F03_mci_emotion_mixed_models.R

2022-02-16

```
## MCI EMO MIXED MODELS SCRIPT ##

# Computes linear mixed-effects regression models with simple contrast coding for the fixed effects of semantics and
# emotional context. Thus, in each model, the estimate of the intercept is the grand mean, while the estimates of the
# slopes contrast "treatment" levels to their respective reference levels (semantics: violation - intuitive, mci -
# intuitive; emotional context (negative - neutral). The maximal random effects structure is used with all by-
# participant and by-item random slopes and random intercepts. Correlations between random effects are removed if the
# model fails two converge with two different numerical optimizers. Planned follow-up contrasts are computed for the
# main effects and the effects of semantics separately within each type of emotional context.

## SETUP ## ------------------------------------------------------------------------------------------------------------

# Load packages
library(MASS)         # version 7.3-51.6
library(lme4)         # version 1.1-23
library(lmerTest)     # version 3.1-2
library(afex)         # version 0.27-2
library(emmeans)      # version 1.4.8
library(tidyverse)    # Version 1.3.0
library(magrittr)     # Version 1.5

# Load preprocessed data
a1 <- readRDS("EEG/export/a1.RDS")

# Remove trials with errors or invalid RTs/ERPs
a1 %<>% filter(!error) %>% na.omit()

# Define simple contrast coding for context emotionality (negative - neutral)
#     H0(Intercept): (mu1+mu2)/2 = 0 <-> mu1+mu2 = 0
```

```
#     H0(Slope): -mu1 + mu2 = 0
#     with mu1 = mean of the neutral contexts and mu2 = mean of the neg contexts
t(contrasts.context <- t(cbind(c("neu" = -1, "neg" = 1))))
```

```
##     [,1]
## neu   -1
## neg    1
```

```
contrasts(a1$context) <- ginv(contrasts.context)

# Define simple contrast coding for semantics (violation - intuitive, mci - intuitive)
#     H0(Intercept): (mu1+mu2+mu3)/3 = 0 <-> mu1+mu2+mu3 = 0
#     H0(Slope1): -1*mu1 +1*mu2 + 0*mu3 = 0
#     H0(Slope2): -1*mu1 +0*mu2 + 1*mu3 = 0
#     with mu1 = mean of intuitive concepts, mu2 = mean of violations, mu3 = mean of MCIs
t(contrasts.semantics <- t(cbind(c("int" = -1, "vio" = 1, "mci" = 0),
                                 c("int" = -1, "vio" = 0, "mci" = 1))))
```

```
##     [,1] [,2]
## int   -1   -1
## vio    1    0
## mci    0    1
```

```
contrasts(a1$semantics) <- ginv(contrasts.semantics)

## LINEAR MIXED-EFFECTS MODELS ## ----------------------------------------------------------------------------------------

# LMM for valence ratings (converged on first attempt)
mod_valence <- lmer(ValenzResp ~ context + (context|participant) + (context|item),
                    data = a1, control = lmerControl(calc.derivs = FALSE))

# LMM for arousal ratings (converged on first attempt)
mod_aroursal <- lmer(ArousalResp ~ context + (context|participant) + (context|item),
                     data = a1, control = lmerControl(calc.derivs = FALSE))

# LMM for verb-related N400 (converged after changing the optimizer and removing correlations between REs)
mod_N400_verb <- lmer_alt(N400_verb ~ semantics*context + (semantics*context||participant) + (semantics*context||item),
```

```
                          data = a1, control = lmerControl(calc.derivs = FALSE,
                                                           optimizer = "bobyqa",
                                                           optCtrl = list(maxfun = 2e5)))

# LMM for picture-related N400 (converged after changing the optimizer)
mod_N400_pict <- lmer(N400_pict ~ semantics*context + (semantics*context|participant) + (semantics*context|item),
                      data = a1, control = lmerControl(calc.derivs = FALSE,
                                                       optimizer = "bobyqa",
                                                       optCtrl = list(maxfun = 2e5)))

# LMM for verb-related P600 (converged after changing the optimizer and removing correlations between REs)
mod_P600_verb <- lmer_alt(P600_verb ~ semantics*context + (semantics*context||participant) + (semantics*context||item),
                          data = a1, control = lmerControl(calc.derivs = FALSE,
                                                           optimizer = "bobyqa",
                                                           optCtrl = list(maxfun = 2e5)))

# LMM for picture-related N400 in a narrower time window (converged after changing the optimizer)
mod_N400_pict_posthoc_narrow250_350 <- lmer(N400_pict_posthoc_narrow250_350 ~ semantics*context + (semantics*context|participant) + (semar
                                            data = a1, control = lmerControl(calc.derivs = FALSE,
                                                                             optimizer = "bobyqa",
                                                                             optCtrl = list(maxfun = 2e5)))

# Create a list of all models
models <- list("VALENCE" = mod_valence, "AROUSAL" = mod_aroursal, "N400_VERB" = mod_N400_verb, "N400_PICT" = mod_N400_pict,
               "P600_VERB" = mod_P600_verb, "N400_PICT_POSTHOC_NARROW250_350" = mod_N400_pict_posthoc_narrow250_350)

# F-tests (type III tests)
(tests <- map(models, anova))
```

```
## $VALENCE
## Type III Analysis of Variance Table with Satterthwaite's method
##         Sum Sq Mean Sq NumDF  DenDF F value    Pr(>F)
## context 87.314  87.314     1 37.808   164.2 2.482e-15 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $AROUSAL
## Type III Analysis of Variance Table with Satterthwaite's method
```

```
##         Sum Sq Mean Sq NumDF  DenDF F value    Pr(>F)
## context 51.534  51.534     1 37.672  83.284 4.413e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $N400_VERB
## Type III Analysis of Variance Table with Satterthwaite's method
##                    Sum Sq Mean Sq NumDF   DenDF F value    Pr(>F)
## semantics         290.572 145.286     2 100.801  8.2640 0.0004748 ***
## context             0.355   0.355     1  24.294  0.0202 0.8881094
## semantics:context  42.207  21.104     2  71.656  1.2004 0.3070538
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $N400_PICT
## Type III Analysis of Variance Table with Satterthwaite's method
##                    Sum Sq Mean Sq NumDF  DenDF F value  Pr(>F)
## semantics          23.533  11.766     2 37.017  0.7277 0.48981
## context             0.085   0.085     1 44.147  0.0053 0.94243
## semantics:context 125.895  62.948     2 52.128  3.8929 0.02656 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $P600_VERB
## Type III Analysis of Variance Table with Satterthwaite's method
##                   Sum Sq Mean Sq NumDF   DenDF F value Pr(>F)
## semantics         47.810 23.9051     2 102.057  1.2009 0.3051
## context            0.207  0.2066     1  29.669  0.0104 0.9195
## semantics:context 31.597 15.7984     2 192.921  0.7936 0.4537
##
## $N400_PICT_POSTHOC_NARROW250_350
## Type III Analysis of Variance Table with Satterthwaite's method
##                   Sum Sq Mean Sq NumDF  DenDF F value Pr(>F)
## semantics         31.105  15.552     2 44.887  0.7366 0.4844
## context            2.376   2.376     1 41.458  0.1126 0.7389
## semantics:context 95.007  47.503     2 69.799  2.2499 0.1130
```

```r
## PLANNED FOLLOW-UP CONTRASTS ## ------------------------------------------------------------------------------

# Allow emmeans to use Satterthwaites p-values
emm_options(lmer.df = "Satterthwaite", lmerTest.limit = Inf)

# We want to test most effects for the *ERP* models only, so let's create a seperate list
models_erp <- models[c("N400_VERB", "N400_PICT", "P600_VERB", "N400_PICT_POSTHOC_NARROW250_350")]

# Follow-up contrasts for the main effect of semantics
(means_semantics <- map(models_erp, function(x){
  emmeans(x, trt.vs.ctrl ~ semantics, infer = TRUE, adjust = "bonferroni")$contrasts
}))
```

```
## NOTE: Results may be misleading due to involvement in interactions
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## $N400_VERB
##  contrast  estimate    SE   df lower.CL upper.CL t.ratio p.value
##  vio - int  -0.0288 0.118 90.5   -0.299    0.241 -0.243  1.0000
##  mci - int  -0.3847 0.102 90.7   -0.617   -0.152 -3.771  0.0006
##
## Results are averaged over the levels of: context
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
## P value adjustment: bonferroni method for 2 tests
##
## $N400_PICT
##  contrast  estimate    SE   df lower.CL upper.CL t.ratio p.value
##  vio - int    0.073 0.129 35.5   -0.228    0.374  0.567  1.0000
##  mci - int   -0.121 0.138 37.7   -0.444    0.202 -0.872  0.7774
##
## Results are averaged over the levels of: context
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
```

```
## P value adjustment: bonferroni method for 2 tests
##
## $P600_VERB
##  contrast  estimate    SE   df lower.CL upper.CL t.ratio p.value
##  vio - int   0.1149 0.109 85.1   -0.133    0.363  1.056  0.5877
##  mci - int  -0.0794 0.132 83.2   -0.380    0.221 -0.603  1.0000
##
## Results are averaged over the levels of: context
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
## P value adjustment: bonferroni method for 2 tests
##
## $N400_PICT_POSTHOC_NARROW250_350
##  contrast  estimate    SE   df lower.CL upper.CL t.ratio p.value
##  vio - int   0.0829 0.145 38.0   -0.256    0.422  0.571  1.0000
##  mci - int  -0.1592 0.178 48.5   -0.572    0.253 -0.893  0.7526
##
## Results are averaged over the levels of: context
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
## P value adjustment: bonferroni method for 2 tests
```

```r
# Follow-up contrasts for the main effect of context
(means_context <- map(models, function(x){
  emmeans(x, trt.vs.ctrl ~ context, infer = TRUE, adjust = "bonferroni")$contrasts
}))
```

```
## NOTE: Results may be misleading due to involvement in interactions
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## $VALENCE
##  contrast  estimate   SE   df lower.CL upper.CL t.ratio p.value
##  neg - neu    -1.41 0.11 37.8    -1.63    -1.19 -12.814 <.0001
##
```

```
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
##
## $AROUSAL
##  contrast  estimate    SE   df lower.CL upper.CL t.ratio p.value
##  neg - neu     1.04 0.114 37.7    0.809     1.27 9.126   <.0001
##
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
##
## $N400_VERB
##  contrast  estimate     SE   df lower.CL upper.CL t.ratio p.value
##  neg - neu   0.0135 0.0946 24.3   -0.182    0.209 0.142   0.8881
##
## Results are averaged over the levels of: semantics
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
##
## $N400_PICT
##  contrast  estimate     SE   df lower.CL upper.CL t.ratio p.value
##  neg - neu -0.00706 0.0972 44.1   -0.203    0.189 -0.073  0.9424
##
## Results are averaged over the levels of: semantics
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
##
## $P600_VERB
##  contrast  estimate    SE   df lower.CL upper.CL t.ratio p.value
##  neg - neu    0.012 0.118 29.7   -0.229    0.253 0.102   0.9195
##
## Results are averaged over the levels of: semantics
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
##
## $N400_PICT_POSTHOC_NARROW250_350
##  contrast  estimate    SE   df lower.CL upper.CL t.ratio p.value
##  neg - neu  -0.0377 0.113 41.5   -0.265    0.189 -0.335  0.7389
##
## Results are averaged over the levels of: semantics
```

```
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
```

```
# Follow-up contrasts for semantics within each contexts
(means_nested <- map(models_erp, function(x){
  emmeans(x, trt.vs.ctrl ~ semantics|context, infer = TRUE, adjust = "bonferroni")$contrasts
}))
```

```
## $N400_VERB
## context = neu:
##  contrast  estimate    SE  df lower.CL upper.CL t.ratio p.value
##  vio - int   -0.174 0.163 182   -0.543    0.196 -1.062  0.5791
##  mci - int   -0.531 0.151 117   -0.874   -0.188 -3.517  0.0012
##
## context = neu:
##  contrast  estimate    SE  df lower.CL upper.CL t.ratio p.value
##  vio - int    0.116 0.163 182   -0.253    0.485  0.711  0.9560
##  mci - int   -0.238 0.151 116   -0.581    0.104 -1.579  0.2342
##
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
## P value adjustment: bonferroni method for 2 tests
##
## $N400_PICT
## context = neu:
##  contrast  estimate    SE   df lower.CL  upper.CL t.ratio p.value
##  vio - int  -0.0363 0.163 34.4   -0.419  0.346616 -0.222  1.0000
##  mci - int  -0.4060 0.175 47.1   -0.811 -0.000838 -2.320  0.0494
##
## context = neu:
##  contrast  estimate    SE   df lower.CL  upper.CL t.ratio p.value
##  vio - int   0.1823 0.178 43.2   -0.230  0.594863  1.026  0.6209
##  mci - int   0.1645 0.170 35.8   -0.233  0.561694  0.969  0.6778
##
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
## P value adjustment: bonferroni method for 2 tests
```

```
##
## $P600_VERB
## context = neu:
##  contrast  estimate    SE  df lower.CL upper.CL t.ratio p.value
##  vio - int  -0.0214 0.156 184   -0.374    0.331 -0.137  1.0000
##  mci - int  -0.1145 0.171 233   -0.500    0.271 -0.671  1.0000
##
## context = neu:
##  contrast  estimate    SE  df lower.CL upper.CL t.ratio p.value
##  vio - int   0.2511 0.156 183   -0.101    0.603  1.613  0.2168
##  mci - int  -0.0443 0.171 232   -0.429    0.341 -0.260  1.0000
##
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
## P value adjustment: bonferroni method for 2 tests
##
## $N400_PICT_POSTHOC_NARROW250_350
## context = neu:
##  contrast  estimate    SE   df lower.CL upper.CL t.ratio p.value
##  vio - int   0.0217 0.186 48.4   -0.408    0.451  0.117  1.0000
##  mci - int  -0.3997 0.224 53.8   -0.915    0.116 -1.788  0.1588
##
## context = neu:
##  contrast  estimate    SE   df lower.CL upper.CL t.ratio p.value
##  vio - int   0.1441 0.201 42.7   -0.324    0.612  0.715  0.9566
##  mci - int   0.0812 0.204 47.0   -0.391    0.553  0.398  1.0000
##
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
## P value adjustment: bonferroni method for 2 tests
```

```
# Follow-up contrasts for contexts within each semantic condition
(means_nested_rev <- map(models_erp, function(x){
  emmeans(x, trt.vs.ctrl ~ context|semantics, infer = TRUE, adjust = "bonferroni")$contrasts
}))
```

```
## $N400_VERB
```

```
## semantics = int:
##  contrast  estimate    SE    df lower.CL upper.CL t.ratio p.value
##  neg - neu   -0.181 0.157 141.4   -0.491    0.129 -1.152  0.2511
##
## semantics = vio:
##  contrast  estimate    SE    df lower.CL upper.CL t.ratio p.value
##  neg - neu    0.109 0.167  82.3   -0.223    0.440  0.654  0.5152
##
## semantics = mci:
##  contrast  estimate    SE    df lower.CL upper.CL t.ratio p.value
##  neg - neu    0.112 0.166  53.5   -0.220    0.444  0.678  0.5006
##
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
##
## $N400_PICT
## semantics = int:
##  contrast  estimate    SE    df lower.CL upper.CL t.ratio p.value
##  neg - neu  -0.2701 0.164  35.4   -0.604   0.0635 -1.643  0.1092
##
## semantics = vio:
##  contrast  estimate    SE    df lower.CL upper.CL t.ratio p.value
##  neg - neu  -0.0515 0.143 188.4   -0.334   0.2308 -0.360  0.7195
##
## semantics = mci:
##  contrast  estimate    SE    df lower.CL upper.CL t.ratio p.value
##  neg - neu   0.3004 0.170  42.4   -0.043   0.6438  1.765  0.0848
##
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
##
## $P600_VERB
## semantics = int:
##  contrast  estimate    SE    df lower.CL upper.CL t.ratio p.value
##  neg - neu   -0.102 0.172 130.2   -0.443    0.239 -0.593  0.5544
##
## semantics = vio:
##  contrast  estimate    SE    df lower.CL upper.CL t.ratio p.value
##  neg - neu    0.170 0.176  83.5   -0.179    0.519  0.970  0.3350
```

```
##
## semantics = mci:
##  contrast  estimate    SE    df lower.CL upper.CL t.ratio p.value
##  neg - neu   -0.032 0.173 131.8   -0.374    0.310 -0.185  0.8535
##
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
##
## $N400_PICT_POSTHOC_NARROW250_350
## semantics = int:
##  contrast  estimate    SE    df lower.CL upper.CL t.ratio p.value
##  neg - neu   -0.239 0.191  49.2   -0.622    0.145 -1.251  0.2168
##
## semantics = vio:
##  contrast  estimate    SE    df lower.CL upper.CL t.ratio p.value
##  neg - neu   -0.116 0.166 119.2   -0.445    0.212 -0.703  0.4837
##
## semantics = mci:
##  contrast  estimate    SE    df lower.CL upper.CL t.ratio p.value
##  neg - neu    0.242 0.188  42.9   -0.137    0.621  1.288  0.2046
##
## Degrees-of-freedom method: satterthwaite
## Confidence level used: 0.95
```

```
# Backup results
save(models, tests, means_semantics, means_context, means_nested, means_nested_rev, file = "EEG/export/stats.RData")

# System specs and package versions
sessionInfo()
```

```
## R version 4.0.2 (2020-06-22)
## Platform: x86_64-apple-darwin17.0 (64-bit)
## Running under: OS X  12.1
##
## Matrix products: default
## LAPACK: /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
```

```
##
## attached base packages:
## [1] stats     graphics  grDevices datasets  utils     methods   base
##
## other attached packages:
##  [1] magrittr_1.5    forcats_0.5.0   stringr_1.4.0   dplyr_1.0.0     purrr_0.3.4     readr_1.3.1
##  [7] tidyr_1.1.0     tibble_3.0.3    ggplot2_3.3.2   tidyverse_1.3.0 emmeans_1.4.8   afex_0.27-2
## [13] lmerTest_3.1-2  lme4_1.1-23     Matrix_1.2-18   MASS_7.3-51.6
##
## loaded via a namespace (and not attached):
##  [1] httr_1.4.2          jsonlite_1.7.0      splines_4.0.2       carData_3.0-4       modelr_0.1.8
##  [6] assertthat_0.2.1    statmod_1.4.34      highr_0.8           blob_1.2.1          renv_0.12.0
## [11] cellranger_1.1.0    yaml_2.2.1          numDeriv_2016.8-1.1 pillar_1.4.6        backports_1.1.8
## [16] lattice_0.20-41     glue_1.4.1          digest_0.6.25       rvest_0.3.5         minqa_1.2.4
## [21] colorspace_1.4-1    htmltools_0.5.0     plyr_1.8.6          pkgconfig_2.0.3     broom_0.7.0.9001
## [26] haven_2.3.1         xtable_1.8-4        mvtnorm_1.1-1       scales_1.1.1        openxlsx_4.1.5
## [31] rio_0.5.16          generics_0.0.2      car_3.0-8           ellipsis_0.3.1      withr_2.2.0
## [36] cli_2.0.2           crayon_1.3.4        readxl_1.3.1        estimability_1.3    evaluate_0.14
## [41] fansi_0.4.1         fs_1.4.2            nlme_3.1-148        xml2_1.3.3          foreign_0.8-80
## [46] tools_4.0.2         data.table_1.13.0   hms_0.5.3           lifecycle_0.2.0     munsell_0.5.0
## [51] reprex_0.3.0        zip_2.1.1           compiler_4.0.2      rlang_0.4.7         grid_4.0.2
## [56] nloptr_1.2.2.2      rstudioapi_0.11     rmarkdown_2.3       boot_1.3-25         gtable_0.3.0
## [61] abind_1.4-5         DBI_1.1.0           curl_4.3            reshape2_1.4.4      R6_2.4.1
## [66] lubridate_1.7.9     knitr_1.29          stringi_1.4.6       parallel_4.0.2      Rcpp_1.0.5
## [71] vctrs_0.3.2         dbplyr_1.4.4        tidyselect_1.1.0    xfun_0.16
```