##          Left            2    1    2    2    2    2    2    2    2
   1
## C001      Right           2    2    2    2    2    2    2    2    2
    2
##          Left            2    2    2    2    2    2    2    2    2
   2
## C002      Right           2    2    2    2    2    2    2    2    2
    2
##          Left            2    2    2    2    1    2    2    2    2
   2
## C003      Right           2    2    2    2    1    2    2    2    2
    2
##          Left            2    2    2    2    2    2    2    2    2
   2
## C004      Right           2    2    2    2    2    2    2    2    2
    2
##          Left            2    2    2    2    2    2    2    2    2
   2
## C005      Right           2    2    2    2    2    2    2    2    2
    2
```

```
##            LEFT              2     2     2     2     2     2     2     2     2
   2
## C006        RIGHT              1     2     2     2     2     2     2     2     2
    2
##            LEFT              2     2     2     2     2     2     2     2     2
   2
## C007        RIGHT              2     2     2     2     2     2     2     2     3
    2
##            LEFT              2     3     2     2     2     2     2     2     2
   3
## C008        RIGHT              2     2     2     2     0     2     2     1     2
    2
##            LEFT              2     3     2     2     2     2     2     2     2
   2
## C009        RIGHT              2     2     1     2     2     2     2     2     2
    2
##            LEFT              2     2     2     2     2     2     2     2     2
   2
## C010        RIGHT              2     2     2     2     2     2     2     2     2
    2
##            LEFT              2     3     2     2     2     2     2     2     2
   2
## C011        RIGHT              2     2     0     2     1     2     4     4     2
    2
##            LEFT              4     2     2     3     1     4     2     1     2
   2
## C012        RIGHT              2     3     2     2     2     2     2     2     2
    2
##            LEFT              2     2     2     2     2     2     2     2     2
   2
## C013        RIGHT              2     3     2     2     2     2     2     2     2
    2
##            LEFT              2     2     2     2     2     2     2     2     2
   2
## C014        RIGHT              2     2     2     2     2     2     2     2     2
    2
##            LEFT              2     2     2     2     2     2     2     2     2
   2
## C018        RIGHT              2     2     2     2     3     2     2     2     2
    2
##            LEFT              2     2     2     2     1     2     2     2     2
   2
## C019        RIGHT              2     2     2     2     2     2     2     2     2
    2
##            LEFT              2     2     2     2     2     2     2     2     2
```

```
   2
## C020       RIGHT             2     2     2     2     2     2     1     2     2
    2
##           LEFT             3     2     2     2     2     2     2     2     2
   2
## C021       RIGHT             2     2     2     2     2     2     2     2     2
    2
##           LEFT             2     2     2     2     2     2     2     2     2
   2
## C022B      RIGHT             3     1     1     2     2     1     1     1     1
    2
##           LEFT             2     2     2     1     2     2     2     2     2
   2
## C023       RIGHT             3     2     2     2     2     2     2     2     2
    2
##           LEFT             2     2     2     2     2     2     2     2     2
   2
## C024       RIGHT             2     2     2     2     2     2     2     2     2
    2
##           LEFT             2     2     2     2     2     2     2     2     2
   2
## C025       RIGHT             2     2     2     2     2     2     2     2     2
    2
##           LEFT             2     2     2     2     2     2     2     2     2
   2
## C027       RIGHT             2     2     2     2     2     2     2     2     2
    2
##           LEFT             2     1     1     1     2     1     1     1     1
   1
## C029       RIGHT             3     2     2     2     2     3     2     2     2
    2
##           LEFT             2     2     2     2     2     2     2     2     2
   2
## C033       RIGHT             2     2     2     2     2     2     2     2     2
    2
##           LEFT             2     2     2     2     2     2     2     2     2
   2
## C034       RIGHT             2     2     2     2     2     2     2     2     2
    2
##           LEFT             2     2     2     2     2     2     2     2     2
   3
## C047       RIGHT             2     2     2     2     2     2     2     2     2
    2
##           LEFT             3     2     2     2     2     2     2     2     2
   2
```

```
## C049        RIGHT            2      1      1      1      2      1      1      2      1
   1
##             LEFT            3      1      1      1      3      1      1      1      1
   1
## C050        RIGHT            2      1      1      2      1      1      1      1      1
   2
##             LEFT            2      2      1      1      1      1      1      1      2
   1
## c1          RIGHT           1      1      1      1      1      1      1      1      1
   1
##             LEFT            1      1      1      1      1      1      1      1      1
   1
## c105        RIGHT           1      1      1      1      1      1      1      1      1
   1
##             LEFT            1      1      1      1      1      1      1      1      1
   1
## c11max      RIGHT           1      1      1      1      2      1      1      1      1
   1
##             LEFT            1      1      1      1      1      1      1      1      1
   1
## c14         RIGHT           1      1      1      1      1      1      1      1      1
   1
##             LEFT            1      1      1      1      1      1      1      1      1
   1
## c2          RIGHT           1      1      1      1      1      1      1      1      1
   1
##             LEFT            1      1      1      1      1      1      1      1      1
   2
## c3          RIGHT           2      0      1      1      1      1      1      1      1
   1
##             LEFT            1      1      1      1      1      1      1      1      1
   1
## c4          RIGHT           1      1      1      1      1      1      1      1      1
   1
##             LEFT            1      1      1      1      1      1      1      1      1
   1
## c40         RIGHT           1      1      1      1      1      1      1      1      1
   1
##             LEFT            1      1      1      1      1      1      1      1      1
   1
## c400        RIGHT           1      1      1      1      1      1      1      1      1
   1
##             LEFT            1      1      1      1      1      1      1      1      1
   1
## c41         RIGHT           1      1      1      1      1      1      1      1      1
```

```
   1
##          Left            0    1    1    1    1    1    1    1    1
   1
## C43       Right           1    2    1    1    1    1    1    1    1
   1
##          Left            1    1    1    1    1    1    1    1    1
   1
## c44       Right           1    1    1    1    1    1    1    1    1
   1
##          Left            1    1    1    1    1    1    1    1    1
   1
## c5        Right           1    1    0    1    1    1    1    1    1
   1
##          Left            2    1    1    1    1    1    1    1    1
   1
## c50       Right           1    1    1    1    1    1    1    1    1
   1
##          Left            1    1    1    1    1    1    1    1    1
   1
## c52       Right           1    1    1    1    1    1    1    1    1
   1
##          Left            1    1    1    1    1    1    1    1    1
   1
## c53       Right           1    1    1    1    1    1    1    1    1
   1
##          Left            1    1    1    0    1    1    1    0    1
   1
## c55       Right           1    1    1    1    1    1    1    1    1
   1
##          Left            1    1    1    1    1    1    1    1    1
   1
## c6        Right           1    0    1    1    1    1    1    1    1
   1
##          Left            1    1    1    1    1    1    1    1    1
   1
## c61       Right           1    1    1    1    1    1    1    1    1
   1
##          Left            1    1    1    1    1    1    1    1    1
   1
## c64       Right           1    1    1    1    1    1    1    1    1
   1
##          Left            1    1    1    1    1    1    1    1    1
   1
## c65       Right           1    1    1    1    1    1    1    1    1
   1
```

```
##            LEFT              1    1    1    1    1    0    1    1    1
   1
## c66         RIGHT             0    0    0    0    0    0    0    0    0
   0
##            LEFT              0    0    0    0    0    0    0    0    0
   0
## c67         RIGHT             1    0    1    1    1    1    1    1    1
   1
##            LEFT              0    1    1    1    1    1    1    1    1
   1
## c68         RIGHT             1    1    1    1    1    1    1    1    1
   1
##            LEFT              1    1    1    1    1    1    1    1    1
   1
## c77         RIGHT             1    1    1    1    1    1    1    1    1
   1
##            LEFT              1    1    1    1    1    1    1    1    1
   1
## c78         RIGHT             1    1    1    1    1    1    1    1    1
   1
##            LEFT              1    1    1    1    1    1    1    1    1
   1
## c8         RIGHT             0    1    1    1    1    1    1    1    1
   1
##            LEFT              1    1    1    1    0    1    1    1    1
   1
## c80         RIGHT             1    1    1    1    1    0    1    1    1
   1
##            LEFT              2    1    1    1    1    1    1    1    0
   1
## c81         RIGHT             1    1    1    1    0    1    1    1    1
   1
##            LEFT              1    1    1    1    0    1    0    1    1
   1
## c83         RIGHT             1    1    1    1    1    1    1    1    1
   1
##            LEFT              1    1    1    1    1    1    1    1    1
   1
## c9         RIGHT             1    1    1    1    1    1    1    1    1
   1
##            LEFT              1    1    1    1    1    1    1    1    1
   1
## GA001        RIGHT             3    2    2    2    2    2    2    2    2
    3
##            LEFT              2    2    2    2    2    2    2    2    2
```

```
   2
## GA002b      Right             0     0    0    0    0    0    0    0    0
    0
##            Left             0     2    1    2    1    1    2    2    1
   1
## GA003b      Right             2     2    2    2    2    2    2    2    2
    2
##            Left             2     2    1    2    1    1    2    2    2
   1
## GA004       Right             3     2    2    2    2    2    2    2    2
    3
##            Left             2     2    2    2    2    2    2    2    2
   2
## GA006       Right             2     2    2    2    2    2    3    2    2
    2
##            Left             3     2    2    3    3    2    2    2    2
   2
## GA008       Right             2     2    2    2    2    2    2    2    2
    2
##            Left             2     2    2    2    2    2    2    2    2
   2
## GA010       Right             2     3    0    2    1    2    2    2    2
    2
##            Left             3     2    2    2    2    2    2    2    2
   2
## GA012       Right             2     2    2    2    2    2    2    2    2
    2
##            Left             1     1    2    2    2    1    2    2    2
   1
## GA014       Right             1     2    3    2    2    2    2    2    2
    2
##            Left             2     2    1    0    2    1    2    2    2
   2
## GA015       Right             2     2    2    2    2    2    2    2    2
    2
##            Left             2     2    2    2    2    1    2    2    2
   2
## GA017       Right             2     2    2    2    2    2    2    2    2
    2
##            Left             2     2    2    2    2    2    2    2    2
   2
## GA018       Right             2     2    2    2    2    2    2    2    2
    2
##            Left             2     2    2    2    2    2    2    2    2
   2
```

```
## GA019      Right          2    2    2    2    2    2    2    2    1
    2
##           Left          2    2    1    1    1    1    1    1    1
   1
## GA020      Right          2    2    2    2    1    2    2    2    2
    2
##           Left          2    2    1    1    1    1    3    2    2
   2
## GA021      Right          2    2    2    2    2    2    2    2    2
    2
##           Left          2    2    2    2    2    1    1    1    1
   1
## GA022      Right          0    2    3    2    1    2    2    2    2
    2
##           Left          2    2    2    2    2    1    1    2    2
   1
## GA023      Right          2    2    2    2    2    2    2    2    2
    2
##           Left          2    2    2    2    2    2    2    2    2
   3
## GA024      Right          1    1    2    2    2    2    2    2    2
    2
##           Left          2    1    1    2    2    2    1    1    2
   2
## GA027      Right          2    2    2    2    2    2    2    2    2
    2
##           Left          2    2    2    2    2    2    2    2    2
   2
## GA028      Right          2    2    2    1    2    2    2    1    2
    2
##           Left          2    1    1    1    2    1    2    1    1
   1
## GA029      Right          2    2    3    3    1    3    2    2    2
    2
##           Left          1    2    2    2    1    2    0    2    3
   2
## GA030      Right          2    2    2    2    2    2    2    2    2
    2
##           Left          2    2    2    2    2    2    2    2    2
   2
## GA031      Right          2    2    2    2    2    2    2    2    2
    2
##           Left          2    2    2    2    2    2    2    2    2
   2
## GA033      Right          3    2    2    2    2    2    3    2    2
```

```
    2
##           LEFT              1    2    2    2    1    1    2    2    2
   2
## GA037      RIGHT             2    2    2    2    2    2    2    2    2
    2
##           LEFT              2    2    1    2    2    2    2    2    2
   2
## GA038      RIGHT             2    2    2    2    2    2    1    2    2
    2
##           LEFT              2    1    2    2    1    2    2    1    1
   2
## GA039      RIGHT             2    2    2    2    2    2    2    2    2
    2
##           LEFT              2    2    2    1    1    2    1    2    2
   2
## GA040      RIGHT             2    2    2    2    0    2    2    2    2
    2
##           LEFT              2    2    2    1    1    1    1    2    1
   2
```

Given the low number of trials in the combination shown in the table, there is no sufficient information to estimate averages and dispersion per participant, per eye and per flash strength.

So dropping flash strength could help in seeing variability per eye and per participant.

```
# THIS IS WHAT A TABLE LOOKS LIKE IN THE CASE JUST DESCRIBED
WITH(ADHD.COMPLETE, FTABLE(PARTICIPANT, EYE))

##           EYE RIGHT LEFT
## PARTICIPANT
## A10            10   10
## A100           10   10
## A20            10   11
## A21            16   13
## A22            10   10
## A23B            7    0
## A25B            0    0
## A27             7    9
## A28            10   10
## A29            10   10
## A3             11   11
## A31             8    7
## A32             8    6
## A33            10   10
## A34            10   11
## A36            10    9
## A37             9    9
```

```
## A43                 9   7
## A46                 8   9
## A47                 9  10
## A48                10  10
## A5                 10  10
## A52                10  10
## A6                 10  10
## A60                10  10
## A61                 8   8
## A7                 11  10
## A8                  9   9
## A9                  9  10
## AD01               20  15
## AD03               19  19
## AD04               20  19
## AD05               20  15
## AD06               19  20
## AD07               21  16
## AD08               22  20
## AD08s1              0  17
## AD09               20  23
## AD1                15  15
## AD10               21  21
## AD13               20  20
## AD14               19  22
## AD15               20  18
## C001               20  20
## C002               20  19
## C003               19  20
## C004               20  20
## C005               20  20
## C006               19  20
## C007               21  22
## C008               17  21
## C009               19  20
## C010               20  21
## C011               21  23
## C012               21  20
## C013               21  20
## C014               20  20
## C018               21  19
## C019               20  20
## C020               19  21
## C021               20  20
## C022B              15  19
```

```
## C023                21  20
## C024                20  20
## C025                20  20
## C027                20  12
## C029                22  20
## C033                20  20
## C034                20  21
## C047                20  21
## C049                13  14
## C050                13  13
## c1                 10  10
## c105                10  10
## c11max             11  10
## c14                10  10
## c2                 10  11
## c3                 10  10
## c4                 10  10
## c40                10  10
## c400                10  10
## c41                10   9
## C43                 11  10
## c44                10  10
## c5                  9  11
## c50                10  10
## c52                10  10
## c53                10   8
## c55                10  10
## c6                  9  10
## c61                10  10
## c64                10  10
## c65                10   9
## c66                 0   0
## c67                 9   9
## c68                10  10
## c77                10  10
## c78                10  10
## c8                  9   9
## c80                 9  10
## c81                 9   8
## c83                10  10
## c9                 10  10
## GA001                22  20
## GA002b                0  13
## GA003b               20  16
## GA004                22  20
```

```
## GA006              21   23
## GA008              20   20
## GA010              18   21
## GA012              20   16
## GA014              20   16
## GA015              20   19
## GA017              20   20
## GA018              20   20
## GA019              19   12
## GA020              19   17
## GA021              20   15
## GA022              18   17
## GA023              20   21
## GA024              18   16
## GA027              20   20
## GA028              18   13
## GA029              22   17
## GA030              20   20
## GA031              20   20
## GA033              22   17
## GA037              20   19
## GA038              19   16
## GA039              20   17
## GA040              18   15
```

This table indicates that while some participants had 10 trials per eye (one for each flash strength); e.g. participant c68, others differed. For example, from participant GA018 it can be inferred that some flash strengths were repeated more than once on each eye.

Some robust estimations

Let's estimate some robust averages for b-amp and BT:

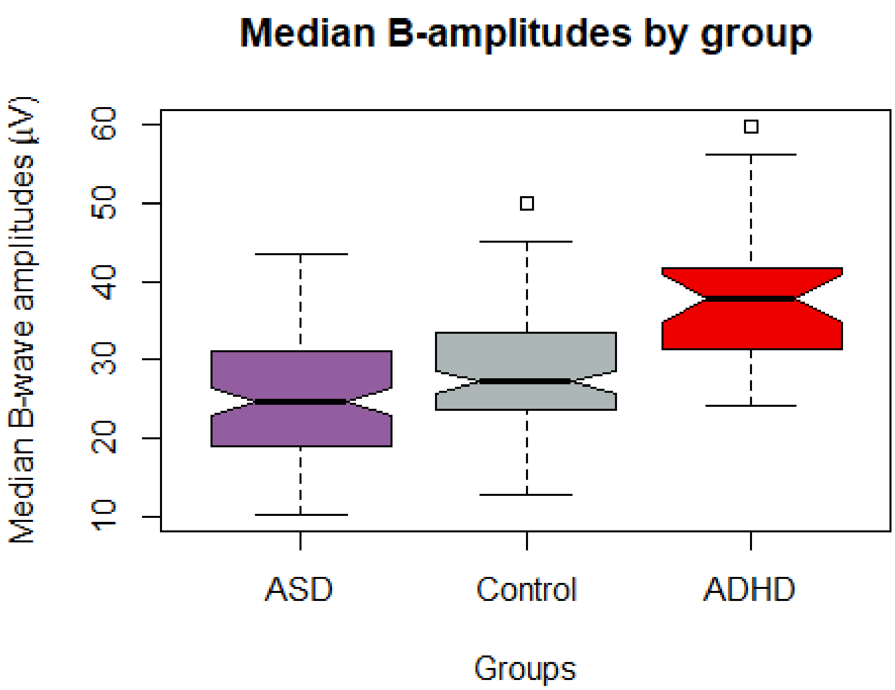
```
# Next, generate a data frame reporting averages and
# dispersion with all variables
# NOTE = Strength,Iris, Ethnicity,Vert, and Medic are not included in order to obtain
a
# broader picture of the trends
stats_by_participants <- ADHD.complete %>%
  group_by(Participant, Age, Gender, Group, Eye) %>%
  summarize(median.b.amp = median(b_amp),
            mad.b.amp=mad(b_amp),
            cv.b.amp = mad(b_amp)/median(b_amp),
            median.BT = median(BT),
            mad.BT=mad(BT),
            cv.BT = mad(BT)/median(BT))
```

Some general trends can be visualised with this data frame.

Groups and median B-wave amplitudes

This plot shows the distribution of the median B-wave amplitudes of each participant across all other variables (i.e. eyes, flash strength, Vert, and Iris)

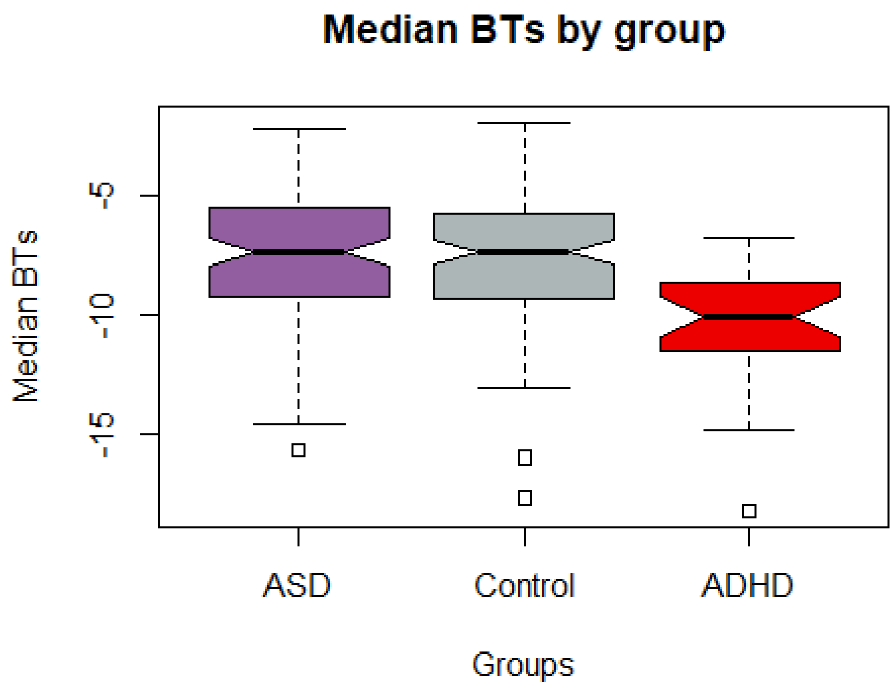
```
boxplot(median.B.amp ~ Group,
        main='Median B-amplitudes by group',
        notch=T, xlab='Groups',
        ylab=expression(paste('Median B-wave amplitudes (',mu,'V)')),
        col=picked.colours,lwd=1, pch=22,
        data = stats_by_participants)
```



The ~95% CIs around the medians indicate possible significant pairwise differences. But the difference between ADHD and ASD and between ADHD and Control seem quite clear.

Groups and median BTs

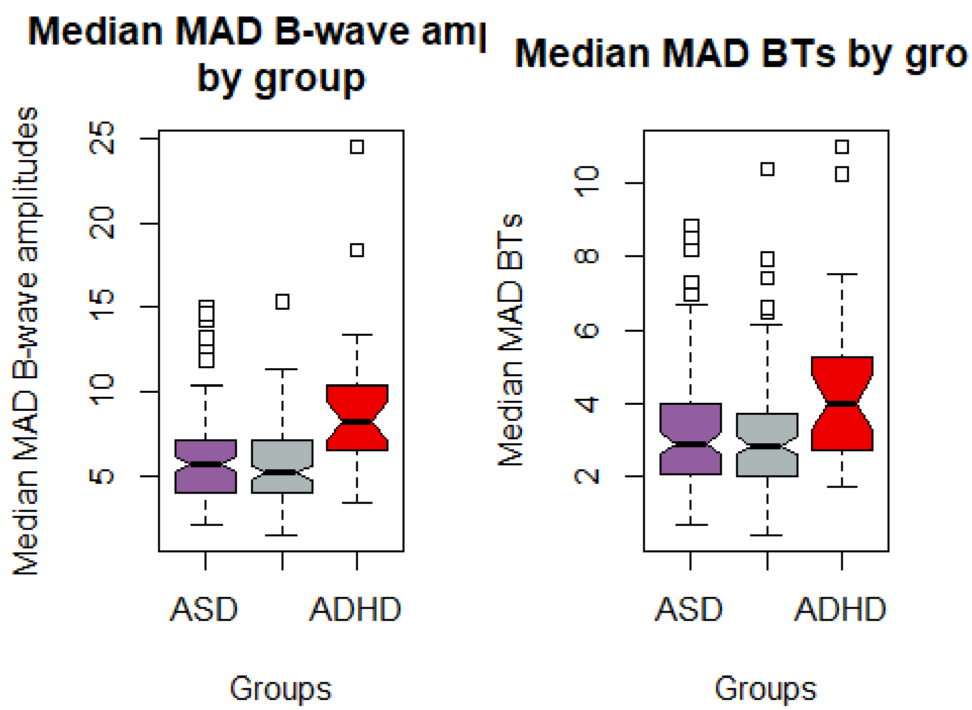
```
boxplot(median.BT ~ Group,
        main='Median BTs by group',
        notch=T, xlab='Groups',
        ylab='Median BTs',
        col=picked.colours,lwd=1, pch=22,
        data = stats_by_participants)
```



These plots indicate that while there seems to be no difference in the average BT between the control and the ASD groups, there is a difference between the ASD and the ADHD groups.

Groups and average median absolute deviations

```
par(mfrow=c(1,2))
boxplot(MAD.B.amp ~ Group,
        main='Median MAD B-wave amps \nby group',
        notch=T, xlab='Groups',
        ylab='Median MAD B-wave amplitudes',
        col=picked.colours,lwd=1, pch=22,
        data = stats_by_participants)

boxplot(MAD.BT ~ Group,
        main='Median MAD BTs by group',
        notch=T, xlab='Groups',
        ylab='Median MAD BTs',
        col=picked.colours,lwd=1, pch=22,
        data = stats_by_participants)
```




```
PAR(MFROW=C(1,1))
```

These plots indicate that the distribution of deviations in the ADHD group are higher and more disperse than the ASD and control groups. There seems to be not much difference in this regard between the ASD and control groups.

Groups and Irises

An important aspect here is that there should be one iris measure per eye per participant. That is, each participant should have two iris measurements; one for the left eye and another for the right eye.

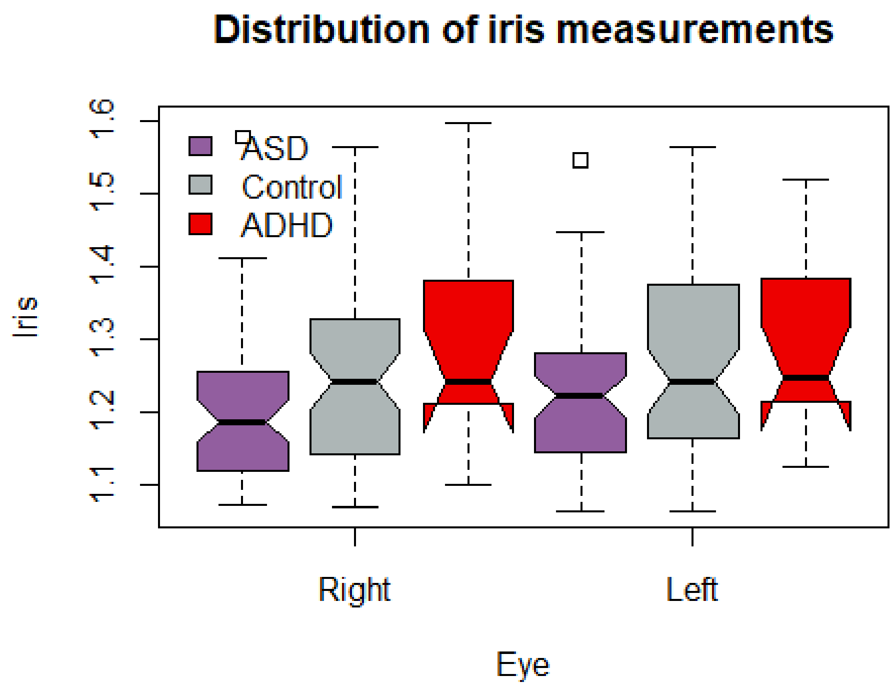
```
# HERE BT IS SIMPLY AN EXCUSE TO OBTAIN UNIQUE VALUES FOR THE OTHER VARIABLES
# THE WAY TO DO IS BY SETTING THE FUNCTION TO 'CLASS'
IRIS.AGGREGATE<-AGGREGATE(DATA=ADHD.COMPLETE, BT ~ PARTICIPANT + GENDER + AGE + ETHNI
CITY + GROUP + EYE + IRIS, FUN='CLASS')

IRIS.AGGREGATE.SORTED<-DATA.FRAME(SORT(TABLE(IRIS.AGGREGATE$PARTICIPANT)))

# THOSE WITH MORE THAN TWO OBSERVATIONS
IRIS.AGGREGATE.SORTED$VAR1[IRIS.AGGREGATE.SORTED$FREQ>2]

## FACTOR(0)
## 131 LEVELS: A25B C66 A23B AD08S1 GA002B A10 A100 A20 A21 A22 A27 A28 A29 ...
GA040

# THOSE WITH LESS THAN 2 OBSERVATIONS
IRIS.AGGREGATE.SORTED$VAR1[IRIS.AGGREGATE.SORTED$FREQ<2]
```

```
## [1] a25b   c66    a23b   AD08s1 GA002b
## 131 Levels: a25b c66 a23b AD08s1 GA002b a10 a100 a20 a21 a22 a27 a28 a29 ...
GA040
```

The previous results show that no participant had more than two iris values per eye. Participants a25b and c66 have no data and participants a23b, AD08s1, and GA002b had iris measurement of one eye only.

Let's observe what the iris data look like:

```
# first off, participant with only one iris measurement (i.e. only one eye
# measured), are excluded
iris.aggregate.2 <-
iris.aggregate[!(iris.aggregate$Participant %in% c('a23b', 'AD08s1', 'GA002b')), ]

boxplot(iris.aggregate.2$Iris ~
          interaction(iris.aggregate.2$Group,iris.aggregate.2$Eye),
        main='Distribution of iris measurements',
        notch=T, xlab='Eye',
        ylab='Iris',
        xaxt='n',
        col=picked.colours,lwd=1, pch=22)

xtick<-seq(from=2, to=  ,
           by=3,length.out = length(levels(iris.aggregate.2$Eye)))
axis(side=1, at=xtick, labels = FALSE)
text(x=xtick,  y=1, # tick location on the y axis
     labels = levels(iris.aggregate.2$Eye), srt = 0, pos = 1, xpd = TRUE)

# a legend
legend('topleft', border='black', bty='n',
       legend=levels(iris.aggregate.2$Group),
       fill=picked.colours,
       cex=1)
```



This plot indicates iris differences between groups but no differences within groups. For example, the median iris of ADHD is larger than that of ASD; but there seems to be no difference between the left and right eye's iris measurements within ADHD group.

Confirmatory data analyses

We revisit the latest data set and remove those participants for whom only one eye was measured (i.e. they only had one iris measurement).

```
ADHD.final<-
  ADHD.complete[!(ADHD.complete$Participant %in% c('A23b', 'AD08s1', 'GA002b')), ]
```

The final data set is then submitted to GEE models. These models were considered given their capability to handle repeated measures data, thus providing valid standard errors of the parameter estimates. GEE also makes no assumption as to the distribution of the response variable [2].

The dependent variables will be a-time, a-amp, b-time, b-amp, bdiva_amp, p72, Tmin, BT, p_ratio and w_ratio. The covariates will be the ones listed early in this extended report.

The GEE modelling is applied with a Gaussian distribution given that (as shown above) while some distributions have a positive skew (e.g. b-amp), others have a negative skew (e.g. a-amp). Thus, we reasoned that the normal distribution provides a compromise between these two types of shapes. According to experts involved in this study, the following is the ranking of significance of the variables (from the most important to

---

[2] see https://rlbarter.github.io/Practical-Statistics/2017/05/10/generalized-estimating-equations-gee/ for further details.

the least important): Strength, Vert, Group, Ethnicity, Iris, Gender, Medication, Age, and Eye. There is also an expected interaction between Group and flash strength.

The results for some cases will be plotted.

Dependent variable a_time

```
library(geepack)

# sorting the participants
id.ordered <- order(adhd.final$Participant)
adhd.final <- adhd.final[id.ordered, ]

# model to analyse.
# note the interaction is added
model <- with(adhd.final,
              formula(a_time ~
              Strength + Vert + Group + Ethnicity + Iris +
              Gender + Medication + Age + Eye +
              Group:Strength))

gee.model <- geeglm(model, id=Participant, data=adhd.final,
                    family=gaussian, corstr="exchangeable")
# note the 'unstructured' correlation structure option produced this error:
# Error: cannot allocate vector of size 2.2 Gb
# hence 'exchangeable' is used

summary(gee.model)

##
## Call:
## geeglm(formula = model, family = gaussian, data = adhd.final,
##     id = Participant, corstr = "exchangeable")
##
##  Coefficients:
##                              Estimate  Std.err    Wald Pr(>|W|)
## (Intercept)                  13.33569  0.57155 544.402  < 2e-16 ***
## Strength-0.119               -0.68780  0.24379   7.960  0.00478 **
## Strength0.114                -1.31417  0.22835  33.119 8.67e-09 ***
## Strength0.398                -1.68955  0.23419  52.047 5.42e-13 ***
## Strength0.477                -2.44474  0.20226 146.094  < 2e-16 ***
## Strength0.602                -2.27232  0.25601  78.780  < 2e-16 ***
## Strength0.799                -2.60723  0.21721 144.077  < 2e-16 ***
## Strength0.949                -2.56948  0.20799 152.618  < 2e-16 ***
## Strength1.114                -2.61558  0.15956 268.707  < 2e-16 ***
## Strength1.204                -2.48668  0.21150 138.233  < 2e-16 ***
## Vert0                         0.03312  0.22819   0.021  0.88459
## Vert1                         0.02128  0.10254   0.043  0.83558
```

```
## Vert3                          0.05944  0.10666   0.311  0.57734
## Vert4                         -0.10541  0.10247   1.058  0.30361
## GroupControl                  -0.01433  0.28823   0.002  0.96035
## GroupADHD                     -0.13785  0.46670   0.087  0.76770
## EthnicityAsian                 0.37941  0.15413   6.060  0.01383 *
## EthnicityAfro-Caribbean        0.41715  0.19243   4.699  0.03018 *
## EthnicityLatino                0.05394  0.19447   0.077  0.78149
## EthnicityMixed                -0.06169  0.14122   0.191  0.66221
## Iris                           0.27282  0.42159   0.419  0.51756
## GenderFemale                  -0.08944  0.08586   1.085  0.29757
## Medicationtaken               -0.24866  0.18851   1.740  0.18714
## Age                            0.01309  0.01126   1.352  0.24487
## EyeLeft                        0.06797  0.04929   1.902  0.16790
## Strength-0.119:GroupControl  0.05860  0.30081   0.038  0.84554
## Strength0.114:GroupControl   0.30058  0.28822   1.088  0.29702
## Strength0.398:GroupControl   0.17153  0.27603   0.386  0.53433
## Strength0.477:GroupControl   0.06441  0.24321   0.070  0.79116
## Strength0.602:GroupControl   0.15576  0.29937   0.271  0.60285
## Strength0.799:GroupControl   0.03224  0.25619   0.016  0.89985
## Strength0.949:GroupControl   0.09488  0.26757   0.126  0.72290
## Strength1.114:GroupControl   0.03370  0.25211   0.018  0.89366
## Strength1.204:GroupControl   0.03399  0.26708   0.016  0.89873
## Strength-0.119:GroupADHD    -0.61685  0.42492   2.107  0.14659
## Strength0.114:GroupADHD     -0.07217  0.46475   0.024  0.87659
## Strength0.398:GroupADHD      0.34369  0.43606   0.621  0.43059
## Strength0.477:GroupADHD     -0.14142  0.37999   0.139  0.70977
## Strength0.602:GroupADHD     -0.09289  0.49098   0.036  0.84994
## Strength0.799:GroupADHD     -0.30969  0.41524   0.556  0.45578
## Strength0.949:GroupADHD     -0.15743  0.41244   0.146  0.70268
## Strength1.114:GroupADHD     -0.07033  0.47110   0.022  0.88133
## Strength1.204:GroupADHD      0.17985  0.45610   0.155  0.69335
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation structure = exchangeable
## Estimated Scale Parameters:
##
##             Estimate Std.err
## (Intercept)    1.844  0.2181
##   Link = identity
##
## Estimated Correlation Parameters:
##       Estimate Std.err
## alpha  0.08832 0.01559
## Number of clusters:   126  Maximum cluster size: 44
```

```r
anova(gee.model)
```

```
## Analysis of 'Wald statistic' Table
## Model: gaussian, link: identity
## Response: a_time
## Terms added sequentially (first to last)
##
##                Df   X2 P(>|Chi|)
## Strength        9 1082    <2e-16 ***
## Vert            4    2     0.808
## Group           2    5     0.064 .
## Ethnicity       4   25     6e-05 ***
## Iris            1    1     0.402
## Gender          1    1     0.324
## Medication      1    2     0.182
## Age             1    1     0.248
## Eye             1    2     0.165
## Strength:Group 18   27     0.074 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Let's organise this output:

```r
gee.anova<-anova(gee.model)
gee.anova[order(gee.anova$X2, decreasing=T),]
```

```
## Analysis of 'Wald statistic' Table
## Model: gaussian, link: identity
## Response: a_time
## Terms added sequentially (first to last)
##
##                Df   X2 P(>|Chi|)
## Strength        9 1082    <2e-16 ***
## Strength:Group 18   27     0.074 .
## Ethnicity       4   25     6e-05 ***
## Group           2    5     0.064 .
## Eye             1    2     0.165
## Medication      1    2     0.182
## Vert            4    2     0.808
## Age             1    1     0.248
## Gender          1    1     0.324
## Iris            1    1     0.402
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# fitness of the model
library(MuMIn) # QIC is also in geepack so specify MuMIn directly
MuMIn::QIC(gee.model)
```

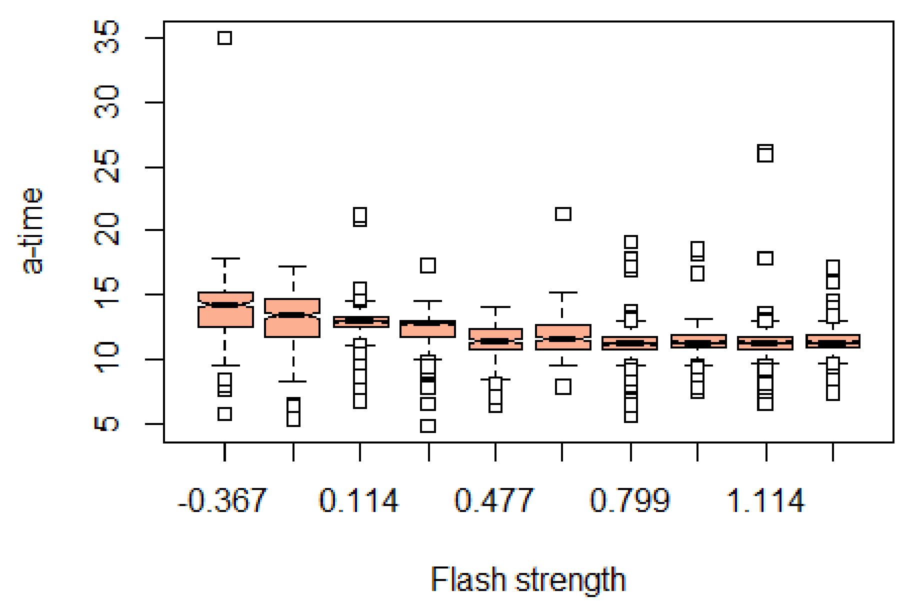
```
##  QIC
## 3894
```

Although Group was close to significance, it did interact with Strength and this interaction was significant. Ethnicity and Strenght were significant main effects.

Graphing some cases...

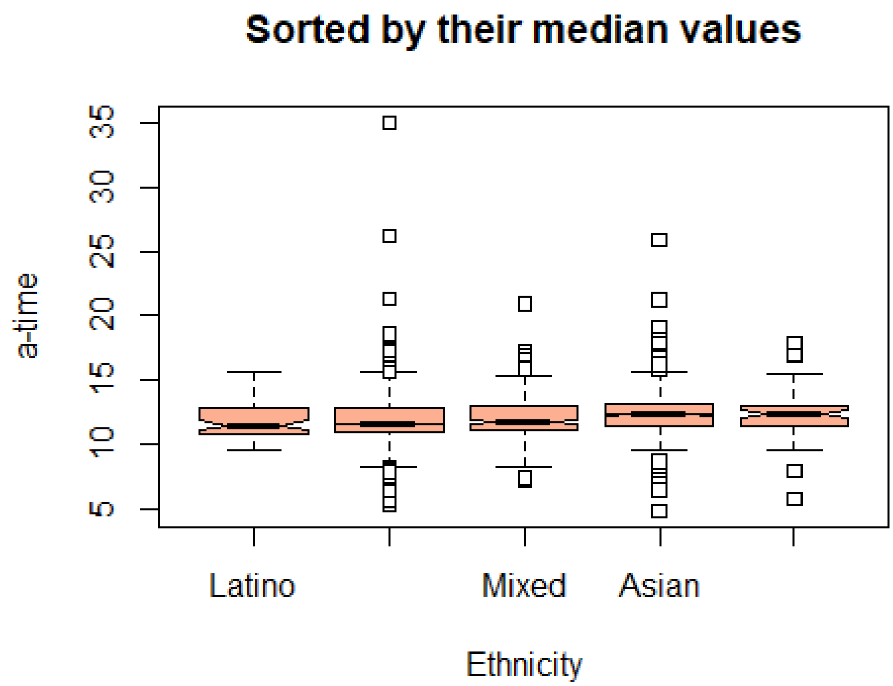
Main effect of flash Strength

```
boxplot(adhd.final$a_time ~ adhd.final$Strength,
        main='',
        notch=T, xlab='Flash strength',
        ylab='a-time',
        col='#FDAF91FF',lwd=1, pch=22)
```



Main effect of Ethnicity

```
# sorting by median value
new_order <- with(adhd.final, reorder(Ethnicity, a_time, median , na.rm=T))

boxplot(adhd.final$a_time ~ new_order,
        main='Sorted by their median values',
        notch=T, xlab='Ethnicity',
        ylab='a-time',
        col='#FDAF91FF',lwd=1, pch=22)
```



Dependent variable a_amplitude

```
# SORTING THE PARTICIPANTS
ID.ORDERED <- ORDER(ADHD.FINAL$PARTICIPANT)
ADHD.FINAL <- ADHD.FINAL[ID.ORDERED, ]

# MODEL TO ANALYSE.
# NOTE THE INTERACTION IS ADDED
MODEL.A_AMP <- WITH(ADHD.FINAL,
             FORMULA(A_AMP ~
             STRENGTH + VERT + GROUP + ETHNICITY + IRIS +
             GENDER + MEDICATION + AGE + EYE +
             GROUP:STRENGTH))

GEE.MODEL.A_AMP <- GEEGLM(MODEL.A_AMP, ID=PARTICIPANT,
                  DATA=ADHD.FINAL,
             FAMILY=GAUSSIAN, CORSTR="EXCHANGEABLE")
# NOTE THE 'UNSTRUCTURED' CORRELATION STRUCTURE OPTION PRODUCED THIS ERROR:
# ERROR: CANNOT ALLOCATE VECTOR OF SIZE 2.2 GB
# HENCE 'EXCHANGEABLE' IS USED
SUMMARY(GEE.MODEL.A_AMP)

##
## CALL:
## GEEGLM(FORMULA = MODEL.A_AMP, FAMILY = GAUSSIAN, DATA = ADHD.FINAL,
##     ID = PARTICIPANT, CORSTR = "EXCHANGEABLE")
```

```
##
##  Coefficients:
##                             Estimate Std.err  Wald Pr(>|W|)
## (Intercept)                  -6.1189  1.4820  17.05  3.6e-05 ***
## Strength-0.119               -0.6164  0.2139   8.31   0.0040 **
## Strength0.114                -1.3416  0.1885  50.68  1.1e-12 ***
## Strength0.398                -2.3288  0.1982 138.03  < 2e-16 ***
## Strength0.477                -3.1322  0.2653 139.43  < 2e-16 ***
## Strength0.602                -3.1392  0.2473 161.18  < 2e-16 ***
## Strength0.799                -3.3535  0.2634 162.11  < 2e-16 ***
## Strength0.949                -3.8883  0.2809 191.61  < 2e-16 ***
## Strength1.114                -4.7893  0.3196 224.53  < 2e-16 ***
## Strength1.204                -4.8765  0.3486 195.64  < 2e-16 ***
## Vert0                         0.8201  1.0971   0.56   0.4547
## Vert1                        -1.1839  0.4631   6.54   0.0106 *
## Vert3                         0.3153  0.2375   1.76   0.1842
## Vert4                         0.8867  0.2951   9.03   0.0027 **
## GroupControl                 -0.4577  0.3430   1.78   0.1821
## GroupADHD                    -1.5758  0.6099   6.68   0.0098 **
## EthnicityAsian                0.0149  0.4913   0.00   0.9758
## EthnicityAfro-Caribbean       0.3454  0.5076   0.46   0.4961
## EthnicityLatino              -0.1291  1.4049   0.01   0.9268
## EthnicityMixed                0.1050  0.3908   0.07   0.7881
## Iris                          1.6976  1.1361   2.23   0.1351
## GenderFemale                 -0.1680  0.3303   0.26   0.6110
## Medicationtaken               0.9286  0.5743   2.61   0.1059
## Age                           0.0434  0.0342   1.61   0.2043
## EyeLeft                       0.0264  0.1075   0.06   0.8057
## Strength-0.119:GroupControl  -0.1092  0.2949   0.14   0.7111
## Strength0.114:GroupControl    0.0761  0.2677   0.08   0.7763
## Strength0.398:GroupControl   -0.3281  0.2764   1.41   0.2352
## Strength0.477:GroupControl   -0.2856  0.3508   0.66   0.4157
## Strength0.602:GroupControl   -0.3183  0.3254   0.96   0.3280
## Strength0.799:GroupControl   -0.5851  0.3784   2.39   0.1221
## Strength0.949:GroupControl   -0.8185  0.3859   4.50   0.0339 *
## Strength1.114:GroupControl   -0.5254  0.4330   1.47   0.2250
## Strength1.204:GroupControl   -0.9932  0.4439   5.01   0.0252 *
## Strength-0.119:GroupADHD     -0.2105  0.3838   0.30   0.5834
## Strength0.114:GroupADHD       0.2466  0.5253   0.22   0.6387
## Strength0.398:GroupADHD      -1.3735  0.6711   4.19   0.0407 *
## Strength0.477:GroupADHD      -0.8077  0.5088   2.52   0.1124
## Strength0.602:GroupADHD      -1.0820  0.6662   2.64   0.1043
## Strength0.799:GroupADHD      -0.2915  0.4860   0.36   0.5487
## Strength0.949:GroupADHD      -0.5824  0.5899   0.97   0.3235
## Strength1.114:GroupADHD      -0.0693  0.6820   0.01   0.9190
```

```
## Strength1.204:GroupADHD     -0.9780  0.7667   1.63   0.2021
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation structure = exchangeable
## Estimated Scale Parameters:
##
##             Estimate Std.err
## (Intercept)     6.94    0.61
##   Link = identity
##
## Estimated Correlation Parameters:
##       Estimate Std.err
## alpha     0.41  0.0316
## Number of clusters:   126  Maximum cluster size: 44
```

```
anova(gee.model.a_amp)
```

```
## Analysis of 'Wald statistic' Table
## Model: gaussian, link: identity
## Response: a_amp
## Terms added sequentially (first to last)
##
##                Df  X2 P(>|Chi|)
## Strength        9 954   < 2e-16 ***
## Vert            4  21   0.00031 ***
## Group           2  14   0.00117 **
## Ethnicity       4   5   0.25733
## Iris            1   3   0.09629 .
## Gender          1   0   0.55158
## Medication      1   2   0.11734
## Age             1   2   0.21004
## Eye             1   0   0.79109
## Strength:Group 18  23   0.17837
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

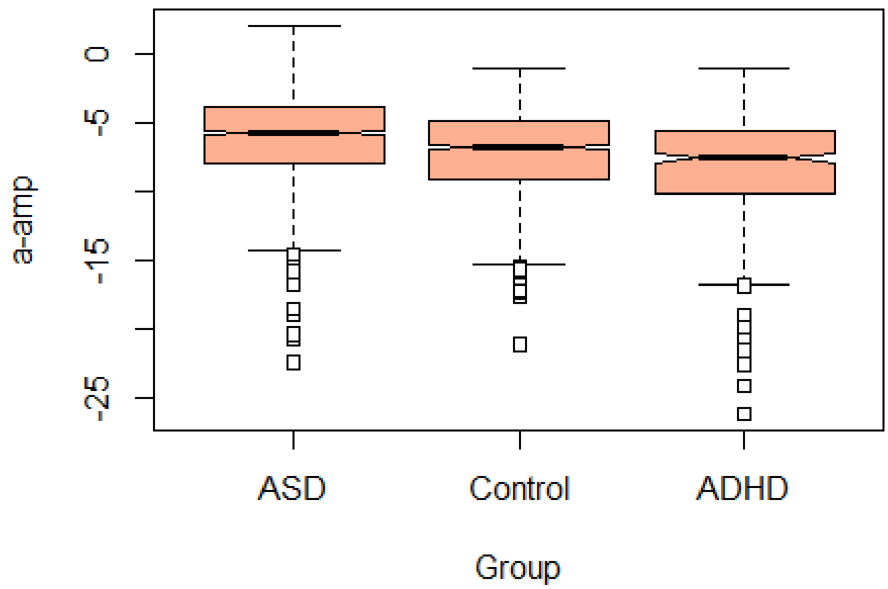
```
# fitness of the model
MuMIn::QIC(gee.model.a_amp)
```

```
##  QIC
## 3937
```

Main effect of Group

```
boxplot(adhd.final$a_amp ~ adhd.final$Group,
        main='',
        notch=T, xlab='Group',
```

```
        ylab='a-amp',
        col='#FDAF91FF',lwd=1, pch=22)
```



Dependent variable b-time

```
# sorting the participants
id.ordered <- order(ADHD.final$Participant)
ADHD.final <- ADHD.final[id.ordered, ]

# Model to analyse.
# Note the interaction is added
model.b_time <- with(ADHD.final,
             formula(b_time ~
             Strength + Vert + Group + Ethnicity + Iris +
             Gender + Medication + Age + Eye +
             Group:Strength))

gee.b.time <- geeglm(model.b_time, id=Participant,
                       data=ADHD.final,
             family=gaussian, corstr="exchangeable")
# Note the 'unstructured' correlation structure option produced this error:
# Error: cannot allocate vector of size 2.2 Gb
# hence 'exchangeable' is used
summary(gee.b.time)
```

```
##
## Call:
## geeglm(formula = model.b_time, family = gaussian, data = adhd.final,
##     id = Participant, corstr = "exchangeable")
##
##  Coefficients:
##                            Estimate  Std.err    Wald Pr(>|W|)
## (Intercept)                21.74427  0.63127 1186.49  < 2e-16 ***
## Strength-0.119              1.10992  0.21978   25.50  4.4e-07 ***
## Strength0.114               2.42607  0.19273  158.45  < 2e-16 ***
## Strength0.398               3.86994  0.18617  432.08  < 2e-16 ***
## Strength0.477               6.11606  0.19540  979.69  < 2e-16 ***
## Strength0.602               5.24226  0.19053  757.02  < 2e-16 ***
## Strength0.799               6.62938  0.20261 1070.62  < 2e-16 ***
## Strength0.949               7.37962  0.20604 1282.87  < 2e-16 ***
## Strength1.114               8.19462  0.22165 1366.83  < 2e-16 ***
## Strength1.204               8.86605  0.26185 1146.46  < 2e-16 ***
## Vert0                       0.07573  0.10605    0.51  0.47518
## Vert1                      -0.00811  0.07977    0.01  0.91897
## Vert3                      -0.06063  0.09107    0.44  0.50554
## Vert4                      -0.20107  0.13677    2.16  0.14151
## GroupControl               -0.39669  0.27193    2.13  0.14461
## GroupADHD                  -0.13583  0.27681    0.24  0.62363
## EthnicityAsian              0.44681  0.18980    5.54  0.01857 *
## EthnicityAfro-Caribbean     1.00632  0.14173   50.42  1.2e-12 ***
## EthnicityLatino            -0.39040  0.45564    0.73  0.39155
## EthnicityMixed              0.23863  0.19612    1.48  0.22371
## Iris                       -0.15969  0.45079    0.13  0.72315
## GenderFemale               -0.13928  0.13585    1.05  0.30526
## Medicationtaken             0.07231  0.27028    0.07  0.78905
## Age                         0.04973  0.02039    5.95  0.01473 *
## EyeLeft                     0.12358  0.03697   11.17  0.00083 ***
## Strength-0.119:GroupControl  0.05550  0.23909    0.05  0.81645
## Strength0.114:GroupControl   0.08134  0.21341    0.15  0.70310
## Strength0.398:GroupControl   0.03896  0.20890    0.03  0.85205
## Strength0.477:GroupControl   0.13623  0.22032    0.38  0.53634
## Strength0.602:GroupControl   0.04369  0.21777    0.04  0.84099
## Strength0.799:GroupControl   0.00568  0.23099    0.00  0.98037
## Strength0.949:GroupControl   0.06312  0.24697    0.07  0.79829
## Strength1.114:GroupControl   0.07063  0.25324    0.08  0.78033
## Strength1.204:GroupControl  -0.04847  0.28848    0.03  0.86658
## Strength-0.119:GroupADHD     0.22602  0.32702    0.48  0.48947
## Strength0.114:GroupADHD      0.20044  0.22153    0.82  0.36558
## Strength0.398:GroupADHD     -0.32310  0.20868    2.40  0.12154
## Strength0.477:GroupADHD     -0.30666  0.26694    1.32  0.25064
```

```
## Strength0.602:GroupADHD    -0.33134  0.23432    2.00  0.15734
## Strength0.799:GroupADHD    -0.47041  0.26857    3.07  0.07985 .
## Strength0.949:GroupADHD    -0.44957  0.24085    3.48  0.06196 .
## Strength1.114:GroupADHD    -0.23160  0.28518    0.66  0.41672
## Strength1.204:GroupADHD    -0.48694  0.32570    2.24  0.13490
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation structure = exchangeable
## Estimated Scale Parameters:
##
##             Estimate Std.err
## (Intercept)     1.18   0.198
##   Link = identity
##
## Estimated Correlation Parameters:
##       Estimate Std.err
## alpha    0.398  0.0632
## Number of clusters:   126  Maximum cluster size: 44
```

```
anova(gee.b.time)
```

```
## Analysis of 'Wald statistic' Table
## Model: gaussian, link: identity
## Response: B_time
## Terms added sequentially (first to last)
##
##                Df   X2 P(>|Chi|)
## Strength        9 9285   < 2e-16 ***
## Vert            4    4   0.43347
## Group           2    3   0.19027
## Ethnicity       4   51   2.5e-10 ***
## Iris            1    0   0.76629
## Gender          1    1   0.26857
## Medication      1    0   0.90797
## Age             1    6   0.01572 *
## Eye             1   11   0.00077 ***
## Strength:Group 18   73   1.4e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# fitness of the model
MuMIn::QIC(gee.b.time)
```

```
##  QIC
## 4061
```

Dependent variable b-amplitude

```
# sorting the participants
id.ordered <- order(adhd.final$Participant)
adhd.final <- adhd.final[id.ordered, ]

# model to analyse.
# note the interaction is added
model.b_amp <- with(adhd.final,
              formula(b_amp ~
              Strength + Vert + Group + Ethnicity + Iris +
              Gender + Medication + Age + Eye +
              Group:Strength))

gee.b.amp <- geeglm(model.b_amp, id=Participant,
                         data=adhd.final,
              family=gaussian, corstr="exchangeable")
# note the 'unstructured' correlation structure option produced this error:
# Error: cannot allocate vector of size 2.2 Gb
# hence 'exchangeable' is used
summary(gee.b.amp)

##
## Call:
## geeglm(formula = model.b_amp, family = gaussian, data = adhd.final,
##     id = Participant, corstr = "exchangeable")
##
##  Coefficients:
##                            Estimate Std.err   Wald Pr(>|W|)
## (Intercept)                 12.2654  5.2758   5.40  0.02008 *
## Strength-0.119               4.3003  0.3803 127.84  < 2e-16 ***
## Strength0.114               13.4014  0.7681 304.40  < 2e-16 ***
## Strength0.398               19.4904  0.8368 542.56  < 2e-16 ***
## Strength0.477               17.3405  0.9225 353.36  < 2e-16 ***
## Strength0.602               19.4638  0.8915 476.67  < 2e-16 ***
## Strength0.799               17.4353  0.7997 475.36  < 2e-16 ***
## Strength0.949               17.0420  0.8324 419.13  < 2e-16 ***
## Strength1.114               16.2607  0.8259 387.68  < 2e-16 ***
## Strength1.204               14.1238  0.7546 350.34  < 2e-16 ***
## Vert0                       -2.4311  1.4110   2.97  0.08488 .
## Vert1                        2.2911  1.2226   3.51  0.06094 .
## Vert3                       -0.5046  0.7334   0.47  0.49147
## Vert4                       -2.2095  1.1652   3.60  0.05792 .
## GroupControl                 1.5468  0.9716   2.53  0.11138
## GroupADHD                    4.6997  1.5922   8.71  0.00316 **
## EthnicityAsian              -3.8479  1.6945   5.16  0.02316 *
## EthnicityAfro-Caribbean     -6.9725  2.9200   5.70  0.01695 *
```

```
## EthnicityLatino             -2.0125  4.2964   0.22  0.63950
## EthnicityMixed              -2.5200  1.6504   2.33  0.12678
## Iris                        -0.8705  3.8852   0.05  0.82271
## GenderFemale                 2.3779  1.2290   3.74  0.05301 .
## Medicationtaken             -2.8045  2.1248   1.74  0.18688
## Age                         -0.0601  0.1227   0.24  0.62440
## EyeLeft                      0.0198  0.3506   0.00  0.95485
## Strength-0.119:GroupControl   0.0413  0.5092   0.01  0.93536
## Strength0.114:GroupControl    0.5490  0.9723   0.32  0.57233
## Strength0.398:GroupControl    1.9761  1.1847   2.78  0.09531 .
## Strength0.477:GroupControl    1.0206  1.3518   0.57  0.45025
## Strength0.602:GroupControl    1.8636  1.2822   2.11  0.14610
## Strength0.799:GroupControl    1.3071  1.2382   1.11  0.29115
## Strength0.949:GroupControl    0.7977  1.1872   0.45  0.50165
## Strength1.114:GroupControl    1.2253  1.1422   1.15  0.28340
## Strength1.204:GroupControl    2.4958  1.1299   4.88  0.02718 *
## Strength-0.119:GroupADHD      2.9836  1.0904   7.49  0.00621 **
## Strength0.114:GroupADHD       6.2827  1.9706  10.16  0.00143 **
## Strength0.398:GroupADHD       9.6264  2.2830  17.78  2.5e-05 ***
## Strength0.477:GroupADHD      11.9742  3.3504  12.77  0.00035 ***
## Strength0.602:GroupADHD      10.7967  2.7534  15.38  8.8e-05 ***
## Strength0.799:GroupADHD       8.3085  2.0719  16.08  6.1e-05 ***
## Strength0.949:GroupADHD       7.4683  1.9919  14.06  0.00018 ***
## Strength1.114:GroupADHD       5.2870  2.2541   5.50  0.01900 *
## Strength1.204:GroupADHD       8.1397  2.1887  13.83  0.00020 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation structure = exchangeable
## Estimated Scale Parameters:
##
##             Estimate Std.err
## (Intercept)     66.3    6.62
##   Link = identity
##
## Estimated Correlation Parameters:
##       Estimate Std.err
## alpha    0.652  0.0341
## Number of clusters:   126  Maximum cluster size: 44
```

```
anova(gee.b.amp)
```

```
## Analysis of 'Wald statistic' Table
## Model: gaussian, link: identity
## Response: b_amp
## Terms added sequentially (first to last)
```

```
##
##                 Df   X2 P(>|Chi|)
## Strength        9 1294   < 2e-16 ***
## Vert            4   15    0.0041 **
## Group           2   24   5.9e-06 ***
## Ethnicity       4   14    0.0061 **
## Iris            1    0    0.8517
## Gender          1    4    0.0444 *
## Medication      1    2    0.1955
## Age             1    0    0.6145
## Eye             1    0    0.9733
## Strength:Group 18   63   7.8e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# fitness of the model
MuMIn::QIC(gee.b.amp)
```

```
##  QIC
## 3956
```

Dependent variable b/a amplitude ratio

```
# sorting the participants
id.ordered <- order(adhd.final$Participant)
adhd.final <- adhd.final[id.ordered, ]

# model to analyse.
# note the interaction is added
model.b.a.ratio <- with(adhd.final,
             formula(bdiva_amp ~
             Strength + Vert + Group + Ethnicity + Iris +
             Gender + Medication + Age + Eye +
             Group:Strength))

gee.b.a.ratio <- geeglm(model.b.a.ratio, id=Participant,
                        data=adhd.final,
             family=gaussian, corstr="exchangeable")
# note the 'unstructured' correlation structure option produced this error:
# Error: cannot allocate vector of size 2.2 Gb
# hence 'exchangeable' is used
summary(gee.b.a.ratio)
```

```
##
## Call:
## geeglm(formula = model.b.a.ratio, family = gaussian, data = adhd.final,
##     id = Participant, corstr = "exchangeable")
##
##  Coefficients:
```

```
##                              Estimate Std.err  Wald Pr(>|W|)    
## (Intercept)                    1.5931  0.8249  3.73  0.05343 .  
## Strength-0.119                 0.5150  0.2096  6.03  0.01403 *  
## Strength0.114                  1.9187  0.2128 81.30  < 2e-16 ***
## Strength0.398                  2.2280  0.2658 70.27  < 2e-16 ***
## Strength0.477                  1.1251  0.1915 34.52  4.2e-09 ***
## Strength0.602                  1.3583  0.2036 44.50  2.5e-11 ***
## Strength0.799                  0.9958  0.2305 18.66  1.6e-05 ***
## Strength0.949                  0.7223  0.2339  9.54  0.00202 ** 
## Strength1.114                 -0.0553  0.1754  0.10  0.75274    
## Strength1.204                 -0.2575  0.2001  1.66  0.19814    
## Vert0                          0.1529  0.6404  0.06  0.81129    
## Vert1                         -0.0899  0.1988  0.20  0.65095    
## Vert3                          0.0162  0.1009  0.03  0.87258    
## Vert4                          0.2146  0.1790  1.44  0.23053    
## GroupControl                  -0.1781  0.1966  0.82  0.36484    
## GroupADHD                     -0.3251  0.2738  1.41  0.23507    
## EthnicityAsian                -0.7926  0.2162 13.44  0.00025 ***
## EthnicityAfro-Caribbean       -1.0995  0.4083  7.25  0.00708 ** 
## EthnicityLatino               -0.5437  0.2934  3.43  0.06386 .  
## EthnicityMixed                -0.5242  0.2362  4.93  0.02647 *  
## Iris                           1.4741  0.6771  4.74  0.02947 *  
## GenderFemale                   0.3603  0.1586  5.16  0.02311 *  
## Medicationtaken                0.1978  0.1938  1.04  0.30730    
## Age                            0.0152  0.0192  0.63  0.42743    
## EyeLeft                       -0.0762  0.0786  0.94  0.33256    
## Strength-0.119:GroupControl  -0.1302  0.2368  0.30  0.58224    
## Strength0.114:GroupControl    0.2256  0.3025  0.56  0.45586    
## Strength0.398:GroupControl   -0.0901  0.3233  0.08  0.78046    
## Strength0.477:GroupControl   -0.1159  0.2157  0.29  0.59109    
## Strength0.602:GroupControl    0.1280  0.2894  0.20  0.65840    
## Strength0.799:GroupControl   -0.2563  0.2590  0.98  0.32225    
## Strength0.949:GroupControl   -0.4429  0.2572  2.96  0.08512 .  
## Strength1.114:GroupControl    0.1355  0.2101  0.42  0.51886    
## Strength1.204:GroupControl   -0.0646  0.2209  0.09  0.76997    
## Strength-0.119:GroupADHD      0.3159  0.4085  0.60  0.43933    
## Strength0.114:GroupADHD       1.6262  0.8981  3.28  0.07019 .  
## Strength0.398:GroupADHD       0.1161  0.5013  0.05  0.81677    
## Strength0.477:GroupADHD       1.2473  0.6990  3.18  0.07437 .  
## Strength0.602:GroupADHD       0.7948  0.3742  4.51  0.03365 *  
## Strength0.799:GroupADHD       0.9936  0.4418  5.06  0.02451 *  
## Strength0.949:GroupADHD       0.6222  0.4601  1.83  0.17624    
## Strength1.114:GroupADHD       1.2935  0.8599  2.26  0.13249    
## Strength1.204:GroupADHD       0.6343  0.3636  3.04  0.08110 .  
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation structure = exchangeable
## Estimated Scale Parameters:
##
##             Estimate Std.err
## (Intercept)     4.07   0.643
##   Link = identity
##
## Estimated Correlation Parameters:
##       Estimate Std.err
## alpha    0.121  0.0282
## Number of clusters:   126  Maximum cluster size: 44
```

```
anova(gee.b.a.ratio)
```

```
## Analysis of 'Wald statistic' Table
## Model: gaussian, link: identity
## Response: BDIVA_amp
## Terms added sequentially (first to last)
##
##                Df  X2 P(>|Chi|)
## Strength        9 512    <2e-16 ***
## Vert            4   2    0.8212
## Group           2  11    0.0045 **
## Ethnicity       4  12    0.0157 *
## Iris            1   4    0.0348 *
## Gender          1   5    0.0256 *
## Medication      1   1    0.3235
## Age             1   1    0.4336
## Eye             1   1    0.3414
## Strength:Group 18  28    0.0632 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# fitness of the model
MuMIn::QIC(gee.b.a.ratio)
```

```
##  QIC
## 3924
```

Dependent variable PhNr (aka P72)

```
# sorting the participants
id.ordered <- order(adhd.final$participant)
adhd.final <- adhd.final[id.ordered, ]

# model to analyse.
# note the interaction is added
```

```
model.phnr <- with(adhd.final,
             formula(p72 ~
             Strength + Vert + Group + Ethnicity + Iris +
             Gender + Medication + Age + Eye +
             Group:Strength))

gee.phnr <- geeglm(model.phnr, id=Participant,
                        data=adhd.final,
             family=gaussian, corstr="exchangeable")
# Note the 'unstructured' correlation structure option produced this error:
# Error: cannot allocate vector of size 2.2 Gb
# hence 'exchangeable' is used
summary(gee.phnr)

##
## Call:
## geeglm(formula = model.phnr, family = gaussian, data = adhd.final,
##     id = Participant, corstr = "exchangeable")
##
##  Coefficients:
##                              Estimate Std.err  Wald Pr(>|W|)
## (Intercept)                   -6.1497  2.1933  7.86   0.005 **
## Strength-0.119                -0.8346  0.5294  2.49   0.115
## Strength0.114                 -1.7935  0.4303 17.37 3.1e-05 ***
## Strength0.398                 -2.5705  0.4472 33.04 9.0e-09 ***
## Strength0.477                 -3.5527  0.4773 55.40 9.8e-14 ***
## Strength0.602                 -3.2395  0.4284 57.18 4.0e-14 ***
## Strength0.799                 -4.0650  0.5025 65.43 5.6e-16 ***
## Strength0.949                 -3.9558  0.4517 76.69 < 2e-16 ***
## Strength1.114                 -4.9472  0.5778 73.30 < 2e-16 ***
## Strength1.204                 -4.9294  0.5627 76.73 < 2e-16 ***
## Vert0                         -0.0890  1.3367  0.00   0.947
## Vert1                         -1.4150  0.5774  6.00   0.014 *
## Vert3                          0.3300  0.3887  0.72   0.396
## Vert4                          0.4679  0.4997  0.88   0.349
## GroupControl                  -0.3480  0.5928  0.34   0.557
## GroupADHD                     -0.2986  0.9270  0.10   0.747
## EthnicityAsian                -0.7414  0.7642  0.94   0.332
## EthnicityAfro-Caribbean       -4.1490  2.8948  2.05   0.152
## EthnicityLatino               -1.0228  1.4071  0.53   0.467
## EthnicityMixed                 1.0638  0.4906  4.70   0.030 *
## Iris                           2.5993  1.7585  2.18   0.139
## GenderFemale                   0.3826  0.3927  0.95   0.330
## MedicationTaken                1.7669  0.6766  6.82   0.009 **
## Age                            0.0212  0.0473  0.20   0.653
## EyeLeft                        0.0756  0.1727  0.19   0.661
```

```
## Strength-0.119:GroupControl  -0.0198  0.6298  0.00    0.975
## Strength0.114:GroupControl    0.6015  0.5607  1.15    0.283
## Strength0.398:GroupControl    0.4708  0.6281  0.56    0.454
## Strength0.477:GroupControl    0.4938  0.6553  0.57    0.451
## Strength0.602:GroupControl   -0.0507  0.6401  0.01    0.937
## Strength0.799:GroupControl   -0.1073  0.6197  0.03    0.862
## Strength0.949:GroupControl   -0.6127  0.6150  0.99    0.319
## Strength1.114:GroupControl    0.5338  0.6823  0.61    0.434
## Strength1.204:GroupControl   -0.1751  0.6980  0.06    0.802
## Strength-0.119:GroupADHD     -1.8368  0.8587  4.58    0.032 *
## Strength0.114:GroupADHD      -0.9180  1.1057  0.69    0.406
## Strength0.398:GroupADHD      -3.0631  1.1921  6.60    0.010 *
## Strength0.477:GroupADHD      -1.4266  0.7546  3.57    0.059 .
## Strength0.602:GroupADHD      -1.0335  1.0821  0.91    0.340
## Strength0.799:GroupADHD       0.4187  0.8874  0.22    0.637
## Strength0.949:GroupADHD      -0.8308  1.0536  0.62    0.430
## Strength1.114:GroupADHD      -2.0485  1.2558  2.66    0.103
## Strength1.204:GroupADHD      -1.2331  1.1054  1.24    0.265
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation structure = exchangeable
## Estimated Scale Parameters:
##
##             Estimate Std.err
## (Intercept)     18.7    2.07
##   Link = identity
##
## Estimated Correlation Parameters:
##       Estimate Std.err
## alpha    0.244   0.035
## Number of clusters:   126  Maximum cluster size: 44
```

```
anova(gee.phnr)
```

```
## Analysis of 'Wald statistic' Table
## Model: gaussian, link: identity
## Response: p72
## Terms added sequentially (first to last)
##
##                Df  X2 P(>|Chi|)
## Strength        9 465   < 2e-16 ***
## Vert            4  10    0.0478 *
## Group           2   4    0.1482
## Ethnicity       4  26   3.2e-05 ***
## Iris            1   3    0.0953 .
```

```
## Gender          1   1    0.3762
## Medication      1   7    0.0094 **
## Age             1   0    0.6581
## Eye             1   0    0.6654
## Strength:Group 18  41     0.0015 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# fitness of the model
MuMIn::QIC(gee.phnr)
```

```
##  QIC
## 4027
```

Dependent variable Tmin

```
# sorting the participants
id.ordered <- order(adhd.final$Participant)
adhd.final <- adhd.final[id.ordered, ]

# model to analyse.
# note the interaction is added
model.tmin <- with(adhd.final,
              formula(Tmin ~
              Strength + Vert + Group + Ethnicity + Iris +
              Gender + Medication + Age + Eye +
              Group:Strength))

gee.tmin <- geeglm(model.tmin, id=Participant,
                         data=adhd.final,
              family=gaussian, corstr="exchangeable")
# note the 'unstructured' correlation structure option produced this error:
# Error: cannot allocate vector of size 2.2 Gb
# hence 'exchangeable' is used
summary(gee.tmin)
```

```
##
## Call:
## geeglm(formula = model.tmin, family = gaussian, data = adhd.final,
##     id = Participant, corstr = "exchangeable")
##
##  Coefficients:
##                              Estimate Std.err   Wald Pr(>|W|)
## (Intercept)                    79.109   7.291 117.74   <2e-16 ***
## Strength-0.119                 -2.794   1.824   2.35   0.1255
## Strength0.114                  -1.275   1.756   0.53   0.4676
## Strength0.398                  -1.987   1.912   1.08   0.2986
## Strength0.477                  -3.745   2.006   3.49   0.0619 .
## Strength0.602                  -2.896   1.856   2.43   0.1187
```

```
## Strength0.799               -1.218   1.913   0.41   0.5243
## Strength0.949               -1.414   2.038   0.48   0.4879
## Strength1.114               -0.460   1.958   0.06   0.8142
## Strength1.204               -0.956   2.105   0.21   0.6498
## Vert0                       -0.651   3.867   0.03   0.8663
## Vert1                       -0.158   1.924   0.01   0.9345
## Vert3                        0.589   1.280   0.21   0.6455
## Vert4                       -1.113   1.700   0.43   0.5127
## GroupControl                -6.129   2.343   6.84   0.0089 **
## GroupADHD                   -3.158   3.795   0.69   0.4053
## EthnicityAsian               4.658   2.714   2.94   0.0862 .
## EthnicityAfro-Caribbean      7.355   2.927   6.31   0.0120 *
## EthnicityLatino              8.114   7.911   1.05   0.3050
## EthnicityMixed              -3.600   2.778   1.68   0.1949
## Iris                         1.396   5.770   0.06   0.8088
## GenderFemale                 4.966   1.623   9.36   0.0022 **
## Medicationtaken             -1.779   3.093   0.33   0.5652
## Age                         -0.160   0.182   0.77   0.3813
## EyeLeft                     -1.151   0.561   4.21   0.0402 *
## Strength-0.119:GroupControl   2.855   2.369   1.45   0.2281
## Strength0.114:GroupControl    0.373   2.347   0.03   0.8738
## Strength0.398:GroupControl    0.681   2.543   0.07   0.7890
## Strength0.477:GroupControl    3.872   2.476   2.45   0.1178
## Strength0.602:GroupControl    2.970   2.414   1.51   0.2187
## Strength0.799:GroupControl    1.866   2.479   0.57   0.4517
## Strength0.949:GroupControl    3.701   2.696   1.88   0.1699
## Strength1.114:GroupControl    2.814   2.522   1.25   0.2645
## Strength1.204:GroupControl    4.938   2.683   3.39   0.0657 .
## Strength-0.119:GroupADHD     -0.378   2.853   0.02   0.8947
## Strength0.114:GroupADHD      -0.247   3.084   0.01   0.9363
## Strength0.398:GroupADHD      -4.557   2.775   2.70   0.1006
## Strength0.477:GroupADHD      -3.628   2.971   1.49   0.2220
## Strength0.602:GroupADHD      -0.490   3.030   0.03   0.8715
## Strength0.799:GroupADHD      -8.133   3.409   5.69   0.0170 *
## Strength0.949:GroupADHD      -4.774   3.395   1.98   0.1596
## Strength1.114:GroupADHD      -5.470   2.931   3.48   0.0620 .
## Strength1.204:GroupADHD      -2.771   3.171   0.76   0.3822
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation structure = exchangeable
## Estimated Scale Parameters:
##
##             Estimate Std.err
## (Intercept)      229    8.19
```

```
##   Link = identity
##
## Estimated Correlation Parameters:
##       Estimate Std.err
## alpha    0.273  0.0318
## Number of clusters:   126  Maximum cluster size: 44
```

```
anova(gee.tmin)
```

```
## Analysis of 'Wald statistic' Table
## Model: gaussian, link: identity
## Response: Tmin
## Terms added sequentially (first to last)
##
##                Df    X2 P(>|Chi|)
## Strength        9 20.85     0.013 *
## Vert            4  0.83     0.934
## Group           2  1.86     0.395
## Ethnicity       4 12.78     0.012 *
## Iris            1  0.08     0.772
## Gender          1  9.56     0.002 **
## Medication      1  0.31     0.579
## Age             1  0.72     0.396
## Eye             1  4.17     0.041 *
## Strength:Group 18 30.31     0.035 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# fitness of the model
MuMIn::QIC(gee.tmin)
```

```
##  QIC
## 4008
```

Dependent variable BT (aka PhNr.Tmin)

```
# sorting the participants
id.ordered <- order(ADHD.final$Participant)
ADHD.final <- ADHD.final[id.ordered, ]

# model to analyse.
# note the interaction is added
model.bt <- with(ADHD.final,
              formula(BT ~
              Strength + Vert + Group + Ethnicity + Iris +
              Gender + Medication + Age + Eye +
              Group:Strength))

gee.bt <- geeglm(model.bt, id=Participant,
```

```
                          data=adhd.final,
              family=gaussian, corstr="exchangeable")
# note the 'unstructured' correlation structure option produced this error:
# Error: cannot allocate vector of size 2.2 Gb
# hence 'exchangeable' is used
summary(gee.bt)
```

```
##
## Call:
## geeglm(formula = model.bt, family = gaussian, data = adhd.final,
##     id = Participant, corstr = "exchangeable")
##
##  Coefficients:
##                               Estimate Std.err  Wald Pr(>|W|)
## (Intercept)                    -9.2435  2.5983 12.66  0.00037 ***
## Strength-0.119                  -0.8819  0.5044  3.06  0.08042 .
## Strength0.114                   -1.5950  0.4215 14.32  0.00015 ***
## Strength0.398                   -2.3464  0.4653 25.42  4.6e-07 ***
## Strength0.477                   -3.5641  0.4141 74.06  < 2e-16 ***
## Strength0.602                   -3.0487  0.4432 47.33  6.0e-12 ***
## Strength0.799                   -4.0350  0.5354 56.80  4.8e-14 ***
## Strength0.949                   -3.8858  0.4768 66.42  3.3e-16 ***
## Strength1.114                   -4.9400  0.5415 83.23  < 2e-16 ***
## Strength1.204                   -5.1127  0.5659 81.63  < 2e-16 ***
## Vert0                          -0.8207  1.6154  0.26  0.61140
## Vert1                          -1.4767  0.6559  5.07  0.02437 *
## Vert3                           0.1059  0.4262  0.06  0.80372
## Vert4                           0.7029  0.4789  2.15  0.14221
## GroupControl                    0.0939  0.7509  0.02  0.90043
## GroupADHD                      -1.9311  1.2820  2.27  0.13198
## EthnicityAsian                 -1.5732  0.9995  2.48  0.11550
## EthnicityAfro-Caribbean        -3.7086  2.6345  1.98  0.15923
## EthnicityLatino                -1.4039  1.0198  1.90  0.16862
## EthnicityMixed                  1.1202  0.7088  2.50  0.11404
## Iris                            2.6641  2.1213  1.58  0.20916
## GenderFemale                   -0.2069  0.5097  0.16  0.68484
## MedicationTaken                 2.3743  0.8300  8.18  0.00423 **
## Age                             0.0717  0.0594  1.46  0.22754
## EyeLeft                         0.1267  0.2093  0.37  0.54508
## Strength-0.119:GroupControl     0.2599  0.7687  0.11  0.73528
## Strength0.114:GroupControl      0.6152  0.7102  0.75  0.38633
## Strength0.398:GroupControl      0.5947  0.6952  0.73  0.39231
## Strength0.477:GroupControl      0.9760  0.7576  1.66  0.19769
## Strength0.602:GroupControl      0.2332  0.8057  0.08  0.77223
## Strength0.799:GroupControl      0.3290  0.6996  0.22  0.63813
## Strength0.949:GroupControl     -0.3843  0.8038  0.23  0.63257
```

```
## Strength1.114:GroupControl    0.6405  0.7787  0.68  0.41079
## Strength1.204:GroupControl   -0.0302  0.8412  0.00  0.97138
## Strength-0.119:GroupADHD     -0.3800  1.2016  0.10  0.75180
## Strength0.114:GroupADHD      -0.3478  1.6775  0.04  0.83575
## Strength0.398:GroupADHD      -2.4019  1.2733  3.56  0.05924 .
## Strength0.477:GroupADHD      -0.3874  1.3018  0.09  0.76604
## Strength0.602:GroupADHD       0.0948  1.3993  0.00  0.94597
## Strength0.799:GroupADHD       1.9238  1.1028  3.04  0.08107 .
## Strength0.949:GroupADHD       0.6410  1.4585  0.19  0.66032
## Strength1.114:GroupADHD      -0.9737  1.4473  0.45  0.50107
## Strength1.204:GroupADHD       0.4221  1.4863  0.08  0.77639
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation structure = exchangeable
## Estimated Scale Parameters:
##
##             Estimate Std.err
## (Intercept)     24.4    3.37
##   Link = identity
##
## Estimated Correlation Parameters:
##       Estimate Std.err
## alpha    0.247  0.0337
## Number of clusters:   126  Maximum cluster size: 44
```

```
anova(gee.bt)
```

```
## Analysis of 'Wald statistic' Table
## Model: gaussian, link: identity
## Response: BT
## Terms added sequentially (first to last)
##
##                Df    X2 P(>|Chi|)
## Strength        9 315.5    <2e-16 ***
## Vert            4  11.7    0.0200 *
## Group           2   6.4    0.0412 *
## Ethnicity       4  14.7    0.0054 **
## Iris            1   2.4    0.1197
## Gender          1   0.3    0.6083
## Medication      1   8.2    0.0043 **
## Age             1   1.4    0.2294
## Eye             1   0.4    0.5473
## Strength:Group 18  32.5    0.0190 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# fitness of the model
MuMIn::QIC(gee.bt)
```

```
##  QIC
## 4017
```

Dependent variable p-ratio

```
# sorting the participants
id.ordered <- order(adhd.final$Participant)
adhd.final <- adhd.final[id.ordered, ]

# model to analyse.
# note the interaction is added
model.p.ratio <- with(adhd.final,
              formula(p_ratio ~
              Strength + Vert + Group + Ethnicity + Iris +
              Gender + Medication + Age + Eye +
              Group:Strength))

gee.p.ratio <- geeglm(model.p.ratio, id=Participant,
                            data=adhd.final,
              family=gaussian, corstr="exchangeable")
# note the 'unstructured' correlation structure option produced this error:
# Error: cannot allocate vector of size 2.2 Gb
# hence 'exchangeable' is used
summary(gee.p.ratio)
```

```
##
## Call:
## geeglm(formula = model.p.ratio, family = gaussian, data = adhd.final,
##     id = Participant, corstr = "exchangeable")
##
##  Coefficients:
##                             Estimate  Std.err  Wald Pr(>|W|)
## (Intercept)                  0.58372  0.20279  8.29  0.00400 **
## Strength-0.119                0.07139  0.05958  1.44  0.23086
## Strength0.114               -0.10018  0.05110  3.84  0.04993 *
## Strength0.398               -0.13052  0.05181  6.35  0.01176 *
## Strength0.477               -0.02376  0.05851  0.16  0.68470
## Strength0.602               -0.07478  0.04943  2.29  0.13031
## Strength0.799                0.02318  0.05356  0.19  0.66526
## Strength0.949                0.02682  0.05376  0.25  0.61781
## Strength1.114                0.11952  0.05390  4.92  0.02659 *
## Strength1.204                0.12105  0.13834  0.77  0.38156
## Vert0                       0.13527  0.09228  2.15  0.14269
## Vert1                       0.02583  0.05608  0.21  0.64512
## Vert3                       0.06066  0.03289  3.40  0.06513 .
```

```
## Vert4                        0.04429  0.04575  0.94  0.33304
## GroupControl                 0.00737  0.08043  0.01  0.92700
## GroupADHD                   -0.35012  0.31672  1.22  0.26895
## EthnicityAsian               0.11571  0.07090  2.66  0.10271
## EthnicityAfro-Caribbean      0.43146  0.12354 12.20  0.00048 ***
## EthnicityLatino              0.08920  0.05228  2.91  0.08799 .
## EthnicityMixed              -0.06200  0.04939  1.58  0.20938
## Iris                        -0.15257  0.16118  0.90  0.34387
## GenderFemale                -0.04863  0.03393  2.05  0.15184
## Medicationtaken             -0.19346  0.07759  6.22  0.01265 *
## Age                         -0.00231  0.00339  0.46  0.49620
## EyeLeft                      0.00042  0.01926  0.00  0.98259
## Strength-0.119:GroupControl -0.09661  0.08499  1.29  0.25565
## Strength0.114:GroupControl  -0.07454  0.07842  0.90  0.34186
## Strength0.398:GroupControl  -0.06449  0.07723  0.70  0.40363
## Strength0.477:GroupControl  -0.07881  0.08277  0.91  0.34101
## Strength0.602:GroupControl  -0.07155  0.07626  0.88  0.34809
## Strength0.799:GroupControl  -0.01058  0.12661  0.01  0.93339
## Strength0.949:GroupControl  -0.03317  0.08230  0.16  0.68694
## Strength1.114:GroupControl  -0.11141  0.08253  1.82  0.17707
## Strength1.204:GroupControl   0.01499  0.15902  0.01  0.92491
## Strength-0.119:GroupADHD     0.33371  0.33968  0.97  0.32590
## Strength0.114:GroupADHD      0.30640  0.32991  0.86  0.35303
## Strength0.398:GroupADHD      0.56159  0.36960  2.31  0.12865
## Strength0.477:GroupADHD      0.22101  0.33922  0.42  0.51471
## Strength0.602:GroupADHD      0.23068  0.33572  0.47  0.49201
## Strength0.799:GroupADHD      0.16999  0.34785  0.24  0.62507
## Strength0.949:GroupADHD      0.21225  0.33322  0.41  0.52414
## Strength1.114:GroupADHD      0.26339  0.33981  0.60  0.43828
## Strength1.204:GroupADHD      0.22995  0.36291  0.40  0.52632
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation structure = exchangeable
## Estimated Scale Parameters:
##
##             Estimate Std.err
## (Intercept)    0.384   0.123
##   Link = identity
##
## Estimated Correlation Parameters:
##       Estimate Std.err
## alpha    0.043  0.0207
## Number of clusters:   126  Maximum cluster size: 44

anova(gee.p.ratio)
```

```
## Analysis of 'Wald statistic' Table
## Model: gaussian, link: identity
## Response: p_ratio
## Terms added sequentially (first to last)
##
##                 Df    X2 P(>|Chi|)
## Strength         9 142.3   < 2e-16 ***
## Vert             4   3.9   0.42544
## Group            2   3.9   0.14066
## Ethnicity        4  20.4   0.00041 ***
## Iris             1   0.8   0.36079
## Gender           1   1.8   0.17955
## Medication       1   6.3   0.01215 *
## Age              1   0.5   0.49372
## Eye              1   0.0   0.97201
## Strength:Group  18  34.7   0.01017 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# fitness of the model
MuMIn::QIC(gee.p.ratio)
```

```
##  QIC
## 3888
```

Dependent variable w-ratio

```
# sorting the participants
id.ordered <- order(adhd.final$Participant)
adhd.final <- adhd.final[id.ordered, ]

# model to analyse.
# note the interaction is added
model.w.ratio <- with(adhd.final,
             formula(w_ratio ~
             Strength + Vert + Group + Ethnicity + Iris +
             Gender + Medication + Age + Eye +
             Group:Strength))

gee.w.ratio <- geeglm(model.w.ratio, id=Participant,
                        data=adhd.final,
             family=gaussian, corstr="exchangeable")
# note the 'unstructured' correlation structure option produced this error:
# Error: cannot allocate vector of size 2.2 Gb
# hence 'exchangeable' is used
summary(gee.w.ratio)
```

```
##
## Call:
```

```
## geeglm(formula = model.w.ratio, family = gaussian, data = adhd.final,
##     id = Participant, corstr = "exchangeable")
##
##  Coefficients:
##                              Estimate   Std.err   Wald Pr(>|W|)
## (Intercept)                   1.417400  0.131530 116.13  < 2e-16 ***
## Strength-0.119                -0.015630  0.045404   0.12  0.73067
## Strength0.114                -0.085298  0.034955   5.95  0.01468 *
## Strength0.398                -0.117711  0.031876  13.64  0.00022 ***
## Strength0.477                -0.090859  0.030634   8.80  0.00302 **
## Strength0.602                -0.118677  0.034234  12.02  0.00053 ***
## Strength0.799                -0.082703  0.035247   5.51  0.01896 *
## Strength0.949                -0.101869  0.036123   7.95  0.00480 **
## Strength1.114                -0.097000  0.034070   8.11  0.00441 **
## Strength1.204                -0.086695  0.039292   4.87  0.02735 *
## Vert0                         0.017757  0.059872   0.09  0.76678
## Vert1                        -0.020888  0.023824   0.77  0.38061
## Vert3                         0.024478  0.018536   1.74  0.18663
## Vert4                         0.011650  0.020524   0.32  0.57028
## GroupControl                 -0.081097  0.048970   2.74  0.09771 .
## GroupADHD                     0.323628  0.241407   1.80  0.18005
## EthnicityAsian                0.131179  0.054540   5.78  0.01616 *
## EthnicityAfro-Caribbean       0.284033  0.093659   9.20  0.00242 **
## EthnicityLatino               0.025118  0.020885   1.45  0.22910
## EthnicityMixed               -0.022764  0.033838   0.45  0.50110
## Iris                         -0.186794  0.106936   3.05  0.08068 .
## GenderFemale                 -0.006407  0.023358   0.08  0.78384
## Medicationtaken              -0.083952  0.025324  10.99  0.00092 ***
## Age                          -0.001074  0.001815   0.35  0.55407
## EyeLeft                       0.010759  0.012787   0.71  0.40009
## Strength-0.119:GroupControl -0.021844  0.055804   0.15  0.69548
## Strength0.114:GroupControl   0.008273  0.048646   0.03  0.86496
## Strength0.398:GroupControl   0.008501  0.043826   0.04  0.84620
## Strength0.477:GroupControl  -0.008291  0.045763   0.03  0.85623
## Strength0.602:GroupControl   0.016462  0.047309   0.12  0.72787
## Strength0.799:GroupControl   0.023610  0.040561   0.34  0.56050
## Strength0.949:GroupControl   0.012260  0.049240   0.06  0.80337
## Strength1.114:GroupControl  -0.002049  0.045748   0.00  0.96427
## Strength1.204:GroupControl   0.000107  0.047260   0.00  0.99819
## Strength-0.119:GroupADHD    -0.305922  0.228442   1.79  0.18052
## Strength0.114:GroupADHD     -0.305155  0.243232   1.57  0.20963
## Strength0.398:GroupADHD     -0.271849  0.222192   1.50  0.22115
## Strength0.477:GroupADHD     -0.351842  0.238229   2.18  0.13970
## Strength0.602:GroupADHD     -0.365483  0.251417   2.11  0.14603
## Strength0.799:GroupADHD     -0.390844  0.238141   2.69  0.10075
```

```
## Strength0.949:GroupADHD     -0.368082  0.252523   2.12  0.14495
## Strength1.114:GroupADHD     -0.285649  0.238000   1.44  0.23006
## Strength1.204:GroupADHD     -0.369992  0.243665   2.31  0.12890
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation structure = exchangeable
## Estimated Scale Parameters:
##
##             Estimate Std.err
## (Intercept)   0.0929  0.0369
##   Link = identity
##
## Estimated Correlation Parameters:
##       Estimate Std.err
## alpha    0.093  0.0459
## Number of clusters:   126  Maximum cluster size: 44
```

```
anova(gee.w.ratio)
```

```
## Analysis of 'Wald statistic' Table
## Model: gaussian, link: identity
## Response: w_ratio
## Terms added sequentially (first to last)
##
##                Df   X2 P(>|Chi|)
## Strength        9 53.9    2e-08 ***
## Vert            4  4.5   0.34310
## Group           2  5.7   0.05780 .
## Ethnicity       4 18.7   0.00091 ***
## Iris            1  3.3   0.07066 .
## Gender          1  0.0   0.83195
## Medication      1 10.7   0.00109 **
## Age             1  0.3   0.56028
## Eye             1  0.8   0.38293
## Strength:Group 18 31.4   0.02603 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# fitness of the model
MuMIn::QIC(gee.w.ratio)
```

```
##  QIC
## 3934
```

Further examination of models in which $FS \cdot G$ was significant

This situation happened in the case of `p72` (aka PhNr), `b-time` and `b-amp`.

The idea here is to examine more parsimonious versions of each model by retaining the significant variables.

The case of PhNr (or p72)

```
# sorting the participants
id.ordered <- order(adhd.final$Participant)
adhd.final <- adhd.final[id.ordered, ]

# model to analyse.
# note the interaction is added
model.phnr.2 <- with(adhd.final,
             formula(p72 ~
             Strength + Ethnicity + Group:Strength))

gee.phnr.2 <- geeglm(model.phnr.2, id=Participant,
                     data=adhd.final,
             family=gaussian, corstr="exchangeable")
# note the 'unstructured' correlation structure option produced this error:
# Error: cannot allocate vector of size 2.2 Gb
# hence 'exchangeable' is used
summary(gee.phnr.2)
```

```
##
## Call:
## geeglm(formula = model.phnr.2, family = gaussian, data = adhd.final,
##     id = Participant, corstr = "exchangeable")
##
##  Coefficients:
##                            Estimate Std.err  Wald Pr(>|W|)
## (Intercept)                 -2.4150  0.4067 35.27  2.9e-09 ***
## Strength-0.119              -0.8346  0.5283  2.50  0.11419
## Strength0.114               -1.7799  0.4319 16.98  3.8e-05 ***
## Strength0.398               -2.5728  0.4480 32.98  9.3e-09 ***
## Strength0.477               -3.5430  0.4779 54.96  1.2e-13 ***
## Strength0.602               -3.2297  0.4290 56.68  5.1e-14 ***
## Strength0.799               -4.0633  0.5019 65.53  5.6e-16 ***
## Strength0.949               -3.9530  0.4525 76.31  < 2e-16 ***
## Strength1.114               -4.9473  0.5781 73.25  < 2e-16 ***
## Strength1.204               -4.9183  0.5624 76.47  < 2e-16 ***
## EthnicityAsian               0.0576  0.5644  0.01  0.91870
## EthnicityAfro-Caribbean     -3.9035  2.9391  1.76  0.18413
## EthnicityLatino             -0.7285  1.6852  0.19  0.66555
## EthnicityMixed               1.5757  0.4104 14.74  0.00012 ***
## Strength-0.367:GroupControl  -0.6220  0.5451  1.30  0.25382
```

```
## Strength-0.119:GroupControl  -0.6581  0.5309  1.54  0.21506
## Strength0.114:GroupControl   -0.0363  0.5154  0.00  0.94382
## Strength0.398:GroupControl   -0.1462  0.5651  0.07  0.79589
## Strength0.477:GroupControl   -0.1355  0.6665  0.04  0.83897
## Strength0.602:GroupControl   -0.6730  0.5956  1.28  0.25851
## Strength0.799:GroupControl   -0.7345  0.6083  1.46  0.22729
## Strength0.949:GroupControl   -1.2327  0.6127  4.05  0.04423 *
## Strength1.114:GroupControl   -0.0960  0.5811  0.03  0.86880
## Strength1.204:GroupControl   -0.8056  0.6526  1.52  0.21705
## Strength-0.367:GroupADHD     -0.6608  0.7784  0.72  0.39592
## Strength-0.119:GroupADHD     -2.4993  0.8194  9.30  0.00229 **
## Strength0.114:GroupADHD      -1.5932  1.1171  2.03  0.15382
## Strength0.398:GroupADHD      -3.7285  1.6435  5.15  0.02329 *
## Strength0.477:GroupADHD      -2.1066  0.9767  4.65  0.03101 *
## Strength0.602:GroupADHD      -1.7093  1.0632  2.58  0.10792
## Strength0.799:GroupADHD      -0.2518  0.7859  0.10  0.74872
## Strength0.949:GroupADHD      -1.5084  0.8554  3.11  0.07784 .
## Strength1.114:GroupADHD      -2.7142  1.3679  3.94  0.04723 *
## Strength1.204:GroupADHD      -1.8956  0.9735  3.79  0.05151 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation structure = exchangeable
## Estimated Scale Parameters:
##
##             Estimate Std.err
## (Intercept)     18.9    2.09
##   Link = identity
##
## Estimated Correlation Parameters:
##       Estimate Std.err
## alpha    0.248  0.0304
## Number of clusters:   126  Maximum cluster size: 44
```

```
anova(gee.phnr.2)
```

```
## Analysis of 'Wald statistic' Table
## Model: gaussian, link: identity
## Response: p72
## Terms added sequentially (first to last)
##
##                Df  X2 P(>|Chi|)
## Strength        9 465   < 2e-16 ***
## Ethnicity       4  26   3.9e-05 ***
## Strength:Group 20  42    0.0026 **
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# fitness of the model
MuMIn::QIC(gee.phnr.2)
```

```
##  QIC
## 3973
```

The case of b-time

```
# sorting the participants
id.ordered <- order(adhd.final$Participant)
adhd.final <- adhd.final[id.ordered, ]

# model to analyse.
# note the interaction is added
model.b_time.2 <- with(adhd.final,
             formula(b_time ~
             Strength + Ethnicity + Eye + Group:Strength))

gee.b.time.2 <- geeglm(model.b_time.2, id=Participant,
                        data=adhd.final,
             family=gaussian, corstr="exchangeable")
# note the 'unstructured' correlation structure option produced this error:
# Error: cannot allocate vector of size 2.2 Gb
# hence 'exchangeable' is used
summary(gee.b.time.2)
```

```
##
## Call:
## geeglm(formula = model.b_time.2, family = gaussian, data = adhd.final,
##     id = Participant, corstr = "exchangeable")
##
##  Coefficients:
##                             Estimate Std.err    Wald Pr(>|W|)
## (Intercept)                  22.1790  0.2244 9765.81  < 2e-16 ***
## Strength-0.119                1.1078  0.2210   25.14  5.3e-07 ***
## Strength0.114                 2.4231  0.1941  155.86  < 2e-16 ***
## Strength0.398                 3.8684  0.1872  427.08  < 2e-16 ***
## Strength0.477                 6.1144  0.1958  975.32  < 2e-16 ***
## Strength0.602                 5.2397  0.1914  749.47  < 2e-16 ***
## Strength0.799                 6.6261  0.2043 1052.27  < 2e-16 ***
## Strength0.949                 7.3771  0.2070 1270.49  < 2e-16 ***
## Strength1.114                 8.1915  0.2231 1348.00  < 2e-16 ***
## Strength1.204                 8.8641  0.2625 1140.33  < 2e-16 ***
## EthnicityAsian                0.5682  0.1480   14.74  0.00012 ***
## EthnicityAfro-Caribbean       1.2023  0.1892   40.39  2.1e-10 ***
## EthnicityLatino              -0.5029  0.4329    1.35  0.24532
```

```
## EthnicityMixed              0.2799  0.2186    1.64  0.20046
## EyeLeft                     0.1205  0.0330   13.35  0.00026 ***
## Strength-0.367:GroupControl  -0.5096  0.2515    4.11  0.04276 *
## Strength-0.119:GroupControl  -0.4502  0.1813    6.16  0.01303 *
## Strength0.114:GroupControl   -0.4240  0.1335   10.09  0.00149 **
## Strength0.398:GroupControl   -0.4681  0.1685    7.71  0.00548 **
## Strength0.477:GroupControl   -0.3705  0.1955    3.59  0.05813 .
## Strength0.602:GroupControl   -0.4636  0.1708    7.36  0.00666 **
## Strength0.799:GroupControl   -0.4999  0.1770    7.97  0.00475 **
## Strength0.949:GroupControl   -0.4428  0.1971    5.05  0.02464 *
## Strength1.114:GroupControl   -0.4345  0.2172    4.00  0.04542 *
## Strength1.204:GroupControl   -0.5553  0.2574    4.65  0.03099 *
## Strength-0.367:GroupADHD     -0.0722  0.2823    0.07  0.79809
## Strength-0.119:GroupADHD      0.1633  0.2706    0.36  0.54624
## Strength0.114:GroupADHD       0.1329  0.2147    0.38  0.53604
## Strength0.398:GroupADHD      -0.3899  0.1861    4.39  0.03613 *
## Strength0.477:GroupADHD      -0.3764  0.2416    2.43  0.11918
## Strength0.602:GroupADHD      -0.3976  0.2025    3.86  0.04953 *
## Strength0.799:GroupADHD      -0.5345  0.2342    5.21  0.02248 *
## Strength0.949:GroupADHD      -0.5151  0.2510    4.21  0.04019 *
## Strength1.114:GroupADHD      -0.2976  0.2426    1.51  0.21983
## Strength1.204:GroupADHD      -0.5527  0.3150    3.08  0.07934 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation structure = exchangeable
## Estimated Scale Parameters:
##
##             Estimate Std.err
## (Intercept)     1.24   0.201
##   Link = identity
##
## Estimated Correlation Parameters:
##       Estimate Std.err
## alpha    0.427  0.0705
## Number of clusters:   126  Maximum cluster size: 44
```

```
anova(gee.b.time.2)
```

```
## Analysis of 'Wald statistic' Table
## Model: gaussian, link: identity
## Response: b_time
## Terms added sequentially (first to last)
##
##                Df   X2 P(>|Chi|)
## Strength        9 9285   < 2e-16 ***
```

```
## Ethnicity       4  170   < 2e-16 ***
## Eye             1   13   0.00026 ***
## Strength:Group 20   92   3.8e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# fitness of the model
MuMIn::QIC(gee.b.time.2)
```

```
##  QIC
## 3941
```

The case of b-amp

```
# sorting the participants
id.ordered <- order(adhd.final$Participant)
adhd.final <- adhd.final[id.ordered, ]

# model to analyse.
# note the interaction is added
model.b_amp.2 <- with(adhd.final,
             formula(b_amp ~
             Strength + Vert + Group + Group:Strength))

gee.b.amp.2 <- geeglm(model.b_amp.2, id=Participant,
                        data=adhd.final,
             family=gaussian, corstr="exchangeable")
# note the 'unstructured' correlation structure option produced this error:
# Error: cannot allocate vector of size 2.2 Gb
# hence 'exchangeable' is used
summary(gee.b.amp.2)
```

```
##
## Call:
## geeglm(formula = model.b_amp.2, family = gaussian, data = adhd.final,
##     id = Participant, corstr = "exchangeable")
##
##  Coefficients:
##                             Estimate Std.err   Wald Pr(>|W|)
## (Intercept)                  10.1519  0.5396 353.95  < 2e-16 ***
## Strength-0.119                4.3013  0.3802 127.98  < 2e-16 ***
## Strength0.114                13.4003  0.7695 303.29  < 2e-16 ***
## Strength0.398                19.4924  0.8361 543.55  < 2e-16 ***
## Strength0.477                17.3404  0.9224 353.42  < 2e-16 ***
## Strength0.602                19.4649  0.8927 475.48  < 2e-16 ***
## Strength0.799                17.4370  0.8014 473.37  < 2e-16 ***
## Strength0.949                17.0442  0.8327 418.94  < 2e-16 ***
## Strength1.114                16.2626  0.8263 387.36  < 2e-16 ***
## Strength1.204                14.1255  0.7546 350.43  < 2e-16 ***
```

```
## Vert0                          -2.4814  1.3600   3.33  0.06808 .
## Vert1                           2.2355  1.2482   3.21  0.07329 .
## Vert3                          -0.5349  0.7431   0.52  0.47161
## Vert4                          -2.2351  1.1648   3.68  0.05500 .
## GroupControl                    1.3882  0.6910   4.04  0.04453 *
## GroupADHD                       4.5927  1.5368   8.93  0.00280 **
## Strength-0.119:GroupControl     0.0413  0.5095   0.01  0.93540
## Strength0.114:GroupControl      0.5521  0.9735   0.32  0.57064
## Strength0.398:GroupControl      1.9743  1.1848   2.78  0.09565 .
## Strength0.477:GroupControl      1.0216  1.3522   0.57  0.44995
## Strength0.602:GroupControl      1.8634  1.2843   2.10  0.14683
## Strength0.799:GroupControl      1.3076  1.2410   1.11  0.29205
## Strength0.949:GroupControl      0.7966  1.1878   0.45  0.50244
## Strength1.114:GroupControl      1.2242  1.1431   1.15  0.28420
## Strength1.204:GroupControl      2.4962  1.1314   4.87  0.02737 *
## Strength-0.119:GroupADHD        2.9849  1.0892   7.51  0.00614 **
## Strength0.114:GroupADHD         6.2837  1.9698  10.18  0.00142 **
## Strength0.398:GroupADHD         9.6266  2.2836  17.77  2.5e-05 ***
## Strength0.477:GroupADHD        11.9744  3.3518  12.76  0.00035 ***
## Strength0.602:GroupADHD        10.7946  2.7542  15.36  8.9e-05 ***
## Strength0.799:GroupADHD         8.3029  2.0723  16.05  6.2e-05 ***
## Strength0.949:GroupADHD         7.4672  1.9937  14.03  0.00018 ***
## Strength1.114:GroupADHD         5.2859  2.2559   5.49  0.01912 *
## Strength1.204:GroupADHD         8.1357  2.1887  13.82  0.00020 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation structure = exchangeable
## Estimated Scale Parameters:
##
##             Estimate Std.err
## (Intercept)     73.2    7.18
##   Link = identity
##
## Estimated Correlation Parameters:
##       Estimate Std.err
## alpha    0.706  0.0326
## Number of clusters:   126  Maximum cluster size: 44
```

```
anova(gee.b.amp.2)
```

```
## Analysis of 'Wald statistic' Table
## Model: gaussian, link: identity
## Response: b_amp
## Terms added sequentially (first to last)
##
```

```
##                 Df   X2 P(>|Chi|)
## strength         9 1294   < 2e-16 ***
## vert             4   15    0.0041 **
## group            2   24   5.9e-06 ***
## strength:group 18   62   1.0e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# fitness of the model
MuMIn::QIC(gee.b.amp.2)
```

```
##  QIC
## 3863
```

Non-parametric multiple comparisons in models where the interaction $ FS G$ was significant

In the following section we'll perform pairwise comparisons between the three groups at each flash strength for each dependent variable. The method proposed by Noguchi et al. (2020) will be used [3].

Because we're comparing independent groups, the `mctp` function is used (with the default parameters; i.e. Tukey-type contrast, global pseudo-rank estimation method, Fisher asymptotic approximation method, and with 95% CIs).

PhNr (aka, p72)

```
library(nparcomp)

# creating subsets for each flash strength
flash1 <- subset(ADHD.final, strength==-0.367)
flash2 <- subset(ADHD.final, strength==-0.119)
flash3 <- subset(ADHD.final, strength==0.114)
flash4 <- subset(ADHD.final, strength==0.398)
flash5 <- subset(ADHD.final, strength==0.477)
flash6 <- subset(ADHD.final, strength==0.602)
flash7 <- subset(ADHD.final, strength==0.799)
flash8 <- subset(ADHD.final, strength==0.949)
flash9 <- subset(ADHD.final, strength==1.114)
flash10 <- subset(ADHD.final, strength==1.204)


# the tests...
f1 <- mctp(p72 ~ group , info=F, data=flash1)
f2 <- mctp(p72 ~ group , info=F, data=flash2)
```

[3] Noguchi, K., Abel, R., Marmolejo-Ramos, F., & Konietschke, F. (2020). Nonparametric multiple comparisons. *Behavior Research Methods, 15* (2), 489-502.

```
F3 <- MCTP(P72 ~ GROUP , INFO=F, DATA=FLASH3)
F4<- MCTP(P72 ~ GROUP , INFO=F, DATA=FLASH4)
F5 <- MCTP(P72 ~ GROUP , INFO=F, DATA=FLASH5)
F6 <- MCTP(P72 ~ GROUP , INFO=F, DATA=FLASH6)
F7 <- MCTP(P72 ~ GROUP , INFO=F, DATA=FLASH7)
F8 <- MCTP(P72 ~ GROUP , INFO=F, DATA=FLASH8)
F9 <- MCTP(P72 ~ GROUP , INFO=F, DATA=FLASH9)
F10 <- MCTP(P72 ~ GROUP ,INFO=F,  DATA=FLASH10)
```

flash -0.367

For all cases recall that (): 1 = ASD 2 = Control 3 = ADHD

```
SUMMARY(F1)

##
##  #----------------NONPARAMETRIC MULTIPLE COMPARISONS FOR RELATIVE EFFECTS-------
--------#
##
##  - ALTERNATIVE HYPOTHESIS:  TRUE DIFFERENCES OF RELATIVE EFFECTS ARE NOT EQUAL TO 0
##  - ESTIMATION METHOD: GLOBAL PSEUDO RANKS
##  - TYPE OF CONTRAST : TUKEY
##  - CONFIDENCE LEVEL: 95 %
##  - METHOD = FISHER WITH 82 DF
##
##  #-------------------------------------------------------------------------
-----------------#
##
##  #----DATA INFO-----------------------------------------------------------
----------------#
##    SAMPLE SIZE EFFECT LOWER UPPER
## 1     ASD  159  0.536 0.501 0.571
## 2 CONTROL  179  0.512 0.478 0.547
## 3    ADHD   53  0.451 0.405 0.499
##
##  #----CONTRAST------------------------------------------------------------
----------------#
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----ANALYSIS------------------------------------------------------------
----------------#
##       ESTIMATOR  LOWER UPPER STATISTIC P.VALUE
## 2 - 1    -0.024 -0.098 0.051    -0.758   0.726
## 3 - 1    -0.085 -0.193 0.025    -1.835   0.161
```

```
## 3 - 2    -0.061 -0.168 0.047    -1.343   0.370
##
##  #----Overall----------------------------------------------------------------
-----------------#
##   Quantile p.Value
## 1     2.37   0.161
##
##  #---------------------------------------------------------------------------
------------------#
```

flash -0.119

```
summary(f2)
```

```
##
##  #-----------------Nonparametric Multiple Comparisons for relative effects-------
---------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 83 DF
##
##  #---------------------------------------------------------------------------
------------------#
##
##  #----Data Info--------------------------------------------------------------
-----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  155  0.572 0.538 0.606
## 2 Control  171  0.549 0.516 0.581
## 3    ADHD   53  0.379 0.338 0.421
##
##  #----Contrast---------------------------------------------------------------
-----------------#
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis---------------------------------------------------------------
-----------------#
##       Estimator  Lower  Upper Statistic  p.Value
## 2 - 1    -0.024 -0.100  0.052    -0.741 7.38e-01
## 3 - 1    -0.194 -0.290 -0.093    -4.531 6.71e-05
## 3 - 2    -0.170 -0.264 -0.072    -4.121 2.80e-04
```

```
##
## #----Overall--------------------------------------------------------------------
----------------#
##   Quantile  p.Value
## 1     2.38 6.71e-05
##
## #-------------------------------------------------------------------------------
-----------------#
```

flash 0.114

```
summary(f3)
```

```
##
## #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 79 DF
##
## #-------------------------------------------------------------------------------
-----------------#
##
## #----Data Info------------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  152  0.537 0.502 0.573
## 2 Control  163  0.546 0.511 0.581
## 3    ADHD   55  0.417 0.369 0.466
##
## #----Contrast-------------------------------------------------------------------
----------------#
##        1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
## #----Analysis-------------------------------------------------------------------
----------------#
##       Estimator  Lower  Upper Statistic p.Value
## 2 - 1     0.009 -0.065  0.082     0.274  0.9586
## 3 - 1    -0.121 -0.231 -0.008    -2.530  0.0342
## 3 - 2    -0.129 -0.238 -0.017    -2.734  0.0201
##
```

```
##  #----Overall----------------------------------------------------------
----------------#
##   Quantile p.Value
## 1     2.37  0.0201
##
##  #---------------------------------------------------------------------
-----------------#
```

flash 0.398

```
summary(f4)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 78 DF
##
##  #---------------------------------------------------------------------
-----------------#
##
##  #----Data Info--------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  154  0.556 0.521 0.591
## 2 Control  168  0.554 0.520 0.587
## 3    ADHD   51  0.390 0.346 0.437
##
##  #----Contrast---------------------------------------------------------
----------------#
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis---------------------------------------------------------
----------------#
##       Estimator  Lower  Upper Statistic p.Value
## 2 - 1    -0.002 -0.076  0.073     -0.06 0.99799
## 3 - 1    -0.166 -0.270 -0.057     -3.62 0.00142
## 3 - 2    -0.164 -0.266 -0.058     -3.67 0.00125
##
##  #----Overall----------------------------------------------------------
```

```
----------------#
##   Quantile p.Value
## 1     2.38 0.00125
##
## #----------------------------------------------------------------------------
-----------------#
```

flash 0.477

```
summary(f5)
```

```
##
## #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 93 DF
##
## #----------------------------------------------------------------------------
-----------------#
##
## #----Data Info----------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  144  0.549 0.513 0.584
## 2 Control  163  0.556 0.522 0.590
## 3    ADHD   54  0.395 0.353 0.440
##
## #----Contrast-----------------------------------------------------------------
----------------#
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
## #----Analysis-----------------------------------------------------------------
----------------#
##       Estimator  Lower  Upper Statistic p.Value
## 2 - 1     0.007 -0.071  0.085     0.213 0.97514
## 3 - 1    -0.154 -0.255 -0.048    -3.454 0.00226
## 3 - 2    -0.161 -0.259 -0.058    -3.712 0.00102
##
## #----Overall------------------------------------------------------------------
----------------#
```

```
##   Quantile p.Value
## 1     2.37 0.00102
##
##  #--------------------------------------------------------------------------------------#
```

flash 0.602

```
summary(f6)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects---------------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 73 DF
##
##  #--------------------------------------------------------------------------------------#
##
##  #----Data Info-------------------------------------------------------------------------#
##    Sample Size Effect Lower Upper
## 1     ASD  150  0.543 0.506 0.578
## 2 Control  168  0.533 0.498 0.569
## 3    ADHD   51  0.424 0.375 0.474
##
##  #----Contrast--------------------------------------------------------------------------#
##        1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis--------------------------------------------------------------------------#
##       Estimator  Lower  Upper Statistic p.Value
## 2 - 1    -0.009 -0.083  0.065    -0.292  0.9533
## 3 - 1    -0.118 -0.231 -0.003    -2.442  0.0428
## 3 - 2    -0.109 -0.220  0.005    -2.280  0.0627
##
##  #----Overall---------------------------------------------------------------------------#
##   Quantile p.Value
```

```
## 1     2.38  0.0428
##
## #------------------------------------------------------------------------------------------#
```

flash 0.799

```
summary(f7)
```

```
##
## #----------------Nonparametric Multiple Comparisons for relative effects---------------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 78 DF
##
## #------------------------------------------------------------------------------------------#
##
## #----Data Info------------------------------------------------------------------------------#
##    Sample Size Effect Lower Upper
## 1     ASD  156  0.521 0.485 0.557
## 2 Control  167  0.496 0.461 0.532
## 3    ADHD   53  0.482 0.433 0.532
##
## #----Contrast-------------------------------------------------------------------------------#
##        1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
## #----Analysis-------------------------------------------------------------------------------#
##       Estimator  Lower Upper Statistic p.Value
## 2 - 1    -0.025 -0.100 0.050    -0.797   0.701
## 3 - 1    -0.039 -0.152 0.075    -0.810   0.693
## 3 - 2    -0.014 -0.126 0.099    -0.288   0.954
##
## #----Overall--------------------------------------------------------------------------------#
##   Quantile p.Value
## 1     2.37   0.693
```

```
##
## #------------------------------------------------------------------------------------#
```

flash 0.949

```
summary(f8)
```

```
##
## #----------------Nonparametric Multiple Comparisons for relative effects---------------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 83 DF
##
## #------------------------------------------------------------------------------------#
##
## #----Data Info------------------------------------------------------------------------#
##    Sample Size Effect Lower Upper
## 1     ASD  154  0.564 0.529 0.599
## 2 Control  167  0.514 0.479 0.549
## 3    ADHD   55  0.422 0.376 0.470
##
## #----Contrast-------------------------------------------------------------------------#
##        1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
## #----Analysis-------------------------------------------------------------------------#
##       Estimator  Lower  Upper Statistic p.Value
## 2 - 1    -0.050 -0.124  0.024     -1.60 0.24492
## 3 - 1    -0.142 -0.249 -0.032     -3.06 0.00799
## 3 - 2    -0.092 -0.199  0.017     -2.00 0.11503
##
## #----Overall--------------------------------------------------------------------------#
##   Quantile p.Value
## 1     2.37 0.00799
##
```

```
## #--------------------------------------------------------------------
-----------------#
```

flash 1.114

```
summary(f9)
```

```
##
## #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
## - Alternative Hypothesis: True differences of relative effects are not equal to 0
## - Estimation Method: Global Pseudo ranks
## - Type of Contrast : Tukey
## - Confidence Level: 95 %
## - Method = Fisher with 77 DF
##
## #--------------------------------------------------------------------
-----------------#
##
## #----Data Info------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  158  0.563 0.528 0.596
## 2 Control  168  0.570 0.537 0.602
## 3    ADHD   54  0.368 0.324 0.413
##
## #----Contrast-------------------------------------------------------
----------------#
##        1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
## #----Analysis-------------------------------------------------------
----------------#
##       Estimator  Lower  Upper Statistic  p.Value
## 2 - 1     0.007 -0.065  0.079     0.237 9.69e-01
## 3 - 1    -0.195 -0.297 -0.089    -4.324 1.12e-04
## 3 - 2    -0.202 -0.302 -0.098    -4.572 4.66e-05
##
## #----Overall--------------------------------------------------------
----------------#
##   Quantile  p.Value
## 1     2.38 4.66e-05
##
```

```
## #--------------------------------------------------------------------
-----------------#
```

flash 1.204

```
summary(f10)

##
## #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
## - Alternative Hypothesis: True differences of relative effects are not equal to 0
## - Estimation Method: Global Pseudo ranks
## - Type of Contrast : Tukey
## - Confidence Level: 95 %
## - Method = Fisher with 85 DF
##
## #--------------------------------------------------------------------
-----------------#
##
## #----Data Info-------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  158  0.559 0.524 0.593
## 2 Control  172  0.534 0.500 0.568
## 3    ADHD   52  0.407 0.362 0.453
##
## #----Contrast--------------------------------------------------------
----------------#
##        1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
## #----Analysis--------------------------------------------------------
----------------#
##       Estimator  Lower  Upper Statistic p.Value
## 2 - 1    -0.024 -0.099  0.050    -0.778 0.71406
## 3 - 1    -0.152 -0.256 -0.045    -3.367 0.00315
## 3 - 2    -0.128 -0.231 -0.022    -2.864 0.01393
##
## #----Overall---------------------------------------------------------
----------------#
##   Quantile p.Value
## 1     2.37 0.00315
##
```

```
## #-------------------------------------------------------------------------------------#
```

b-time

```
# THE TESTS...
F1.B.TIME <- MCTP(B_TIME ~ GROUP , INFO=F, DATA=FLASH1)
F2.B.TIME  <- MCTP(B_TIME ~ GROUP , INFO=F, DATA=FLASH2)
F3.B.TIME  <- MCTP(B_TIME ~ GROUP , INFO=F, DATA=FLASH3)
F4.B.TIME <- MCTP(B_TIME ~ GROUP , INFO=F, DATA=FLASH4)
F5.B.TIME  <- MCTP(B_TIME ~ GROUP , INFO=F, DATA=FLASH5)
F6.B.TIME  <- MCTP(B_TIME ~ GROUP , INFO=F, DATA=FLASH6)
F7.B.TIME  <- MCTP(B_TIME ~ GROUP , INFO=F, DATA=FLASH7)
F8.B.TIME  <- MCTP(B_TIME ~ GROUP , INFO=F, DATA=FLASH8)
F9.B.TIME  <- MCTP(B_TIME ~ GROUP , INFO=F, DATA=FLASH9)
F10.B.TIME  <- MCTP(B_TIME ~ GROUP ,INFO=F,  DATA=FLASH10)
```

flash -0.367

For all cases recall that (): 1 = ASD 2 = Control 3 = ADHD

```
SUMMARY(F1.B.TIME)

##
## #----------------NONPARAMETRIC MULTIPLE COMPARISONS FOR RELATIVE EFFECTS---------------#
##
## - ALTERNATIVE HYPOTHESIS:  TRUE DIFFERENCES OF RELATIVE EFFECTS ARE NOT EQUAL TO 0
## - ESTIMATION METHOD: GLOBAL PSEUDO RANKS
## - TYPE OF CONTRAST : TUKEY
## - CONFIDENCE LEVEL: 95 %
## - METHOD = FISHER WITH 91 DF
##
## #-------------------------------------------------------------------------------------#
##
## #----DATA INFO-----------------------------------------------------------------------#
##   SAMPLE SIZE EFFECT LOWER UPPER
## 1     ASD  159  0.498 0.464 0.533
## 2 CONTROL  179  0.438 0.405 0.472
## 3    ADHD   53  0.564 0.519 0.608
##
## #----CONTRAST------------------------------------------------------------------------#
##        1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
```

```
##
##  #----Analysis------------------------------------------------------------------
----------------#
##       Estimator  Lower Upper Statistic p.Value
## 2 - 1    -0.060 -0.134 0.015     -1.91   0.139
## 3 - 1     0.065 -0.040 0.169      1.48   0.303
## 3 - 2     0.126  0.022 0.226      2.88   0.013
##
##  #----Overall-------------------------------------------------------------------
----------------#
##   Quantile p.Value
## 1     2.37   0.013
##
##  #------------------------------------------------------------------------------
-----------------#
```

flash -0.119

```
summary(f2.b.time)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 83 DF
##
##  #------------------------------------------------------------------------------
-----------------#
##
##  #----Data Info-----------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  155  0.496 0.461 0.532
## 2 Control  171  0.424 0.391 0.459
## 3    ADHD   53  0.579 0.532 0.625
##
##  #----Contrast------------------------------------------------------------------
----------------#
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
```

```
##  #----Analysis--------------------------------------------------------------
----------------#
##       Estimator  Lower Upper Statistic p.Value
## 2 - 1    -0.072 -0.145 0.002     -2.31 0.05886
## 3 - 1     0.083 -0.027 0.190      1.80 0.17199
## 3 - 2     0.155  0.048 0.258      3.42 0.00269
##
##  #----Overall---------------------------------------------------------------
----------------#
##   Quantile p.Value
## 1     2.37 0.00269
##
##  #--------------------------------------------------------------------------
-----------------#
```

flash 0.114

```
summary(f3.b.time)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 80 DF
##
##  #--------------------------------------------------------------------------
-----------------#
##
##  #----Data Info-------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  152  0.511 0.475 0.547
## 2 Control  163  0.427 0.393 0.461
## 3    ADHD   55  0.562 0.515 0.608
##
##  #----Contrast--------------------------------------------------------------
----------------#
##        1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis--------------------------------------------------------------
```

```
----------------#
##       Estimator  Lower  Upper Statistic p.Value
## 2 - 1    -0.085 -0.160 -0.009     -2.65 0.02527
## 3 - 1     0.051 -0.059  0.159      1.10 0.51215
## 3 - 2     0.135  0.029  0.239      3.01 0.00933
##
##  #----Overall--------------------------------------------------------------
----------------#
##   Quantile p.Value
## 1     2.38 0.00933
##
##  #--------------------------------------------------------------------------
-----------------#
```

flash 0.398

```
summary(f4.b.time)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 86 DF
##
##  #--------------------------------------------------------------------------
-----------------#
##
##  #----Data Info------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  154  0.561 0.525 0.595
## 2 Control  168  0.465 0.430 0.500
## 3    ADHD   51  0.474 0.429 0.521
##
##  #----Contrast-------------------------------------------------------------
----------------#
##        1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis-------------------------------------------------------------
----------------#
```

```
##       Estimator  Lower  Upper Statistic p.Value
## 2 - 1    -0.095 -0.171 -0.018    -2.938  0.0112
## 3 - 1    -0.086 -0.192  0.021    -1.902  0.1412
## 3 - 2     0.009 -0.097  0.116     0.205  0.9768
##
##  #----Overall---------------------------------------------------------------
----------------#
##   Quantile p.Value
## 1     2.37  0.0112
##
##  #--------------------------------------------------------------------------
-----------------#
```

flash 0.477

```
summary(f5.b.time)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 87 DF
##
##  #--------------------------------------------------------------------------
-----------------#
##
##  #----Data Info-------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  144  0.544 0.508 0.580
## 2 Control  163  0.494 0.459 0.529
## 3    ADHD   54  0.462 0.416 0.508
##
##  #----Contrast--------------------------------------------------------------
----------------#
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis--------------------------------------------------------------
----------------#
##       Estimator  Lower Upper Statistic p.Value
```

```
## 2 - 1    -0.050 -0.129 0.029     -1.50   0.293
## 3 - 1    -0.082 -0.190 0.027     -1.79   0.176
## 3 - 2    -0.032 -0.138 0.074     -0.72   0.750
##
##  #----Overall-------------------------------------------------------------
----------------#
##   Quantile p.Value
## 1     2.37   0.176
##
##  #------------------------------------------------------------------------
-----------------#
```

flash 0.602

```
summary(f6.b.time)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 92 DF
##
##  #------------------------------------------------------------------------
-----------------#
##
##  #----Data Info-----------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  150  0.562 0.526 0.597
## 2 Control  168  0.480 0.445 0.515
## 3    ADHD   51  0.458 0.414 0.504
##
##  #----Contrast------------------------------------------------------------
----------------#
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis------------------------------------------------------------
----------------#
##       Estimator  Lower  Upper Statistic p.Value
## 2 - 1    -0.082 -0.160 -0.004    -2.490  0.0375
```

```
## 3 - 1    -0.104 -0.208  0.003    -2.307  0.0586
## 3 - 2    -0.021 -0.125  0.083    -0.483  0.8783
##
##  #----Overall---------------------------------------------------------------
----------------#
##   Quantile p.Value
## 1     2.37  0.0375
##
##  #--------------------------------------------------------------------------
-----------------#
```

flash 0.799

```
summary(f7.b.time)
```

```
##
##  #-----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 88 DF
##
##  #--------------------------------------------------------------------------
-----------------#
##
##  #----Data Info-------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  156  0.580 0.545 0.614
## 2 Control  167  0.489 0.454 0.523
## 3    ADHD   53  0.431 0.387 0.476
##
##  #----Contrast--------------------------------------------------------------
----------------#
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis--------------------------------------------------------------
----------------#
##       Estimator  Lower  Upper Statistic p.Value
## 2 - 1    -0.091 -0.167 -0.015     -2.83 0.01520
## 3 - 1    -0.149 -0.251 -0.044     -3.35 0.00335
```

```
## 3 - 2    -0.058 -0.160  0.046    -1.32 0.38541
##
##  #----Overall-----------------------------------------------------------------
----------------#
##   Quantile p.Value
## 1    2.37 0.00335
##
##  #----------------------------------------------------------------------------
-----------------#
```

flash 0.949

```
summary(f8.b.time)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 86 DF
##
##  #----------------------------------------------------------------------------
-----------------#
##
##  #----Data Info----------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  154  0.565 0.529 0.599
## 2 Control  167  0.491 0.456 0.526
## 3    ADHD   55  0.444 0.399 0.490
##
##  #----Contrast-----------------------------------------------------------------
----------------#
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis-----------------------------------------------------------------
----------------#
##      Estimator  Lower  Upper Statistic p.Value
## 2 - 1    -0.074 -0.149  0.003    -2.29  0.0603
## 3 - 1    -0.120 -0.225 -0.013    -2.66  0.0243
## 3 - 2    -0.047 -0.152  0.059    -1.05  0.5453
```

```
##
##  #----Overall--------------------------------------------------------------
----------------#
##   Quantile p.Value
## 1     2.37  0.0243
##
##  #-------------------------------------------------------------------------
-----------------#
```

flash 1.114

```
summary(f9.b.time)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 89 DF
##
##  #-------------------------------------------------------------------------
-----------------#
##
##  #----Data Info------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  158  0.543 0.507 0.578
## 2 Control  168  0.469 0.434 0.503
## 3    ADHD   54  0.488 0.444 0.533
##
##  #----Contrast-------------------------------------------------------------
----------------#
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis-------------------------------------------------------------
----------------#
##       Estimator  Lower Upper Statistic p.Value
## 2 - 1    -0.074 -0.152 0.004    -2.253  0.0666
## 3 - 1    -0.054 -0.158 0.050    -1.234  0.4330
## 3 - 2     0.020 -0.082 0.122     0.462  0.8880
##
```

```
## #----Overall--------------------------------------------------------------------------#
##   Quantile p.Value
## 1     2.38  0.0666
## 
## #---------------------------------------------------------------------------------------#
```

flash 1.204

```
summary(f10.b.time)
```

```
## 
## #----------------Nonparametric Multiple Comparisons for relative effects---------------#
## 
## - Alternative Hypothesis:  True differences of relative effects are not equal to 0
## - Estimation Method: Global Pseudo ranks
## - Type of Contrast : Tukey
## - Confidence Level: 95 %
## - Method = Fisher with 77 DF
## 
## #---------------------------------------------------------------------------------------#
## 
## #----Data Info--------------------------------------------------------------------------#
##    Sample Size Effect Lower Upper
## 1     ASD  158  0.586 0.551 0.620
## 2 Control  172  0.493 0.459 0.527
## 3    ADHD   52  0.421 0.376 0.468
## 
## #----Contrast---------------------------------------------------------------------------#
##        1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
## 
## #----Analysis---------------------------------------------------------------------------#
##       Estimator  Lower  Upper Statistic p.Value
## 2 - 1    -0.093 -0.167 -0.018     -2.94 0.01154
## 3 - 1    -0.165 -0.270 -0.056     -3.60 0.00166
## 3 - 2    -0.072 -0.177  0.035     -1.60 0.24665
## 
## #----Overall----------------------------------------------------------------
```

```
----------------#
##   Quantile p.Value
## 1     2.38 0.00166
##
##  #-------------------------------------------------------------------------
-----------------#
```

b-amplitude

```
# the tests...
f1.b.amp <- mctp(b_amp ~ Group , info=F, data=flash1)
f2.b.amp  <- mctp(b_amp ~ Group , info=F, data=flash2)
f3.b.amp  <- mctp(b_amp ~ Group , info=F, data=flash3)
f4.b.amp <- mctp(b_amp ~ Group , info=F, data=flash4)
f5.b.amp  <- mctp(b_amp ~ Group , info=F, data=flash5)
f6.b.amp  <- mctp(b_amp ~ Group , info=F, data=flash6)
f7.b.amp  <- mctp(b_amp ~ Group , info=F, data=flash7)
f8.b.amp  <- mctp(b_amp ~ Group , info=F, data=flash8)
f9.b.amp  <- mctp(b_amp ~ Group , info=F, data=flash9)
f10.b.amp  <- mctp(b_amp ~ Group ,info=F,  data=flash10)
```

flash -0.367

For all cases recall that (): 1 = ASD 2 = Control 3 = ADHD

```
summary(f1.b.amp)

##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 76 DF
##
##  #-------------------------------------------------------------------------
-----------------#
##
##  #----Data Info-------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  159  0.409 0.376 0.443
## 2 Control  179  0.467 0.434 0.501
## 3    ADHD   53  0.624 0.576 0.669
##
##  #----Contrast--------------------------------------------------------------
----------------#
```

```
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis------------------------------------------------------------
----------------#
##       Estimator  Lower Upper Statistic  p.Value
## 2 - 1     0.058 -0.012 0.128      1.96 1.26e-01
## 3 - 1     0.215  0.106 0.319      4.63 3.37e-05
## 3 - 2     0.157  0.049 0.261      3.45 2.40e-03
##
##  #----Overall-------------------------------------------------------------
----------------#
##   Quantile  p.Value
## 1    2.38 3.37e-05
##
##  #-----------------------------------------------------------------------
-----------------#
```

flash -0.119

```
summary(f2.b.amp)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 70 DF
##
##  #-----------------------------------------------------------------------
-----------------#
##
##  #----Data Info-----------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  155  0.400 0.368 0.433
## 2 Control  171  0.433 0.402 0.466
## 3    ADHD   53  0.667 0.622 0.709
##
##  #----Contrast------------------------------------------------------------
----------------#
##       1  2 3
```

```
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis------------------------------------------------------------
----------------#
##       Estimator  Lower Upper Statistic  p.Value
## 2 - 1     0.033 -0.036 0.102      1.15 4.83e-01
## 3 - 1     0.266  0.163 0.364      5.97 1.47e-07
## 3 - 2     0.233  0.131 0.331      5.33 2.26e-06
##
##  #----Overall-------------------------------------------------------------
----------------#
##   Quantile  p.Value
## 1     2.38 1.47e-07
##
##  #------------------------------------------------------------------------
-----------------#
```

flash 0.114

```
summary(f3.b.amp)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 71 DF
##
##  #------------------------------------------------------------------------
-----------------#
##
##  #----Data Info-----------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  152  0.393 0.360 0.426
## 2 Control  163  0.435 0.403 0.467
## 3    ADHD   55  0.673 0.627 0.716
##
##  #----Contrast------------------------------------------------------------
----------------#
##       1  2 3
## 2 - 1 -1  1 0
```

```
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis--------------------------------------------------------------
----------------#
##       Estimator  Lower Upper Statistic  p.Value
## 2 - 1     0.042 -0.027 0.110      1.46 3.11e-01
## 3 - 1     0.280  0.175 0.380      6.14 6.12e-08
## 3 - 2     0.238  0.134 0.337      5.33 2.61e-06
##
##  #----Overall---------------------------------------------------------------
----------------#
##   Quantile  p.Value
## 1     2.38 6.12e-08
##
##  #--------------------------------------------------------------------------
-----------------#
```

flash 0.398

```
summary(f4.b.amp)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 85 DF
##
##  #--------------------------------------------------------------------------
-----------------#
##
##  #----Data Info-------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  154  0.374 0.344 0.405
## 2 Control  168  0.440 0.409 0.472
## 3    ADHD   51  0.686 0.646 0.723
##
##  #----Contrast--------------------------------------------------------------
----------------#
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
```

```
## 3 - 2  0 -1 1
##
##  #----Analysis--------------------------------------------------------------------------------#
##       Estimator  Lower Upper Statistic  p.Value
## 2 - 1    0.066 -0.003 0.135      2.26 6.53e-02
## 3 - 1    0.311  0.219 0.398      7.70 3.71e-11
## 3 - 2    0.245  0.152 0.335      6.11 6.47e-08
##
##  #----Overall---------------------------------------------------------------------------------#
##   Quantile  p.Value
## 1     2.38 3.71e-11
##
##  #---------------------------------------------------------------------------------------------#
```

flash 0.477

```
summary(f5.b.amp)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects---------------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 101 DF
##
##  #---------------------------------------------------------------------------------------------#
##
##  #----Data Info-------------------------------------------------------------------------------#
##    Sample Size Effect Lower Upper
## 1     ASD  144  0.383 0.353 0.414
## 2 Control  163  0.420 0.390 0.450
## 3    ADHD   54  0.697 0.662 0.731
##
##  #----Contrast--------------------------------------------------------------------------------#
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
```

```
##
## #----Analysis--------------------------------------------------------------------------#
##       Estimator  Lower Upper Statistic  p.Value
## 2 - 1     0.037 -0.035 0.108      1.22 4.43e-01
## 3 - 1     0.315  0.229 0.395      8.35 2.44e-13
## 3 - 2     0.278  0.193 0.358      7.57 1.18e-10
##
## #----Overall---------------------------------------------------------------------------#
##   Quantile  p.Value
## 1     2.38 2.44e-13
##
## #-----------------------------------------------------------------------------------------#
```

flash 0.602

```
summary(f6.b.amp)
```

```
##
## #----------------Nonparametric Multiple Comparisons for relative effects---------------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 116 DF
##
## #-----------------------------------------------------------------------------------------#
##
## #----Data Info-------------------------------------------------------------------------#
##    Sample Size Effect Lower Upper
## 1     ASD  150  0.369 0.340 0.399
## 2 Control  168  0.434 0.405 0.464
## 3    ADHD   51  0.697 0.664 0.727
##
## #----Contrast--------------------------------------------------------------------------#
##        1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
```

```
##  #----Analysis--------------------------------------------------------------
----------------#
##       Estimator  Lower Upper Statistic  p.Value
## 2 - 1     0.065 -0.007 0.137      2.15 8.36e-02
## 3 - 1     0.328  0.249 0.402      9.38 4.44e-16
## 3 - 2     0.262  0.183 0.338      7.66 5.58e-12
##
##  #----Overall---------------------------------------------------------------
----------------#
##   Quantile  p.Value
## 1     2.37 4.44e-16
##
##  #--------------------------------------------------------------------------
-----------------#
```

flash 0.799

```
summary(f7.b.amp)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
---------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 122 DF
##
##  #--------------------------------------------------------------------------
-----------------#
##
##  #----Data Info-------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  156  0.377 0.348 0.406
## 2 Control  167  0.431 0.401 0.461
## 3    ADHD   53  0.692 0.659 0.724
##
##  #----Contrast--------------------------------------------------------------
----------------#
##        1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis--------------------------------------------------------------
```

```
----------------#
##       Estimator  Lower Upper Statistic  p.Value
## 2 - 1     0.054 -0.018 0.125      1.78 1.79e-01
## 3 - 1     0.315  0.236 0.391      8.99 3.44e-15
## 3 - 2     0.262  0.180 0.340      7.37 3.35e-11
##
##  #----Overall----------------------------------------------------------------
----------------#
##   Quantile  p.Value
## 1     2.37 3.44e-15
##
##  #---------------------------------------------------------------------------
-----------------#
```

flash 0.949

```
summary(f8.b.amp)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 109 DF
##
##  #---------------------------------------------------------------------------
-----------------#
##
##  #----Data Info--------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  154  0.384 0.354 0.414
## 2 Control  167  0.425 0.395 0.455
## 3    ADHD   55  0.691 0.656 0.724
##
##  #----Contrast---------------------------------------------------------------
----------------#
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis---------------------------------------------------------------
----------------#
```

```
##      Estimator  Lower Upper Statistic  p.Value
## 2 - 1    0.041 -0.029 0.112     1.39 3.50e-01
## 3 - 1    0.307  0.223 0.387     8.34 2.78e-13
## 3 - 2    0.266  0.182 0.346     7.30 4.68e-11
##
##  #----Overall---------------------------------------------------------------
----------------#
##   Quantile  p.Value
## 1    2.37 2.78e-13
##
##  #--------------------------------------------------------------------------
-----------------#
```

flash 1.114

```
summary(f9.b.amp)
```

```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 85 DF
##
##  #--------------------------------------------------------------------------
-----------------#
##
##  #----Data Info-------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  158  0.399 0.367 0.432
## 2 Control  168  0.457 0.425 0.490
## 3    ADHD   54  0.644 0.601 0.684
##
##  #----Contrast--------------------------------------------------------------
----------------#
##       1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis--------------------------------------------------------------
----------------#
##      Estimator  Lower Upper Statistic  p.Value
```

```
## 2 - 1    0.058 -0.014 0.130     1.90 1.42e-01
## 3 - 1    0.244  0.146 0.338     5.79 2.46e-07
## 3 - 2    0.187  0.089 0.281     4.49 6.20e-05
##
##  #----Overall----------------------------------------------------------------
----------------#
##   Quantile  p.Value
## 1     2.38 2.46e-07
##
##  #---------------------------------------------------------------------------
-----------------#
```

flash 1.204

```
summary(f10.b.amp)
```

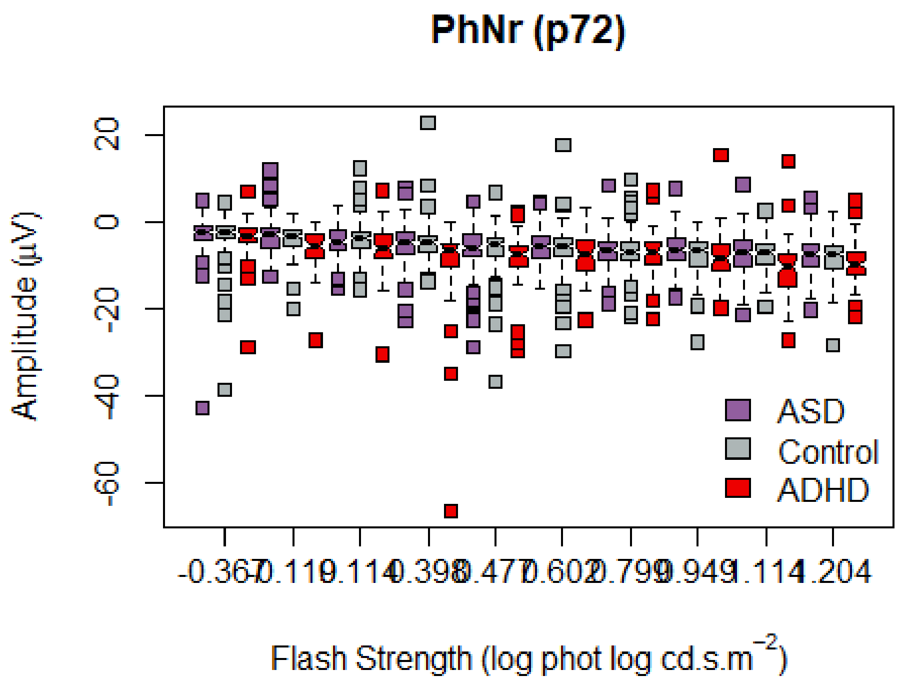
```
##
##  #----------------Nonparametric Multiple Comparisons for relative effects-------
--------#
##
##  - Alternative Hypothesis:  True differences of relative effects are not equal to 0
##  - Estimation Method: Global Pseudo ranks
##  - Type of Contrast : Tukey
##  - Confidence Level: 95 %
##  - Method = Fisher with 85 DF
##
##  #---------------------------------------------------------------------------
-----------------#
##
##  #----Data Info--------------------------------------------------------------
----------------#
##    Sample Size Effect Lower Upper
## 1     ASD  158  0.363 0.334 0.393
## 2 Control  172  0.455 0.424 0.486
## 3    ADHD   52  0.682 0.643 0.719
##
##  #----Contrast---------------------------------------------------------------
----------------#
##        1  2 3
## 2 - 1 -1  1 0
## 3 - 1 -1  0 1
## 3 - 2  0 -1 1
##
##  #----Analysis---------------------------------------------------------------
----------------#
##       Estimator Lower Upper Statistic  p.Value
## 2 - 1    0.091 0.023 0.159     3.17 5.89e-03
```

```
## 3 - 1     0.319 0.230 0.403     8.11 1.58e-12
## 3 - 2     0.228 0.135 0.316     5.76 2.49e-07
##
##  #----Overall-----------------------------------------------------------
----------------#
##   Quantile  p.Value
## 1     2.38 1.58e-12
##
##  #-----------------------------------------------------------------------
-----------------#
```

Graphing the interactions

PhNr (aka p72)

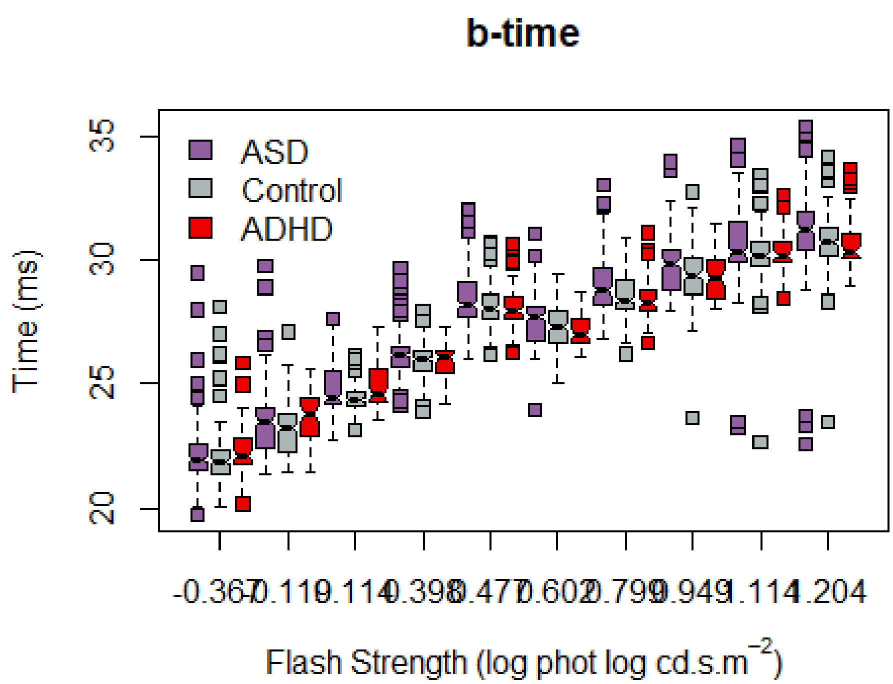
```
boxplot(adhd.final$p72 ~ interaction(adhd.final$Group,adhd.final$Strength),
        main='PhNr (p72)',
        notch=T, xlab=expression('Flash Strength (log phot log cd.s.m'^-2*')'),
        ylab=expression(paste('Amplitude (',mu,'V)')),
        xaxt='n',bg=picked.colours,
        col=picked.colours,lwd=1, pch=22)
# Changing x axis so that the labels for the flash strength are shown
# underneath the second group for every flash strength
xtick<-seq(from=2, to=  ,
           by=3,length.out = length(levels(adhd.final$Strength)))
axis(side=1, at=xtick, labels = FALSE)
text(x=xtick,  y=-73, # tick location on the y axis
     labels = levels(adhd.final$Strength), srt = 0, pos = 1, xpd = TRUE)

# a legend
legend('bottomright', border='black', bty='n',
       legend=levels(adhd.final$Group),
       fill=picked.colours,
       cex=1)
```



b-time

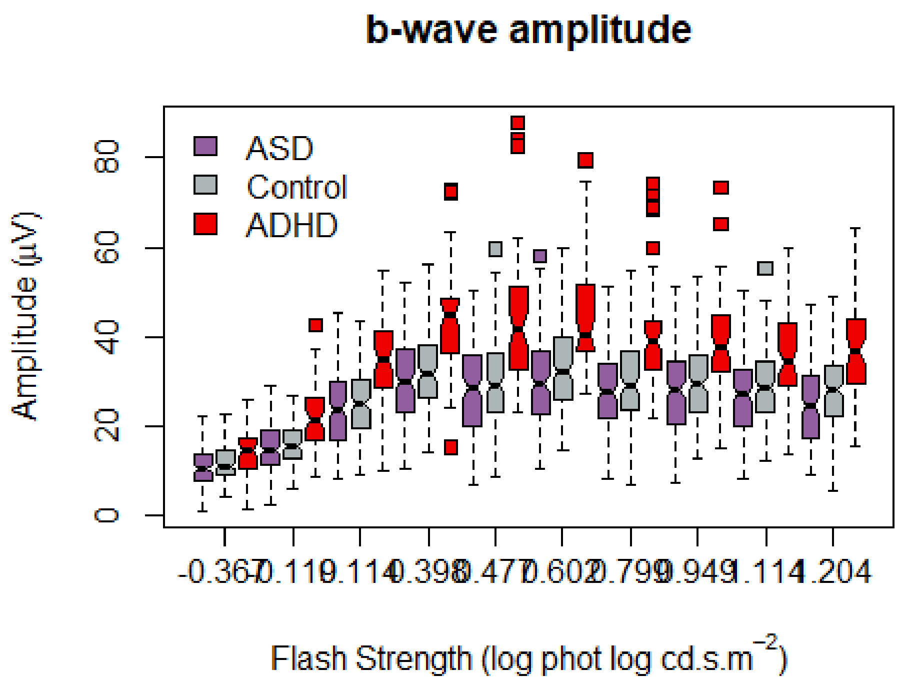
```
# previous observations showed that participant A61 had a large value of 45.796. Havin
g this value distorts the plot so it's removed...

b.time2 <- subset(adhd.final, b_time < 45)

boxplot(b.time2$b_time ~ interaction(b.time2$Group,b.time2$Strength),
        main='b-time',
        notch=T, xlab=expression('Flash Strength (log phot log cd.s.m'^-2*')'),
        ylab='Time (ms)',
        xaxt='n',bg=picked.colours,
        col=picked.colours,lwd=1, pch=22)
# Changing x axis so that the labels for the flash strength are shown
# underneath the second group for every flash strength
xtick<-seq(from=2, to=  ,
           by=3,length.out = length(levels(adhd.final$Strength)))
axis(side=1, at=xtick, labels = FALSE)
text(x=xtick,  y=18, # tick location on the y axis
     labels = levels(adhd.final$Strength), srt = 0, pos = 1, xpd = TRUE)

# a legend
legend('topleft', border='black', bty='n',
       legend=levels(adhd.final$Group),
```

```
        fill=picked.colours,
        cex=1)
```



b-amp

```
boxplot(adhd.final$b_amp ~ interaction(adhd.final$Group,adhd.final$Strength),
        main='b-wave amplitude',
        notch=T, xlab=expression('Flash Strength (log phot log cd.s.m'^-2*')'),
        ylab=expression(paste('Amplitude (',mu,'V)')),
        xaxt='n',bg=picked.colours,
        col=picked.colours,lwd=1, pch=22)
# Changing x axis so that the labels for the flash strength are shown
# underneath the second group for every flash strength
xtick<-seq(from=2, to=  ,
           by=3,length.out = length(levels(adhd.final$Strength)))
axis(side=1, at=xtick, labels = FALSE)
text(x=xtick,  y=-5, # tick location on the Y axis
     labels = levels(adhd.final$Strength), srt = 0, pos = 1, xpd = TRUE)

# a legend
legend('topleft', border='black', bty='n',
        legend=levels(adhd2$Group),
        fill=picked.colours,
        cex=1)
```


b-wave amplitude
ASD
Control
ADHD
Amplitude (µV)
0
20
40
60
80
-0.367
-0.119
0.114
0.398
0.477
0.602
0.799
0.949
1.114
1.204
Flash Strength (log phot log cd.s.m^{-2})