Data analysis Morphological masked priming experiment on L1-ITA, L2-ENG bilingual speakers/readers

Paper titled *Masked morphological priming tracks the development of a fully mature lexical system in L2* - Submitted to JML in June 2019

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03 June 2020

Contents

This script takes preprocessed data and produces all the analyses that are reported in the paper.

clean WS, set WD and load data

Set your local working directory. This should be (and is assumed to be in the rest of the code) the highest point in your local folder:

```
localGitDir <- 'C:/Users/eva_v/Documents/GitHub/M2-maskedprimingBilinguals'
setwd(localGitDir);
```

This script works on the outcome of preProcessing.R, which you can upload here:

```
read.table(paste(localGitDir, '/preprocessedData.txt', sep = ''), header = T, sep='\t', dec='.',
           colClasses=c("prime"="factor",
                        "target"="factor",
                        "lexicality"="factor",
                        "morphType"="factor",
                        "relatedness"="factor",
                        "aoa3.context"="factor",
                        "aoa4.contextMultling"="factor",
                        "aoa6.otherLang"="factor",
                        "language"="factor",
                         "gender"="factor",
                         "handedness"="factor"
                        )) -> masterFile;

head(masterFile);
summary(masterFile);
```

Load packages and create functions

```
library(ggplot2);
library(rms);
library(effects);
library(plyr);
library(corrplot);
library(lme4);
library(ggpubr);

inv <- function(x) {-1000/x};
```

GLMMs takes a lot of time to run, depending on the machine and the dataset. We have saved the models that successfully converged in a folder.

```
df <- list.files(paste(localGitDir, "/LMMs and GLMMs/", sep = ""));
length(df);
```

```
## [1] 45
```

```
for (i in 1:length(df)){
  gsub(".rds$", "", df[i]) -> id
  assign(id, data.frame())
  readRDS(paste(localGitDir, "/LMMs and GLMMs/", df[i],sep = "")) -> temp
```

```
  assign(paste0(id), temp)
};
rm(temp)
```

Participants

```
temp <- unique(masterFile[,c('subject','age','gender','handedness')]);
```

Number of participants: 81

age, education and handedness:

```
summary(temp)
```

```
##     subject           age           gender   handedness
##  Min.   : 1.00   Min.   :18.00   Female:56   Left :11
##  1st Qu.:21.00   1st Qu.:22.00   Male  :28   Right:73
##  Median :41.50   Median :24.00
##  Mean   :41.65   Mean   :24.32
##  3rd Qu.:62.25   3rd Qu.:26.00
##  Max.   :84.00   Max.   :34.00
```

Stimuli

```
temp <- unique(masterFile[,c('target','prime','lexicality','morphType','relatedness','freqTarget','freq
summary(temp);
```

```
##      target          prime       lexicality  morphType  relatedness
##  abito  :  2   abbazia  :  1   nonword:300   op  :200   ctrl:450
##  acid   :  2   ability  :  1   word   :600   or  :200   rel :450
##  acre   :  2   abitudine:  1                 tr  :200
##  adopt  :  2   absence  :  1                 NA's:300
##  again  :  2   abstain  :  1
##  agree  :  2   abstract :  1
##  (Other):888   (Other)  :894
##    freqTarget      freqPrime      lengthTarget   lengthPrime
##  Min.   :1.367   Min.   :1.170   Min.   :3.00   Min.   : 5.000
##  1st Qu.:3.382   1st Qu.:2.630   1st Qu.:4.00   1st Qu.: 6.000
##  Median :3.913   Median :3.155   Median :5.00   Median : 7.000
##  Mean   :3.875   Mean   :3.233   Mean   :4.92   Mean   : 7.423
##  3rd Qu.:4.446   3rd Qu.:3.860   3rd Qu.:5.00   3rd Qu.: 8.000
##  Max.   :5.840   Max.   :6.290   Max.   :8.00   Max.   :13.000
##  NA's   :300     NA's   :2
##     nTarget          nPrime       language
##  Min.   : 0.00   Min.   : 0.000   eng:450
##  1st Qu.: 5.00   1st Qu.: 1.000   ita:450
##  Median :10.00   Median : 2.000
```

```
##  Mean   :13.43   Mean   : 3.131
##  3rd Qu.:19.00   3rd Qu.: 4.000
##  Max.   :54.00   Max.   :36.000
##
```

Target features, ITA

Frequency of the targets, mean and sd

```
##   morphType freqTarget
## 1        op    3.63032
## 2        or    3.94728
## 3        tr    3.96898
```

```
##   morphType freqTarget
## 1        op  0.8779550
## 2        or  0.8523670
## 3        tr  0.6718303
```

Length of the targets, mean and sd

```
##   morphType lengthTarget
## 1        op         5.08
## 2        or         4.94
## 3        tr         5.16
```

```
##   morphType lengthTarget
## 1        op    0.8490042
## 2        or    0.8855746
## 3        tr    1.0704478
```

Coltheart's N, mean and sd

```
##   morphType nTarget
## 1        op   20.12
## 2        or   21.56
## 3        tr   18.14
```

```
##   morphType  nTarget
## 1        op 11.91492
## 2        or 13.45274
## 3        tr 11.32265
```

Prime features, ITA

Frequency of the primes, mean and sd

```
##   relatedness morphType freqPrime
## 1        ctrl        op  3.095800
## 2         rel        op  3.157653
```

```
## 3        ctrl        or  3.198040
## 4         rel        or  3.228920
## 5        ctrl        tr  2.913200
## 6         rel        tr  2.923460
```

```
##   relatedness morphType freqPrime
## 1        ctrl        op 0.8518056
## 2         rel        op 0.7863899
## 3        ctrl        or 0.6784778
## 4         rel        or 0.6984253
## 5        ctrl        tr 0.6843910
## 6         rel        tr 0.8404621
```

Length of the primes, mean and sd

```
##   relatedness morphType lengthPrime
## 1        ctrl        op        7.96
## 2         rel        op        7.96
## 3        ctrl        or        7.52
## 4         rel        or        7.52
## 5        ctrl        tr        7.70
## 6         rel        tr        7.70
```

```
##   relatedness morphType lengthPrime
## 1        ctrl        op    1.211509
## 2         rel        op    1.211509
## 3        ctrl        or    1.182181
## 4         rel        or    1.182181
## 5        ctrl        tr    1.249490
## 6         rel        tr    1.249490
```

Coltheart's N, mean and sd

```
##   relatedness morphType nPrime
## 1        ctrl        op   3.84
## 2         rel        op   3.52
## 3        ctrl        or   3.54
## 4         rel        or   4.24
## 5        ctrl        tr   3.82
## 6         rel        tr   3.62
```

```
##   relatedness morphType   nPrime
## 1        ctrl        op 2.937165
## 2         rel        op 2.628261
## 3        ctrl        or 2.525058
## 4         rel        or 6.169576
## 5        ctrl        tr 2.973969
## 6         rel        tr 2.905940
```

Outliers trimming, ITA

```
subset(masterFile, language=="ita") -> masterFileIta;
```

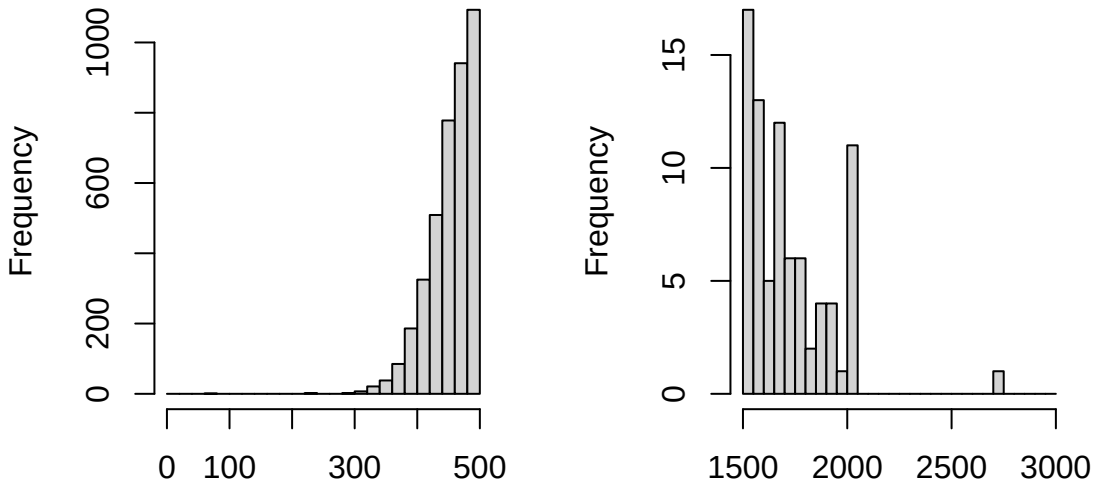
The following code generates target and sbj means and SDs, and the outlier graphs in the file 'ita.jpg'

```
sbj.id <- masterFileIta$subject;
acc <- masterFileIta$accuracy;
lexicality <- tolower(masterFileIta$lexicality);
target <- masterFileIta$target;
rt <- masterFileIta$rt;

source(paste(localGitDir, "/tools/diagnostics.R", sep=''));
outlierGraphStore <- 'Desktop';
diagnostics.f(rt = rt, acc = acc, sbj.id = sbj.id, target = target, lexicality = lexicality, paste(outli
rm(outlierGraphStore, rt, target, lexicality, acc, sbj.id);
```

Based on the graphs in 'ita.jpg': we exclude **sbj 2** and **31** for an abnormal error rate on nonwords (<80%); and target words **GUANO**, **UGGIA** and **VELLO** with abnormally low accuracy (<60%). **sbj 15** is excluded because s/he reported having seen the primes.

Individual RTs distribution seems fine, but let's check the tails more carefully:

```
par(mfrow=c(1,2))
hist(masterFileIta$rt[masterFileIta$rt<500], breaks=seq(0,500,20), main = " ", xlab = " ");
hist(masterFileIta$rt[masterFileIta$rt>1500], breaks=seq(1500,3000,50), main = " ", xlab = " ");
```



```
par(mfrow=c(1,1))
```

Based on these graph we cut distributions at **2500ms** and **280ms**

```
dataItaAcc <- subset(masterFileIta, lexicality=="word");
dataItaTemp <- subset(dataItaAcc, accuracy==1);
dataIta <- subset(dataItaTemp, rt>280 & rt<2000 & subject!=15 & subject!=2 & subject!=31 & target!= "gu
```

- Number of datapoints trimmed: 526
- Percentage of datapoints trimmed: 4.56%
- Number of datapoints left: 11009

Summary of the dataset trimmed:

```
summary(dataIta)
```

```
##     subject           age           gender     handedness     trialCount
##  Min.   : 1.00   Min.   :18.00   Female:7362   Left :1284   Min.   :  1.0
##  1st Qu.:22.00   1st Qu.:22.00   Male  :3647   Right:9725   1st Qu.: 77.0
##  Median :43.00   Median :24.00                              Median :150.0
##  Mean   :42.19   Mean   :24.44                              Mean   :150.5
##  3rd Qu.:62.00   3rd Qu.:27.00                              3rd Qu.:225.0
##  Max.   :84.00   Max.   :34.00                              Max.   :300.0
##
##        rt              resp    trialType           lexicality    morphType
##  Min.   : 284.0   Min.   :2   Length:11009       nonword:    0   op:3717
##  1st Qu.: 499.0   1st Qu.:2   Class :character   word   :11009   or:3621
##  Median : 564.0   Median :2   Mode  :character                    tr:3671
##  Mean   : 594.5   Mean   :2
##  3rd Qu.: 652.0   3rd Qu.:2
##  Max.   :1960.0   Max.   :2
##
##      target            prime       relatedness   freqTarget      freqPrime
##  abito  :   78   abitudine:   39   ctrl:5498   Min.   :1.367   Min.   :1.191
##  ballo  :   78   albergo  :   39   rel :5511   1st Qu.:3.435   1st Qu.:2.562
##  banca  :   78   alleanza :   39               Median :3.989   Median :3.039
##  cambio :   78   areola   :   39               Mean   :3.915   Mean   :3.093
##  corda  :   78   ballatoio:   39               3rd Qu.:4.450   3rd Qu.:3.606
##  corte  :   78   bancario :   39               Max.   :5.671   Max.   :4.909
##  (Other):10541   (Other)  :10775                               NA's   :37
##   lengthTarget    lengthPrime        nTarget          nPrime
##  Min.   :3.000   Min.   : 5.000   Min.   : 0.00   Min.   : 0.000
##  1st Qu.:4.000   1st Qu.: 7.000   1st Qu.:11.00   1st Qu.: 2.000
##  Median :5.000   Median : 8.000   Median :18.00   Median : 3.000
##  Mean   :5.064   Mean   : 7.756   Mean   :20.13   Mean   : 3.723
##  3rd Qu.:6.000   3rd Qu.: 9.000   3rd Qu.:30.00   3rd Qu.: 5.000
##  Max.   :8.000   Max.   :10.000   Max.   :47.00   Max.   :36.000
##
##    rotation         language      oscTarget        accuracy phonemicFluency
##  Length:11009       eng:    0   Min.   : NA     Min.   :1   Min.   : 0.00
##  Class :character   ita:11009   1st Qu.: NA     1st Qu.:1   1st Qu.:17.00
##  Mode  :character               Median : NA     Median :1   Median :23.00
```

```
##                                 Mean   :NaN     Mean   :1   Mean   :22.52
##                                 3rd Qu.: NA     3rd Qu.:1   3rd Qu.:27.00
##                                 Max.   : NA     Max.   :1   Max.   :45.00
##                                 NA's   :11009
##  phonemicComprehension morphComprehension    spelling      readingComprehension
##  Min.   : 0.000        Min.   : 4.000     Min.   : 0.000   Min.   :1.000
##  1st Qu.: 8.000        1st Qu.: 8.000     1st Qu.: 4.000   1st Qu.:3.000
##  Median : 9.000        Median : 9.000     Median : 7.000   Median :5.000
##  Mean   : 8.828        Mean   : 8.929     Mean   : 8.155   Mean   :4.564
##  3rd Qu.:10.000        3rd Qu.:10.000     3rd Qu.:11.000   3rd Qu.:6.000
##  Max.   :13.000        Max.   :10.000     Max.   :18.000   Max.   :7.000
##
##    vocabulary    oralComprehension    aoa1.Aoa        aoa2.usage
##  Min.   : 8.00   Min.   :1.000     Min.   : 0.000   Min.   :1.00
##  1st Qu.:14.00   1st Qu.:3.000     1st Qu.: 6.000   1st Qu.:2.00
##  Median :15.00   Median :5.000     Median : 6.000   Median :3.00
##  Mean   :15.28   Mean   :4.593     Mean   : 6.544   Mean   :3.12
##  3rd Qu.:17.00   3rd Qu.:6.000     3rd Qu.: 8.000   3rd Qu.:4.00
##  Max.   :19.00   Max.   :6.000     Max.   :15.000   Max.   :5.00
##
##  aoa3.context  aoa4.contextMultling aoa5.selfRatedProf aoa6.otherLang
##  home  :1433   no :8446             Min.   :1.00       no :2673
##  school:9576   yes:2563             1st Qu.:3.00       yes:8336
##                                     Median :4.00
##                                     Mean   :3.54
##                                     3rd Qu.:4.00
##                                     Max.   :5.00
##
```

Outliers trimming, ENG

```
subset(masterFile, language=="eng") -> masterFileEng;
```

The following code generates target and sbj means and SDs, and the outlier graphs in the file 'eng.jpg'

```
outlierGraphStore <- 'Desktop';
sbj.id <- masterFileEng$subject;
acc <- masterFileEng$accuracy;
lexicality <- masterFileEng$lexicality;
lexicality <- tolower(masterFileEng$lexicality);
target <- masterFileEng$target;
rt <- masterFileEng$rt;

diagnostics.f(rt = rt, acc = acc, sbj.id = sbj.id, target = target, lexicality = lexicality, paste(outli
rm(outlierGraphStore, rt, target, lexicality, acc, sbj.id);
```

sbj 26 likely confused YES/NO buttons. Let's check the frequency effect, just to confirm:

```
cor(masterFileEng[masterFileEng$subject==26 & masterFileEng$lexicality=='word', c('rt','freqTarget')],
```

```
##                     rt freqTarget
## rt          1.0000000 -0.2116401
## freqTarget -0.2116401  1.0000000
```

```
masterFileEng$accuracy[masterFileEng$subject==26] <- car::recode(masterFileEng$accuracy[masterFileEng$su
```

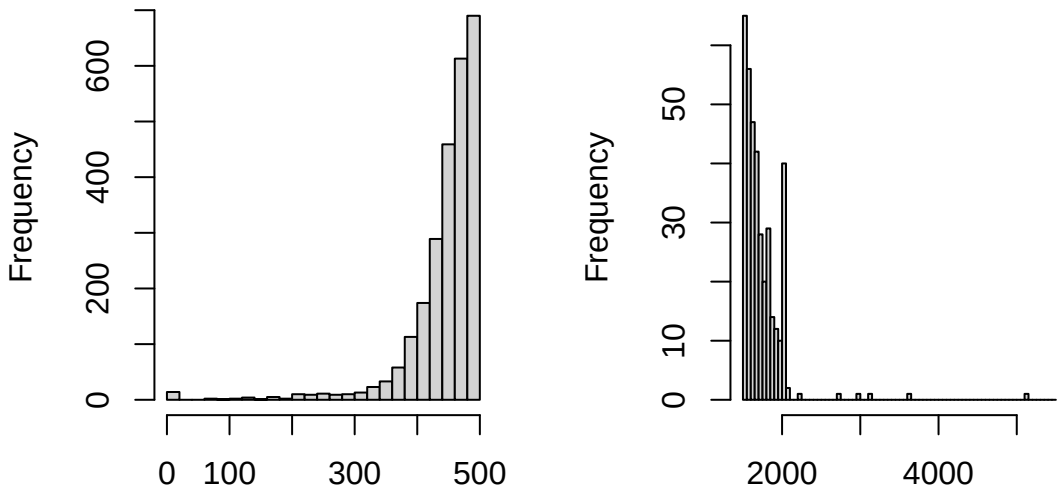
ok, we can now rerun diagnostics:

```
outlierGraphStore <- 'Desktop';
sbj.id <- masterFileEng$subject;
acc <- masterFileEng$accuracy;
lexicality <- masterFileEng$lexicality;
lexicality <- tolower(masterFileEng$lexicality);
target <- masterFileEng$target;
rt <- masterFileEng$rt;

diagnostics.f(rt = rt, acc = acc, sbj.id = sbj.id, target = target, lexicality = lexicality, paste(outli
rm(outlierGraphStore, rt, target, lexicality, acc, sbj.id);
```

Based on the graphs in 'eng.jpg': we exclude **sbj 22** for a very atypical performance (average **RT<200ms**). We would exclude no target, even though some of them do elicit bad performance–the distribution is very continuous, no sign of glaring outliers. Plus, this is L2, so low performance is to be expected. **sbj 15** and **43** reported having seen the primes.

Individual RTs distribution seems fine, but let's check the tails more carefully:

```
par(mfrow=c(1,2))
hist(masterFileEng$rt[masterFileEng$rt<500], breaks=seq(0,500,20), main = "", xlab = "");
hist(masterFileEng$rt[masterFileEng$rt>1500], breaks=seq(1500,5500,50), main = "", xlab = "");
```



- First graph: very continuous towards zero; perhaps some technical problem with the response box? Weird though, only in English. Anyway, deflection in the curve around 300ms, so let's cut there.
- Second graph: clear outliers over 2000ms

```
dataEngAcc <- subset(masterFileEng, lexicality=="word");
dataEngTemp <- subset(dataEngAcc, accuracy==1);
dataEng <- subset(dataEngTemp, rt>300 & rt<2000 & subject!=15 & subject!=22 & subject!=43);
```

- Number of datapoints trimmed: 281
- Percentage of datapoints trimmed: 3.05%
- Number of datapoints left: 8938

Summary of the trimmed dataset:

```
summary(dataEng);
```

```
##     subject           age           gender     handedness     trialCount
##  Min.   : 1.00   Min.   :18.00   Female:6170   Left : 907   Min.   :  1.0
##  1st Qu.:20.00   1st Qu.:22.00   Male  :2768   Right:8031   1st Qu.: 74.0
##  Median :42.00   Median :24.00                              Median :150.0
##  Mean   :41.76   Mean   :24.19                              Mean   :149.8
##  3rd Qu.:63.00   3rd Qu.:26.00                              3rd Qu.:224.0
##  Max.   :84.00   Max.   :34.00                              Max.   :300.0
##
##        rt              resp        trialType           lexicality   morphType
##  Min.   : 312.0   Min.   :0.000   Length:8938        nonword:   0   op:2946
##  1st Qu.: 544.0   1st Qu.:2.000   Class :character   word   :8938   or:2762
##  Median : 622.0   Median :2.000   Mode  :character                   tr:3230
##  Mean   : 672.1   Mean   :1.986
##  3rd Qu.: 742.0   3rd Qu.:2.000
##  Max.   :1998.0   Max.   :2.000
##
##      target           prime      relatedness   freqTarget      freqPrime
##  again  :  78   against  :  40   ctrl:4388   Min.   :1.650   Min.   :1.170
##  angel  :  78   angelic  :  40   rel :4550   1st Qu.:3.555   1st Qu.:2.820
##  legend :  78   cloudless:  40               Median :4.050   Median :3.410
##  unit   :  78   dreamer  :  40               Mean   :4.058   Mean   :3.472
##  blood  :  77   drunkard :  40               3rd Qu.:4.680   3rd Qu.:4.080
##  fruit  :  77   extract  :  40               Max.   :5.840   Max.   :6.290
##  (Other):8472   (Other)  :8698
##   lengthTarget    lengthPrime        nTarget          nPrime
##  Min.   :3.000   Min.   : 5.000   Min.   : 0.000   Min.   : 0.000
##  1st Qu.:4.000   1st Qu.: 6.000   1st Qu.: 4.000   1st Qu.: 0.000
##  Median :5.000   Median : 7.000   Median : 7.000   Median : 1.000
##  Mean   :4.828   Mean   : 7.215   Mean   : 8.785   Mean   : 2.485
##  3rd Qu.:5.000   3rd Qu.: 8.000   3rd Qu.:12.000   3rd Qu.: 3.000
##  Max.   :7.000   Max.   :13.000   Max.   :44.000   Max.   :24.000
##
##    rotation         language     oscTarget          accuracy phonemicFluency
##  Length:8938        eng:8938   Min.   :-0.0940   Min.   :1   Min.   : 0.00
##  Class :character   ita:   0   1st Qu.: 0.2630   1st Qu.:1   1st Qu.:17.00
##  Mode  :character              Median : 0.6230   Median :1   Median :23.00
```

```
##                               Mean   : 0.5767   Mean   :1   Mean   :22.61
##                               3rd Qu.: 0.8990   3rd Qu.:1   3rd Qu.:27.00
##                               Max.   : 1.0000   Max.   :1   Max.   :45.00
##                               NA's   :155
##  phonemicComprehension morphComprehension    spelling      readingComprehension
##  Min.   : 0.000        Min.   : 4.000     Min.   : 0.000   Min.   :1.000
##  1st Qu.: 8.000        1st Qu.: 8.000     1st Qu.: 5.000   1st Qu.:3.000
##  Median : 9.000        Median : 9.000     Median : 8.000   Median :5.000
##  Mean   : 8.866        Mean   : 8.975     Mean   : 8.342   Mean   :4.478
##  3rd Qu.:11.000        3rd Qu.:10.000     3rd Qu.:12.000   3rd Qu.:6.000
##  Max.   :13.000        Max.   :10.000     Max.   :18.000   Max.   :7.000
##
##    vocabulary    oralComprehension    aoa1.Aoa        aoa2.usage
##  Min.   : 8.00   Min.   :1.00      Min.   : 0.000   Min.   :1.000
##  1st Qu.:14.00   1st Qu.:3.00      1st Qu.: 6.000   1st Qu.:2.000
##  Median :16.00   Median :5.00      Median : 6.000   Median :3.000
##  Mean   :15.34   Mean   :4.59      Mean   : 6.433   Mean   :3.174
##  3rd Qu.:17.00   3rd Qu.:6.00      3rd Qu.: 8.000   3rd Qu.:4.000
##  Max.   :19.00   Max.   :6.00      Max.   :15.000   Max.   :5.000
##
##  aoa3.context  aoa4.contextMultling aoa5.selfRatedProf aoa6.otherLang
##  home  :1231   no :6811             Min.   :1.000      no :2062
##  school:7707   yes:2127             1st Qu.:3.000      yes:6876
##                                     Median :3.000
##                                     Mean   :3.526
##                                     3rd Qu.:4.000
##                                     Max.   :5.000
##
```

Raw means

- Mean accuracy ITA: 95%
- Mean RT ITA: 594.51 ms
- Mean accuracy ENG: 76%
- Mean RT ENG: 672.1 ms

Mean RT and sd by relatedness and morphtype - ITA dataset:

```
aggregate(rt ~ relatedness + morphType, FUN=mean, data=dataIta);
```

```
##   relatedness morphType       rt
## 1        ctrl        op 614.4428
## 2         rel        op 598.8104
## 3        ctrl        or 607.0192
## 4         rel        or 606.5746
## 5        ctrl        tr 589.1723
## 6         rel        tr 551.3402
```

```
aggregate(rt ~ relatedness + morphType, FUN=sd, data=dataIta);
```

```
##   relatedness morphType       rt
```

```
## 1        ctrl        op 150.3067
## 2         rel        op 157.5980
## 3        ctrl        or 145.9696
## 4         rel        or 155.8299
## 5        ctrl        tr 131.0569
## 6         rel        tr 126.2728
```

Mean RT and sd by relatedness and morphtype - ENG dataset:

```
aggregate(rt ~ relatedness + morphType, FUN=mean, data=dataEng);
```

```
##   relatedness morphType       rt
## 1        ctrl        op 685.2774
## 2         rel        op 666.6475
## 3        ctrl        or 703.1108
## 4         rel        or 688.2460
## 5        ctrl        tr 667.2606
## 6         rel        tr 630.8267
```

```
aggregate(rt ~ relatedness + morphType, FUN=sd, data=dataEng);
```

```
##   relatedness morphType       rt
## 1        ctrl        op 196.6292
## 2         rel        op 214.0158
## 3        ctrl        or 214.4669
## 4         rel        or 207.4222
## 5        ctrl        tr 177.6199
## 6         rel        tr 183.6509
```

Modelling, ITA

```
dataIta$morphType <- relevel(dataIta$morphType, "or");
contrasts(dataIta$relatedness);
```

```
##      rel
## ctrl   0
## rel    1
```

```
contrasts(dataIta$morphType);
```

```
##    op tr
## or  0  0
## op  1  0
## tr  0  1
```

```
itaglmer0<- glmer(rt ~ 1 + (1|subject) + (1|target), data= dataIta, family=Gamma(link="identity"));
```

```
itaglmer1<- glmer(rt ~ trialCount + rotation + (1|subject) + (1|target), data= dataIta, family=Gamma(li
```

```
anova(itaglmer0, itaglmer1);
```

```
## Data: dataIta
## Models:
## itaglmer0: rt ~ 1 + (1 | subject) + (1 | target)
## itaglmer1: rt ~ trialCount + rotation + (1 | subject) + (1 | target)
##           npar    AIC    BIC logLik deviance  Chisq Df Pr(>Chisq)
## itaglmer0    4 134591 134620 -67291   134583
## itaglmer1    6 134593 134637 -67291   134581 1.4915  2     0.4744
```

no effect of rotation here

```
itaglmer1a<- glmer(rt ~ freqTarget + lengthTarget + nTarget + (1|subject) + (1|target), data= dataIta, 
```

```
anova(itaglmer0, itaglmer1a);
```

```
## Data: dataIta
## Models:
## itaglmer0: rt ~ 1 + (1 | subject) + (1 | target)
## itaglmer1a: rt ~ freqTarget + lengthTarget + nTarget + (1 | subject) + (1 |
## itaglmer1a:     target)
##            npar    AIC    BIC logLik deviance  Chisq Df Pr(>Chisq)
## itaglmer0     4 134591 134620 -67291   134583
## itaglmer1a    7 134540 134592 -67263   134526 56.328  3  3.576e-12 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

strong improvement in GoF

```
car::Anova(itaglmer1a)
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                 Chisq Df Pr(>Chisq)
## freqTarget   234.6265  1     <2e-16 ***
## lengthTarget   1.6941  1     0.1931
## nTarget        0.2406  1     0.6238
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

To which only freq seems to contribute. We introduce the variables of interest now:

```
itaglmer2<- glmer(rt ~ relatedness * morphType + freqTarget + (1|subject) + (1|target), data= dataIta, 
```

```
summary(itaglmer2)-> modelsum2
car::Anova(itaglmer2)-> itaglmer2.anova
itaglmer2.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                          Chisq Df Pr(>Chisq)
## relatedness            63.282  1  1.791e-15 ***
## morphType              70.279  2  5.484e-16 ***
## freqTarget            420.382  1  < 2.2e-16 ***
## relatedness:morphType 228.836  2  < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

With "orthographic" and "unrelated/ctrl" as base contrast:

```
knitr::kable(round(modelsum2$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	800.1365	3.9876	200.6554	0.0000
relatednessrel	-1.3974	1.8425	-0.7584	0.4482
morphTypeop	-11.6087	2.6859	-4.3221	0.0000
morphTypetr	-17.7294	2.7439	-6.4614	0.0000
freqTarget	-44.2176	2.1566	-20.5032	0.0000
relatednessrel:morphTypeop	-14.2715	2.2082	-6.4628	0.0000
relatednessrel:morphTypetr	-36.8151	2.5344	-14.5262	0.0000

Let's relevel for transparent versus opaque condition:

```
dataIta$morphType <- relevel(dataIta$morphType, "op");
```

```
itaglmer2c<- glmer(rt ~ relatedness * morphType + freqTarget + (1|subject) + (1|target), data= dataIta,
```

```
summary(itaglmer2c)->modelsum2c
car::Anova(itaglmer2c)-> itaglmer2c.anova
itaglmer2c.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                          Chisq Df Pr(>Chisq)
## relatedness            112.873  1  < 2.2e-16 ***
## morphType               13.006  2   0.001499 **
## freqTarget             488.101  1  < 2.2e-16 ***
## relatedness:morphType 100.900  2  < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(modelsum2c$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	788.5277	4.0865	192.9579	0.0000
relatednessrel	-15.6690	2.1883	-7.1604	0.0000
morphTypeor	11.6097	4.3057	2.6964	0.0070
morphTypetr	-6.1195	3.3664	-1.8178	0.0691
freqTarget	-44.2179	2.0014	-22.0930	0.0000
relatednessrel:morphTypeor	14.2720	2.7368	5.2148	0.0000
relatednessrel:morphTypetr	-22.5436	3.2858	-6.8608	0.0000

Is proficiency in L2 (ENG) able to modulate priming in L1 (ITA)?

Phonemic fluency:

```
itaglmer_phonFlu<- glmer(rt ~ relatedness * morphType * phonemicFluency + freqTarget + (1|subject) + (1
```

Phonemic comprehension:

```
itaglmer_phonCom<- glmer(rt ~ relatedness * morphType * phonemicComprehension + freqTarget + (1|subject
```

Unfortunately the other proficiency tests the model don't converge. Morphological awareness:

```
itaglmer_morphAw<- glmer(rt ~ relatedness * morphType * morphComprehension + freqTarget + (1|subject) +
```

Spelling:

```
itaglmer_spell<- glmer(rt ~ relatedness * morphType * spelling + freqTarget + (1|subject) + (1|target),
car::Anova(itaglmer_spell)
```

Vocabulary:

```
itaglmer_voc<- glmer(rt ~ relatedness * morphType * vocabulary + freqTarget + (1|subject) + (1|target),
car::Anova(itaglmer_voc)
```

Reading comprehension:

```
itaglmer_read<- glmer(rt ~ relatedness * morphType * readingComprehension + freqTarget + (1|subject) +
car::Anova(itaglmer_read)
```

Oral comprehension:

```
itaglmer_oral<- glmer(rt ~ relatedness * morphType * oralComprehension + freqTarget + (1|subject) + (1|
car::Anova(itaglmer_oral)
```

Summary of the results for ITA dataset

The model itaglmer2 found a main effect of relatedness [$\chi^2 = 63.28$, $p < 0.0001$]. A main effect of morphType [$\chi^2 = 70.28$, $p < 0.0001$], and a main effect of frequency [$\chi^2 = 420.38$, $p < 0.0001$]. More importantly, itaglmer2 shows a significant interaction between relatedness and morphtype [$\chi^2 = 228.84$, $p < 0.0001$], such

that among related trials there were faster reaction times to orthographic trials compared to opaque trials [β = -14.27, $p < 0.0001$], and to transparent trials [β = -36.82, $p < 0.0001$]. By setting the base contrast to opaque trials, itaglmer2c shows that opaque trials are faster than transparent trials [β = -22.54, $p < 0.0001$].

We have also checked whether proficiency tests obtained on the second language, English, would influence the pattern of results in Italian. Only two tests showed convergence: phonological comprehension and phonological fluency, however both showed non significant results [both $p > 1$].

Modelling, ENG

Set contrasts:

```
dataEng$morphType <- relevel(dataEng$morphType, "or");
contrasts(dataEng$relatedness);
```

```
##      rel
## ctrl   0
## rel    1
```

```
contrasts(dataEng$morphType);
```

```
##    op tr
## or  0  0
## op  1  0
## tr  0  1
```

```
engglmer0 <- glmer(rt ~ 1+ (1|subject) + (1|target), data = dataEng,
      family=Gamma(link="identity"));
```

```
engglmer1 <- glmer(rt ~ trialCount + rotation+ (1|subject) + (1|target), data = dataEng, family=Gamma(li
```

```
anova(engglmer0, engglmer1);
```

```
## Data: dataEng
## Models:
## engglmer0: rt ~ 1 + (1 | subject) + (1 | target)
## engglmer1: rt ~ trialCount + rotation + (1 | subject) + (1 | target)
##           npar    AIC    BIC logLik deviance  Chisq Df Pr(>Chisq)
## engglmer0    4 113778 113806 -56885   113770
## engglmer1    6 113778 113820 -56883   113766 3.8608  2     0.1451
```

Again like in the ITA dataset, no effect of rotation here.

```
engglmer1c <- glmer(rt ~ freqTarget + lengthTarget + nTarget + (1|subject) + (1|target), data = dataEng
```

```
anova(engglmer0, engglmer1c);
```

```
## Data: dataEng
## Models:
## engglmer0: rt ~ 1 + (1 | subject) + (1 | target)
## engglmer1c: rt ~ freqTarget + lengthTarget + nTarget + (1 | subject) + (1 |
## engglmer1c:     target)
##            npar    AIC    BIC logLik deviance  Chisq Df Pr(>Chisq)
## engglmer0     4 113778 113806 -56885   113770
## engglmer1c    7 113719 113769 -56853   113705 64.523  3  6.344e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

strong improvement in GoF

```
car::Anova(engglmer1c)
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                 Chisq Df Pr(>Chisq)
## freqTarget   301.5128  1     <2e-16 ***
## lengthTarget  92.6719  1     <2e-16 ***
## nTarget        0.0036  1     0.9523
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Frequency and length contribute.

We introduce our variable of interest now:

```
engglmer2 <- glmer(rt ~ relatedness * morphType + freqTarget + lengthTarget + (1|subject) + (1|target),
```

```
engglmer2.anova <- car::Anova(engglmer2)
engglmer2.modelsum <- summary(engglmer2)
engglmer2.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                          Chisq Df Pr(>Chisq)
## relatedness           115.6393  1  < 2.2e-16 ***
## morphType               3.3445  2     0.1878
## freqTarget            663.8526  1  < 2.2e-16 ***
## lengthTarget           97.4373  1  < 2.2e-16 ***
## relatedness:morphType  32.9506  2  6.996e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Summary of the engglmer2 model:

```
knitr::kable(round(engglmer2.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1148.3132	3.0478	376.7719	0.0000
relatednessrel	-19.0099	2.5847	-7.3548	0.0000
morphTypeop	0.0623	3.5746	0.0174	0.9861
morphTypetr	-0.7171	4.8117	-0.1490	0.8815
freqTarget	-72.1990	2.8022	-25.7653	0.0000
lengthTarget	-26.4356	2.6781	-9.8710	0.0000
relatednessrel:morphTypeop	-5.6052	2.9651	-1.8904	0.0587
relatednessrel:morphTypetr	-17.1599	3.1044	-5.5275	0.0000

We set the base contrast on the opaque condition and re-run the model:

```
dataEng$morphType <- relevel(dataEng$morphType, "op");
```

```
engglmer2c <- glmer(rt ~ relatedness * morphType + freqTarget + lengthTarget + (1|subject) + (1|target)
```

```
engglmer2c.anova <- car::Anova(engglmer2c)
engglmer2c.modelsum <- summary(engglmer2c)
engglmer2c.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                          Chisq Df Pr(>Chisq)
## relatedness           107.6610  1  < 2.2e-16 ***
## morphType               1.4125  2  0.4934930
## freqTarget            398.3679  1  < 2.2e-16 ***
## lengthTarget           54.1887  1  1.821e-13 ***
## relatedness:morphType  16.7656  2  0.0002288 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(engglmer2c.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1148.3958	4.1030	279.8895	0.0000
relatednessrel	-24.6153	2.7411	-8.9800	0.0000
morphTypeor	-0.0644	4.3638	-0.0148	0.9882
morphTypetr	-0.7773	8.3555	-0.0930	0.9259
freqTarget	-72.2010	3.6174	-19.9592	0.0000
lengthTarget	-26.4380	3.5915	-7.3613	0.0000
relatednessrel:morphTypeor	5.6057	4.1280	1.3580	0.1745
relatednessrel:morphTypetr	-11.5547	3.0514	-3.7866	0.0002

Summary of the results for ENG dataset

The model engglmer2 found a main effect of relatedness [χ^2 = 115.64, $p < 0.0001$]. A main effect of frequency [χ^2 = 663.85, $p < 0.0001$], and also a main effect of length [χ^2 = 97.44, $p < 0.0001$]. The effect of MorphType was not significant [χ^2 = 3.34, $p = 0.1878$]. However, itaglmer2 shows a significant interaction between relatedness and morphtype [χ^2 = 32.95, $p < 0.0001$], such that among related trials there were faster reaction times to orthographic trials compared to opaque trials, although only marginally significant [β = -5.61, $p = 0.0587$], and to transparent trials [β = -17.16, $p < 0.0001$]. By setting the base contrast to opaque trials, engglmer2c shows that opaque trials are faster than transparent trials [β = -11.55, $p < 0.0002$].

Cross language interaction

```
rbind(dataEng, dataIta) -> crossExp
summary(crossExp)
```

```
##     subject        age           gender      handedness      trialCount
##  Min.   : 1   Min.   :18.00   Female:13532   Left : 2191   Min.   :  1.0
##  1st Qu.:21   1st Qu.:22.00   Male  : 6415   Right:17756   1st Qu.: 75.0
##  Median :42   Median :24.00                                Median :150.0
##  Mean   :42   Mean   :24.33                                Mean   :150.2
##  3rd Qu.:62   3rd Qu.:26.00                                3rd Qu.:225.0
##  Max.   :84   Max.   :34.00                                Max.   :300.0
##
##        rt              resp        trialType           lexicality    morphType
##  Min.   : 284.0   Min.   :0.000   Length:19947       nonword:    0   op:6663
##  1st Qu.: 517.0   1st Qu.:2.000   Class :character   word   :19947   or:6383
##  Median : 588.0   Median :2.000   Mode  :character                    tr:6901
##  Mean   : 629.3   Mean   :1.994
##  3rd Qu.: 693.0   3rd Qu.:2.000
##  Max.   :1998.0   Max.   :2.000
##
##      target            prime       relatedness    freqTarget      freqPrime
##  abito  :   78   against  :   40   ctrl: 9886   Min.   :1.367   Min.   :1.170
##  again  :   78   angelic  :   40   rel :10061   1st Qu.:3.470   1st Qu.:2.670
##  angel  :   78   cloudless:   40                Median :4.011   Median :3.180
##  ballo  :   78   dreamer  :   40                Mean   :3.979   Mean   :3.263
##  banca  :   78   drunkard :   40                3rd Qu.:4.520   3rd Qu.:3.867
##  cambio :   78   extract  :   40                Max.   :5.840   Max.   :6.290
##  (Other):19479   (Other)  :19707                                NA's   :37
##   lengthTarget    lengthPrime        nTarget          nPrime
##  Min.   :3.000   Min.   : 5.000   Min.   : 0.00   Min.   : 0.000
##  1st Qu.:4.000   1st Qu.: 7.000   1st Qu.: 6.00   1st Qu.: 1.000
##  Median :5.000   Median : 7.000   Median :12.00   Median : 2.000
##  Mean   :4.958   Mean   : 7.514   Mean   :15.04   Mean   : 3.169
##  3rd Qu.:5.000   3rd Qu.: 8.000   3rd Qu.:22.00   3rd Qu.: 4.000
##  Max.   :8.000   Max.   :13.000   Max.   :47.00   Max.   :36.000
##
##    rotation         language      oscTarget         accuracy phonemicFluency
##  Length:19947       eng: 8938   Min.   :-0.094   Min.   :1   Min.   : 0.00
##  Class :character   ita:11009   1st Qu.: 0.263   1st Qu.:1   1st Qu.:17.00
```

```
##  Mode  :character              Median : 0.623   Median :1   Median :23.00
##                                 Mean   : 0.577   Mean   :1   Mean   :22.56
##                                 3rd Qu.: 0.899   3rd Qu.:1   3rd Qu.:27.00
##                                 Max.   : 1.000   Max.   :1   Max.   :45.00
##                                 NA's   :11164
##  phonemicComprehension morphComprehension    spelling      readingComprehension
##  Min.   : 0.000        Min.   : 4.00      Min.   : 0.000   Min.   :1.000
##  1st Qu.: 8.000        1st Qu.: 8.00      1st Qu.: 5.000   1st Qu.:3.000
##  Median : 9.000        Median : 9.00      Median : 8.000   Median :5.000
##  Mean   : 8.845        Mean   : 8.95      Mean   : 8.239   Mean   :4.525
##  3rd Qu.:10.000        3rd Qu.:10.00      3rd Qu.:12.000   3rd Qu.:6.000
##  Max.   :13.000        Max.   :10.00      Max.   :18.000   Max.   :7.000
##
##    vocabulary    oralComprehension    aoa1.Aoa        aoa2.usage
##  Min.   : 8.00   Min.   :1.000     Min.   : 0.000   Min.   :1.000
##  1st Qu.:14.00   1st Qu.:3.000     1st Qu.: 6.000   1st Qu.:2.000
##  Median :15.00   Median :5.000     Median : 6.000   Median :3.000
##  Mean   :15.31   Mean   :4.591     Mean   : 6.494   Mean   :3.145
##  3rd Qu.:17.00   3rd Qu.:6.000     3rd Qu.: 8.000   3rd Qu.:4.000
##  Max.   :19.00   Max.   :6.000     Max.   :15.000   Max.   :5.000
##
##  aoa3.context   aoa4.contextMultling aoa5.selfRatedProf aoa6.otherLang
##  home  : 2664   no :15257            Min.   :1.000      no : 4735
##  school:17283   yes: 4690            1st Qu.:3.000      yes:15212
##                                      Median :4.000
##                                      Mean   :3.534
##                                      3rd Qu.:4.000
##                                      Max.   :5.000
##
```

Setting out base contrast to orthographic, defaul of relatedness is "unrelated/ctrl":

```
crossExp$morphType <- relevel(crossExp$morphType, "or");
```

```
crossglmer <- glmer(rt ~ relatedness * morphType * language + freqTarget + lengthTarget + (1|subject) +
```

```
crossglmer.modelsum <- summary(crossglmer)
crossglmer.anova <- car::Anova(crossglmer)
crossglmer.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                  Chisq Df Pr(>Chisq)
## relatedness                    200.067  1  < 2.2e-16 ***
## morphType                       39.044  2  3.325e-09 ***
## language                      1765.815  1  < 2.2e-16 ***
## freqTarget                     842.282  1  < 2.2e-16 ***
## lengthTarget                    38.695  1  4.956e-10 ***
## relatedness:morphType          136.567  2  < 2.2e-16 ***
## relatedness:language            60.080  1  9.108e-15 ***
## morphType:language              32.571  2  8.459e-08 ***
## relatedness:morphType:language  61.727  2  3.946e-14 ***
```

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

Summary:

```
knitr::kable(round(crossglmer.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1015.4226	2.0309	499.9902	0.0000
relatednessrel	-18.3962	1.8571	-9.9060	0.0000
morphTypeop	-4.7311	2.3889	-1.9804	0.0477
morphTypetr	-11.5795	2.1260	-5.4465	0.0000
languageita	-89.1579	2.2066	-40.4049	0.0000
freqTarget	-59.0016	2.0330	-29.0221	0.0000
lengthTarget	-10.1169	1.6264	-6.2205	0.0000
relatednessrel:morphTypeop	-5.9379	2.1402	-2.7744	0.0055
relatednessrel:morphTypetr	-18.5042	2.1512	-8.6019	0.0000
relatednessrel:languageita	17.0474	1.7390	9.8030	0.0000
morphTypeop:languageita	-10.7867	2.8390	-3.7995	0.0001
morphTypetr:languageita	-3.0255	2.1983	-1.3763	0.1687
relatednessrel:morphTypeop:languageita	-8.8894	2.3634	-3.7613	0.0002
relatednessrel:morphTypetr:languageita	-18.1998	2.5149	-7.2368	0.0000

```
crossExp$morphType <- relevel(crossExp$morphType, "op");
```

```
crossglmerc <- glmer(rt ~ relatedness * morphType * language + freqTarget + lengthTarget + (1|subject) +
```

```
crossglmerc.modelsum <- summary(crossglmerc)
crossglmerc.anova <- car::Anova(crossglmerc)
crossglmerc.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                  Chisq Df Pr(>Chisq)
## relatedness                    347.480  1  < 2.2e-16 ***
## morphType                       71.744  2  2.636e-16 ***
## language                      2418.082  1  < 2.2e-16 ***
## freqTarget                     943.784  1  < 2.2e-16 ***
## lengthTarget                    29.549  1  5.451e-08 ***
## relatedness:morphType           59.972  2  9.490e-14 ***
## relatedness:language            21.906  1  2.864e-06 ***
## morphType:language              42.098  2  7.221e-10 ***
## relatedness:morphType:language  44.627  2  2.039e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(crossglmerc.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1010.7039	1.8982	532.4559	0.0000
relatednessrel	-24.3339	1.4798	-16.4438	0.0000
morphTypeor	4.7242	2.0056	2.3555	0.0185
morphTypetr	-6.8469	3.7620	-1.8200	0.0688
languageita	-99.9490	2.1581	-46.3134	0.0000
freqTarget	-59.0028	1.9206	-30.7211	0.0000
lengthTarget	-10.1180	1.8613	-5.4359	0.0000
relatednessrel:morphTypeor	5.9377	1.7657	3.3628	0.0008
relatednessrel:morphTypetr	-12.5666	2.6633	-4.7183	0.0000
relatednessrel:languageita	8.1579	2.0027	4.0735	0.0000
morphTypeor:languageita	10.8020	2.3890	4.5216	0.0000
morphTypetr:languageita	7.7589	2.7490	2.8225	0.0048
relatednessrel:morphTypeor:languageita	8.8895	1.8392	4.8333	0.0000
relatednessrel:morphTypetr:languageita	-9.3100	2.3367	-3.9842	0.0001
# Proficiency scores, correlation and dis	tribution			
Create a dataframe with one row per parti	cipant			

```
pptFeatures <- unique(dataEng[,c('subject','age','gender','handedness','rotation','phonemicFluency', 'pl
summary(pptFeatures)
```

```
##     subject           age           gender   handedness   rotation
##  Min.   : 1.00   Min.   :18.00   Female:54   Left : 8   Length:78
##  1st Qu.:21.50   1st Qu.:22.00   Male  :24   Right:70   Class :character
##  Median :41.50   Median :24.00                          Mode  :character
##  Mean   :41.74   Mean   :24.28
##  3rd Qu.:61.75   3rd Qu.:26.00
##  Max.   :84.00   Max.   :34.00
##  phonemicFluency phonemicComprehension morphComprehension    spelling
##  Min.   : 0.00   Min.   : 0.000        Min.   : 4.000     Min.   : 0.000
##  1st Qu.:16.25   1st Qu.: 8.000        1st Qu.: 8.000     1st Qu.: 4.000
##  Median :22.00   Median : 9.000        Median : 9.000     Median : 7.000
##  Mean   :22.17   Mean   : 8.769        Mean   : 8.897     Mean   : 8.026
##  3rd Qu.:27.00   3rd Qu.:10.000        3rd Qu.:10.000     3rd Qu.:11.000
##  Max.   :45.00   Max.   :13.000        Max.   :10.000     Max.   :18.000
##  readingComprehension   vocabulary    oralComprehension    aoa1.Aoa
##  Min.   :1.000        Min.   : 8.00   Min.   :1.0       Min.   : 0.000
##  1st Qu.:3.000        1st Qu.:14.00   1st Qu.:3.0       1st Qu.: 6.000
##  Median :5.000        Median :15.00   Median :5.0       Median : 6.000
##  Mean   :4.423        Mean   :15.24   Mean   :4.5       Mean   : 6.487
##  3rd Qu.:6.000        3rd Qu.:17.00   3rd Qu.:6.0       3rd Qu.: 8.000
##  Max.   :7.000        Max.   :19.00   Max.   :6.0       Max.   :15.000
##    aoa2.usage    aoa3.context aoa4.contextMultling aoa5.selfRatedProf
##  Min.   :1.000   home  :10    no :60               Min.   :1.000
##  1st Qu.:2.000   school:68    yes:18               1st Qu.:3.000
##  Median :3.000                                     Median :3.000
##  Mean   :3.115                                     Mean   :3.487
##  3rd Qu.:4.000                                     3rd Qu.:4.000
##  Max.   :5.000                                     Max.   :5.000
##  aoa6.otherLang
##  no :18
##  yes:60
```

```
##
##
##
##
```

```
knitr::kable(round(cor(pptFeatures[,c(6:12)], use='pairwise.complete.obs'), digits=2))
```

	phonemicFluency	phonemicComprehension	morphComprehension	spelling	readingCompr
phonemicFluency	1.00	0.25	0.54	0.61	
phonemicComprehension	0.25	1.00	0.43	0.46	
morphComprehension	0.54	0.43	1.00	0.64	
spelling	0.61	0.46	0.64	1.00	
readingComprehension	0.35	0.44	0.40	0.49	
vocabulary	0.45	0.44	0.54	0.65	
oralComprehension	0.43	0.45	0.68	0.62	

Proficiency modelling

Set base contrasts to orthographic

```
dataEng$morphType <- relevel(dataEng$morphType, "or");
```

This model establishes the baseline model, with no proficiency score:

```
proficiencyglmer0 <- glmer(rt ~ relatedness * morphType  + freqTarget + lengthTarget + (1|subject) + (1
```

Now we test whether each individual proficiency score guarantees a better overall fit:

Phonemic fluency

```
proficiencyglmer1 <- glmer(rt ~ relatedness  * morphType * phonemicFluency + lengthTarget + freqTarget +
      + (1|target), data = dataEng, family=Gamma(link="identity"), control=glmerControl(optimizer="boby
```

```
anova(proficiencyglmer0, proficiencyglmer1);
```

```
## Data: dataEng
## Models:
## proficiencyglmer0: rt ~ relatedness * morphType + freqTarget + lengthTarget + (1 |
## proficiencyglmer0:     subject) + (1 | target)
## proficiencyglmer1: rt ~ relatedness * morphType * phonemicFluency + lengthTarget +
## proficiencyglmer1:     freqTarget + (1 | subject) + (1 | target)
##                   npar    AIC    BIC logLik deviance  Chisq Df Pr(>Chisq)
## proficiencyglmer0   11 113629 113707 -56803   113607
## proficiencyglmer1   17 113621 113742 -56793   113587 19.855  6   0.002939 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Increase in GoF

Phonemic comprehension

```
proficiencyglmer2<- glmer(rt ~ relatedness  * morphType * phonemicComprehension + lengthTarget + freqTa
        + (1|target), data = dataEng, family=Gamma(link="identity"), control=glmerControl(optimizer="b
```

```
anova(proficiencyglmer0, proficiencyglmer2);
```

```
## Data: dataEng
## Models:
## proficiencyglmer0: rt ~ relatedness * morphType + freqTarget + lengthTarget + (1 |
## proficiencyglmer0:     subject) + (1 | target)
## proficiencyglmer2: rt ~ relatedness * morphType * phonemicComprehension + lengthTarget +
## proficiencyglmer2:     freqTarget + (1 | subject) + (1 | target)
##                    npar    AIC    BIC logLik deviance  Chisq Df Pr(>Chisq)
## proficiencyglmer0   11 113629 113707 -56803   113607
## proficiencyglmer2   17 113619 113740 -56793   113585 21.519  6    0.00148 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Increase in GoF

Morphologic awareness

```
proficiencyglmer3<- glmer(rt ~ relatedness  * morphType * morphComprehension + lengthTarget + freqTarge
```

```
anova(proficiencyglmer0, proficiencyglmer3);
```

```
## Data: dataEng
## Models:
## proficiencyglmer0: rt ~ relatedness * morphType + freqTarget + lengthTarget + (1 |
## proficiencyglmer0:     subject) + (1 | target)
## proficiencyglmer3: rt ~ relatedness * morphType * morphComprehension + lengthTarget +
## proficiencyglmer3:     freqTarget + (1 | subject) + (1 | target)
##                    npar    AIC    BIC logLik deviance  Chisq Df Pr(>Chisq)
## proficiencyglmer0   11 113629 113707 -56803   113607
## proficiencyglmer3   17 113614 113734 -56790   113580 27.227  6  0.0001313 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Increase in GoF

Spelling

```
proficiencyglmer4<- glmer(rt ~ relatedness  * morphType * spelling + lengthTarget + freqTarget + (1|sub
```

```
anova(proficiencyglmer0, proficiencyglmer4);
```

```
## Data: dataEng
## Models:
## proficiencyglmer0: rt ~ relatedness * morphType + freqTarget + lengthTarget + (1 |
## proficiencyglmer0:     subject) + (1 | target)
## proficiencyglmer4: rt ~ relatedness * morphType * spelling + lengthTarget + freqTarget +
## proficiencyglmer4:     (1 | subject) + (1 | target)
##                   npar    AIC    BIC logLik deviance  Chisq Df Pr(>Chisq)
## proficiencyglmer0   11 113629 113707 -56803   113607
## proficiencyglmer4   17 113621 113741 -56793   113587 20.196  6   0.002556 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Increase in GoF

Reading comprehension

```
proficiencyglmer5<- glmer(rt ~ relatedness  * morphType * readingComprehension + lengthTarget + freqTarg
```

```
anova(proficiencyglmer0, proficiencyglmer5);
```

```
## Data: dataEng
## Models:
## proficiencyglmer0: rt ~ relatedness * morphType + freqTarget + lengthTarget + (1 |
## proficiencyglmer0:     subject) + (1 | target)
## proficiencyglmer5: rt ~ relatedness * morphType * readingComprehension + lengthTarget +
## proficiencyglmer5:     freqTarget + (1 | subject) + (1 | target)
##                   npar    AIC    BIC logLik deviance  Chisq Df Pr(>Chisq)
## proficiencyglmer0   11 113629 113707 -56803   113607
## proficiencyglmer5   17 113622 113743 -56794   113588 18.739  6   0.004628 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Increase in GoF

Vocabulary

```
proficiencyglmer6<- glmer(rt ~ relatedness  * morphType * vocabulary + lengthTarget + freqTarget + (1|su
```

```
anova(proficiencyglmer0, proficiencyglmer6)
```

```
## Data: dataEng
## Models:
## proficiencyglmer0: rt ~ relatedness * morphType + freqTarget + lengthTarget + (1 |
## proficiencyglmer0:     subject) + (1 | target)
## proficiencyglmer6: rt ~ relatedness * morphType * vocabulary + lengthTarget + freqTarget +
```

```
## proficiencyglmer6:     (1 | subject) + (1 | target)
##                    npar    AIC    BIC logLik deviance  Chisq Df Pr(>Chisq)
## proficiencyglmer0    11 113629 113707 -56803   113607
## proficiencyglmer6    17 113624 113744 -56795   113590 16.974  6   0.009381 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Increase in GoF

Oral comprehension

```
proficiencyglmer7<- glmer(rt ~ relatedness  * morphType * oralComprehension + lengthTarget + freqTarget
```

```
anova(proficiencyglmer0, proficiencyglmer7)
```

```
## Data: dataEng
## Models:
## proficiencyglmer0: rt ~ relatedness * morphType + freqTarget + lengthTarget + (1 |
## proficiencyglmer0:     subject) + (1 | target)
## proficiencyglmer7: rt ~ relatedness * morphType * oralComprehension + lengthTarget +
## proficiencyglmer7:     freqTarget + (1 | subject) + (1 | target)
##                    npar    AIC    BIC logLik deviance  Chisq Df Pr(>Chisq)
## proficiencyglmer0    11 113629 113707 -56803   113607
## proficiencyglmer7    17 113628 113749 -56797   113594 12.826  6    0.04587 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Increase in GoF

All tests seem to increase the goodness of fit of the base model proficiencyglmer0.

Does proficiency specifically interact with priming?

We're going to inspect the anova and summary of each model first with the base contrast set to orthographic, and then with base contrast set to opaque.

Phonemic fluency

```
proficiencyglmer1.anova <- car::Anova(proficiencyglmer1)
proficiencyglmer1.modelsum <- summary(proficiencyglmer1)
proficiencyglmer1.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                      Chisq Df Pr(>Chisq)
## relatedness                       149.9141  1  < 2.2e-16 ***
## morphType                          55.5984  2  8.452e-13 ***
```

```
## phonemicFluency                          0.1490  1    0.69946
## lengthTarget                            59.0381  1  1.546e-14 ***
## freqTarget                             247.7524  1  < 2.2e-16 ***
## relatedness:morphType                   12.7430  2    0.00171 **
## relatedness:phonemicFluency              6.4054  1    0.01138 *
## morphType:phonemicFluency               20.1663  2  4.178e-05 ***
## relatedness:morphType:phonemicFluency    4.6787  2    0.09639 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(proficiencyglmer1.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1134.8547	4.0888	277.5538	0.0000
relatednessrel	-31.6121	3.6873	-8.5732	0.0000
morphTypeop	4.7598	4.9646	0.9588	0.3377
morphTypetr	24.7012	3.6178	6.8277	0.0000
phonemicFluency	0.7018	1.0012	0.7009	0.4834
lengthTarget	-26.8585	3.4955	-7.6836	0.0000
freqTarget	-72.2249	4.5886	-15.7402	0.0000
relatednessrel:morphTypeop	-14.2252	5.1627	-2.7554	0.0059
relatednessrel:morphTypetr	-6.9186	4.5080	-1.5347	0.1248
relatednessrel:phonemicFluency	0.5560	0.2662	2.0889	0.0367
morphTypeop:phonemicFluency	-0.2189	0.3966	-0.5519	0.5810
morphTypetr:phonemicFluency	-1.1214	0.3811	-2.9425	0.0033
relatednessrel:morphTypeop:phonemicFluency	0.4064	0.3690	1.1012	0.2708
relatednessrel:morphTypetr:phonemicFluency	-0.4492	0.3411	-1.3169	0.1879

```
dataEng$morphType <- relevel(dataEng$morphType, "op");
```

```
proficiencyglmer1b <- glmer(rt ~ relatedness  * morphType * phonemicFluency + lengthTarget + freqTarget
      + (1|target), data = dataEng, family=Gamma(link="identity"), control=glmerControl(optimizer="boby
```

```
proficiencyglmer1b.anova <- car::Anova(proficiencyglmer1b)
proficiencyglmer1b.modelsum <- summary(proficiencyglmer1b)
proficiencyglmer1b.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                          Chisq Df Pr(>Chisq)
## relatedness                          288.0903  1  < 2.2e-16 ***
## morphType                              4.6475  2  0.0979071 .
## phonemicFluency                        0.0169  1  0.8964806
## lengthTarget                          66.6933  1  3.172e-16 ***
## freqTarget                           353.1834  1  < 2.2e-16 ***
## relatedness:morphType                 81.2126  2  < 2.2e-16 ***
## relatedness:phonemicFluency           11.8989  1  0.0005617 ***
## morphType:phonemicFluency             16.7373  2  0.0002320 ***
## relatedness:morphType:phonemicFluency 50.4393  2  1.115e-11 ***
```

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

```
knitr::kable(round(proficiencyglmer1b.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1117.5070	4.5333	246.5109	0.0000
relatednessrel	-56.4754	3.5793	-15.7782	0.0000
morphTypeor	-3.4588	3.1128	-1.1111	0.2665
morphTypetr	3.9184	3.9380	0.9950	0.3197
phonemicFluency	0.0543	0.9325	0.0582	0.9536
lengthTarget	-27.7346	3.3961	-8.1666	0.0000
freqTarget	-67.8810	3.6120	-18.7932	0.0000
relatednessrel:morphTypeor	24.8902	3.1630	7.8691	0.0000
relatednessrel:morphTypetr	32.1827	3.9124	8.2257	0.0000
relatednessrel:phonemicFluency	1.4174	0.2242	6.3229	0.0000
morphTypeor:phonemicFluency	0.2584	0.3291	0.7852	0.4324
morphTypetr:phonemicFluency	-0.0995	0.3190	-0.3119	0.7551
relatednessrel:morphTypeor:phonemicFluency	-0.7568	0.2845	-2.6605	0.0078
relatednessrel:morphTypetr:phonemicFluency	-2.0029	0.2823	-7.0955	0.0000

Phonemic comprehension

```
proficiencyglmer2.anova <- car::Anova(proficiencyglmer2)
proficiencyglmer2.modelsum <- summary(proficiencyglmer2)
proficiencyglmer2.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                              Chisq Df Pr(>Chisq)
## relatedness                                190.6468  1  < 2.2e-16 ***
## morphType                                   38.4328  2  4.513e-09 ***
## phonemicComprehension                        4.2647  1    0.03891 *
## lengthTarget                                38.6991  1  4.944e-10 ***
## freqTarget                                 247.5258  1  < 2.2e-16 ***
## relatedness:morphType                       94.7005  2  < 2.2e-16 ***
## relatedness:phonemicComprehension            4.5962  1    0.03204 *
## morphType:phonemicComprehension             23.3758  2  8.395e-06 ***
## relatedness:morphType:phonemicComprehension 42.5724  2  5.695e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(proficiencyglmer2.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1081.7928	10.7410	100.7165	0.0000
relatednessrel	-52.2509	4.2269	-12.3616	0.0000

	Estimate	Std. Error	t value	Pr(>|z|)
morphTypeop	0.1424	5.7203	0.0249	0.9801
morphTypetr	35.9996	4.4364	8.1146	0.0000
phonemicComprehension	7.6788	2.6089	2.9433	0.0032
lengthTarget	-26.5325	4.2651	-6.2209	0.0000
freqTarget	-72.3439	4.5982	-15.7330	0.0000
relatednessrel:morphTypeop	43.9669	3.9545	11.1183	0.0000
relatednessrel:morphTypetr	8.5439	4.1758	2.0461	0.0408
relatednessrel:phonemicComprehension	3.7867	0.7156	5.2916	0.0000
morphTypeop:phonemicComprehension	-0.0161	1.1564	-0.0139	0.9889
morphTypetr:phonemicComprehension	-4.1631	1.1514	-3.6157	0.0003
relatednessrel:morphTypeop:phonemicComprehension	-5.6581	0.8770	-6.4517	0.0000
relatednessrel:morphTypetr:phonemicComprehension	-2.9423	0.8527	-3.4507	0.0006

```
dataEng$morphType <- relevel(dataEng$morphType, "op");
```

```
proficiencyglmer2b <- glmer(rt ~ relatedness  * morphType * phonemicComprehension + lengthTarget + freq
      + (1|target), data = dataEng, family=Gamma(link="identity"), control=glmerControl(optimizer="boby
```

```
proficiencyglmer2b.anova <- car::Anova(proficiencyglmer2b)
proficiencyglmer2b.modelsum <- summary(proficiencyglmer2b)
proficiencyglmer2b.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                                Chisq Df Pr(>Chisq)
## relatedness                                174.9357  1  < 2.2e-16 ***
## morphType                                   53.2608  2  2.720e-12 ***
## phonemicComprehension                       11.0448  1  0.0008894 ***
## lengthTarget                                64.0166  1  1.234e-15 ***
## freqTarget                                 552.0537  1  < 2.2e-16 ***
## relatedness:morphType                       34.1079  2  3.922e-08 ***
## relatedness:phonemicComprehension            1.3885  1  0.2386511
## morphType:phonemicComprehension             22.5979  2  1.239e-05 ***
## relatedness:morphType:phonemicComprehension  9.0798  2  0.0106747 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(proficiencyglmer2b.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1057.2324	3.4268	308.5158	0.0000
relatednessrel	-24.0579	3.1487	-7.6405	0.0000
morphTypeor	-5.4762	3.9364	-1.3911	0.1642
morphTypetr	26.6542	3.2615	8.1724	0.0000
phonemicComprehension	6.9144	2.2068	3.1333	0.0017
lengthTarget	-27.4608	3.4322	-8.0010	0.0000
freqTarget	-68.1731	2.9015	-23.4958	0.0000
relatednessrel:morphTypeor	-10.1777	3.9825	-2.5556	0.0106

	Estimate	Std. Error	t value	Pr(>|z|)
relatednessrel:morphTypetr	-16.3573	3.7107	-4.4082	0.0000
relatednessrel:phonemicComprehension	-0.2154	0.5638	-0.3820	0.7025
morphTypeor:phonemicComprehension	0.8294	0.9615	0.8626	0.3883
morphTypetr:phonemicComprehension	-2.8532	0.9344	-3.0536	0.0023
relatednessrel:morphTypeor:phonemicComprehension	2.3120	0.7692	3.0059	0.0026
relatednessrel:morphTypetr:phonemicComprehension	0.5461	0.7292	0.7489	0.4539

Morphological awareness

```
proficiencyglmer3.anova <- car::Anova(proficiencyglmer3)
proficiencyglmer3.modelsum <- summary(proficiencyglmer3)
proficiencyglmer3.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                          Chisq Df Pr(>Chisq)
## relatedness                            152.563  1  < 2.2e-16 ***
## morphType                              524.480  2  < 2.2e-16 ***
## morphComprehension                      31.407  1  2.092e-08 ***
## lengthTarget                            51.218  1  8.265e-13 ***
## freqTarget                             215.887  1  < 2.2e-16 ***
## relatedness:morphType                  108.661  2  < 2.2e-16 ***
## relatedness:morphComprehension          23.800  1  1.069e-06 ***
## morphType:morphComprehension            54.872  2  1.215e-12 ***
## relatedness:morphType:morphComprehension  16.297  2  0.0002891 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(proficiencyglmer3.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1038.9463	6.1748	168.2550	0.0000
relatednessrel	-32.4576	4.5194	-7.1818	0.0000
morphTypeop	33.8259	5.4833	6.1689	0.0000
morphTypetr	97.3078	4.9178	19.7870	0.0000
morphComprehension	12.4166	2.4773	5.0121	0.0000
lengthTarget	-26.4624	3.6976	-7.1567	0.0000
freqTarget	-72.5024	4.9345	-14.6931	0.0000
relatednessrel:morphTypeop	-43.0410	6.4120	-6.7126	0.0000
relatednessrel:morphTypetr	-25.1422	3.9168	-6.4191	0.0000
relatednessrel:morphComprehension	1.5220	0.7987	1.9055	0.0567
morphTypeop:morphComprehension	-3.8026	1.4157	-2.6860	0.0072
morphTypetr:morphComprehension	-10.9238	1.4274	-7.6530	0.0000
relatednessrel:morphTypeop:morphComprehension	4.2340	1.0488	4.0370	0.0001
relatednessrel:morphTypetr:morphComprehension	0.8449	0.8661	0.9755	0.3293

```
dataEng$morphType <- relevel(dataEng$morphType, "op");
```

```
proficiencyglmer3b<- glmer(rt ~ relatedness  * morphType * morphComprehension + lengthTarget + freqTarg
```

```
proficiencyglmer3b.anova <- car::Anova(proficiencyglmer3b)
proficiencyglmer3b.modelsum <- summary(proficiencyglmer3b)
proficiencyglmer3b.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                          Chisq Df Pr(>Chisq)
## relatedness                           308.0157  1  < 2.2e-16 ***
## morphType                              78.0208  2  < 2.2e-16 ***
## morphComprehension                      4.8901  1    0.02701 *
## lengthTarget                           68.2622  1  < 2.2e-16 ***
## freqTarget                            244.9858  1  < 2.2e-16 ***
## relatedness:morphType                  48.4653  2  2.991e-11 ***
## relatedness:morphComprehension         33.4050  1  7.483e-09 ***
## morphType:morphComprehension           60.6706  2  6.692e-14 ***
## relatedness:morphType:morphComprehension  45.9456  2  1.055e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(proficiencyglmer3b.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1054.6027	4.5686	230.8358	0.0000
relatednessrel	-71.0514	4.3546	-16.3166	0.0000
morphTypeor	-30.1665	6.1510	-4.9044	0.0000
morphTypetr	49.5455	4.6677	10.6145	0.0000
morphComprehension	6.9006	2.5011	2.7590	0.0058
lengthTarget	-27.0451	3.2734	-8.2621	0.0000
freqTarget	-68.1457	4.3538	-15.6520	0.0000
relatednessrel:morphTypeor	44.3050	7.0870	6.2516	0.0000
relatednessrel:morphTypetr	37.1531	4.9787	7.4624	0.0000
relatednessrel:morphComprehension	5.1647	0.6525	7.9158	0.0000
morphTypeor:morphComprehension	3.5995	1.2520	2.8749	0.0040
morphTypetr:morphComprehension	-5.3315	1.2085	-4.4116	0.0000
relatednessrel:morphTypeor:morphComprehension	-3.9468	1.0220	-3.8618	0.0001
relatednessrel:morphTypetr:morphComprehension	-5.5851	0.8487	-6.5805	0.0000

Spelling

```
proficiencyglmer4.anova <- car::Anova(proficiencyglmer4)
proficiencyglmer4.modelsum <- summary(proficiencyglmer4)
proficiencyglmer4.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
```

```
## Response: rt
##                                   Chisq Df Pr(>Chisq)
## relatedness                    134.1645  1  < 2.2e-16 ***
## morphType                       27.4114  2  1.116e-06 ***
## spelling                         1.7117  1    0.19076
## lengthTarget                    43.1821  1  4.987e-11 ***
## freqTarget                     484.5839  1  < 2.2e-16 ***
## relatedness:morphType           30.6629  2  2.196e-07 ***
## relatedness:spelling             4.7912  1    0.02861 *
## morphType:spelling              19.0341  2  7.359e-05 ***
## relatedness:morphType:spelling   1.4888  2    0.47502
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(proficiencyglmer4.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1171.0568	3.5566	329.2639	0.0000
relatednessrel	-35.2546	3.7784	-9.3305	0.0000
morphTypeor	-9.2844	3.9463	-2.3527	0.0186
morphTypetr	17.2039	3.2317	5.3234	0.0000
spelling	-3.0051	2.2525	-1.3341	0.1822
lengthTarget	-26.3075	4.0034	-6.5713	0.0000
freqTarget	-72.2192	3.2807	-22.0133	0.0000
relatednessrel:morphTypeor	13.1761	3.5253	3.7376	0.0002
relatednessrel:morphTypetr	-11.4206	4.1772	-2.7341	0.0063
relatednessrel:spelling	1.2902	0.6058	2.1296	0.0332
morphTypeor:spelling	1.0854	0.7777	1.3956	0.1628
morphTypetr:spelling	-2.0594	0.7404	-2.7815	0.0054
relatednessrel:morphTypeor:spelling	-0.9101	0.7961	-1.1432	0.2530
relatednessrel:morphTypetr:spelling	-0.0719	0.7685	-0.0936	0.9254

```
dataEng$morphType <- relevel(dataEng$morphType, "op");
```

```
proficiencyglmer4b<- glmer(rt ~ relatedness  * morphType * spelling + lengthTarget + freqTarget + (1|su
```

```
proficiencyglmer4b.anova <- car::Anova(proficiencyglmer4b)
proficiencyglmer4b.modelsum <- summary(proficiencyglmer4b)
proficiencyglmer4b.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                   Chisq Df Pr(>Chisq)
## relatedness                    190.7043  1  < 2.2e-16 ***
## morphType                        6.2936  2   0.042990 *
## spelling                         1.8417  1   0.174746
## lengthTarget                    66.9171  1  2.832e-16 ***
## freqTarget                     305.4612  1  < 2.2e-16 ***
## relatedness:morphType           33.7450  2  4.703e-08 ***
```

```
## relatedness:spelling             1.0397  1   0.307902
## morphType:spelling              25.7411  2  2.573e-06 ***
## relatedness:morphType:spelling  10.2678  2   0.005894 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(proficiencyglmer4b.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1137.4869	5.3156	213.9913	0.0000
relatednessrel	-37.9314	3.5927	-10.5578	0.0000
morphTypeor	-3.6070	3.6578	-0.9861	0.3241
morphTypetr	13.6607	3.9968	3.4180	0.0006
spelling	-2.8889	1.8754	-1.5404	0.1235
lengthTarget	-27.1608	3.3203	-8.1803	0.0000
freqTarget	-67.8268	3.8808	-17.4774	0.0000
relatednessrel:morphTypeor	18.3245	3.7504	4.8860	0.0000
relatednessrel:morphTypetr	5.3533	3.8062	1.4065	0.1596
relatednessrel:spelling	1.4781	0.5415	2.7298	0.0063
morphTypeor:spelling	0.6788	0.6788	1.0001	0.3173
morphTypetr:spelling	-1.3550	0.6364	-2.1291	0.0332
relatednessrel:morphTypeor:spelling	-1.1394	0.7143	-1.5950	0.1107
relatednessrel:morphTypetr:spelling	-2.1023	0.6678	-3.1482	0.0016

Reading comprehension

```
proficiencyglmer5.anova <- car::Anova(proficiencyglmer5)
proficiencyglmer5.modelsum <- summary(proficiencyglmer5)
proficiencyglmer5.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                          Chisq Df Pr(>Chisq)
## relatedness                           107.3151  1  < 2.2e-16 ***
## morphType                              30.6589  2  2.200e-07 ***
## readingComprehension                    2.8110  1    0.09362 .
## lengthTarget                           47.2183  1  6.350e-12 ***
## freqTarget                            238.0712  1  < 2.2e-16 ***
## relatedness:morphType                   2.9111  2    0.23327
## relatedness:readingComprehension        0.4667  1    0.49450
## morphType:readingComprehension         24.5211  2  4.735e-06 ***
## relatedness:morphType:readingComprehension   4.7872  2    0.09130 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(proficiencyglmer5.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1120.0242	4.9253	227.4028	0.0000
relatednessrel	-30.2895	6.6045	-4.5862	0.0000
morphTypeop	7.7289	8.2889	0.9324	0.3511
morphTypetr	25.3555	5.1036	4.9681	0.0000
readingComprehension	6.5530	3.7596	1.7430	0.0813
lengthTarget	-26.4444	3.8484	-6.8716	0.0000
freqTarget	-72.3485	4.6890	-15.4296	0.0000
relatednessrel:morphTypeop	6.5187	10.0629	0.6478	0.5171
relatednessrel:morphTypetr	2.8760	7.9395	0.3622	0.7172
relatednessrel:readingComprehension	2.5117	1.6692	1.5047	0.1324
morphTypeop:readingComprehension	-1.7530	1.9071	-0.9192	0.3580
morphTypetr:readingComprehension	-5.8572	1.8995	-3.0835	0.0020
relatednessrel:morphTypeop:readingComprehension	-2.6925	2.4439	-1.1017	0.2706
relatednessrel:morphTypetr:readingComprehension	-4.5258	2.1070	-2.1480	0.0317

```
dataEng$morphType <- relevel(dataEng$morphType, "op");
```

```
proficiencyglmer5b<- glmer(rt ~ relatedness  * morphType * readingComprehension + lengthTarget + freqTa
```

```
proficiencyglmer5b.anova <- car::Anova(proficiencyglmer5b)
proficiencyglmer5b.modelsum <- summary(proficiencyglmer5b)
proficiencyglmer5b.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                            Chisq Df Pr(>Chisq)
## relatedness                             111.7743  1  < 2.2e-16 ***
## morphType                                 5.4697  2   0.064902 .
## readingComprehension                      3.9589  1   0.046625 *
## lengthTarget                             30.1253  1  4.050e-08 ***
## freqTarget                              276.6214  1  < 2.2e-16 ***
## relatedness:morphType                    11.1129  2   0.003862 **
## relatedness:readingComprehension          0.1612  1   0.688045
## morphType:readingComprehension           20.9944  2  2.761e-05 ***
## relatedness:morphType:readingComprehension  1.3950  2   0.497816
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(proficiencyglmer5b.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1012.7534	31.7721	31.8756	0.0000
relatednessrel	-21.3113	12.1704	-1.7511	0.0799
morphTypeor	2.4386	14.3158	0.1703	0.8647
morphTypetr	21.0404	13.8040	1.5242	0.1275
readingComprehension	7.5404	3.1820	2.3697	0.0178
lengthTarget	-23.3681	4.2575	-5.4887	0.0000
freqTarget	-64.4392	3.8744	-16.6319	0.0000

	Estimate	Std. Error	t value	Pr(>|z|)
relatednessrel:morphTypeor	-3.1886	17.7521	-0.1796	0.8575
relatednessrel:morphTypetr	-5.2726	16.7712	-0.3144	0.7532
relatednessrel:readingComprehension	-0.9684	2.5839	-0.3748	0.7078
morphTypeor:readingComprehension	0.3061	2.7209	0.1125	0.9104
morphTypetr:readingComprehension	-5.2326	2.5825	-2.0262	0.0427
relatednessrel:morphTypeor:readingComprehension	2.9554	3.7715	0.7836	0.4333
relatednessrel:morphTypetr:readingComprehension	-1.3077	3.5386	-0.3695	0.7117

Vocabulary

```
proficiencyglmer6.anova <- car::Anova(proficiencyglmer6)
proficiencyglmer6.modelsum <- summary(proficiencyglmer6)
proficiencyglmer6.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                    Chisq Df Pr(>Chisq)
## relatedness                      363.795  1  < 2.2e-16 ***
## morphType                        100.233  2  < 2.2e-16 ***
## vocabulary                         1.540  1     0.2146
## lengthTarget                      26.524  1  2.603e-07 ***
## freqTarget                       403.518  1  < 2.2e-16 ***
## relatedness:morphType             51.289  2  7.290e-12 ***
## relatedness:vocabulary            64.775  1  8.397e-16 ***
## morphType:vocabulary              25.618  2  2.737e-06 ***
## relatedness:morphType:vocabulary  39.369  2  2.826e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(proficiencyglmer6.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1188.2727	4.3258	274.6936	0.0000
relatednessrel	-83.6997	4.0119	-20.8628	0.0000
morphTypeop	-2.8159	3.4086	-0.8261	0.4087
morphTypetr	35.8139	3.8939	9.1975	0.0000
vocabulary	-2.5755	1.8260	-1.4105	0.1584
lengthTarget	-26.6260	5.1700	-5.1501	0.0000
freqTarget	-72.2009	3.5943	-20.0878	0.0000
relatednessrel:morphTypeop	21.4149	3.8695	5.5343	0.0000
relatednessrel:morphTypetr	33.0798	4.5225	7.3145	0.0000
relatednessrel:vocabulary	4.2189	0.4231	9.9711	0.0000
morphTypeop:vocabulary	0.1896	0.8300	0.2285	0.8193
morphTypetr:vocabulary	-2.3500	0.8294	-2.8334	0.0046
relatednessrel:morphTypeop:vocabulary	-1.7518	0.5288	-3.3129	0.0009
relatednessrel:morphTypetr:vocabulary	-3.2847	0.5285	-6.2147	0.0000

```
dataEng$morphType <- relevel(dataEng$morphType, "op");
```

```
proficiencyglmer6b<- glmer(rt ~ relatedness  * morphType * vocabulary + lengthTarget + freqTarget + (1|
```

```
proficiencyglmer6b.anova <- car::Anova(proficiencyglmer6b)
proficiencyglmer6b.modelsum <- summary(proficiencyglmer6b)
proficiencyglmer6b.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                    Chisq Df Pr(>Chisq)
## relatedness                     306.0907  1  < 2.2e-16 ***
## morphType                        96.1525  2  < 2.2e-16 ***
## vocabulary                        0.0783  1     0.7796
## lengthTarget                     48.7342  1  2.931e-12 ***
## freqTarget                      370.9151  1  < 2.2e-16 ***
## relatedness:morphType             2.9168  2     0.2326
## relatedness:vocabulary           36.7855  1  1.319e-09 ***
## morphType:vocabulary             29.5597  2  3.812e-07 ***
## relatedness:morphType:vocabulary 34.7464  2  2.850e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(proficiencyglmer6b.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1137.8423	5.6940	199.8331	0.0000
relatednessrel	-54.5748	4.0569	-13.4522	0.0000
morphTypeor	6.7985	4.8077	1.4141	0.1573
morphTypetr	47.1190	4.8970	9.6219	0.0000
vocabulary	-1.4249	1.7199	-0.8285	0.4074
lengthTarget	-27.7565	3.9760	-6.9810	0.0000
freqTarget	-67.3156	3.4953	-19.2592	0.0000
relatednessrel:morphTypeor	-9.4822	4.4362	-2.1374	0.0326
relatednessrel:morphTypetr	23.8131	8.1969	2.9051	0.0037
relatednessrel:vocabulary	1.8978	0.3746	5.0662	0.0000
morphTypeor:vocabulary	-0.3569	0.7363	-0.4847	0.6279
morphTypetr:vocabulary	-2.9586	0.7072	-4.1839	0.0000
relatednessrel:morphTypeor:vocabulary	1.2299	0.4838	2.5420	0.0110
relatednessrel:morphTypetr:vocabulary	-2.3265	0.6233	-3.7328	0.0002

Oral comprehension

```
proficiencyglmer7.anova <- car::Anova(proficiencyglmer7)
proficiencyglmer7.modelsum <- summary(proficiencyglmer7)
proficiencyglmer7.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                          Chisq Df Pr(>Chisq)
## relatedness                           148.4503  1  < 2.2e-16 ***
## morphType                             138.1402  2  < 2.2e-16 ***
## oralComprehension                       0.4328  1    0.51063
## lengthTarget                           91.6203  1  < 2.2e-16 ***
## freqTarget                            352.8560  1  < 2.2e-16 ***
## relatedness:morphType                  20.9182  2  2.869e-05 ***
## relatedness:oralComprehension           3.0700  1    0.07975 .
## morphType:oralComprehension            21.3570  2  2.303e-05 ***
## relatedness:morphType:oralComprehension  0.7190  2    0.69802
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(proficiencyglmer7.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1151.4971	5.3597	214.8429	0.0000
relatednessrel	-23.9274	3.6114	-6.6255	0.0000
morphTypeop	19.2799	4.7451	4.0631	0.0000
morphTypetr	35.4399	3.6540	9.6989	0.0000
oralComprehension	-0.9326	3.9715	-0.2348	0.8144
lengthTarget	-26.2976	2.7474	-9.5718	0.0000
freqTarget	-72.3171	3.8498	-18.7845	0.0000
relatednessrel:morphTypeop	-12.8680	7.3714	-1.7457	0.0809
relatednessrel:morphTypetr	-19.5969	4.6647	-4.2011	0.0000
relatednessrel:oralComprehension	1.1364	1.1931	0.9524	0.3409
morphTypeop:oralComprehension	-4.1494	1.7829	-2.3274	0.0199
morphTypetr:oralComprehension	-7.7514	1.7610	-4.4018	0.0000
relatednessrel:morphTypeop:oralComprehension	1.5364	1.8156	0.8462	0.3974
relatednessrel:morphTypetr:oralComprehension	0.4198	1.5258	0.2751	0.7832

```
dataEng$morphType <- relevel(dataEng$morphType, "op");
```

```
proficiencyglmer7b<- glmer(rt ~ relatedness  * morphType * oralComprehension + lengthTarget + freqTarge
```

```
proficiencyglmer7b.anova <- car::Anova(proficiencyglmer7b)
proficiencyglmer7b.modelsum <- summary(proficiencyglmer7b)
proficiencyglmer7b.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                          Chisq Df Pr(>Chisq)
## relatedness                           242.9122  1  < 2.2e-16 ***
## morphType                              12.6312  2   0.001808 **
## oralComprehension                       1.2854  1   0.256893
## lengthTarget                           67.0173  1  2.691e-16 ***
```

```
## freqTarget                                330.2657  1  < 2.2e-16 ***
## relatedness:morphType                      35.5801  2  1.879e-08 ***
## relatedness:oralComprehension               2.8583  1   0.090904 .
## morphType:oralComprehension                19.5765  2  5.611e-05 ***
## relatedness:morphType:oralComprehension     7.1928  2   0.027422 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(proficiencyglmer7b.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1131.9377	4.2024	269.3556	0.0000
relatednessrel	-39.2651	3.3166	-11.8391	0.0000
morphTypeor	-7.6802	3.9429	-1.9478	0.0514
morphTypetr	21.1512	4.8673	4.3456	0.0000
oralComprehension	-3.8344	2.9304	-1.3085	0.1907
lengthTarget	-27.2475	3.3284	-8.1864	0.0000
freqTarget	-67.6627	3.7232	-18.1732	0.0000
relatednessrel:morphTypeor	22.5775	4.2902	5.2626	0.0000
relatednessrel:morphTypetr	1.7790	3.5574	0.5001	0.6170
relatednessrel:oralComprehension	2.8856	1.0144	2.8445	0.0044
morphTypeor:oralComprehension	2.1804	1.5563	1.4010	0.1612
morphTypetr:oralComprehension	-4.0872	1.5430	-2.6489	0.0081
relatednessrel:morphTypeor:oralComprehension	-2.7044	1.4128	-1.9142	0.0556
relatednessrel:morphTypetr:oralComprehension	-2.9646	1.2412	-2.3886	0.0169

AoA

correlation

Correlation between the individual scores, and between aoa and proficiency:

```
round(cor(pptFeatures[,c(13,14,17)], use='pairwise.complete.obs', method='spearman'), digits=2);
```

```
##                    aoa1.Aoa aoa2.usage aoa5.selfRatedProf
## aoa1.Aoa               1.00      -0.15               0.04
## aoa2.usage            -0.15       1.00               0.49
## aoa5.selfRatedProf     0.04       0.49               1.00
```

```
round(cor(pptFeatures[,c(6:12, 13)], use='pairwise.complete.obs', method='spearman'), digits=2)[8,];
```

```
##       phonemicFluency phonemicComprehension    morphComprehension
##                  0.04                 -0.21                 -0.13
##              spelling  readingComprehension            vocabulary
##                 -0.23                 -0.15                 -0.13
##     oralComprehension              aoa1.Aoa
##                 -0.19                  1.00
```

aoa2 and aoa5 are quite correlated (unsurprisingly)

scores, modelling

Set base contrast to "orthographic"

```
dataEng$morphType <- relevel(dataEng$morphType, "or");
```

```
aoaglmer1<- glmer(rt ~ relatedness * morphType*aoa1.Aoa + freqTarget + (1|subject) + (1|target), data= d
```

```
anova(proficiencyglmer0, aoaglmer1)
```

```
## Data: dataEng
## Models:
## proficiencyglmer0: rt ~ relatedness * morphType + freqTarget + lengthTarget + (1 |
## proficiencyglmer0:     subject) + (1 | target)
## aoaglmer1: rt ~ relatedness * morphType * aoa1.Aoa + freqTarget + (1 | subject) +
## aoaglmer1:     (1 | target)
##                    npar    AIC    BIC logLik deviance  Chisq Df Pr(>Chisq)
## proficiencyglmer0   11 113629 113707 -56803   113607
## aoaglmer1           16 113636 113750 -56802   113604 2.3202  5     0.8033
```

No increase in GoF

```
aoaglmer2<- glmer(rt ~ relatedness * morphType*aoa2.usage + freqTarget + (1|subject) + (1|target), data=
```

```
anova(proficiencyglmer0, aoaglmer2)
```

```
## Data: dataEng
## Models:
## proficiencyglmer0: rt ~ relatedness * morphType + freqTarget + lengthTarget + (1 |
## proficiencyglmer0:     subject) + (1 | target)
## aoaglmer2: rt ~ relatedness * morphType * aoa2.usage + freqTarget + (1 |
## aoaglmer2:     subject) + (1 | target)
##                    npar    AIC    BIC logLik deviance  Chisq Df Pr(>Chisq)
## proficiencyglmer0   11 113629 113707 -56803   113607
## aoaglmer2           16 113631 113745 -56800   113599 7.3367  5     0.1968
```

No increase in GoF

```
aoaglmer3<- glmer(rt ~ relatedness * morphType*aoa3.context + freqTarget + (1|subject) + (1|target), da
```

```
anova(proficiencyglmer0, aoaglmer3)
```

```
## Data: dataEng
## Models:
## proficiencyglmer0: rt ~ relatedness * morphType + freqTarget + lengthTarget + (1 |
## proficiencyglmer0:     subject) + (1 | target)
## aoaglmer3: rt ~ relatedness * morphType * aoa3.context + freqTarget + (1 |
## aoaglmer3:     subject) + (1 | target)
##                    npar    AIC    BIC logLik deviance Chisq Df Pr(>Chisq)
## proficiencyglmer0   11 113629 113707 -56803   113607
## aoaglmer3           16 113641 113755 -56805   113609     0  5          1
```

No increase in GoF

```
aoaglmer4<- glmer(rt ~ relatedness * morphType*aoa4.contextMultling + freqTarget + (1|subject) + (1|tarç
```

```
anova(proficiencyglmer0, aoaglmer4)
```

```
## Data: dataEng
## Models:
## proficiencyglmer0: rt ~ relatedness * morphType + freqTarget + lengthTarget + (1 |
## proficiencyglmer0:     subject) + (1 | target)
## aoaglmer4: rt ~ relatedness * morphType * aoa4.contextMultling + freqTarget +
## aoaglmer4:     (1 | subject) + (1 | target)
##                    npar    AIC    BIC logLik deviance Chisq Df Pr(>Chisq)
## proficiencyglmer0    11 113629 113707 -56803   113607
## aoaglmer4            16 113641 113755 -56805   113609     0  5          1
```

No Increase in GoF

```
aoaglmer5<- glmer(rt ~ relatedness * morphType*aoa5.selfRatedProf + freqTarget + lengthTarget + (1|subjç
```

```
anova(proficiencyglmer0, aoaglmer5)
```

```
## Data: dataEng
## Models:
## proficiencyglmer0: rt ~ relatedness * morphType + freqTarget + lengthTarget + (1 |
## proficiencyglmer0:     subject) + (1 | target)
## aoaglmer5: rt ~ relatedness * morphType * aoa5.selfRatedProf + freqTarget +
## aoaglmer5:     lengthTarget + (1 | subject) + (1 | target)
##                    npar    AIC    BIC logLik deviance  Chisq Df Pr(>Chisq)
## proficiencyglmer0    11 113629 113707 -56803   113607
## aoaglmer5            17 113623 113744 -56794   113589 17.787  6   0.006789 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Self rated proficiency appears to increase GoF

```
aoaglmer6<- glmer(rt ~ relatedness * morphType*aoa6.otherLang + freqTarget + lengthTarget + (1|subject)
```

```
anova(proficiencyglmer0, aoaglmer6)
```

```
## Data: dataEng
## Models:
## proficiencyglmer0: rt ~ relatedness * morphType + freqTarget + lengthTarget + (1 |
## proficiencyglmer0:     subject) + (1 | target)
## aoaglmer6: rt ~ relatedness * morphType * aoa6.otherLang + freqTarget +
## aoaglmer6:     (1 | subject) + (1 | target)
##                    npar    AIC    BIC logLik deviance Chisq Df Pr(>Chisq)
## proficiencyglmer0    11 113629 113707 -56803   113607
## aoaglmer6            16 113644 113758 -56806   113612     0  5          1
```

No Increase in GoF

Let's change the contrast to "opaque" now:

```
dataEng$morphType <- relevel(dataEng$morphType, "op");
```

```
aoaglmer1c<- glmer(rt ~ relatedness * morphType*aoa1.Aoa + freqTarget + (1|subject) + (1|target), data=
```

```
aoaglmer2c<- glmer(rt ~ relatedness * morphType*aoa2.usage + freqTarget + (1|subject) + (1|target), data
```

```
aoaglmer3c<- glmer(rt ~ relatedness * morphType*aoa2.context + freqTarget + (1|subject) + (1|target), da
```

```
aoaglmer4c<- glmer(rt ~ relatedness * morphType*aoa4.contextMultling + freqTarget + (1|subject) + (1|ta
```

```
aoaglmer5c<- glmer(rt ~ relatedness * morphType*aoa5.selfRatedProf + freqTarget + (1|subject) + (1|targ
```

```
aoaglmer6c<- glmer(rt ~ relatedness * morphType*aoa6.otherLang + freqTarget + (1|subject) + (1|target),
```

```
aoaglmer1.anova <- car::Anova(aoaglmer1)
aoaglmer1c.anova <- car::Anova(aoaglmer1c)
aoaglmer1.modelsum <- summary(aoaglmer1)
aoaglmer1c.modelsum <- summary(aoaglmer1c)
```

Anova of aoaglmer1 - or contrast

```
aoaglmer1.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                   Chisq Df Pr(>Chisq)
## relatedness                    147.1853  1  < 2.2e-16 ***
## morphType                      136.6736  2  < 2.2e-16 ***
## aoa1.Aoa                         7.2479  1   0.007098 **
## freqTarget                     390.3539  1  < 2.2e-16 ***
## relatedness:morphType           30.6241  2  2.239e-07 ***
## relatedness:aoa1.Aoa             1.0688  1   0.301216
## morphType:aoa1.Aoa               7.1315  2   0.028276 *
## relatedness:morphType:aoa1.Aoa  36.7215  2  1.062e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(aoaglmer1.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1065.3439	4.0794	261.1534	0.0000
relatednessrel	-37.6734	4.5342	-8.3087	0.0000
morphTypeop	-6.9483	3.3388	-2.0810	0.0374
morphTypetr	-45.8923	4.0326	-11.3803	0.0000

	Estimate	Std. Error	t value	Pr(>|z|)
aoa1.Aoa	-7.2188	2.4008	-3.0068	0.0026
freqTarget	-69.4579	3.5155	-19.7574	0.0000
relatednessrel:morphTypeop	-0.3865	6.1742	-0.0626	0.9501
relatednessrel:morphTypetr	22.3288	3.0399	7.3452	0.0000
relatednessrel:aoa1.Aoa	2.8539	0.9182	3.1081	0.0019
morphTypeop:aoa1.Aoa	0.3297	1.3148	0.2508	0.8020
morphTypetr:aoa1.Aoa	5.5318	1.2664	4.3682	0.0000
relatednessrel:morphTypeop:aoa1.Aoa	-0.8039	1.3168	-0.6104	0.5416
relatednessrel:morphTypetr:aoa1.Aoa	-6.0672	1.0510	-5.7726	0.0000

Anova of aoaglmer1c - op contrast

```
aoaglmer1c.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                    Chisq Df Pr(>Chisq)
## relatedness                    149.2574  1  < 2.2e-16 ***
## morphType                       13.6248  2   0.001100 **
## aoa1.Aoa                         6.2726  1   0.012262 *
## freqTarget                     332.2366  1  < 2.2e-16 ***
## relatedness:morphType           11.7886  2   0.002755 **
## relatedness:aoa1.Aoa             1.4647  1   0.226176
## morphType:aoa1.Aoa               4.9247  2   0.085232 .
## relatedness:morphType:aoa1.Aoa  34.2866  2  3.587e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(aoaglmer1c.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1058.3942	4.0485	261.4303	0.0000
relatednessrel	-38.0602	4.4646	-8.5249	0.0000
morphTypeor	6.9564	3.9917	1.7427	0.0814
morphTypetr	-38.9403	12.0542	-3.2304	0.0012
aoa1.Aoa	-6.8888	2.4528	-2.8085	0.0050
freqTarget	-69.4589	3.8107	-18.2274	0.0000
relatednessrel:morphTypeor	0.3829	3.8127	0.1004	0.9200
relatednessrel:morphTypetr	22.7143	3.9820	5.7042	0.0000
relatednessrel:aoa1.Aoa	2.0500	0.8996	2.2790	0.0227
morphTypeor:aoa1.Aoa	-0.3303	1.2881	-0.2564	0.7976
morphTypetr:aoa1.Aoa	5.2019	1.3206	3.9392	0.0001
relatednessrel:morphTypeor:aoa1.Aoa	0.8044	1.0975	0.7329	0.4636
relatednessrel:morphTypetr:aoa1.Aoa	-5.2632	1.0522	-5.0020	0.0000

```
aoaglmer2.anova <- car::Anova(aoaglmer2)
aoaglmer2c.anova <- car::Anova(aoaglmer2c)
```

```
aoaglmer2.modelsum <- summary(aoaglmer2)
aoaglmer2c.modelsum <- summary(aoaglmer2c)
```

Anova of aoaglmer2 - or contrast

```
aoaglmer2.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                    Chisq Df Pr(>Chisq)
## relatedness                     221.0385  1  < 2.2e-16 ***
## morphType                         0.8731  2   0.646273
## aoa2.usage                        0.2344  1   0.628264
## freqTarget                      594.1524  1  < 2.2e-16 ***
## relatedness:morphType             9.5127  2   0.008597 **
## relatedness:aoa2.usage           19.1904  1  1.183e-05 ***
## morphType:aoa2.usage             12.4446  2   0.001985 **
## relatedness:morphType:aoa2.usage 19.8405  2  4.917e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(aoaglmer2.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1008.8140	4.3403	232.4319	0.0000
relatednessrel	-51.5715	3.7709	-13.6762	0.0000
morphTypeop	1.8958	3.3523	0.5655	0.5717
morphTypetr	5.9059	4.6465	1.2710	0.2037
aoa2.usage	2.8479	3.3890	0.8404	0.4007
freqTarget	-69.2448	2.8408	-24.3752	0.0000
relatednessrel:morphTypeop	10.2784	3.4085	3.0155	0.0026
relatednessrel:morphTypetr	6.5114	3.9510	1.6480	0.0993
relatednessrel:aoa2.usage	10.3616	1.7518	5.9149	0.0000
morphTypeop:aoa2.usage	-2.1007	2.5761	-0.8155	0.4148
morphTypetr:aoa2.usage	-4.9514	2.1994	-2.2512	0.0244
relatednessrel:morphTypeop:aoa2.usage	-5.0028	2.0351	-2.4582	0.0140
relatednessrel:morphTypetr:aoa2.usage	-7.5540	1.8106	-4.1721	0.0000

Anova of aoaglmer2c - op contrast

```
aoaglmer2c.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                    Chisq Df Pr(>Chisq)
## relatedness                     204.6584  1  < 2.2e-16 ***
## morphType                         0.2466  2    0.88401
```

```
## aoa2.usage                          0.0949  1    0.75803
## freqTarget                        531.4092  1  < 2.2e-16 ***
## relatedness:morphType               6.2196  2    0.04461 *
## relatedness:aoa2.usage             20.5887  1  5.693e-06 ***
## morphType:aoa2.usage               11.1510  2    0.00379 **
## relatedness:morphType:aoa2.usage   10.6047  2    0.00498 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(aoaglmer2c.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1010.6973	3.2757	308.5464	0.0000
relatednessrel	-41.2928	3.4545	-11.9532	0.0000
morphTypeor	-1.8942	3.0906	-0.6129	0.5400
morphTypetr	4.0100	4.1432	0.9678	0.3331
aoa2.usage	0.7503	2.9865	0.2512	0.8016
freqTarget	-69.2444	3.0038	-23.0523	0.0000
relatednessrel:morphTypeor	-10.2732	4.0885	-2.5127	0.0120
relatednessrel:morphTypetr	-3.7669	3.3324	-1.1304	0.2583
relatednessrel:aoa2.usage	5.3587	1.4626	3.6637	0.0002
morphTypeor:aoa2.usage	2.1010	2.3084	0.9102	0.3627
morphTypetr:aoa2.usage	-2.8509	2.1377	-1.3336	0.1823
relatednessrel:morphTypeor:aoa2.usage	5.0014	2.0999	2.3818	0.0172
relatednessrel:morphTypetr:aoa2.usage	-2.5512	1.8387	-1.3875	0.1653

```
aoaglmer3.anova <- car::Anova(aoaglmer3)
aoaglmer3c.anova <- car::Anova(aoaglmer3c)
aoaglmer3.modelsum <- summary(aoaglmer3)
aoaglmer3c.modelsum <- summary(aoaglmer3c)
```

Anova of aoaglmer3 - or contrast

```
aoaglmer3.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                     Chisq Df Pr(>Chisq)
## relatedness                       112.2561  1  < 2.2e-16 ***
## morphType                          58.1050  2  2.414e-13 ***
## aoa3.context                        5.6946  1  0.0170176 *
## freqTarget                        554.3539  1  < 2.2e-16 ***
## relatedness:morphType              17.3889  2  0.0001675 ***
## relatedness:aoa3.context            1.6211  1  0.2029450
## morphType:aoa3.context             53.9894  2  1.889e-12 ***
## relatedness:morphType:aoa3.context 12.7531  2  0.0017010 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(aoaglmer3.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1010.3281	4.0408	250.0303	0.0000
relatednessrel	-15.7640	2.5784	-6.1139	0.0000
morphTypeop	-20.2492	4.6900	-4.3175	0.0000
morphTypetr	-29.6723	5.4359	-5.4586	0.0000
aoa3.contextschool	8.6139	4.0124	2.1468	0.0318
freqTarget	-69.3765	2.9466	-23.5447	0.0000
relatednessrel:morphTypeop	-7.8865	3.5802	-2.2028	0.0276
relatednessrel:morphTypetr	-9.4440	2.9994	-3.1487	0.0016
relatednessrel:aoa3.contextschool	-3.7625	2.9816	-1.2619	0.2070
morphTypeop:aoa3.contextschool	18.1619	3.4790	5.2204	0.0000
morphTypetr:aoa3.contextschool	23.2368	3.8477	6.0391	0.0000
relatednessrel:morphTypeop:aoa3.contextschool	2.6407	2.7957	0.9446	0.3449
relatednessrel:morphTypetr:aoa3.contextschool	-8.9994	2.6306	-3.4211	0.0006

Anova of aoaglmer3c - op contrast

```
aoaglmer3c.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                      Chisq Df Pr(>Chisq)
## relatedness                       124.8011  1  < 2.2e-16 ***
## morphType                          45.5467  2  1.287e-10 ***
## aoa3.context                       48.2869  1  3.682e-12 ***
## freqTarget                        481.4402  1  < 2.2e-16 ***
## relatedness:morphType               6.4028  2  0.0407056 *
## relatedness:aoa3.context            0.8070  1  0.3690075
## morphType:aoa3.context             16.9403  2  0.0002096 ***
## relatedness:morphType:aoa3.context  8.0212  2  0.0181227 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(aoaglmer3c.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	990.0474	11.1235	89.0047	0.0000
relatednessrel	-23.6486	3.1099	-7.6043	0.0000
morphTypeor	20.2524	3.7346	5.4229	0.0000
morphTypetr	-9.4203	4.7280	-1.9925	0.0463
aoa3.contextschool	26.8035	3.6248	7.3945	0.0000
freqTarget	-69.3751	3.1618	-21.9417	0.0000
relatednessrel:morphTypeor	7.8848	4.1938	1.8801	0.0601
relatednessrel:morphTypetr	-1.5600	3.5857	-0.4351	0.6635
relatednessrel:aoa3.contextschool	-1.1238	3.6388	-0.3088	0.7575
morphTypeor:aoa3.contextschool	-18.1640	4.5644	-3.9795	0.0001

	Estimate	Std. Error	t value	Pr(>|z|)
morphTypetr:aoa3.contextschool	5.0720	3.9001	1.3005	0.1934
relatednessrel:morphTypeor:aoa3.contextschool	-2.6390	5.9862	-0.4408	0.6593
relatednessrel:morphTypetr:aoa3.contextschool	-11.6374	4.1993	-2.7713	0.0056

```
aoaglmer4.anova <- car::Anova(aoaglmer4)
aoaglmer4c.anova <- car::Anova(aoaglmer4c)
aoaglmer4.modelsum <- summary(aoaglmer4)
aoaglmer4c.modelsum <- summary(aoaglmer4c)
```

Anova of aoaglmer4 - or contrast

```
aoaglmer4.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                            Chisq Df Pr(>Chisq)
## relatedness                              138.033  1  < 2.2e-16 ***
## morphType                                 11.109  2  0.0038704 **
## aoa4.contextMultling                      13.357  1  0.0002575 ***
## freqTarget                               487.766  1  < 2.2e-16 ***
## relatedness:morphType                     34.899  2  2.641e-08 ***
## relatedness:aoa4.contextMultling          16.465  1  4.955e-05 ***
## morphType:aoa4.contextMultling            37.648  2  6.680e-09 ***
## relatedness:morphType:aoa4.contextMultling  89.579  2  < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(aoaglmer4.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1014.8046	5.7263	177.2179	0.0000
relatednessrel	-16.0639	2.6856	-5.9814	0.0000
morphTypeop	-0.1632	3.9786	-0.0410	0.9673
morphTypetr	-7.7779	4.5384	-1.7138	0.0866
aoa4.contextMultlingyes	14.7674	3.3393	4.4224	0.0000
freqTarget	-69.3824	3.1415	-22.0854	0.0000
relatednessrel:morphTypeop	-14.2395	3.0575	-4.6573	0.0000
relatednessrel:morphTypetr	-19.4036	3.5524	-5.4621	0.0000
relatednessrel:aoa4.contextMultlingyes	-12.5803	3.0768	-4.0887	0.0000
morphTypeop:aoa4.contextMultlingyes	-19.0786	3.5764	-5.3346	0.0000
morphTypetr:aoa4.contextMultlingyes	-8.9828	3.4055	-2.6378	0.0083
relatednessrel:morphTypeop:aoa4.contextMultlingyes	37.3186	4.0395	9.2383	0.0000
relatednessrel:morphTypetr:aoa4.contextMultlingyes	9.3316	4.3502	2.1451	0.0319

Anova of aoaglmer4c - op contrast

```
aoaglmer4c.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                              Chisq Df Pr(>Chisq)
## relatedness                                118.4592  1  < 2.2e-16 ***
## morphType                                    8.0640  2  0.0177388 *
## aoa4.contextMultling                         0.0178  1  0.8938698
## freqTarget                                 381.5908  1  < 2.2e-16 ***
## relatedness:morphType                       21.4154  2  2.237e-05 ***
## relatedness:aoa4.contextMultling            12.8175  1  0.0003434 ***
## morphType:aoa4.contextMultling              67.6195  2  2.073e-15 ***
## relatedness:morphType:aoa4.contextMultling 112.2455  2  < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(aoaglmer4c.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1014.6335	3.7310	271.9502	0.0000
relatednessrel	-30.3036	2.6323	-11.5120	0.0000
morphTypeor	0.1644	3.5029	0.0469	0.9626
morphTypetr	-7.6135	3.6554	-2.0828	0.0373
aoa4.contextMultlingyes	-4.3090	4.1699	-1.0333	0.3014
freqTarget	-69.3810	3.5517	-19.5343	0.0000
relatednessrel:morphTypeor	14.2400	2.9286	4.8624	0.0000
relatednessrel:morphTypetr	-5.1641	4.0898	-1.2627	0.2067
relatednessrel:aoa4.contextMultlingyes	24.7394	3.6402	6.7962	0.0000
morphTypeor:aoa4.contextMultlingyes	19.0799	3.5817	5.3270	0.0000
morphTypetr:aoa4.contextMultlingyes	10.0963	3.3269	3.0347	0.0024
relatednessrel:morphTypeor:aoa4.contextMultlingyes	-37.3209	4.4065	-8.4695	0.0000
relatednessrel:morphTypetr:aoa4.contextMultlingyes	-27.9879	4.0259	-6.9520	0.0000

```
aoaglmer5.anova <- car::Anova(aoaglmer5)
aoaglmer5c.anova <- car::Anova(aoaglmer5c)
aoaglmer5.modelsum <- summary(aoaglmer5)
aoaglmer5c.modelsum <- summary(aoaglmer5c)
```

Anova of aoaglmer5 - or contrast

```
aoaglmer5.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                    Chisq Df Pr(>Chisq)
## relatedness                    208.3417  1  < 2.2e-16 ***
## morphType                        7.5328  2   0.023135 *
## aoa5.selfRatedProf               7.0812  1   0.007790 **
```

```
## freqTarget                                371.8232  1  < 2.2e-16 ***
## lengthTarget                               78.5755  1  < 2.2e-16 ***
## relatedness:morphType                     126.4083  2  < 2.2e-16 ***
## relatedness:aoa5.selfRatedProf             30.3694  1  3.571e-08 ***
## morphType:aoa5.selfRatedProf               10.1555  2   0.006234 **
## relatedness:morphType:aoa5.selfRatedProf   68.0810  2  1.646e-15 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(aoaglmer5.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1190.5452	6.3788	186.6397	0.0000
relatednessrel	-70.9797	5.0746	-13.9872	0.0000
morphTypeop	15.0837	3.9889	3.7814	0.0002
morphTypetr	8.5210	3.9509	2.1568	0.0310
aoa5.selfRatedProf	-12.1673	4.3049	-2.8264	0.0047
freqTarget	-72.1470	3.7415	-19.2827	0.0000
lengthTarget	-26.5652	2.9969	-8.8643	0.0000
relatednessrel:morphTypeop	41.7713	3.9409	10.5995	0.0000
relatednessrel:morphTypetr	31.2858	4.0719	7.6834	0.0000
relatednessrel:aoa5.selfRatedProf	14.7631	1.7101	8.6330	0.0000
morphTypeop:aoa5.selfRatedProf	-4.1976	2.7160	-1.5455	0.1222
morphTypetr:aoa5.selfRatedProf	-2.5407	2.3469	-1.0826	0.2790
relatednessrel:morphTypeop:aoa5.selfRatedProf	-13.4543	2.0818	-6.4629	0.0000
relatednessrel:morphTypetr:aoa5.selfRatedProf	-13.7726	1.9811	-6.9521	0.0000

Anova of aoaglmer5c - op contrast

```
aoaglmer5c.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                            Chisq Df Pr(>Chisq)
## relatedness                              178.378  1  < 2.2e-16 ***
## morphType                                 15.949  2  0.0003442 ***
## aoa5.selfRatedProf                        18.979  1  1.321e-05 ***
## freqTarget                               551.733  1  < 2.2e-16 ***
## relatedness:morphType                    107.112  2  < 2.2e-16 ***
## relatedness:aoa5.selfRatedProf            16.315  1  5.363e-05 ***
## morphType:aoa5.selfRatedProf              12.829  2  0.0016376 **
## relatedness:morphType:aoa5.selfRatedProf  57.396  2  3.441e-13 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(aoaglmer5c.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1069.7679	4.3337	246.8492	0.0000
relatednessrel	-28.9715	2.9596	-9.7891	0.0000
morphTypeor	-10.2669	4.1874	-2.4519	0.0142
morphTypetr	-10.9334	4.1105	-2.6599	0.0078
aoa5.selfRatedProf	-16.3513	3.6982	-4.4214	0.0000
freqTarget	-69.2447	2.9480	-23.4890	0.0000
relatednessrel:morphTypeor	-41.7143	3.5639	-11.7047	0.0000
relatednessrel:morphTypetr	-10.5767	3.8383	-2.7556	0.0059
relatednessrel:aoa5.selfRatedProf	1.2412	1.3897	0.8932	0.3718
morphTypeor:aoa5.selfRatedProf	4.2182	2.6033	1.6203	0.1052
morphTypetr:aoa5.selfRatedProf	1.6447	2.3242	0.7076	0.4792
relatednessrel:morphTypeor:aoa5.selfRatedProf	13.4287	1.8466	7.2723	0.0000
relatednessrel:morphTypetr:aoa5.selfRatedProf	-0.3072	1.8570	-0.1654	0.8686

```
aoaglmer6.anova <- car::Anova(aoaglmer6)
aoaglmer6c.anova <- car::Anova(aoaglmer6c)
aoaglmer6.modelsum <- summary(aoaglmer6)
aoaglmer6c.modelsum <- summary(aoaglmer6c)
```

Anova of aoaglmer6 - or contrast

```
aoaglmer6.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                        Chisq Df Pr(>Chisq)
## relatedness                          94.3669  1  < 2.2e-16 ***
## morphType                             6.1065  2    0.04721 *
## aoa6.otherLang                       24.5541  1  7.225e-07 ***
## freqTarget                          492.3427  1  < 2.2e-16 ***
## relatedness:morphType                54.5036  2  1.461e-12 ***
## relatedness:aoa6.otherLang            3.1366  1    0.07656 .
## morphType:aoa6.otherLang              1.0621  2    0.58797
## relatedness:morphType:aoa6.otherLang 25.4509  2  2.974e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(aoaglmer6.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1005.2142	4.7982	209.4997	0.0000
relatednessrel	-8.9288	2.9942	-2.9820	0.0029
morphTypeop	1.5979	3.8290	0.4173	0.6765
morphTypetr	-12.2422	3.8726	-3.1612	0.0016
aoa6.otherLangyes	16.7862	6.1024	2.7507	0.0059
freqTarget	-69.3289	3.1245	-22.1888	0.0000
relatednessrel:morphTypeop	-19.3675	4.0133	-4.8258	0.0000
relatednessrel:morphTypetr	-25.3511	3.3966	-7.4638	0.0000

	Estimate	Std. Error	t value	Pr(>|z|)
relatednessrel:aoa6.otherLangyes	-13.3232	3.5199	-3.7851	0.0002
morphTypeop:aoa6.otherLangyes	-8.4471	4.2259	-1.9989	0.0456
morphTypetr:aoa6.otherLangyes	2.8512	3.5963	0.7928	0.4279
relatednessrel:morphTypeop:aoa6.otherLangyes	18.1754	4.4657	4.0700	0.0000
relatednessrel:morphTypetr:aoa6.otherLangyes	10.8099	3.4435	3.1392	0.0017

Anova of aoaglmer5c - op contrast

```
aoaglmer6c.anova
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: rt
##                                        Chisq Df Pr(>Chisq)
## relatedness                         157.6142  1  < 2.2e-16 ***
## morphType                            24.3774  2  5.088e-06 ***
## aoa6.otherLang                        2.3460  1  0.1256046
## freqTarget                          470.5704  1  < 2.2e-16 ***
## relatedness:morphType                17.0403  2  0.0001994 ***
## relatedness:aoa6.otherLang            1.0043  1  0.3162694
## morphType:aoa6.otherLang             16.6182  2  0.0002463 ***
## relatedness:morphType:aoa6.otherLang 28.3287  2  7.055e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
knitr::kable(round(aoaglmer6c.modelsum$coefficients, 4))
```

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	1006.8022	3.7388	269.2883	0.0000
relatednessrel	-28.2969	3.0307	-9.3367	0.0000
morphTypeor	-1.6004	3.6196	-0.4421	0.6584
morphTypetr	-13.8407	3.2983	-4.1963	0.0000
aoa6.otherLangyes	8.3424	3.4133	2.4440	0.0145
freqTarget	-69.3273	3.1959	-21.6926	0.0000
relatednessrel:morphTypeor	19.3686	3.7056	5.2268	0.0000
relatednessrel:morphTypetr	-5.9826	3.5372	-1.6913	0.0908
relatednessrel:aoa6.otherLangyes	4.8529	3.3157	1.4636	0.1433
morphTypeor:aoa6.otherLangyes	8.4488	3.1001	2.7253	0.0064
morphTypetr:aoa6.otherLangyes	11.2997	3.2771	3.4481	0.0006
relatednessrel:morphTypeor:aoa6.otherLangyes	-18.1763	3.6070	-5.0392	0.0000
relatednessrel:morphTypetr:aoa6.otherLangyes	-7.3672	3.0128	-2.4453	0.0145

OSC

First, let's try to pit OSC against priming condition – these two are typically confounded:

```
temp <- unique(masterFile[masterFile$lexicality=='word' & masterFile$language=='eng',c('target','prime'
aggregate(oscTarget ~ morphType, FUN=fivenum, data=temp)
```

```
##   morphType oscTarget.1 oscTarget.2 oscTarget.3 oscTarget.4 oscTarget.5
## 1        op     -0.0940      0.2300      0.4580      0.8130      0.9750
## 2        or     -0.0020      0.1220      0.2625      0.6950      0.9990
## 3        tr      0.3640      0.6040      0.8260      0.9180      1.0000
```

Indeed they are. This tests it via NHST

```
summary(aov(oscTarget~morphType, data=subset(temp, relatedness=='rel')));
```

```
##              Df Sum Sq Mean Sq F value   Pr(>F)
## morphType     2  3.433  1.7163   21.02 9.75e-09 ***
## Residuals   144 11.755  0.0816
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 3 observations deleted due to missingness
```

modelling

```
osc1 <- glmer(rt ~ relatedness *  oscTarget * phonemicFluency + freqTarget + lengthTarget + (1|subject)
```

```
osc1.anova <-car::Anova(osc1)
```

```
osc2 <- glmer(rt ~ relatedness *  oscTarget * vocabulary + freqTarget + lengthTarget + (1|subject) + (1
```

```
osc2.anova<-car::Anova(osc2)
```

```
osc3 <- glmer(rt ~ relatedness *  oscTarget * phonemicComprehension + freqTarget + lengthTarget + (1|su
```

```
osc3.anova<-car::Anova(osc3)
```

```
osc4 <- glmer(rt ~ relatedness *  oscTarget * morphComprehension + freqTarget + lengthTarget + (1|subje
```

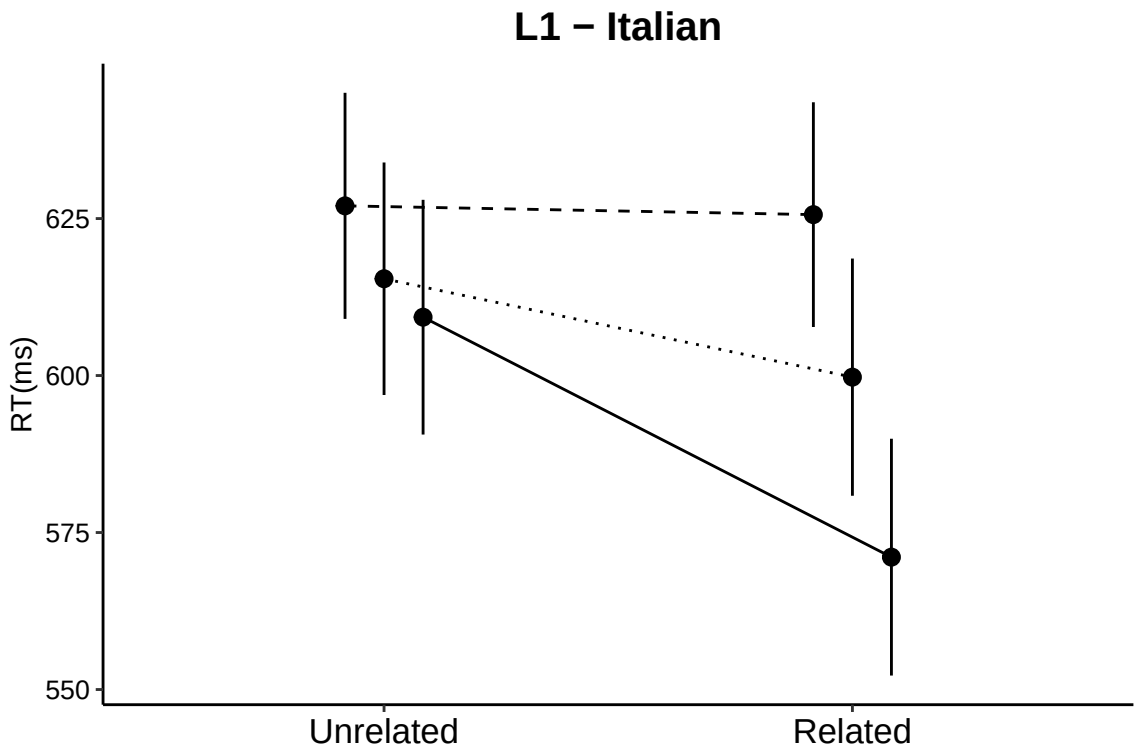
```
osc4.anova<-car::Anova(osc4)
```

Plots

Figure 1 - plot of estimated RTs

```
df <- effect("relatedness:morphType",itaglmer2);
df <- as.data.frame(df);
revalue(df$relatedness, c("ctrl"="Unrelated"))-> df$relatedness;
revalue(df$relatedness, c("rel"="Related"))-> df$relatedness;
```

```
dodge1 <- position_dodge(width = 0.25);
bb  <-ggplot(data = df, aes(x = relatedness, y = fit,group = morphType)) +
  geom_point(size = 2, position = dodge1) +
  geom_line(aes(linetype=morphType), position = dodge1) +
  scale_linetype_manual(values=c("dashed", "dotted", "solid")) +
  theme_classic();
bb  <- bb + geom_pointrange(aes(ymin = df$lower, ymax = df$upper), position = dodge1) ;
bb  <- bb + scale_y_continuous("RT(ms)") ;
bb  <- bb + theme(axis.title.y = element_text(size = rel(1), angle = 90));
bb  <- bb + theme(axis.text.y = element_text(angle = 00, hjust = 1, size=10, colour = 'black'));
bb  <- bb + theme(axis.title.x = element_blank()) + theme(axis.text.x = element_text(size=13, colour =
bb <- bb + labs(title='L1 - Italian');
bb <- bb + theme(plot.title= element_text(angle = 00, hjust=0.5, size=15, face = 'bold', colour = 'blac
bb <- bb + theme(legend.position="none")
bb
```




```
df <- effect("relatedness:morphType",engglmer2);
df <- as.data.frame(df);
revalue(df$relatedness, c("ctrl"="Unrelated"))-> df$relatedness;
revalue(df$relatedness, c("rel"="Related"))-> df$relatedness;

dodge <- position_dodge(width = 0.25);
gg  <-ggplot(data = df, aes(x = relatedness, y = fit,group = morphType)) +
  geom_point(size = 2, position = dodge) +
  geom_line(aes(linetype=morphType), position = dodge) +
  scale_linetype_manual(values=c( "dotted", "dashed", "solid")) +
  theme_classic();
```

```
gg  <- gg + geom_pointrange(aes(ymin = df$lower, ymax = df$upper), position = dodge);
gg  <- gg + scale_y_continuous("RT (ms)") ;
gg  <- gg + theme(axis.text.y = element_text(angle = 00, hjust = 1, size=10, colour = 'black'));
gg  <- gg + theme(axis.title.x = element_blank()) + theme(axis.text.x = element_text(size=13, colour =
gg <- gg + labs(title='L2 - English');
gg <- gg + theme(plot.title= element_text(angle = 00, hjust=0.5, size=15, face = 'bold', colour = 'blac
gg<- gg + theme(legend.position="none")
gg
```

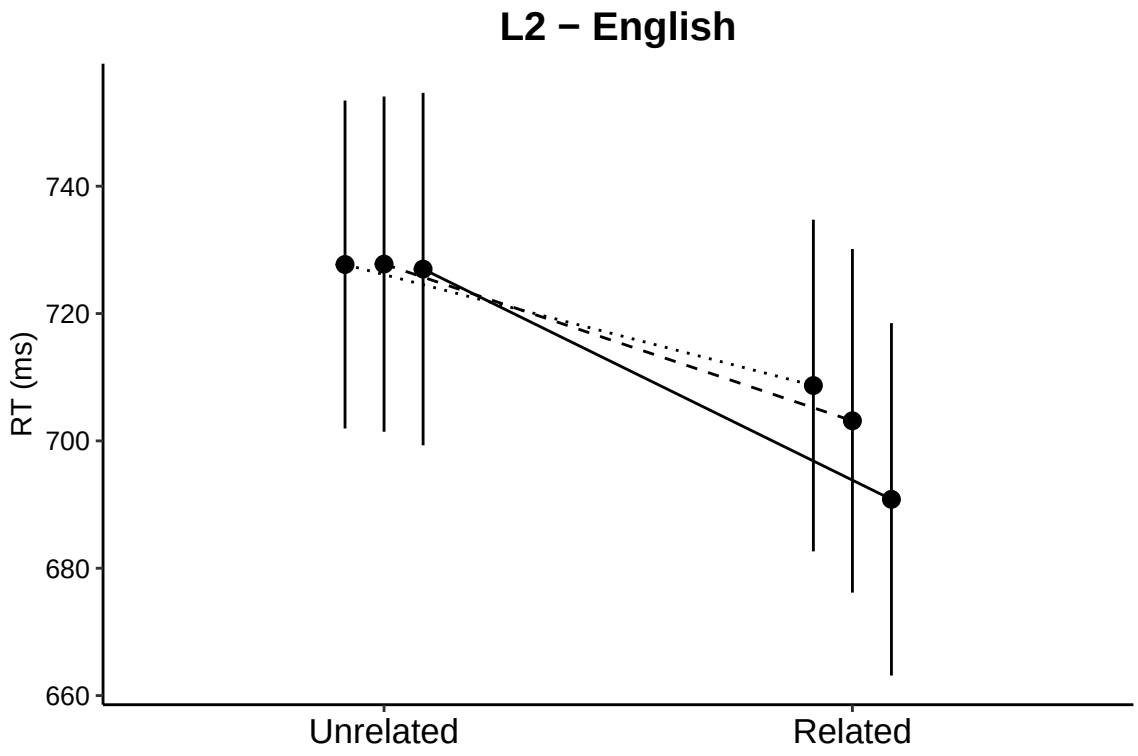


Figure 2 - Participants' score distributions for each proficiency subtest

```
par(mfrow=c(2,4));
par(mar=c(5,5,4,.5)+.1);
par(lwd=2);

attach(pptFeatures);

hist(phonemicFluency, breaks = seq(0,50,5), main = '(a) Phon Fluency', cex.main=2, xlab = 'Scores', ylab
axis(1, cex.axis=2);
axis(2, at=c(0,50), cex.axis=2, las=1);

hist(phonemicComprehension, breaks = seq(0,13,1), main = '(b) Phon Comprehension', cex.main=2, xlab = 'S
axis(1, cex.axis=2);
axis(2, at=c(0,50), cex.axis=2, las=1);

hist(morphComprehension, breaks = seq(0,10,1), main = '(c) Morph Awareness', cex.main=2, xlab = 'Scores
```

```
axis(1, cex.axis=2);
axis(2, at=c(0,50), cex.axis=2, las=1);

hist(spelling, breaks = seq(0,20,2), main = '(d) Spelling', cex.main=2, xlab = 'Scores', ylab = 'N of pa
axis(1, cex.axis=2);
axis(2, at=c(0,50), cex.axis=2, las=1);

hist(readingComprehension, breaks = seq(0,7,1), main = '(e) Read Comprehension', cex.main=2, xlab = 'Sc
axis(1, cex.axis=2);
axis(2, at=c(0,50), cex.axis=2, las=1);

hist(vocabulary, breaks = seq(0,20,2), main = '(f) Vocabulary', cex.main=2, xlab = 'Scores', ylab = 'N
axis(1, cex.axis=2);
axis(2, at=c(0,50), cex.axis=2, las=1);

hist(oralComprehension, breaks = seq(0,6,1), main = '(g) Oral comprehension', cex.main=2, xlab = 'Score
axis(1, cex.axis=2);
axis(2, at=c(0,50), cex.axis=2, las=1);
#dev.off()
detach(pptFeatures);
```

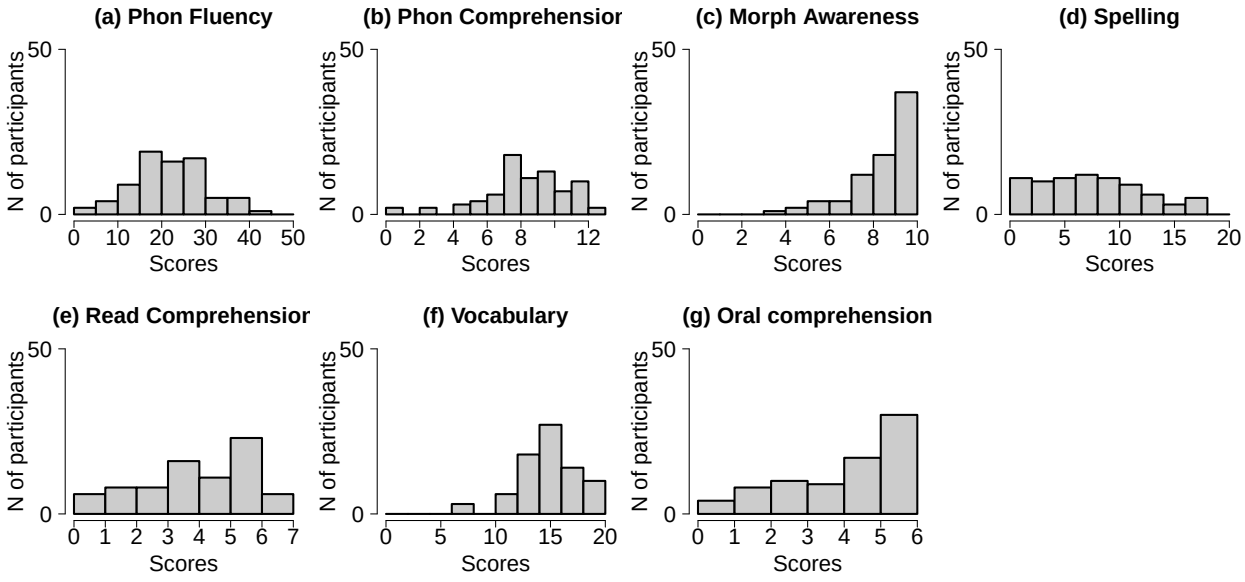


Figure 3 - Interaction by phonemic comprehension by relatedness and morphtype

```
temp <- data.frame(effect('relatedness:morphType:phonemicComprehension', proficiencyglmer2, se=list(leve
revalue(temp$relatedness, c("rel"="Related"))-> temp$relatedness;
revalue(temp$relatedness, c("ctrl"="Unrelated"))-> temp$relatedness;

phonComprehension_names <- c(
  "5" = "Low phonComprehension",
  "9" = "Medium phonComprehension",
```

```
  "12" = "High phonComprehension");

ggplot(data = temp, aes(x=relatedness, y=fit, group=morphType)) +
  geom_point(size = 2, position = position_dodge(width = 0.25)) +
  geom_line(aes(linetype=morphType), position = position_dodge(width = 0.25)) +
  scale_linetype_manual(values=c("dashed", "dotted", "solid")) +
  theme_bw() +
  theme(panel.grid.major = element_blank()) +
  ylab('RTs (ms)') + xlab('') +
  theme(axis.text.y = element_text(angle = 00, hjust = 1, size=8, colour = 'black'))+
  theme(axis.text.x = element_text(size=13, colour = 'black'))+
  geom_pointrange(aes(ymin = lower, ymax = upper), position = position_dodge(width = 0.25)) +
  facet_grid(~ phonemicComprehension,
             labeller = labeller(phonemicComprehension = as_labeller(phonComprehension_names))) +
  theme(strip.text = element_text(size=12)) +
  theme(legend.position="none");
```

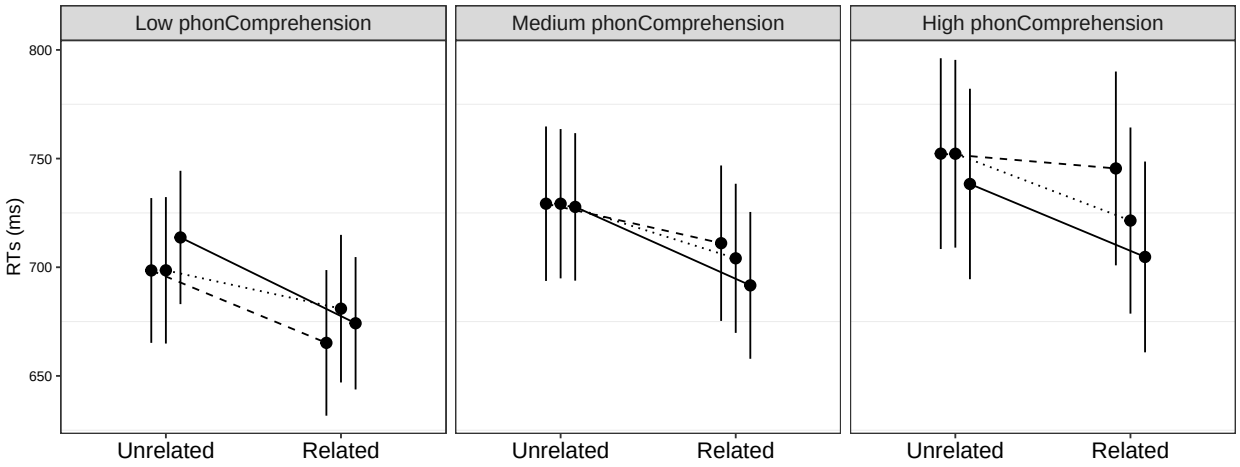


Figure 4 - Interaction by morphological awareness/comprehension by relatedness and morphtype

```
temp <- data.frame(effect('relatedness:morphType:morphComprehension', proficiencyglmer3, se=list(level=
revalue(temp$relatedness, c("rel"="Related"))-> temp$relatedness;
revalue(temp$relatedness, c("ctrl"="Unrelated"))-> temp$relatedness;

morphComprehension_names <- c(
  "6" = "Low morphComprehension",
  "9" = "Medium morphComprehension",
  "10" = "High morphComprehension");

ggplot(data = temp, aes(x=relatedness, y=fit, group=morphType)) +
  geom_point(size = 2, position = position_dodge(width = 0.25)) +
  geom_line(aes(linetype=morphType), position = position_dodge(width = 0.25)) +
  scale_linetype_manual(values=c("dashed", "dotted", "solid")) +
```

```
  theme_bw() +
  theme(panel.grid.major = element_blank()) +
  ylab('RTs (ms)') + xlab('') +
  theme(axis.text.y = element_text(angle = 00, hjust = 1, size=8, colour = 'black'))+
  theme(axis.text.x = element_text(size=13, colour = 'black'))+
  geom_pointrange(aes(ymin = lower, ymax = upper), position = position_dodge(width = 0.25)) +
  facet_grid(~ morphComprehension,
             labeller = labeller(morphComprehension = as_labeller(morphComprehension_names))) +
  theme(strip.text = element_text(size=12)) +
  theme(legend.position="none");
```

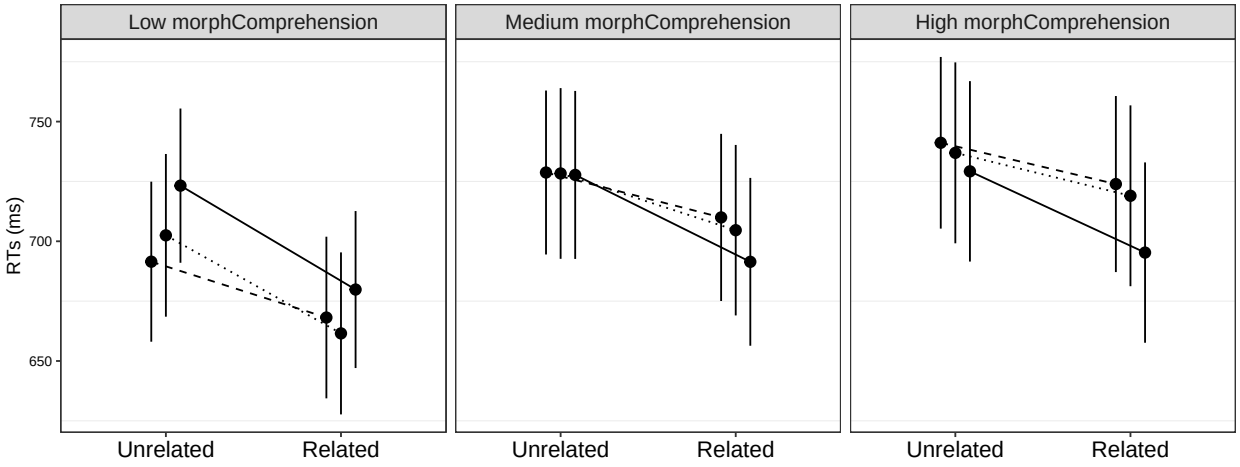


Figure 5 - Interaction by vocabulary by relatedness and morphtype

```
temp <- data.frame(effect('relatedness:morphType:vocabulary', proficiencyglmer6, se=list(level=.95), xl
revalue(temp$relatedness, c("rel"="Related"))-> temp$relatedness;
revalue(temp$relatedness, c("ctrl"="Unrelated"))-> temp$relatedness;

vocabulary_names <- c(
  "11" = "Low vocabulary",
  "16" = "Medium vocabulary",
  "19" = "High vocabulary");

ggplot(data = temp, aes(x=relatedness, y=fit, group=morphType)) +
  geom_point(size = 2, position = position_dodge(width = 0.25)) +
  geom_line(aes(linetype=morphType), position = position_dodge(width = 0.25)) +
  scale_linetype_manual(values=c("dashed", "dotted", "solid")) +
  theme_bw() +
  theme(panel.grid.major = element_blank()) +
  ylab('RTs (ms)') + xlab('') +
  theme(axis.text.y = element_text(angle = 00, hjust = 1, size=8, colour = 'black'))+
  theme(axis.text.x = element_text(size=13, colour = 'black'))+
  geom_pointrange(aes(ymin = lower, ymax = upper), position = position_dodge(width = 0.25)) +
  facet_grid(~ vocabulary,
```

```
            labeller = labeller(vocabulary = as_labeller(vocabulary_names))) +
  theme(strip.text = element_text(size=12)) +
  theme(legend.position="none");
```

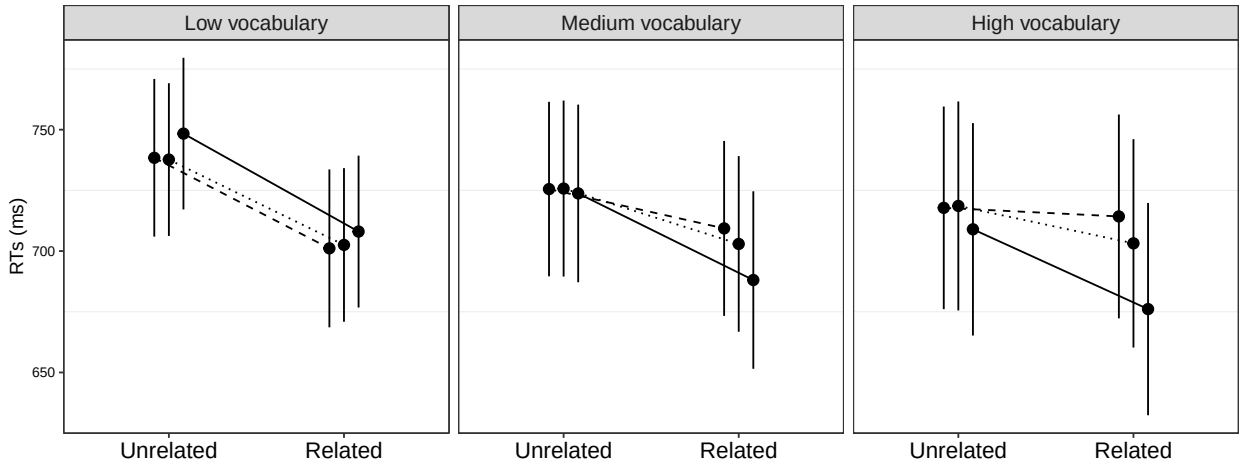


Figure 6 - Interaction by phonemic Fluency by relatedness and morphtype

```
temp <- data.frame(effect('relatedness:morphType:phonemicFluency', proficiencyglmer1, se=list(level=.95)
revalue(temp$relatedness, c("rel"="Related"))-> temp$relatedness;
revalue(temp$relatedness, c("ctrl"="Unrelated"))-> temp$relatedness;

phonemicFluency_names <- c(
  "10" = "Low phonFluency",
  "23" = "Medium phonFluency",
  "39" = "High phonFluency");

ggplot(data = temp, aes(x=relatedness, y=fit, group=morphType)) +
  geom_point(size = 2, position = position_dodge(width = 0.25)) +
  geom_line(aes(linetype=morphType), position = position_dodge(width = 0.25)) +
  scale_linetype_manual(values=c("dashed", "dotted", "solid")) +
  theme_bw() +
  theme(panel.grid.major = element_blank()) +
  ylab('RTs (ms)') + xlab('') +
  theme(axis.text.y = element_text(angle = 00, hjust = 1, size=8, colour = 'black'))+
  theme(axis.text.x = element_text(size=13, colour = 'black'))+
  geom_pointrange(aes(ymin = lower, ymax = upper), position = position_dodge(width = 0.25)) +
  facet_grid(~ phonemicFluency,
             labeller = labeller(phonemicFluency = as_labeller(phonemicFluency_names))) +
  theme(strip.text = element_text(size=12)) +
  theme(legend.position="none");
```

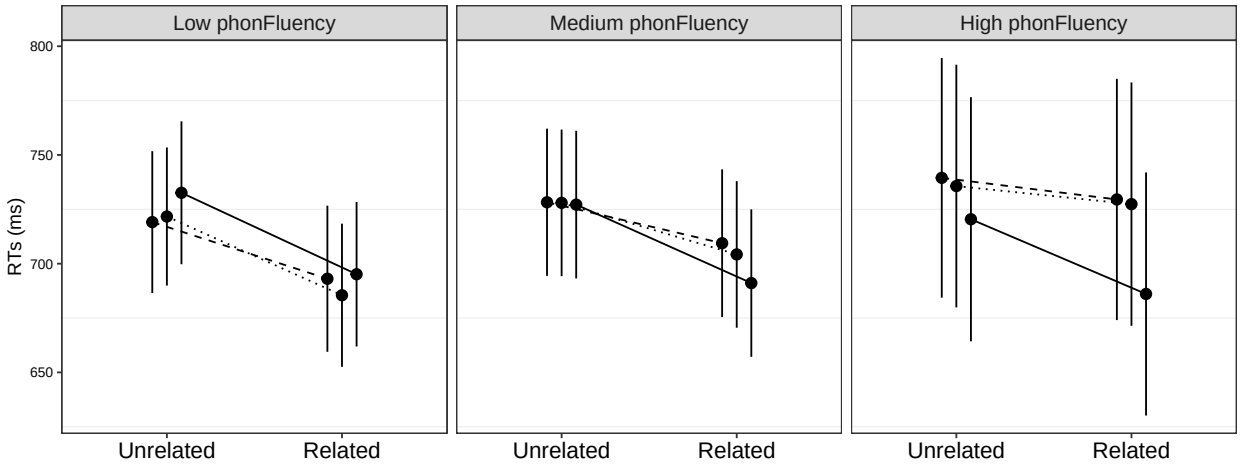
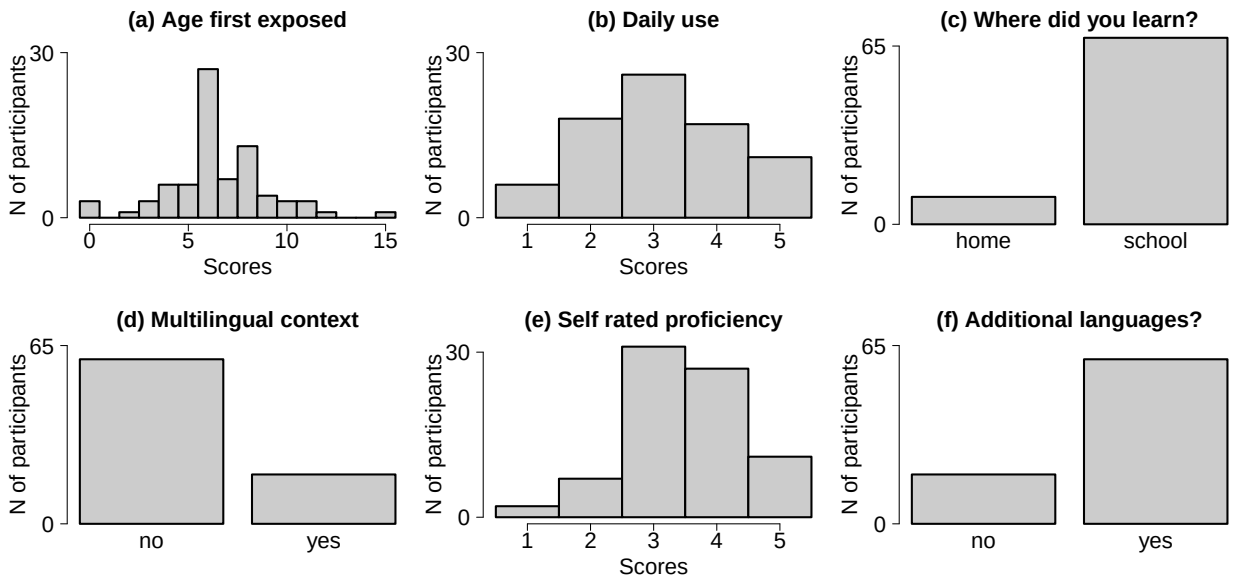


Figure 7 - Scores distributions in the AoA questionnaire

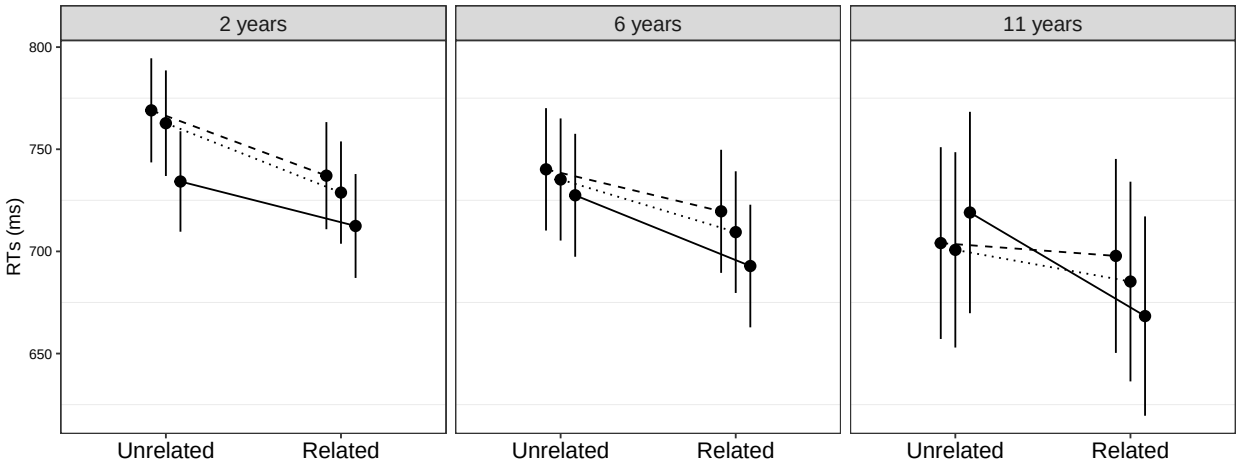
```
#jpeg(filename = paste(localGitDir,'/aoaScores.jpg', sep = ''), res=300, height=2200, width=4400);
par(mfrow=c(2,3));
par(mar=c(5,5,4,.5)+.1);
par(lwd=2);

attach(pptFeatures);

hist(aoa1.Aoa, breaks = seq(-.5,15.5,1), main = '(a) Age first exposed', cex.main=2, xlab = 'Scores', yl
axis(1, cex.axis=2);
axis(2, at=c(0,30), cex.axis=2, las=1);

hist(aoa2.usage, breaks = seq(.5,5.5,1), main = '(b) Daily use', cex.main=2, xlab = 'Scores', ylab = 'N
axis(1, cex.axis=2);
axis(2, at=c(0,30), cex.axis=2, las=1);

barplot(table(aoa3.context), main = '(c) Where did you learn?', cex.main=2,  ylab = 'N of participants'
axis(2, at=c(0,65), cex.axis=2, las=1);

barplot(table(aoa4.contextMultling), main = '(d) Multilingual context', cex.main=2, ylab = 'N of partici
axis(2, at=c(0,65), cex.axis=2, las=1);

hist(aoa5.selfRatedProf, breaks = seq(.5,5.5,1), main = '(e) Self rated proficiency', cex.main=2, xlab =
axis(1, cex.axis=2);
axis(2, at=c(0,30), cex.axis=2, las=1);

barplot(table(aoa6.otherLang), main = '(f) Additional languages?', cex.main=2, ylab = 'N of participants
axis(2, at=c(0,65), cex.axis=2, las=1);
```




```
detach(pptFeatures);

par(mfrow=c(1,1));
#dev.off();
```

Figure 8 - Interaction by AoA1 by relatedness and morphtype

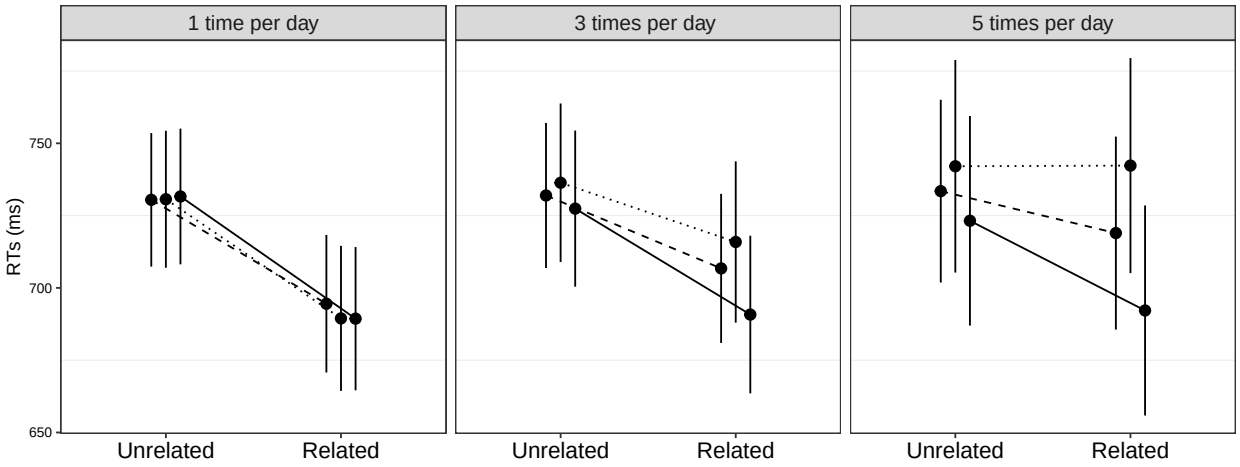
```
temp <- data.frame(effect('relatedness:morphType:aoa1.Aoa', aoaglmer1, se=list(level=.95), xlevels=list
revalue(temp$relatedness, c("rel"="Related"))-> temp$relatedness;
revalue(temp$relatedness, c("ctrl"="Unrelated"))-> temp$relatedness;

aoa1.Aoa_names <- c(
  "2" = "2 years",
  "6" = "6 years",
  "11" = "11 years");

ggplot(data = temp, aes(x=relatedness, y=fit, group=morphType)) +
  geom_point(size = 2, position = position_dodge(width = 0.25)) +
  geom_line(aes(linetype=morphType), position = position_dodge(width = 0.25)) +
  scale_linetype_manual(values=c("dashed", "dotted", "solid")) +
  theme_bw() +
  theme(panel.grid.major = element_blank()) +
  ylab('RTs (ms)') + xlab('') +
  theme(axis.text.y = element_text(angle = 00, hjust = 1, size=8, colour = 'black'))+
  theme(axis.text.x = element_text(size=13, colour = 'black'))+
  geom_pointrange(aes(ymin = lower, ymax = upper), position = position_dodge(width = 0.25)) +
  facet_grid(~ aoa1.Aoa,
             labeller = labeller(aoa1.Aoa = as_labeller(aoa1.Aoa_names))) +
  theme(strip.text = element_text(size=12)) +
  theme(legend.position="none");
```




```
#ggsave("aoa1.AoA.jpg", width = 7, height = 3, dpi = 300);
```

Figure 9 - Interaction by AoA2 by relatedness and morphtype

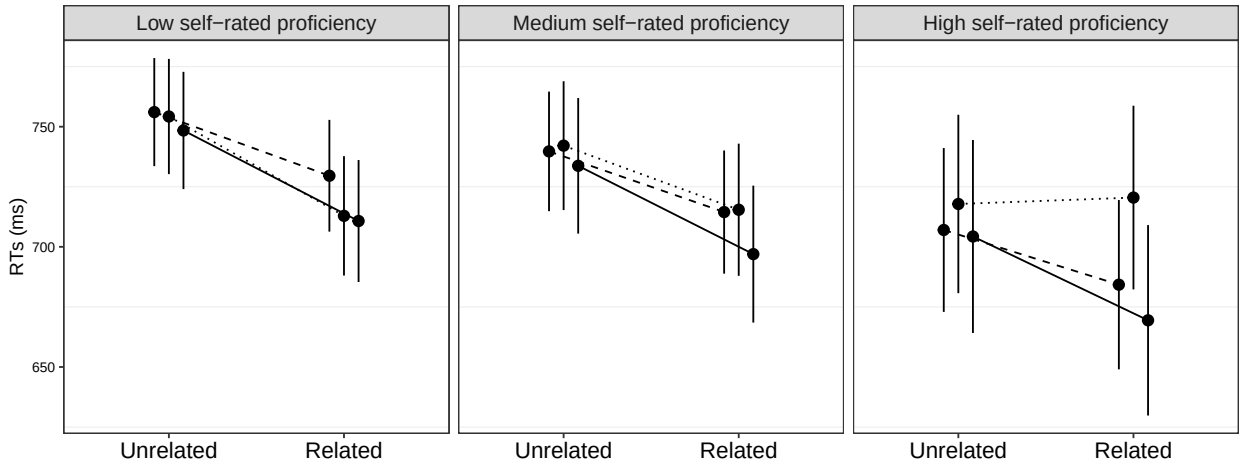
```
temp <- data.frame(effect('relatedness:morphType:aoa2.usage', aoaglmer2c, se=list(level=.95), xlevels=li
revalue(temp$relatedness, c("rel"="Related"))-> temp$relatedness;
revalue(temp$relatedness, c("ctrl"="Unrelated"))-> temp$relatedness;

aoa2.usage_names <- c(
  "1" = "1 time per day",
  "3" = "3 times per day ",
  "5" = "5 times per day");

ggplot(data = temp, aes(x=relatedness, y=fit, group=morphType)) +
  geom_point(size = 2, position = position_dodge(width = 0.25)) +
  geom_line(aes(linetype=morphType), position = position_dodge(width = 0.25)) +
  scale_linetype_manual(values=c("dashed", "dotted", "solid")) +
  theme_bw() +
  theme(panel.grid.major = element_blank()) +
  ylab('RTs (ms)') + xlab('') +
  theme(axis.text.y = element_text(angle = 00, hjust = 1, size=8, colour = 'black'))+
  theme(axis.text.x = element_text(size=13, colour = 'black'))+
  geom_pointrange(aes(ymin = lower, ymax = upper), position = position_dodge(width = 0.25)) +
  facet_grid(~ aoa2.usage,
             labeller = labeller(aoa2.usage = as_labeller(aoa2.usage_names))) +
  theme(strip.text = element_text(size=12)) +
  theme(legend.position="none");
```




```
#ggsave("aoa2.usage.jpg", width = 7, height = 3, dpi = 300);
```

Figure 10 - Interaction by AoA5 by relatedness and morphtype

```
temp <- data.frame(effect('relatedness:morphType:aoa5.selfRatedProf', aoaglmer5c, se=list(level=.95), x
revalue(temp$relatedness, c("rel"="Related"))-> temp$relatedness;
revalue(temp$relatedness, c("ctrl"="Unrelated"))-> temp$relatedness;

aoa5.selfRatedProf_names <- c(
  "2" = "Low self-rated proficiency",
  "3" = "Medium self-rated proficiency",
  "5" = "High self-rated proficiency");

ggplot(data = temp, aes(x=relatedness, y=fit, group=morphType)) +
  geom_point(size = 2, position = position_dodge(width = 0.25)) +
  geom_line(aes(linetype=morphType), position = position_dodge(width = 0.25)) +
  scale_linetype_manual(values=c("dashed", "dotted", "solid")) +
  theme_bw() +
  theme(panel.grid.major = element_blank()) +
  ylab('RTs (ms)') + xlab('') +
  theme(axis.text.y = element_text(angle = 00, hjust = 1, size=8, colour = 'black'))+
  theme(axis.text.x = element_text(size=13, colour = 'black'))+
  geom_pointrange(aes(ymin = lower, ymax = upper), position = position_dodge(width = 0.25)) +
  facet_grid(~ aoa5.selfRatedProf,
             labeller = labeller(aoa5.selfRatedProf = as_labeller(aoa5.selfRatedProf_names))) +
  theme(strip.text = element_text(size=12)) +
  theme(legend.position="none");
```




```
#ggsave("aoa5.selfratedProf.jpg", width = 7.5, height = 3, dpi = 300);
```

Figure 11 - OSC by morphtype

```
temp <- unique(masterFile[masterFile$lexicality=='word' & masterFile$language=='eng',c('target','prime'

revalue(temp$morphType, c("or"="Orthographic", 'op'='Opaque', 'tr'='Transparent'))-> temp$morphType;
library(ggpubr);
ggboxplot(subset(temp, oscTarget>0), "morphType", "oscTarget",
          color = "black", fill = grey(.80),
          width = 0.5, ylab = 'OSC', xlab = '');
```

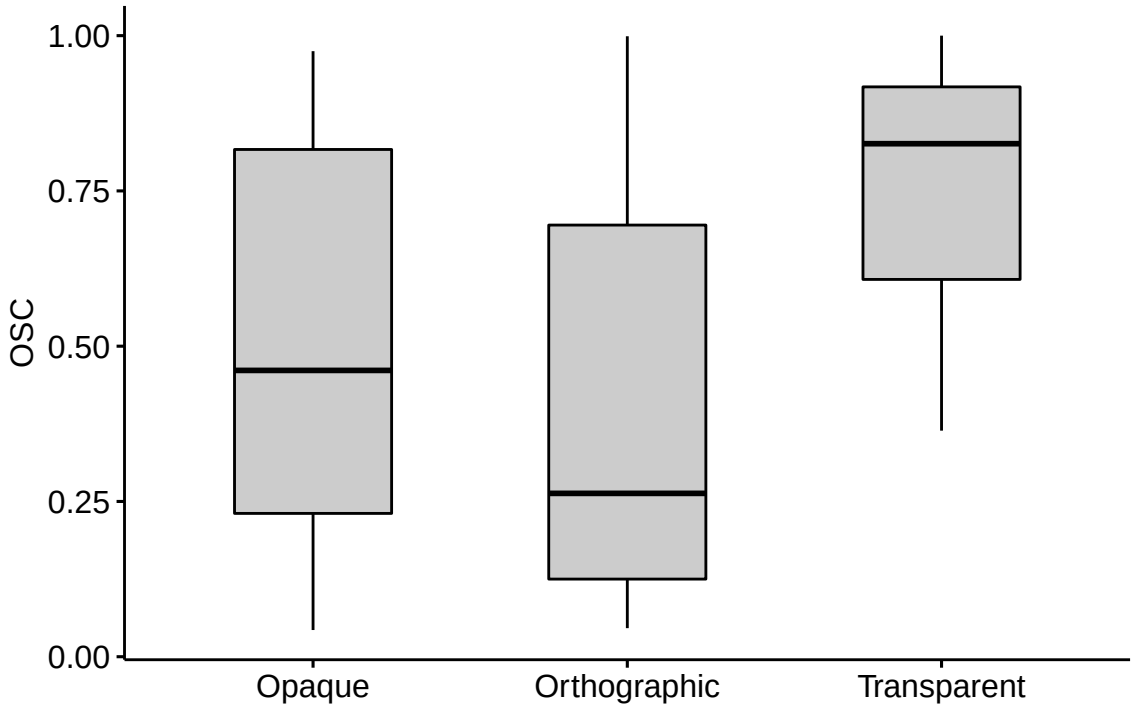
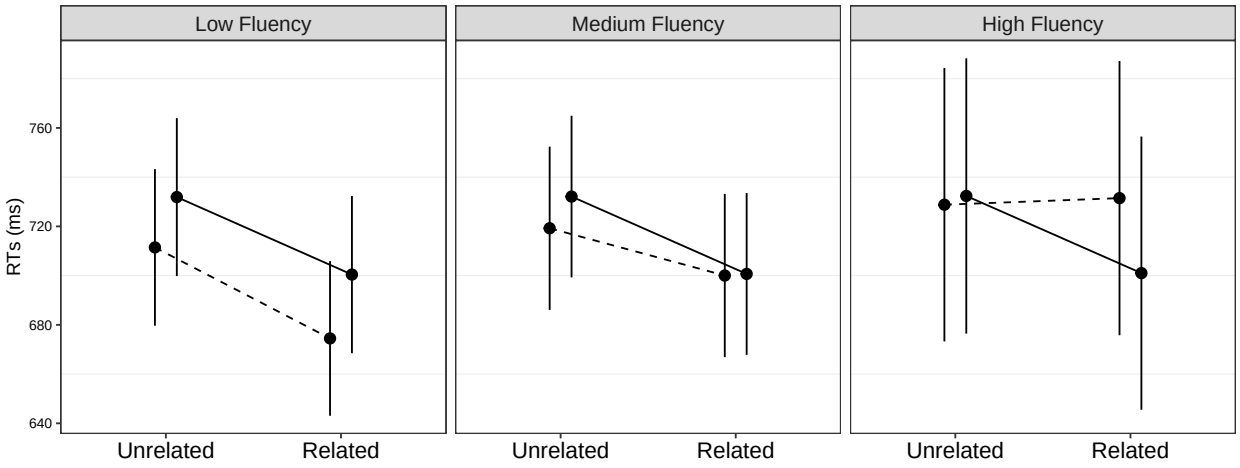


Figure 12 - OSC by phonemic fluency by relatedness

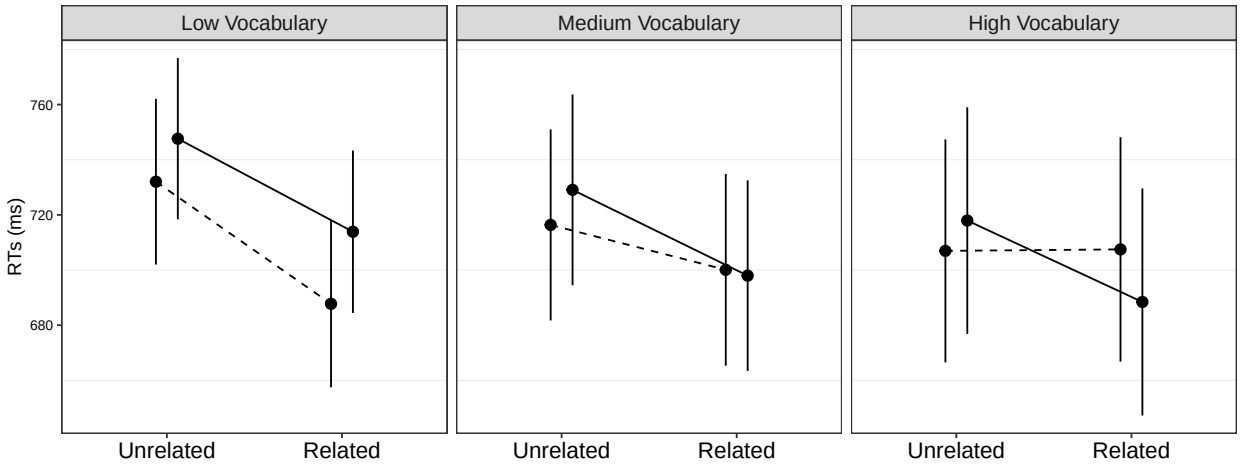
```
temp <- data.frame(effect('relatedness:oscTarget:phonemicFluency', osc1, se=list(level=.95), xlevels=lis
revalue(temp$relatedness, c("rel"="Related"))-> temp$relatedness;
revalue(temp$relatedness, c("ctrl"="Unrelated"))-> temp$relatedness;

phonemicFluency_names <- c(
  "10" = "Low Fluency",
  "23" = "Medium Fluency",
  "39" = "High Fluency"
);

temp$oscTarget <- as.factor(temp$oscTarget);
ggplot(data = temp, aes(x=relatedness, y=fit, group=oscTarget)) +
  geom_point(position = position_dodge(width = 0.25)) +
  geom_line(aes(linetype = oscTarget), position = position_dodge(width = 0.25)) +
  scale_linetype_manual(values=c("dashed", "solid")) +
  theme_bw() +
  theme(panel.grid.major = element_blank()) +
  ylab('RTs (ms)') + xlab('') +
  theme(axis.text.y = element_text(angle = 00, hjust = 1, size=8, colour = 'black'))+
  theme(axis.text.x = element_text(size=13, colour = 'black'))+
  geom_pointrange(aes(ymin = lower, ymax = upper), position = position_dodge(width = 0.25)) +
  facet_grid(~ phonemicFluency,
             labeller = labeller(phonemicFluency = as_labeller(phonemicFluency_names))) +
  theme(strip.text = element_text(size=12))+
  theme(legend.position="none");
```




```
ggsave("oscModel.jpg", width = 7, height = 3, dpi = 300);
```

Figure 13 - OSC by vocabulary by relatedness

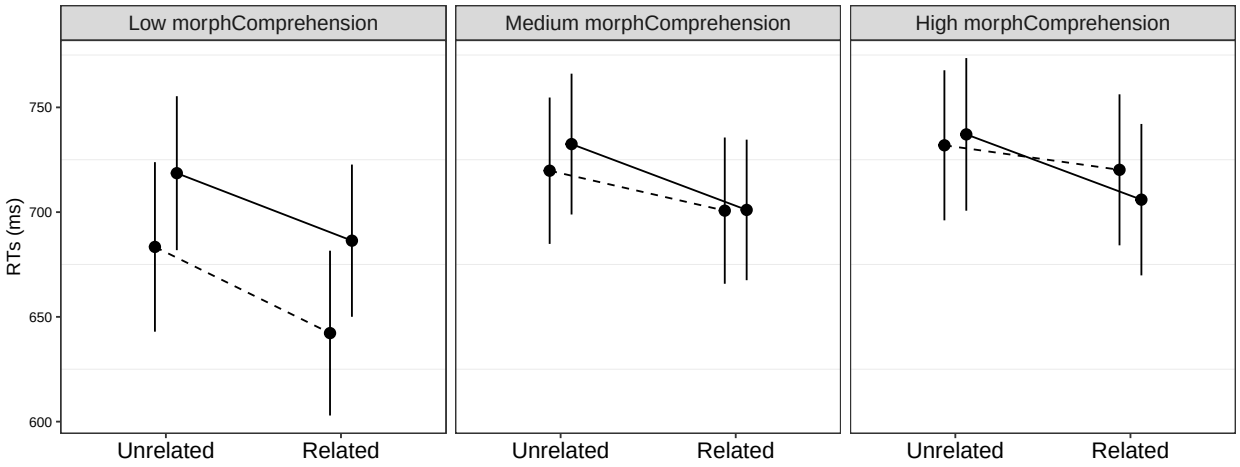
```
temp <- data.frame(effect('relatedness:oscTarget:vocabulary', osc2, se=list(level=.95), xlevels=list(os
revalue(temp$relatedness, c("rel"="Related"))-> temp$relatedness;
revalue(temp$relatedness, c("ctrl"="Unrelated"))-> temp$relatedness;

vocabulary_names <- c(
  "11" = "Low Vocabulary",
  "16" = "Medium Vocabulary",
  "19" = "High Vocabulary"
);

temp$oscTarget <- as.factor(temp$oscTarget);
ggplot(data = temp, aes(x=relatedness, y=fit, group=oscTarget)) +
  geom_point(position = position_dodge(width = 0.25)) +
  geom_line(aes(linetype = oscTarget), position = position_dodge(width = 0.25)) +
  scale_linetype_manual(values=c("dashed", "solid")) +
  theme_bw() +
  theme(panel.grid.major = element_blank()) +
  ylab('RTs (ms)') + xlab('') +
  theme(axis.text.y = element_text(angle = 00, hjust = 1, size=8, colour = 'black'))+
  theme(axis.text.x = element_text(size=13, colour = 'black'))+
  geom_pointrange(aes(ymin = lower, ymax = upper), position = position_dodge(width = 0.25)) +
  facet_grid(~ vocabulary,
             labeller = labeller(vocabulary = as_labeller(vocabulary_names))) +
  theme(strip.text = element_text(size=12))+
  theme(legend.position="none");
```




```
ggsave("vocabulary.jpg", width = 7.5, height = 3, dpi = 300);
```

Figure 14 - morphComprehension by relatedness

```
temp <- data.frame(effect('relatedness:oscTarget:morphComprehension', osc4, se=list(level=.95), xlevels=
revalue(temp$relatedness, c("rel"="Related"))-> temp$relatedness;
revalue(temp$relatedness, c("ctrl"="Unrelated"))-> temp$relatedness;

morphComprehension_names <- c(
  "6" = "Low morphComprehension",
  "9" = "Medium morphComprehension",
  "10" = "High morphComprehension"
);

temp$oscTarget <- as.factor(temp$oscTarget);
ggplot(data = temp, aes(x=relatedness, y=fit, group=oscTarget)) +
  geom_point(position = position_dodge(width = 0.25)) +
  geom_line(aes(linetype = oscTarget), position = position_dodge(width = 0.25)) +
  scale_linetype_manual(values=c("dashed", "solid")) +
  theme_bw() +
  theme(panel.grid.major = element_blank()) +
  ylab('RTs (ms)') + xlab('') +
  theme(axis.text.y = element_text(angle = 00, hjust = 1, size=8, colour = 'black'))+
  theme(axis.text.x = element_text(size=13, colour = 'black'))+
  geom_pointrange(aes(ymin = lower, ymax = upper), position = position_dodge(width = 0.25)) +
  facet_grid(~ morphComprehension,
             labeller = labeller(morphComprehension = as_labeller(morphComprehension_names))) +
  theme(strip.text = element_text(size=12))+
  theme(legend.position="none");
```




```
ggsave("figure14.jpg", width = 7.7, height = 3, dpi = 300);
```