

# Supplement to ‘No clear or consistent evidence that wearing an eye mask leads to meaningful improvement in learning and alertness: A reanalysis of Greco et al. (2023)’

Stephen Rhodes\*

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## Code and R output

Additional code for results not presented here is available at <https://github.com/stephenrho/sleep/blob/main/reanalysis.Rmd>

```
knitr::opts_chunk$set(echo = T, warning = F, message = F)
```

```
library(data.table)
library(ggplot2)
library(lme4)
```

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

```
library(lmerTest)
```

```
##
```

```
## Attaching package: 'lmerTest'
```

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

```
##
```

```
##      lmer
```

```
## The following object is masked from 'package:stats':
```

```
##
```

```
##      step
```

```
library(afex)
```

```
## *****
```

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

```
## - Functions for ANOVAs: aov_car(), aov_ez(), and aov_4()
```

```
## - Methods for calculating p-values with mixed(): 'S', 'KR', 'LRT', and 'PB'
```

```
## - 'afex_aov' and 'mixed' objects can be passed to emmeans() for follow-up tests
```

```
## - NEWS: emmeans() for ANOVA models now uses model = 'multivariate' as default.
```

```
## - Get and set global package options with: afex_options()
```

```
## - Set orthogonal sum-to-zero contrasts globally: set_sum_contrasts()
```

```
## - For example analyses see: browseVignettes("afex")
```

```
## *****
```

---

\*steverho89@gmail.com

```

##
## Attaching package: 'afex'

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

theme_set(theme_bw())

# get the data
proj_url = "https://osf.io/q4p9v/"

if (!dir.exists("data/")){
  library(osfr)
  dir.create("data/")
  osf = osf_retrieve_node(proj_url)
  osf_download(osf_ls_files(osf), recurse = T, path = "data/")
}

readdat <- function(file){
  # reshape the data
  exp = ifelse(grepl("Experiment1", file), 1, 2)

  if (exp == 1){
    dat = readxl::read_xlsx(file, skip = 1)

    stopifnot(all(colnames(dat) == c('Participants', 'YearOfExperiment',
                                     'Eyemask...3', 'ControlMask...4',
                                     'Eyemask...5', 'ControlMask...6'))))

    dv_cols = paste(
      rep(c("Eyemask", "Control"), 2),
      rep(c("day6", "day7"), each = 2),
      sep = "_"
    )

    colnames(dat)[3:6] = dv_cols
  } else{
    dat = readxl::read_xlsx(file)

    stopifnot(all(colnames(dat) == c('Participants', 'YearOfExperiment',
                                     'Eyemask', 'ControlMask'))))

    dv_cols = c("Eyemask", "Control")
    colnames(dat)[3:4] = dv_cols
  }

  colnames(dat)[2] = "year"

  dat$ID = paste(dat$Participants, dat$year, sep = "_")
  # wide to long
  d = reshape2::melt(dat, id.vars = c("ID", "year"), measure.vars = dv_cols, variable.name = "condition")

  d$eye_mask = as.numeric(grepl("Eyemask", d$condition))

  if (exp == 1){

```

```

    d$day = ifelse(grepl("day7", d$condition), "day 7", "day 6")
    d$day = as.factor(d$day)
    d$condition = gsub("_day6|_day7", "", d$condition)
  }

  d$condition = as.factor(d$condition)
  d$year = as.factor(d$year)

  return(d)
}

pal1 = readdat("data/Tasks&Questionnaire/PAL/PAL_Experiment1.xlsx")

## New names:
## * 'Eyemask' -> 'Eyemask...3'
## * 'ControlMask' -> 'ControlMask...4'
## * 'Eyemask' -> 'Eyemask...5'
## * 'ControlMask' -> 'ControlMask...6'

pvt1 = readdat("data/Tasks&Questionnaire/PVT/PVT_Experiment1.xlsx")

## New names:
## * 'Eyemask' -> 'Eyemask...3'
## * 'ControlMask' -> 'ControlMask...4'
## * 'Eyemask' -> 'Eyemask...5'
## * 'ControlMask' -> 'ControlMask...6'

msl1 = readdat("data/Tasks&Questionnaire/MSL/MSL_Experiment1.xlsx")

## New names:
## * 'Eyemask' -> 'Eyemask...3'
## * 'ControlMask' -> 'ControlMask...4'
## * 'Eyemask' -> 'Eyemask...5'
## * 'ControlMask' -> 'ControlMask...6'

pal2 = readdat("data/Tasks&Questionnaire/PAL/PAL_Experiment2.xlsx")
pvt2 = readdat("data/Tasks&Questionnaire/PVT/PVT_Experiment2.xlsx")

```

## Paired associates learning

```

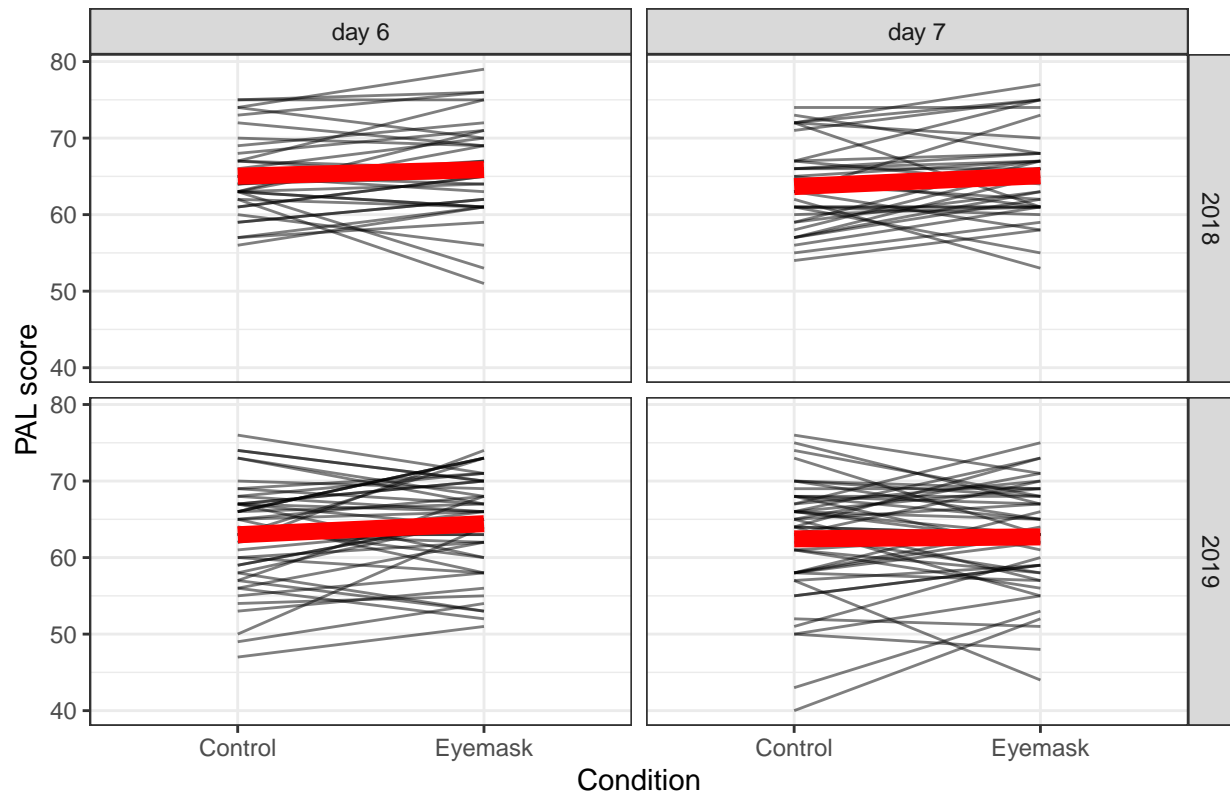
### PAL (primary outcome) ----
length(unique(pal1$ID))

## [1] 83

ggplot(pal1, aes(x = condition, y=y, group=ID)) +
  geom_line(alpha=1/2) +
  stat_summary(aes(x = condition, y=y, group=1),
    fun="mean", geom="line", inherit.aes = F,
    lwd=3, col="red") +
  #facet_wrap(~day) +
  facet_grid(year ~ day) +
  labs(x="Condition", y="PAL score", title="Experiment 1")

```

## Experiment 1



```
aggregate(y ~ eye_mask, data = subset(pal1, day == "day 6"), FUN = mean)
```

```
##   eye_mask      y
## 1         0 63.86747
## 2         1 65.06024
```

```
aggregate(y ~ eye_mask, data = subset(pal1, day == "day 7"), FUN = mean)
```

```
##   eye_mask      y
## 1         0 62.97590
## 2         1 63.73494
```

```
aggregate(y ~ eye_mask, data = pal1, FUN = mean)
```

```
##   eye_mask      y
## 1         0 63.42169
## 2         1 64.39759
```

```
# original model
```

```
lmer(y ~ eye_mask + (1 | ID) + (1 | year), data = subset(pal1, day == "day 6"),
      REML = FALSE) |>
summary()
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
## method [lmerModLmerTest]
## Formula: y ~ eye_mask + (1 | ID) + (1 | year)
## Data: subset(pal1, day == "day 6")
##
##      AIC      BIC    logLik deviance df.resid
## 1026.0   1041.6   -508.0   1016.0     161
```

```
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.31541 -0.47568 -0.01511  0.47858  1.81248
##
## Random effects:
##   Groups   Name            Variance Std.Dev.
##   ID       (Intercept) 2.688e+01 5.184e+00
##   year     (Intercept) 9.193e-09 9.588e-05
##   Residual                1.097e+01 3.312e+00
## Number of obs: 166, groups: ID, 83; year, 2
##
## Fixed effects:
##              Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)  63.8675     0.6752 110.3482   94.58 <2e-16 ***
## eye_mask      1.1928     0.5141  82.9998    2.32  0.0228 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##          (Intr)
## eye_mask -0.381
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help('isSingular')
```

```
# analysis reported in supplement
paliw = reshape2::dcast(pal1, formula = ... ~ day, value.var = "y")
paliw$y = paliw$`day 6` - paliw$`day 7`

lmer(y ~ eye_mask + (1 | ID) + (1 | year), data = paliw,
      REML = FALSE) |>
summary()
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
## method [lmerModLmerTest]
## Formula: y ~ eye_mask + (1 | ID) + (1 | year)
## Data: paliw
##
##      AIC      BIC    logLik deviance df.resid
##    910.8    926.3   -450.4    900.8     161
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.67741 -0.46148 -0.07879  0.52334  3.15008
##
## Random effects:
##   Groups   Name            Variance Std.Dev.
##   ID       (Intercept) 5.071     2.252
##   year     (Intercept) 0.000     0.000
##   Residual                9.171     3.028
## Number of obs: 166, groups: ID, 83; year, 2
##
## Fixed effects:
##              Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)   0.8916     0.4142 147.3209    2.152  0.033 *
```

```

## eye_mask      0.4337      0.4701  83.0000   0.923    0.359
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##      (Intr)
## eye_mask -0.567
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help('isSingular')

# note: in both cases there is a singular fit warning
# most likely trying to estimate random effect for 2 groups...

# more appropriate model
# (1) analyze the data from the PAL task as a whole.
# no need to separate days.
# (2) account for ID level variability in difference
# between eye mask and control
# (3) year = different control conditions, so should account
# for *interaction* between eye mask and year
# doesn't make sense to include year as random effect

# make contrast for year and day sum to zero so coefficient
# for mask is at 'average' year
contrasts(pal1$year) = c(-1,1)
contrasts(pal1$day) = c(-1,1)
mod = lmer(y ~ eye_mask + year + day + eye_mask:year + eye_mask:day +
           (1 + eye_mask + day | ID),
           data = pal1, REML = FALSE)

summary(mod)

## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
## method [lmerModLmerTest]
## Formula: y ~ eye_mask + year + day + eye_mask:year + eye_mask:day + (1 +
## eye_mask + day | ID)
## Data: pal1
##
##      AIC      BIC   logLik deviance df.resid
## 1934.7   1984.1   -954.3   1908.7     319
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.4422 -0.3903  0.0354  0.4336  1.8659
##
## Random effects:
## Groups   Name                Variance Std.Dev. Corr
## ID      (Intercept)    34.929     5.910
##          eye_mask      16.315     4.039   -0.37
##          day1          1.268     1.126    0.15  0.04
## Residual                4.585     2.141
## Number of obs: 332, groups: ID, 83
##
## Fixed effects:
##              Estimate Std. Error      df t value Pr(>|t|)

```

```
## (Intercept)      63.5294      0.6756  83.0275  94.040  <2e-16 ***
## eye_mask         0.9949      0.5063  83.0007   1.965  0.0527 .
## year1           -0.8127      0.6720  82.9971  -1.209  0.2299
## day1            -0.4458      0.2071 147.3204  -2.152  0.0330 *
## eye_mask:year1   -0.1432      0.5062  82.9992  -0.283  0.7780
## eye_mask:day1    -0.2169      0.2350  83.0008  -0.923  0.3589
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##          (Intr) ey_msk year1  day1   ey_msk:yr1
## eye_mask   -0.399
## year1      -0.132  0.053
## day1        0.085  0.018  0.000
## eye_msk:yr1 0.053 -0.132 -0.404  0.000
## eye_msk:dy1 0.000  0.000  0.000 -0.567  0.000
```

```
confint(mod)
```

```
##              2.5 %      97.5 %
## .sig01        5.053420664  7.00022554
## .sig02       -0.562801918 -0.13689757
## .sig03       -0.158218807  0.44300848
## .sig04        3.288056165  4.93011533
## .sig05       -0.298900327  0.36696218
## .sig06        0.725117612  1.49258991
## .sigma        1.852737338  2.51354342
## (Intercept)   62.189849761 64.86888442
## eye_mask      -0.009002654  1.99875178
## year1         -2.145130099  0.51972010
## day1          -0.854400642 -0.03716564
## eye_mask:year1 -1.146831500  0.86047341
## eye_mask:day1  -0.682932725  0.24919783
```

```
# some warnings but profile plots/zeta diagrams look ok
# https://stackoverflow.com/questions/74018300/warnings-when-computing-confidence-intervals-using-confi
# pp = profile(mod)
# lattice::xyplot(pp)
```

```
# mixed ANOVA (note: tests extra interactions)
aov_car(y ~ condition*year*day + Error(ID/(condition*day)),
        data = pal1, fun_aggregate = mean)
```

```
## Anova Table (Type 3 tests)
```

```
##
```

```
## Response: y
```

```
##      Effect      df      MSE      F      ges p.value
## 1      year 1, 81 128.37      2.01 .019 .160
## 2      condition 1, 81 21.42      3.77 + .006 .056
## 3      year:condition 1, 81 21.42      0.08 <.001 .780
## 4      day 1, 81 9.89 10.07 ** .007 .002
## 5      year:day 1, 81 9.89      0.00 <.001 .949
## 6      condition:day 1, 81 4.51      0.46 <.001 .501
## 7      year:condition:day 1, 81 4.51      3.45 + .001 .067
## ---
```

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

```
# Experiment 2
```

```
# n unique IDs don't match N = 33 reported in paper  
length(unique(pal2$ID))
```

```
## [1] 28
```

```
aggregate(y ~ condition, pal2, mean)
```

```
##   condition      y
```

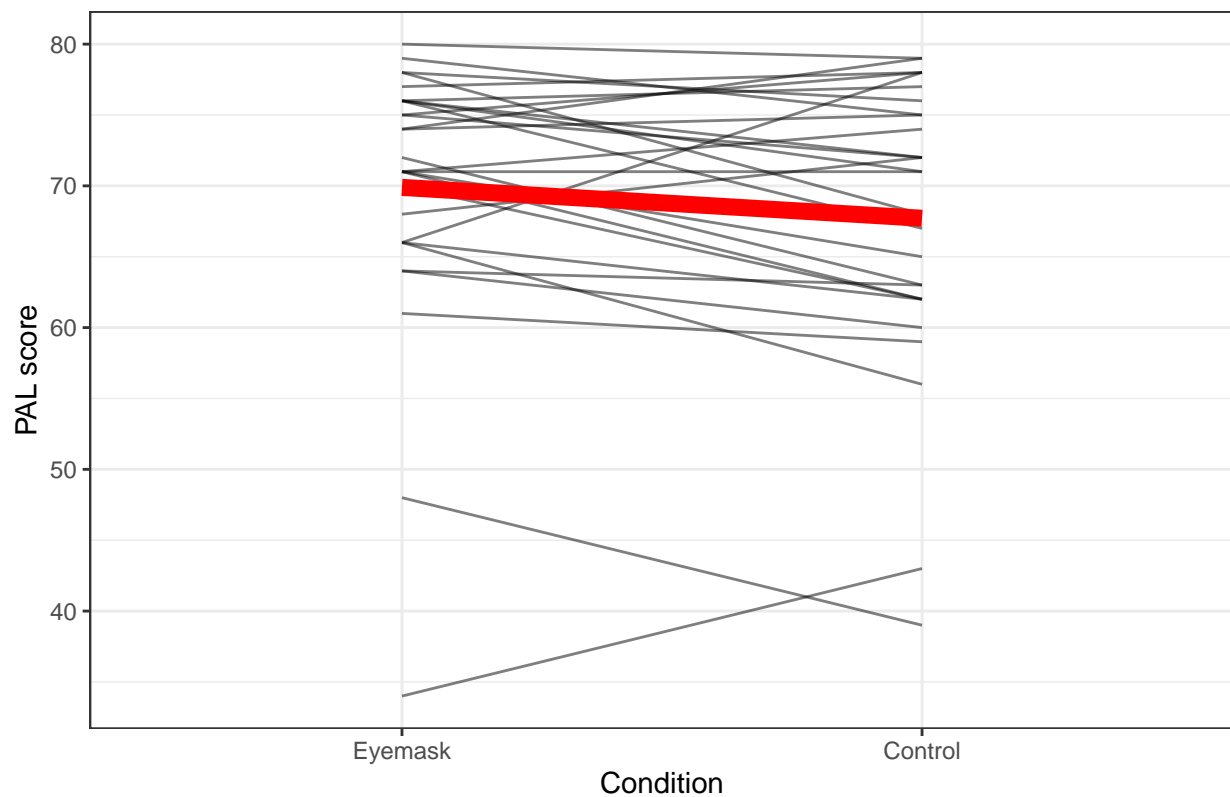
```
## 1   Eyemask 69.89286
```

```
## 2   Control 67.71429
```

```
# the means match though...
```

```
ggplot(pal2, aes(x = condition, y=y, group=ID)) +  
  geom_line(alpha=1/2) +  
  stat_summary(aes(x = condition, y=y, group=1),  
               fun="mean", geom="line", inherit.aes = F,  
               lwd=3, col="red") +  
  labs(x="Condition", y="PAL score", title="Experiment 2")
```

## Experiment 2



```
# recreate original analysis
```

```
mod = lmer(y ~ eye_mask + (1 | ID), data = pal2, REML = F)
```

```
summary(mod)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
```

```
##   method [lmerModLmerTest]
```



```
## Formula: y ~ eye_mask + (1 | ID)
## Data: pal2
##
## AIC      BIC    logLik deviance df.resid
## 389.1    397.2   -190.5   381.1     52
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.08816 -0.40609  0.05209  0.53920  1.85424
##
## Random effects:
## Groups Name Variance Std.Dev.
## ID      (Intercept) 80.33   8.963
## Residual          15.82   3.978
## Number of obs: 56, groups: ID, 28
##
## Fixed effects:
## Estimate Std. Error df t value Pr(>|t|)
## (Intercept) 67.714 1.853 32.981 36.541 <2e-16 ***
## eye_mask 2.179 1.063 28.000 2.049 0.0499 *
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
## (Intr)
## eye_mask -0.287
```

```
confint(mod)
```

```
##           2.5 %    97.5 %
## .sig01      6.79628773 12.198409
## .sigma      3.12625783 5.299753
## (Intercept) 63.97268304 71.455888
## eye_mask     0.02132378 4.335819
```

```
aov_car(y ~ condition + Error(ID/condition), data = pal2, fun_aggregate = mean)
```

```
## Anova Table (Type 3 tests)
##
## Response: y
## Effect df MSE F ges p.value
## 1 condition 1, 27 16.41 4.05 + .012 .054
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1 ' ' 1
```

## Psychomotor vigilance test

```
### PVT ----
```

```
length(unique(pvt1$ID))
```

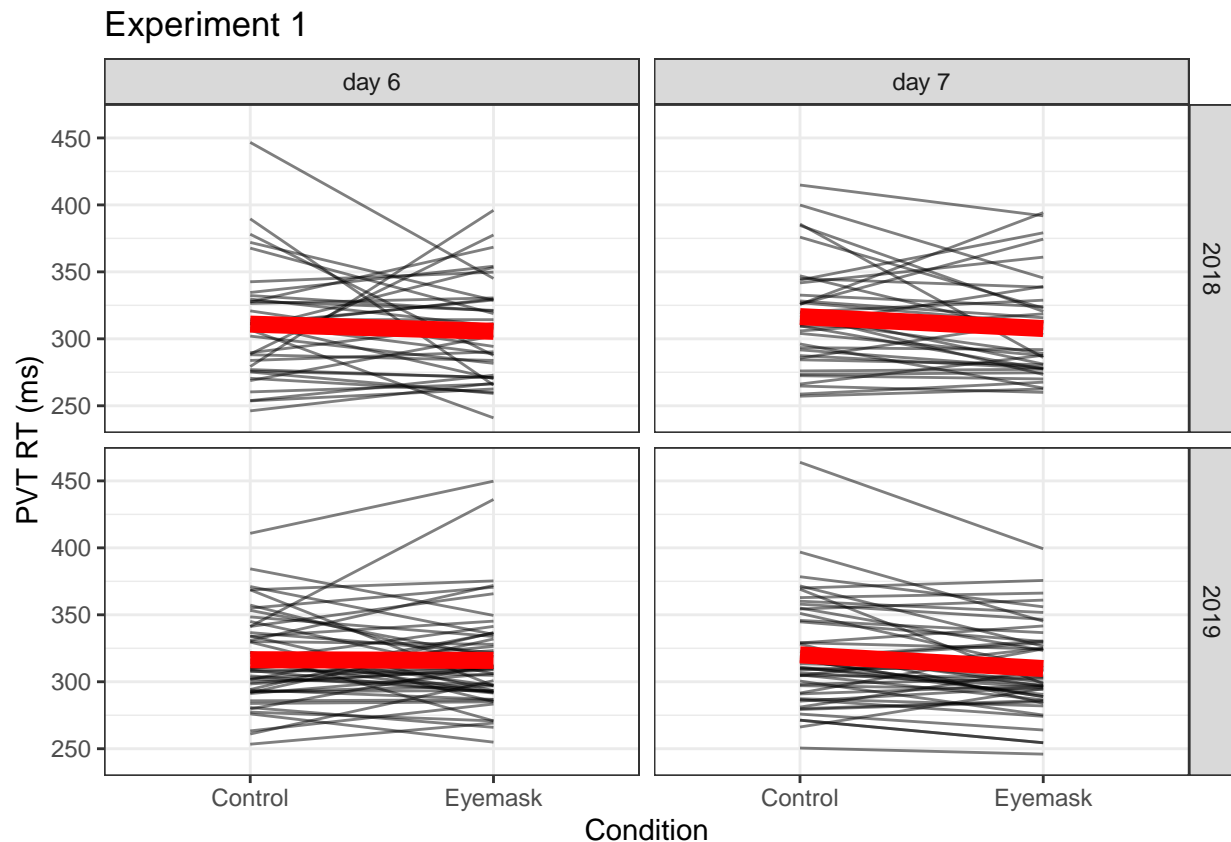
```
## [1] 85
```

```
ggplot(pvt1, aes(x = condition, y=y, group=ID)) +
  geom_line(alpha=1/2) +
  stat_summary(aes(x = condition, y=y, group=1),
    fun="mean", geom="line", inherit.aes = F,
```

```

    lwd=3, col="red") +
#facet_wrap(~day) +
facet_grid(year ~ day) +
labs(x="Condition", y="PVT RT (ms)", title="Experiment 1")

```



```

# this matches reported means (but figure 2b means look different?)
aggregate(y ~ eye_mask, data = pvt1, FUN = mean)

```

```

##   eye_mask      y
## 1      0 316.3667
## 2      1 310.2642

```

```

# original model

```

```

lmer(y ~ eye_mask + (1 | ID) + (1 | year), data = pvt1, REML = FALSE) |>
summary()

```

```

## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
## method [lmerModLmerTest]
## Formula: y ~ eye_mask + (1 | ID) + (1 | year)
## Data: pvt1
##
##      AIC      BIC    logLik deviance df.resid
##  3229.9   3249.0  -1609.9   3219.9     335
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.1558 -0.5352 -0.0691  0.4103  3.9252
##

```

```

## Random effects:
##   Groups   Name      Variance Std.Dev.
##   ID       (Intercept) 9.650e+02 3.106e+01
##   year     (Intercept) 1.661e-13 4.076e-07
##   Residual                4.264e+02 2.065e+01
## Number of obs: 340, groups:  ID, 85; year, 2
##
## Fixed effects:
##               Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)   316.367      3.723 102.416  84.975  < 2e-16 ***
## eye_mask      -6.103      2.240 255.000  -2.725  0.00688 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##          (Intr)
## eye_mask -0.301
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help('isSingular')

# note: boundary (singular) fit: see help('isSingular')

# more appropriate model
contrasts(pvt1$year) = c(-1,1)
mod = lmer(y ~ eye_mask*year + (1 + eye_mask | ID), data = pvt1, REML = FALSE)

summary(mod)

## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: y ~ eye_mask * year + (1 + eye_mask | ID)
##   Data: pvt1
##
##      AIC      BIC    logLik deviance df.resid
## 3191.8    3222.4   -1587.9   3175.8      332
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.7233 -0.4018 -0.0342  0.3265  4.0790
##
## Random effects:
##   Groups   Name      Variance Std.Dev. Corr
##   ID       (Intercept) 1221.5   34.95
##           eye_mask     549.2   23.44  -0.43
##   Residual                243.1   15.59
## Number of obs: 340, groups:  ID, 85
##
## Fixed effects:
##               Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)   316.0236      4.0223  84.9998  78.568  <2e-16 ***
## eye_mask      -6.2391      3.0894  85.0002  -2.019  0.0466 *
## year1         2.2433      4.0223  84.9998   0.558  0.5785
## eye_mask:year1  0.8929      3.0894  85.0002   0.289  0.7733
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

```
##
## Correlation of Fixed Effects:
##          (Intr) ey_msk year1
## eye_mask    -0.462
## year1       -0.153  0.071
## eye_mask:yr1  0.071 -0.153 -0.462

confint(mod)

##                2.5 %      97.5 %
## .sig01         29.7633896  41.4972967
## .sig02        -0.6217213 -0.1952631
## .sig03         18.5268658  29.1157177
## .sigma         14.0705657  17.4081695
## (Intercept)   308.0501885 323.9970280
## eye_mask      -12.3633000 -0.1148689
## year1         -5.7300893  10.2167502
## eye_mask:year1 -5.2313556   7.0170756

# mixed ANOVA (averages day 6 and 7)
aov_car(y ~ condition*year + Error(ID/condition),
        data = pvt1, fun_aggregate = mean)

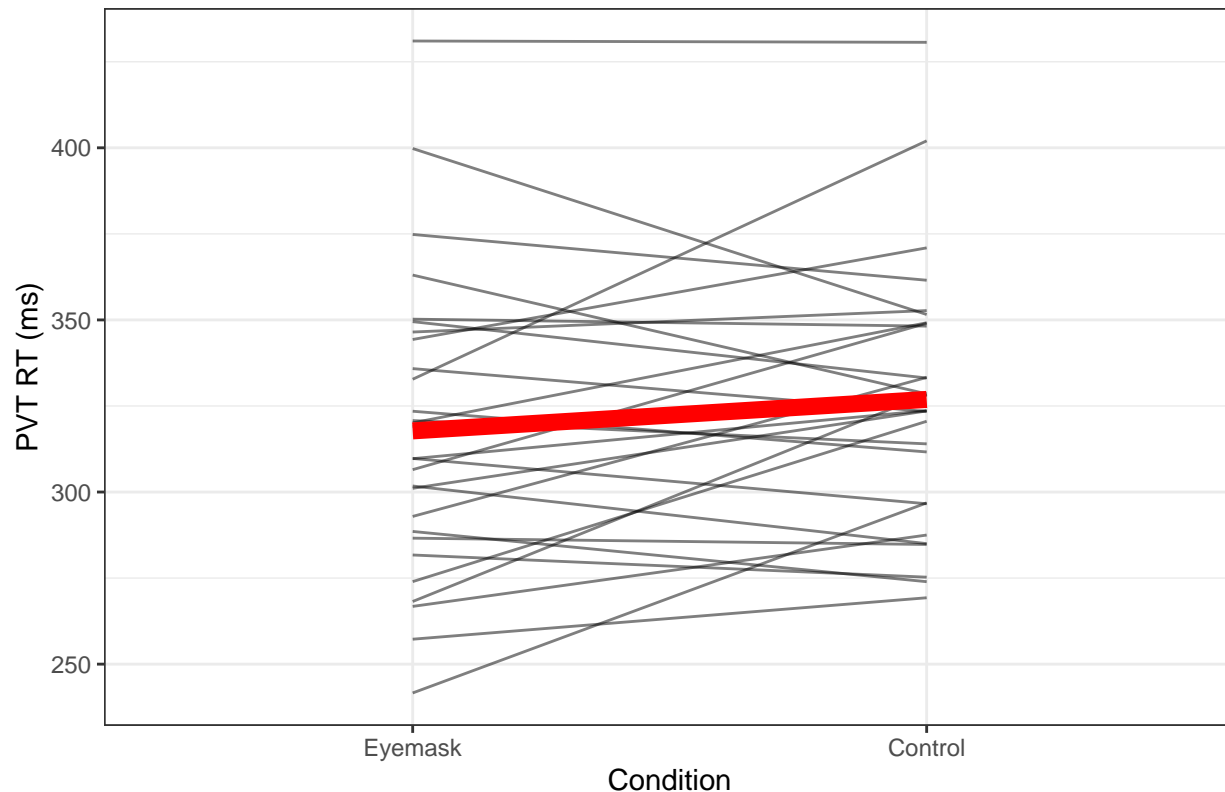
## Anova Table (Type 3 tests)
##
## Response: y
##          Effect    df    MSE      F    ges p.value
## 1          year 1, 83 2180.32   0.55   .006   .460
## 2      condition 1, 83  405.70  3.98 *   .007   .049
## 3 year:condition 1, 83  405.70   0.08 <.001   .776
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

# Experiment 2
# also 28, not 33
length(unique(pvt2$ID))

## [1] 28

ggplot(pvt2, aes(x = condition, y=y, group=ID)) +
  geom_line(alpha=1/2) +
  stat_summary(aes(x = condition, y=y, group=1),
              fun="mean", geom="line", inherit.aes = F,
              lwd=3, col="red") +
  labs(x="Condition", y="PVT RT (ms)", title="Experiment 2")
```

## Experiment 2



```
aggregate(y ~ condition, pvt2, mean)
```

```
##   condition      y
## 1  Eyemask 317.7671
## 2   Control 326.8975
```

```
aov_car(y ~ condition + Error(ID/condition), data = pvt2, fun_aggregate = mean)
```

```
## Anova Table (Type 3 tests)
```

```
##
```

```
## Response: y
```

```
##      Effect    df    MSE    F ges p.value
## 1 condition 1, 27 420.39 2.78 .013   .107
```

```
## ---
```

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

```
lmer(y ~ eye_mask + (1 | ID), data = pvt2, REML = F) |>
  summary()
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
```

```
## method [lmerModLmerTest]
```

```
## Formula: y ~ eye_mask + (1 | ID)
```

```
## Data: pvt2
```

```
##
```

```
##      AIC      BIC    logLik deviance df.resid
##    556.9    565.0   -274.4    548.9      52
```

```
##
```

```
## Scaled residuals:
```

```
##      Min      1Q    Median      3Q      Max
```

```

## -1.53243 -0.54374 0.00569 0.56357 1.82262
##
## Random effects:
## Groups Name Variance Std.Dev.
## ID (Intercept) 1175.6 34.29
## Residual 405.4 20.13
## Number of obs: 56, groups: ID, 28
##
## Fixed effects:
## Estimate Std. Error df t value Pr(>|t|)
## (Intercept) 326.898 7.514 36.061 43.503 <2e-16 ***
## eye_mask -9.130 5.381 28.000 -1.697 0.101
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
## (Intr)
## eye_mask -0.358

```