m21_rt

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Setup

Load libraries

1. Set `ggplot2` parameters

Load Files and Format Files

Load Files

```
rt_1 <- read_csv("rt_data_chrt1.csv")
rt_2 <- read_csv("rt_data_chrt2.csv")
frq_w <- read_csv("stimuli_cw_frq.csv")
frq_nw <- read_csv("frq_nw.csv")
dmg <- read_csv("demo_lang_vsl_pca.csv")
```

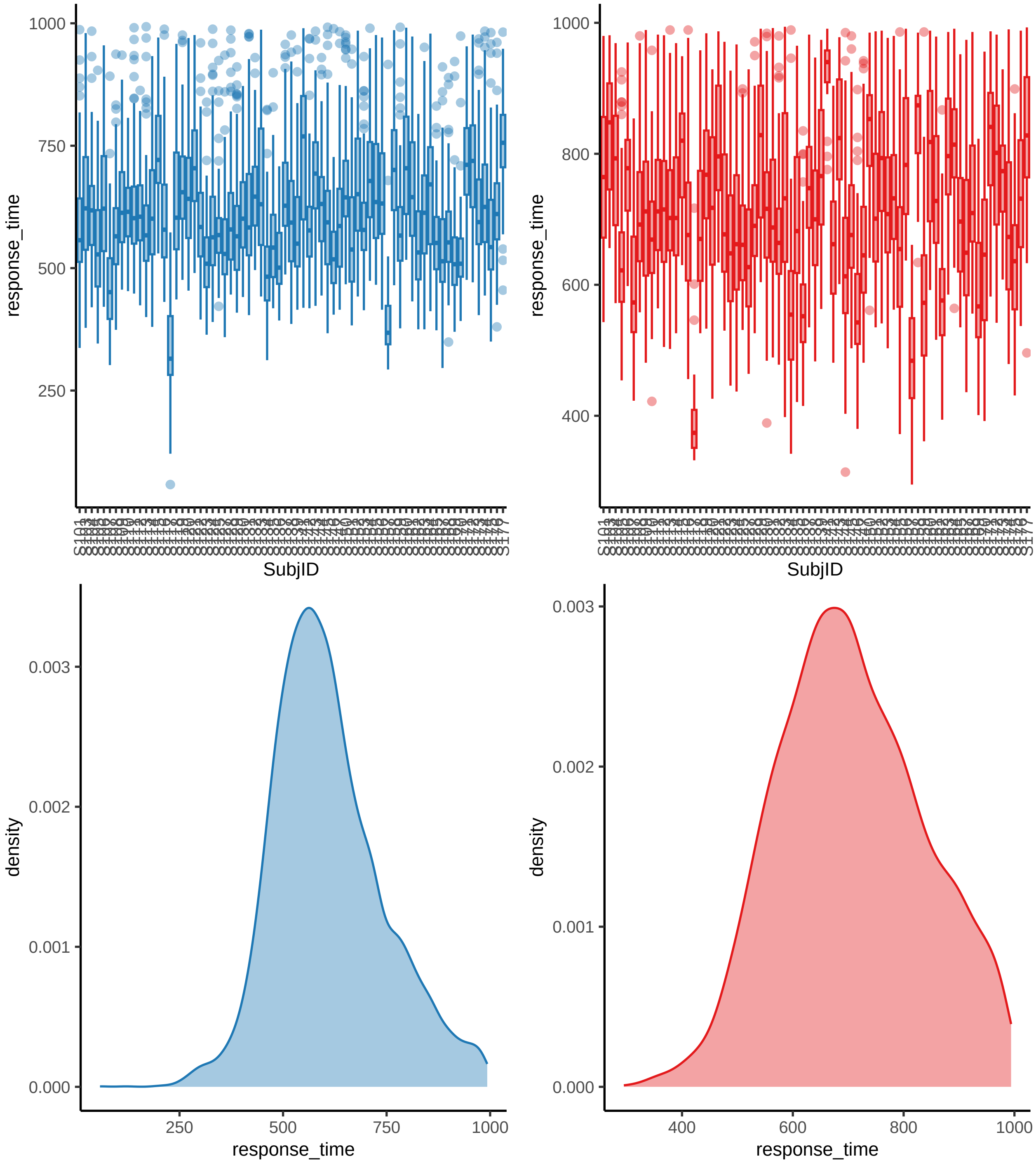
Format Files

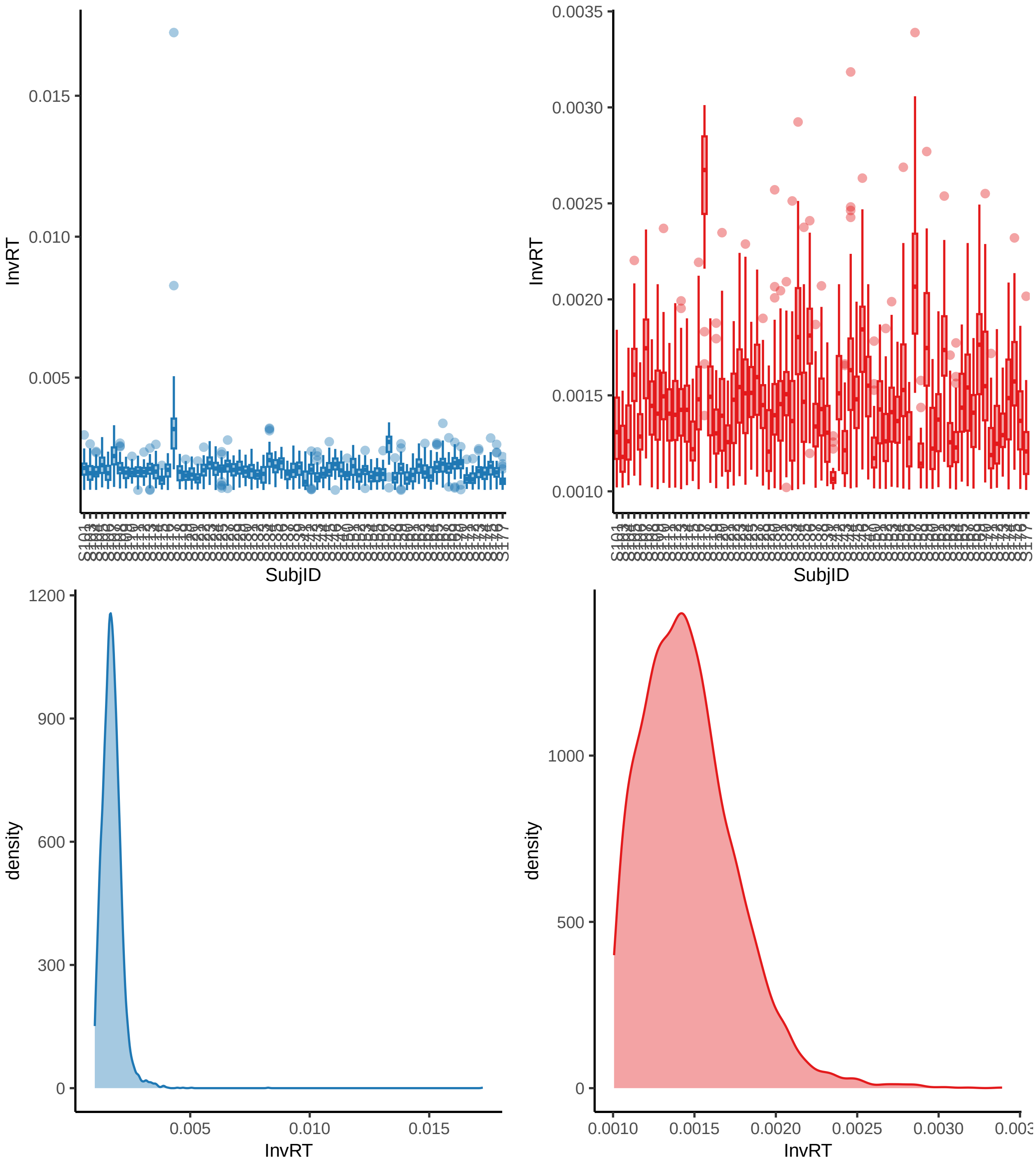
```
# Concatenate datasets
rt <- bind_rows(Hampshire = rt_1,
                Providence =rt_2,
                .id = "location")
rt_dmg<- right_join(dmg, rt, join_by(SubjID == subject_nr))  # Join Participant Demographic and Lang Data
rt_dmg <- rt_dmg |> mutate(target = tolower(target))
rt_dmg_cor <- rt_dmg |> filter(correct == 1)

# Divide into Experimental and Filler Items
rt_fill <- rt_dmg_cor |> filter(str_detect(targ_type, "^FILL"))
rt_exp <- rt_dmg_cor |> filter(!str_detect(targ_type, "^FILL"))

# Define Factors and Conditions
rt_exp_cln <- rt_exp |>
  separate(targ_type, into = c("trial_type", "family_size", "complexity"), sep = "_",
           remove = TRUE,
           extra = "drop",
           fill = "right")

# Divide into Words and Nonwords
rt_words <- rt_exp_cln |> filter(trial_type == "CW") |> select(- complexity)
rt_nwords <- rt_exp_cln |> filter(trial_type == "NW")

# Join Stimulus Frequency Data
rt_words_frq <- left_join(rt_words, frq_w, join_by(target))|>
  select(-cond_trig.y, -word_trig.y) |>
  rename(cond_trig = cond_trig.x, word_trig = word_trig.x)  # remove duplicate columns

rt_nwords_frq <-  left_join(rt_nwords, frq_nw, join_by(target==word))


# Create a median-split factor for base frequency
rt_words_frq$BF_MedianSplit <- ifelse(
  rt_words_frq$Log10BF <= median(rt_words_frq$Log10BF, na.rm = TRUE),
  "Low", "High")
rt_words_frq$BF_MedianSplit <- factor(rt_words_frq$BF_MedianSplit, levels = c("Low", "High"))
rt_words_frq$FS_Split <- factor(rt_words_frq$FS_Split)

rt_nwords_frq$BF_Split <- factor(rt_nwords_frq$BF_Split)
rt_nwords_frq$FS_Split <- factor(rt_nwords_frq$FS_Split)
```

```r
# Divide into cohorts
rt_words_1 <- rt_words_frq |> filter(location == "Hampshire") |> select(- location)
rt_words_2 <- rt_words_frq |> filter(location == "Providence") |> select(- location)

rt_nwords_1 <- rt_nwords_frq |> filter(location == "Hampshire") |> select(- location)
rt_nwords_2 <- rt_nwords_frq |> filter(location == "Providence") |> select(- location)
# str(rt_words_1)
```

Analyse Data

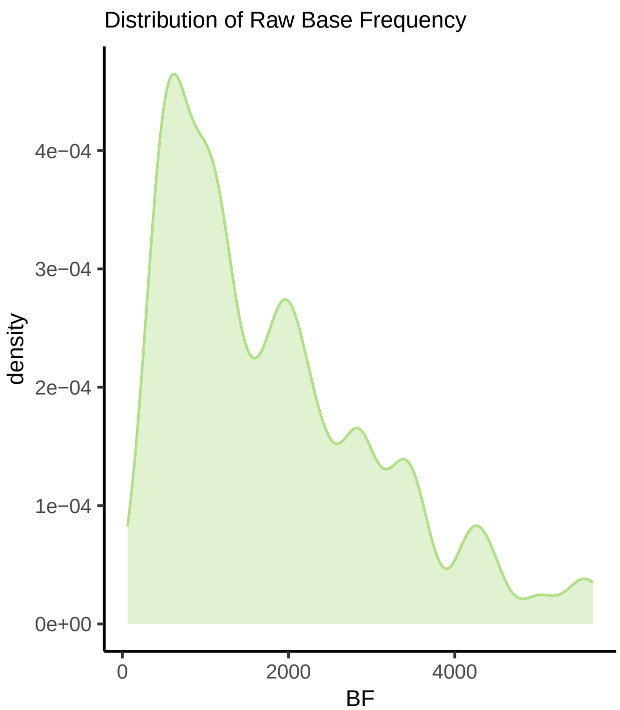
Plot RT distributions

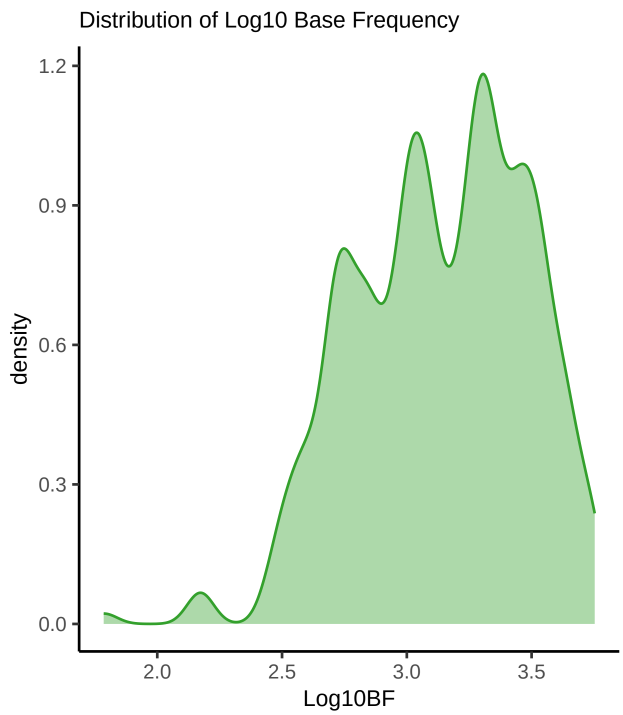




Is Base Frequency Skewed

. . .






```
|| [1] 0.9870676
```

```
|| [1] -0.4166518
```

ANOVA Words

Use `complete.cases()` to find which rows had missing data in the model-relevant variables:

Standardize the predictors

```
rt_words_1_cmpl$Log10BF_std <- as.numeric(scale(rt_words_1_cmpl$Log10BF, center = TRUE, scale = TRUE))
rt_words_1_cmpl$FS_std <- as.numeric(scale(rt_words_1_cmpl$FS, center = TRUE, scale = TRUE))
rt_words_1_cmpl$Log10WF_std <- as.numeric(scale(rt_words_1_cmpl$Log10WF, center = TRUE, scale = TRUE))
rt_words_1_cmpl$Dim.2_std <- as.numeric(scale(rt_words_1_cmpl$Dim.2, center = TRUE, scale = TRUE))
```

Anova with Continuous Log10BF

```
anova_model_1 <- mixed(
  InvRT ~ Log10BF_std * FS_Split * lang_type_ortho + (1  | SubjID),
  data = rt_words_1_cmpl,
  method = "KR"
)
anova_model_1
```

```
|| Mixed Model Anova Table (Type 3 tests, KR-method)
||
|| Model: InvRT ~ Log10BF_std * FS_Split * lang_type_ortho + (1 | SubjID)
|| Data: rt_words_1_cmpl
||                                Effect         df         F p.value
|| 1                         Log10BF_std 1, 5792.69 41.88 ***   <.001
|| 2                            FS_Split 1, 5792.31 23.20 ***   <.001
|| 3                     lang_type_ortho   1, 64.02      2.40    .127
|| 4                Log10BF_std:FS_Split 1, 5792.52      0.03    .854
|| 5         Log10BF_std:lang_type_ortho 1, 5792.69    4.76 *    .029
|| 6            FS_Split:lang_type_ortho 1, 5792.31      1.00    .318
|| 7 Log10BF_std:FS_Split:lang_type_ortho 1, 5792.52      0.24    .623
|| ---
|| Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1 ' ' 1
```

```
summary(anova_model_1)
```

```
|| Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
|| Formula: InvRT ~ Log10BF_std * FS_Split * lang_type_ortho + (1 | SubjID)
||    Data: data
||
```

```
|| REML criterion at convergence: -75938.7
||
|| Scaled residuals:
||    Min     1Q Median     3Q    Max
|| -4.265 -0.536 -0.017  0.527 38.870
||
|| Random effects:
||  Groups   Name        Variance  Std.Dev.
||  SubjID   (Intercept) 7.771e-08 0.0002788
||  Residual             1.293e-07 0.0003596
|| Number of obs: 5864, groups:  SubjID, 66
||
|| Fixed effects:
||                                         Estimate Std. Error         df t value Pr(>|t|)
|| (Intercept)                            1.734e-03  3.504e-05  6.390e+01  49.479  < 2e-16 ***
|| Log10BF_std                            3.204e-05  4.950e-06  5.793e+03   6.472 1.05e-10 ***
|| FS_Split1                              2.301e-05  4.777e-06  5.792e+03   4.816 1.50e-06 ***
|| lang_type_ortho1                       5.423e-05  3.504e-05  6.390e+01   1.548   0.1266
|| Log10BF_std:FS_Split1                  9.119e-07  4.948e-06  5.792e+03   0.184   0.8538
|| Log10BF_std:lang_type_ortho1           1.079e-05  4.950e-06  5.793e+03   2.181   0.0293 *
|| FS_Split1:lang_type_ortho1            -4.767e-06  4.777e-06  5.792e+03  -0.998   0.3183
|| Log10BF_std:FS_Split1:lang_type_ortho1  2.435e-06  4.948e-06  5.792e+03   0.492   0.6227
|| ---
|| Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
||
|| Correlation of Fixed Effects:
||              (Intr) Lg10BF_ FS_Sp1 lng__1 Lg10BF_:FS_S1 L10BF_:_ FS_S1:
|| Log10BF_std   -0.003
|| FS_Split1      0.001 -0.079
|| lng_typ_rt1    0.152  0.000   0.002
|| Lg10BF_:FS_S1 -0.011  0.249  -0.020 -0.002
|| Lg10BF_:__1    0.000  0.188  -0.013 -0.003  0.068
|| FS_Spl1:__1    0.002 -0.013   0.160  0.001 -0.004        -0.079
|| L10BF_:FS_S1: -0.002  0.068  -0.004 -0.011  0.188         0.249   -0.020
```

Main Findings:

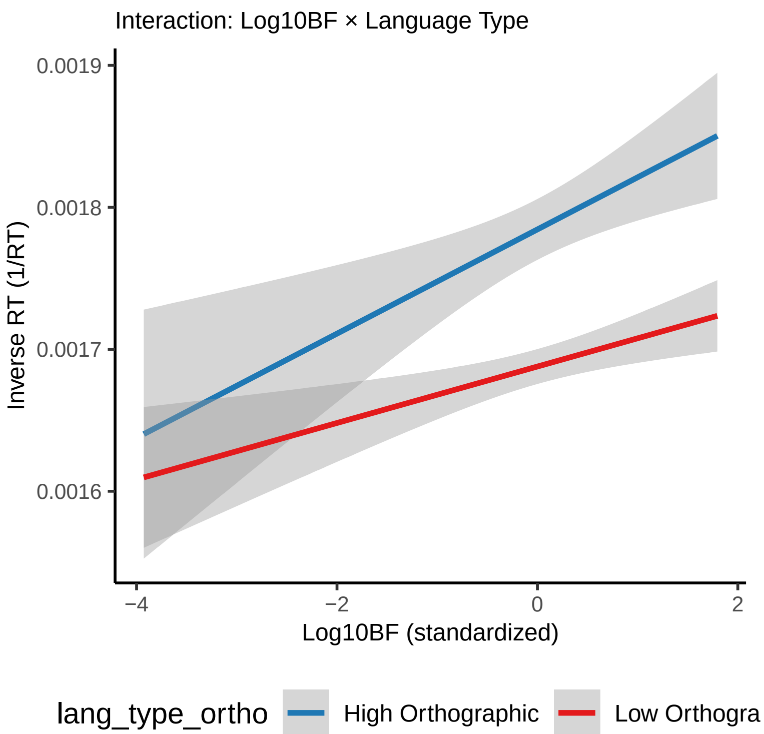
Effect	df	F	p.value
Log10BF_std	1, 5792.69	41.88 ***	<.001
FS_Split	1, 5792.31	23.20 ***	<.001
Log10BF_std:lang_type_ortho	1, 5792.69	4.76 *	.029

Data show that as Log10BF increases (e.g., more frequent or predictable words), processing becomes faster (inverse RT goes up → RT goes down).

Statistical models were fit using inverse response time (1/RT) to capture processing speed, but all reported means and figures are back-transformed to milliseconds for interpretability.

Plots

Plotting Processing Efficiency



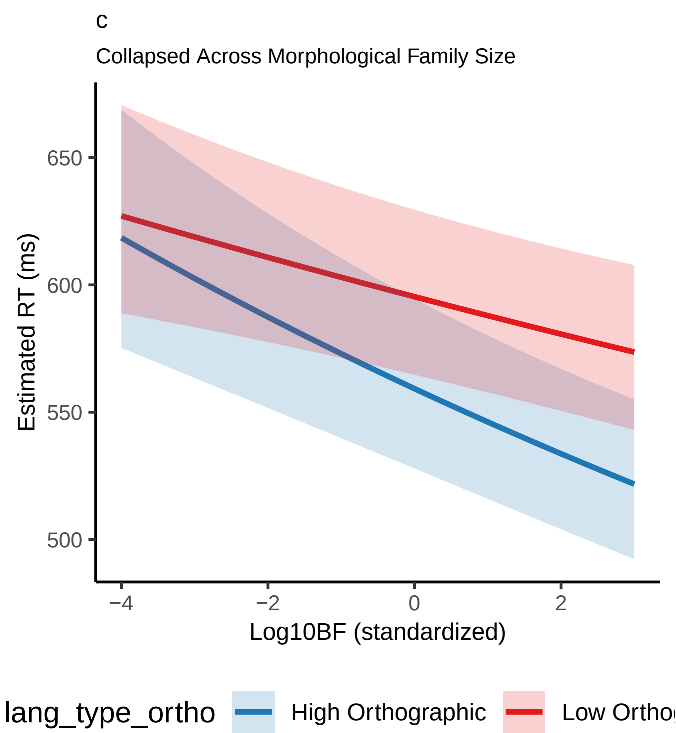
Plotting Latency To plot predicted values in milliseconds (RT) instead of inverse RT, you must:

```
1.  Predict inverse RT values from the model

2.  Back-transform to milliseconds with RT_ms = 1000 / InvRT

3.  Plot the transformed values
```

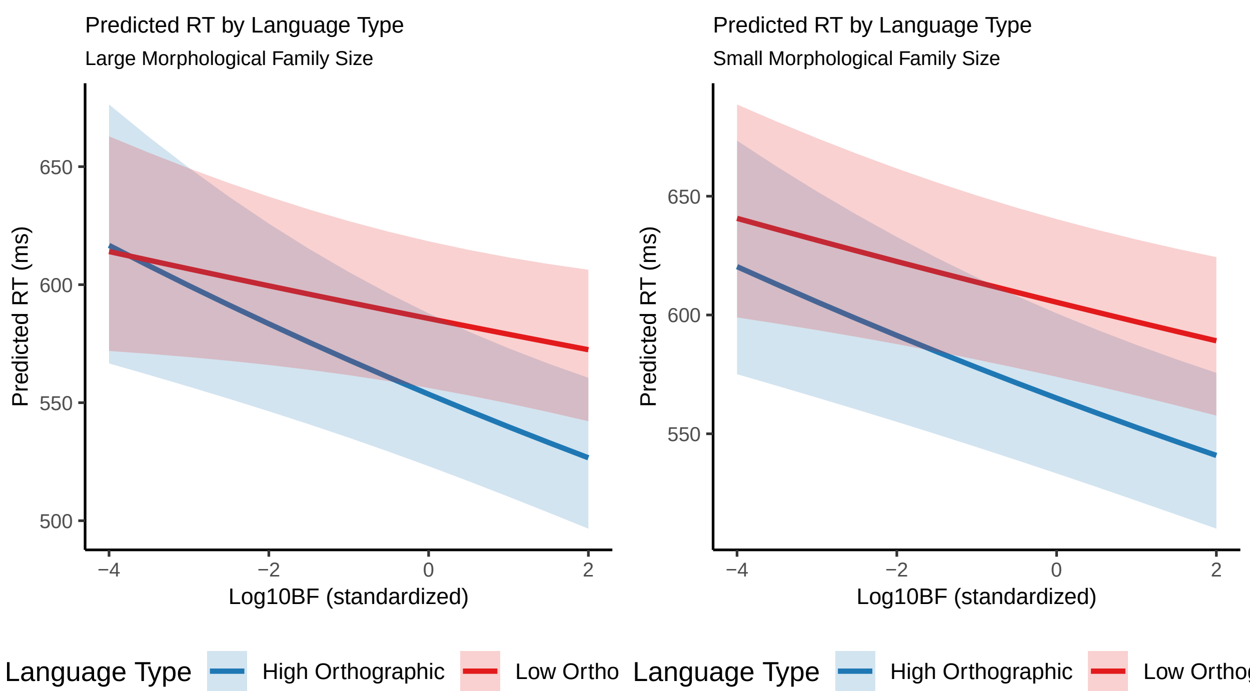
When using ggeffects (or emmeans) with models fit using afex::mixed(). The mixed() function wraps lmer() from lme4, but the result isn't always fully compatible with tools like ggeffects because of the extra layers (especially when using Kenward-Roger or parametric bootstrap methods for inference).

Because we are only using mixed() for the Kenward-Roger p-values but don't need it for prediction, refit our model with lmer():

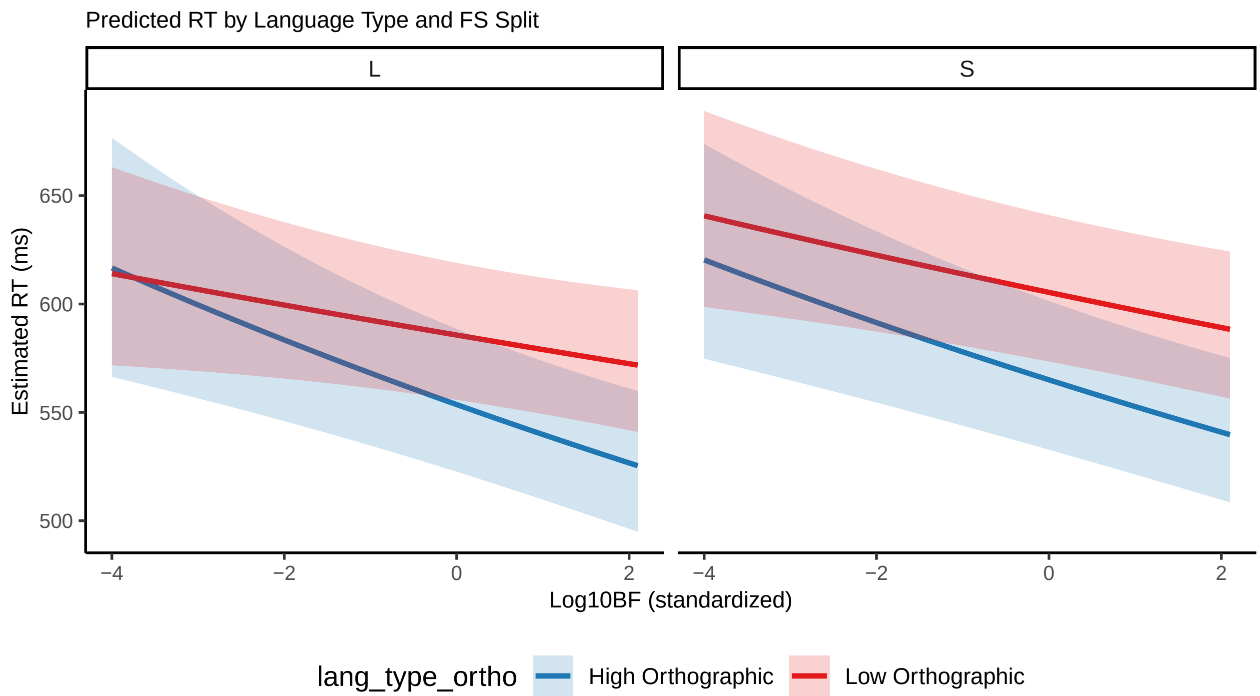
Option 1: Collapsed across Family Size ...



Option 2: LogBR x Language Type as a function of FS . . .



Option 3: LogBR x Language Type as a function of FS (Faceted Plot) . . .



Interpret Interactions

```r
# Marginal trends (i.e., slopes of Log10BF for each language group)
emtrends(anova_model_1, ~ lang_type_ortho, var = "Log10BF_std")
```

Contrast Slopes

```
||  lang_type_ortho   Log10BF_std.trend       SE   df lower.CL upper.CL
||  High Orthographic          4.28e-05 7.63e-06 5793 2.79e-05 5.78e-05
||  Low Orthographic           2.12e-05 6.31e-06 5793 8.88e-06 3.36e-05
||
|| Results are averaged over the levels of: FS_Split
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
```

```r
# Formal contrast of slopes
emtrends(anova_model_1, pairwise ~ lang_type_ortho, var = "Log10BF_std")
```

```
|| $emtrends
||  lang_type_ortho   Log10BF_std.trend       SE   df lower.CL upper.CL
||  High Orthographic          4.28e-05 7.63e-06 5793 2.79e-05 5.78e-05
||  Low Orthographic           2.12e-05 6.31e-06 5793 8.88e-06 3.36e-05
||
|| Results are averaged over the levels of: FS_Split
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
||
|| $contrasts
||  contrast                              estimate      SE   df t.ratio p.value
||  High Orthographic - Low Orthographic 2.16e-05 9.9e-06 5793   2.181  0.0293
||
|| Results are averaged over the levels of: FS_Split
|| Degrees-of-freedom method: kenward-roger
```

```r
library(emmeans)

# Estimate inverse RT at mean frequency for each group
emm <- emmeans(anova_model_lmer, ~ lang_type_ortho, at = list(Log10BF_std = 0))
emm_df <- as.data.frame(emm)

# Back-transform to ms
emm_df$RT_ms <- 1 / emm_df$emmean

print(emm_df)
```

Get ms estimates

```
## lang_type_ortho        emmean           SE    df    lower.CL    upper.CL    RT_ms
## High Orthographic 0.001788147 5.318219e-05 64.02 0.001681904 0.001894390 559.2381
## Low Orthographic  0.001679678 4.564910e-05 64.01 0.001588483 0.001770872 595.3523
##
## Results are averaged over the levels of: FS_Split
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
```

Other ANOVA Models

```r
# Anova with Continuous Log10BF AND Continous FS
anova_model_2 <- mixed(
  InvRT ~ Log10BF_std * FS * lang_type_ortho + (1  | SubjID),
  data = rt_words_1_cmpl,
  method = "KR"
)
anova_model_2
```

```
## Mixed Model Anova Table (Type 3 tests, KR-method)
##
## Model: InvRT ~ Log10BF_std * FS * lang_type_ortho + (1 | SubjID)
## Data: rt_words_1_cmpl
##                           Effect         df         F p.value
## 1                    Log10BF_std 1, 5792.43 13.78 ***   <.001
## 2                             FS 1, 5792.32   9.15 **    .003
## 3                lang_type_ortho   1, 70.20    2.97 +    .089
## 4                 Log10BF_std:FS 1, 5792.35      0.02    .902
## 5    Log10BF_std:lang_type_ortho 1, 5792.43      0.32    .570
## 6             FS:lang_type_ortho 1, 5792.32      1.07    .300
## 7 Log10BF_std:FS:lang_type_ortho 1, 5792.35      0.53    .469
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1 ' ' 1
```

```r
summary(anova_model_2)
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
## Formula: InvRT ~ Log10BF_std * FS * lang_type_ortho + (1 | SubjID)
##    Data: data
##
## REML criterion at convergence: -75909.6
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
## -4.289 -0.536 -0.012  0.525 38.796
##
## Random effects:
##  Groups   Name        Variance  Std.Dev.
##  SubjID   (Intercept) 7.778e-08 0.0002789
##  Residual             1.296e-07 0.0003601
## Number of obs: 5864, groups:  SubjID, 66
##
## Fixed effects:
##                                   Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)                      1.711e-03  3.588e-05  7.008e+01  47.676  < 2e-16 ***
## Log10BF_std                      3.266e-05  8.798e-06  5.792e+03   3.712 0.000207 ***
## FS                               2.250e-06  7.440e-07  5.792e+03   3.024 0.002503 **
## lang_type_ortho1                 6.185e-05  3.588e-05  7.008e+01   1.724 0.089165 .
## Log10BF_std:FS                  -1.068e-07  8.677e-07  5.792e+03  -0.123 0.902013
## Log10BF_std:lang_type_ortho1     5.003e-06  8.798e-06  5.792e+03   0.569 0.569624
## FS:lang_type_ortho1             -7.705e-07  7.440e-07  5.792e+03  -1.036 0.300396
## Log10BF_std:FS:lang_type_ortho1  6.288e-07  8.677e-07  5.792e+03   0.725 0.468733
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) Lg10BF_ FS     lng__1 Lg10BF_:FS L10BF_:_ FS:__1
## Log10BF_std -0.010
## FS          -0.212  0.122
## lng_typ_rt1  0.152 -0.002  -0.033
## Lg10BF_s:FS  0.029 -0.837  -0.223  0.005
## Lg10BF_:__1 -0.002  0.170   0.019 -0.010 -0.142
## FS:lng_ty_1 -0.033  0.019   0.161 -0.212 -0.036      0.122
## L10BF_:FS:_  0.005 -0.142  -0.036  0.029  0.174     -0.837   -0.223
```

```r
# Anova with Categorical Log10BF and Categorial Log10BF
anova_model_2 <- mixed(
  InvRT ~ BF_MedianSplit * FS_Split * lang_type_ortho + (1  | SubjID),
  data = rt_words_1_cmpl,
  method = "KR"
)
anova_model_2
```

```
|| Mixed Model Anova Table (Type 3 tests, KR-method)
||
|| Model: InvRT ~ BF_MedianSplit * FS_Split * lang_type_ortho + (1 | SubjID)
|| Data: rt_words_1_cmpl
||                                 Effect         df         F p.value
|| 1                       BF_MedianSplit 1, 5792.35 34.10 ***   <.001
|| 2                             FS_Split 1, 5792.32 27.80 ***   <.001
|| 3                      lang_type_ortho   1, 64.00      2.43    .124
|| 4              BF_MedianSplit:FS_Split 1, 5792.32    4.69 *    .030
|| 5       BF_MedianSplit:lang_type_ortho 1, 5792.35      1.38    .239
|| 6             FS_Split:lang_type_ortho 1, 5792.32      0.70    .404
|| 7 BF_MedianSplit:FS_Split:lang_type_ortho 1, 5792.32   0.33    .566
|| ---
|| Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1 ' ' 1
```

```
summary(anova_model_2)
```

```
|| Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
|| Formula: InvRT ~ BF_MedianSplit * FS_Split * lang_type_ortho + (1 | SubjID)
||    Data: data
||
|| REML criterion at convergence: -75932.5
||
|| Scaled residuals:
||    Min     1Q Median     3Q    Max
|| -4.245 -0.535 -0.007  0.526 38.831
||
|| Random effects:
||  Groups   Name        Variance  Std.Dev.
||  SubjID   (Intercept) 7.741e-08 0.0002782
||  Residual             1.295e-07 0.0003598
|| Number of obs: 5864, groups:  SubjID, 66
||
|| Fixed effects:
||                                          Estimate Std. Error         df t value Pr(>|t|)
|| (Intercept)                             1.734e-03  3.498e-05  6.389e+01  49.586  < 2e-16 ***
|| BF_MedianSplit1                        -2.782e-05  4.765e-06  5.792e+03  -5.839 5.52e-09 ***
|| FS_Split1                               2.512e-05  4.765e-06  5.792e+03   5.272 1.40e-07 ***
|| lang_type_ortho1                        5.450e-05  3.498e-05  6.389e+01   1.558   0.1241
|| BF_MedianSplit1:FS_Split1               1.031e-05  4.765e-06  5.792e+03   2.165   0.0305 *
|| BF_MedianSplit1:lang_type_ortho1       -5.607e-06  4.765e-06  5.792e+03  -1.177   0.2393
|| FS_Split1:lang_type_ortho1             -3.976e-06  4.765e-06  5.792e+03  -0.835   0.4040
|| BF_MedianSplit1:FS_Split1:lang_type_ortho1  2.738e-06  4.765e-06  5.792e+03   0.575   0.5656
|| ---
|| Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
||
|| Correlation of Fixed Effects:
||              (Intr) BF_MdS1 FS_Sp1 lng__1 BF_MdS1:FS_S1 BF_MS1:_ FS_S1:
|| BF_MdnSplt1   -0.001
|| FS_Split1      0.001  0.007
|| lng_typ_rt1    0.152 -0.001   0.002
|| BF_MdS1:FS_S1  0.001  0.006  -0.011 -0.001
|| BF_MdS1:__1   -0.001  0.161  -0.003 -0.001  0.011
|| FS_Spl1:__1    0.002 -0.003   0.161  0.001 -0.005         0.007
|| BF_MS1:FS_S1: -0.001  0.011  -0.005  0.001  0.161         0.006   -0.011
```

ANOVA Non-Words

Use `complete.cases()` to find which rows had missing data in the model-relevant variables:

Standardize the predictors

```
rt_nwords_1_cmpl$LogBF_std <- as.numeric(scale(rt_nwords_1_cmpl$LogBF, center = TRUE, scale = TRUE))
rt_nwords_1_cmpl$FS_std <- as.numeric(scale(rt_nwords_1_cmpl$FS, center = TRUE, scale = TRUE))
rt_nwords_1_cmpl$BF_std <- as.numeric(scale(rt_nwords_1_cmpl$BF, center = TRUE, scale = TRUE))
rt_nwords_1_cmpl$Dim.2_std <- as.numeric(scale(rt_nwords_1_cmpl$Dim.2, center = TRUE, scale = TRUE))
```

Anova with Continuous Log10BF

```
anova_model_2 <- mixed(
  InvRT ~ LogBF_std * FS_Split * lang_type_ortho + (1  | SubjID),
  data = rt_nwords_1_cmpl,
  method = "KR"
)
anova_model_2
```

```
|| Mixed Model Anova Table (Type 3 tests, KR-method)
||
|| Model: InvRT ~ LogBF_std * FS_Split * lang_type_ortho + (1 | SubjID)
```

```
|| Data: rt_nwords_1_cmpl
||                              Effect         df         F p.value
|| 1                        LogBF_std 1, 4599.88 18.20 ***   <.001
|| 2                         FS_Split 1, 4599.59      0.45    .503
|| 3                   lang_type_ortho   1, 64.77      2.08    .154
|| 4                LogBF_std:FS_Split 1, 4599.56    2.71 +    .100
|| 5         LogBF_std:lang_type_ortho 1, 4599.88      0.00    .963
|| 6          FS_Split:lang_type_ortho 1, 4599.59      1.95    .163
|| 7 LogBF_std:FS_Split:lang_type_ortho 1, 4599.56      0.08    .771
|| ---
|| Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1 ' ' 1
```

```r
summary(anova_model_2)
```

```
|| Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
|| Formula: InvRT ~ LogBF_std * FS_Split * lang_type_ortho + (1 | SubjID)
||    Data: data
||
|| REML criterion at convergence: -64447.7
||
|| Scaled residuals:
||     Min      1Q  Median      3Q     Max
|| -4.5501 -0.6812 -0.0551  0.6288  6.5563
||
|| Random effects:
||  Groups   Name        Variance  Std.Dev.
||  SubjID   (Intercept) 4.687e-08 0.0002165
||  Residual             5.428e-08 0.0002330
|| Number of obs: 4671, groups:  SubjID, 66
||
|| Fixed effects:
||                                       Estimate Std. Error         df t value Pr(>|t|)
|| (Intercept)                          1.466e-03  2.729e-05  6.309e+01  53.731  < 2e-16 ***
|| LogBF_std                           -1.747e-05  4.096e-06  4.598e+03  -4.266 2.03e-05 ***
|| FS_Split1                            2.730e-06  4.072e-06  4.598e+03   0.670   0.5026
|| lang_type_ortho1                     3.940e-05  2.729e-05  6.309e+01   1.443   0.1538
|| LogBF_std:FS_Split1                  6.736e-06  4.093e-06  4.598e+03   1.646   0.0999 .
|| LogBF_std:lang_type_ortho1          -1.894e-07  4.096e-06  4.598e+03  -0.046   0.9631
|| FS_Split1:lang_type_ortho1           5.684e-06  4.072e-06  4.598e+03   1.396   0.1629
|| LogBF_std:FS_Split1:lang_type_ortho1  1.192e-06  4.093e-06  4.598e+03   0.291   0.7709
|| ---
|| Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
||
|| Correlation of Fixed Effects:
||             (Intr) LgBF_s FS_Sp1 lng__1 LgBF_:FS_S1 LBF_:_ FS_S1:
|| LogBF_std   -0.013
|| FS_Split1    0.011 -0.535
|| lng_typ_rt1  0.150 -0.001 -0.001
|| LgBF_:FS_S1 -0.080  0.136 -0.087 -0.010
|| LgBF_st:__1 -0.001  0.115 -0.065 -0.013 -0.009
|| FS_Spl1:__1 -0.001 -0.065  0.119  0.011  0.001      -0.535
|| LBF_:FS_S1: -0.010 -0.009  0.001 -0.080  0.114       0.136 -0.087
```

Main Findings:

Effect	df	F	p.value
Log10BF_std	1, 4599.88	18.20 ***	<.001

Data show that as Log10BF increases (e.g., more frequent or predictable words), processing becomes faster (inverse RT goes up → RT goes down).

Statistical models were fit using inverse response time (1/RT) to capture processing speed, but all reported means and figures are back-transformed to milliseconds for interpretability.

Follow up analyses

```r
emtrends(anova_model_2, ~1, var = "LogBF_std")
```

Report Estimated Trend (Slope) for LogBF

```
||  1       LogBF_std.trend      SE   df  lower.CL  upper.CL
||  overall       -1.75e-05 4.1e-06 4600 -2.55e-05 -9.44e-06
||
|| Results are averaged over the levels of: FS_Split, lang_type_ortho
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
```

```r
# estimate the slope of LogBF at each level of FS_Split:
emtrends(anova_model_2, ~ FS_Split, var = "LogBF_std")
```

Probe the Marginal LogBF × FS_Split Interaction

```
||  FS_Split LogBF_std.trend       SE   df  lower.CL  upper.CL
||  L               -1.07e-05 6.17e-06 4600 -2.28e-05  1.37e-06
||  S               -2.42e-05 5.38e-06 4600 -3.48e-05 -1.37e-05
||
|| Results are averaged over the levels of: lang_type_ortho
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
```

```r
# compare the two trends:
emtrends(anova_model_2, pairwise ~ FS_Split, var = "LogBF_std")
```

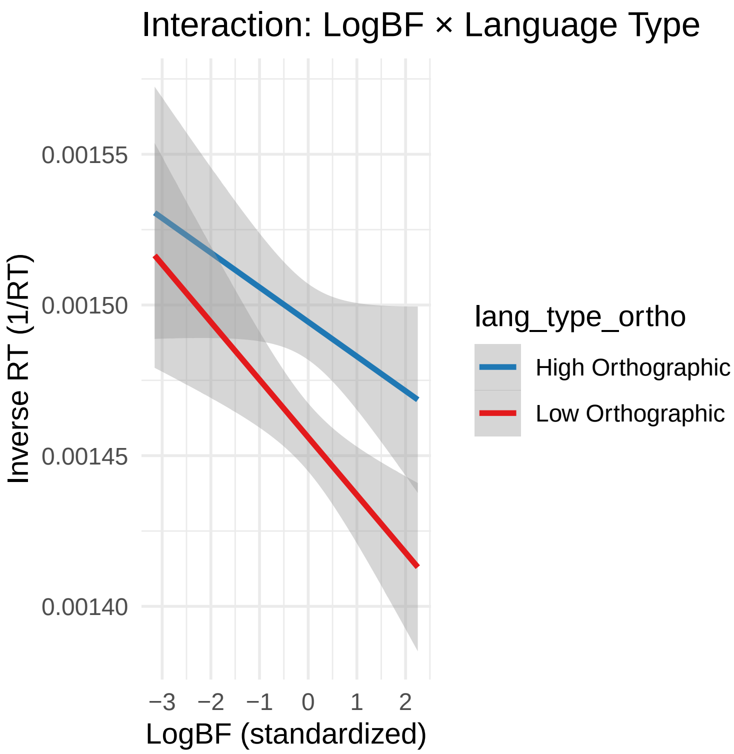
```
|| $emtrends
||  FS_Split LogBF_std.trend       SE   df  lower.CL  upper.CL
||  L               -1.07e-05 6.17e-06 4600 -2.28e-05  1.37e-06
||  S               -2.42e-05 5.38e-06 4600 -3.48e-05 -1.37e-05
||
|| Results are averaged over the levels of: lang_type_ortho
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
||
|| $contrasts
||  contrast estimate       SE   df t.ratio p.value
||  L - S    1.35e-05 8.19e-06 4600   1.646  0.0999
||
|| Results are averaged over the levels of: lang_type_ortho
|| Degrees-of-freedom method: kenward-roger
```

```r
# Estimate marginal means of inverse RT at LogBF_std = 0
emm <- emmeans(anova_model_2, ~ FS_Split, at = list(LogBF_std = 0))
emm_df <- as.data.frame(emm)

# Back-transform to milliseconds
emm_df$RT_ms <- 1 / emm_df$emmean
emm_df$CI_low_ms <- 1 / emm_df$upper.CL  # Note: upper bound of InvRT → lower RT
emm_df$CI_high_ms <- 1 / emm_df$lower.CL  # lower bound of InvRT → upper RT
print(emm_df)
```

```
||  FS_Split      emmean           SE    df    lower.CL    upper.CL    RT_ms CI_low_ms CI_high_ms
||  L        0.001469183 2.763687e-05 68.10 0.001414036 0.001524330 680.6503  656.0258   707.1956
||  S        0.001463722 2.755216e-05 67.27 0.001408732 0.001518713 683.1896  658.4523   709.8581
||
|| Results are averaged over the levels of: lang_type_ortho
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
```

Plots

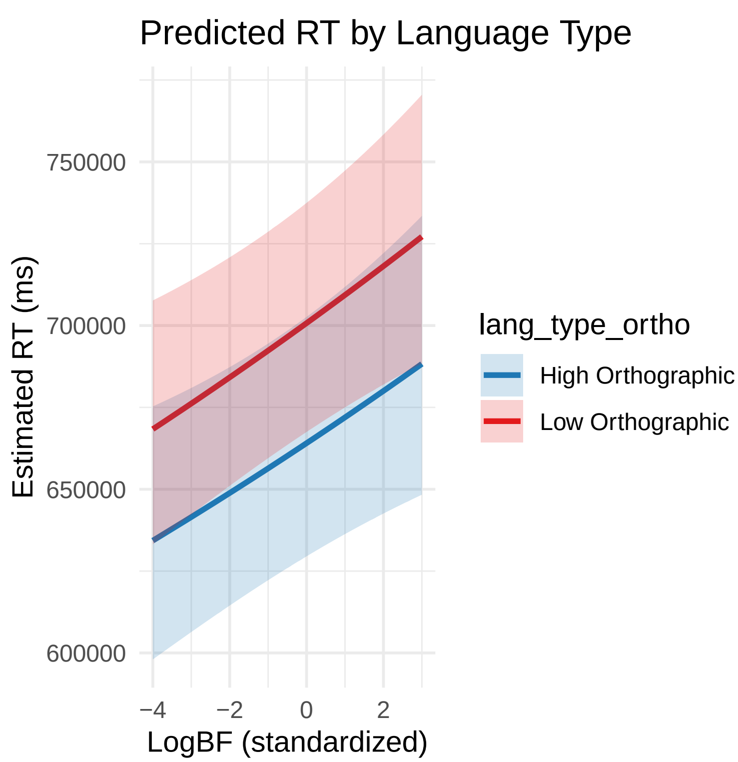
Plotting Processing Efficiency



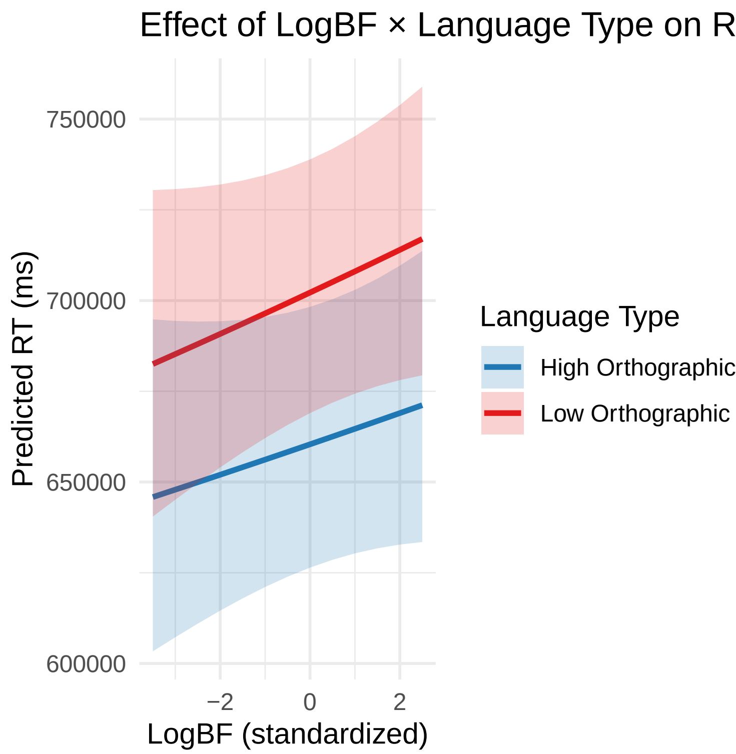
Plotting Latency To plot predicted values in milliseconds (RT) instead of inverse RT, you must: 1. Predict inverse RT values from the model 2. Back-transform to milliseconds with RT_ms = 1000 / InvRT 3. Plot the transformed values

When using ggeffects (or emmeans) with models fit using afex::mixed(). The mixed() function wraps lmer() from lme4, but the result isn't always fully compatible with tools like ggeffects because of the extra layers (especially when using Kenward-Roger or parametric bootstrap methods for inference).

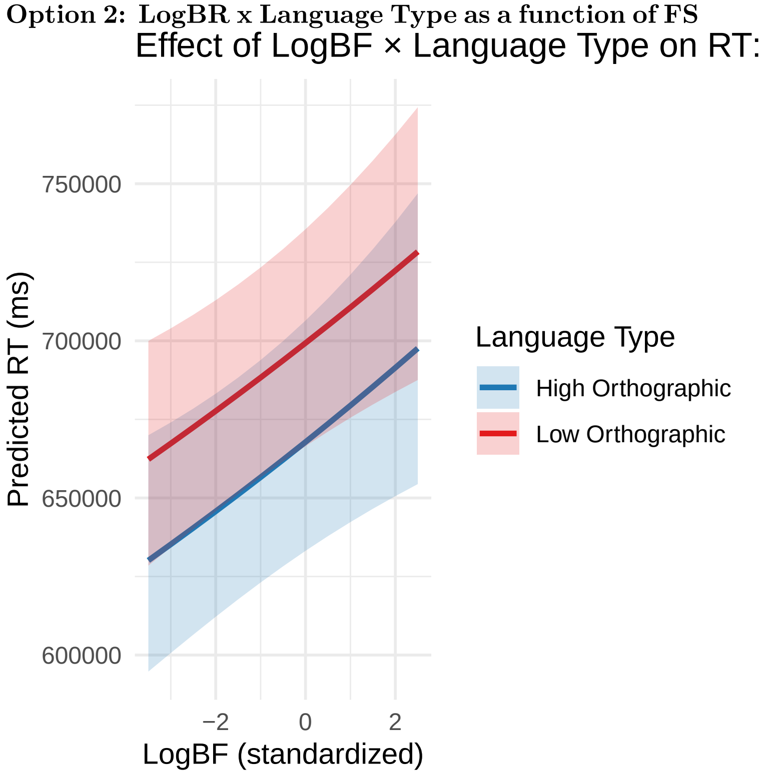
Because we are only using mixed() for the Kenward-Roger p-values but don't need it for prediction, refit our model with lmer():

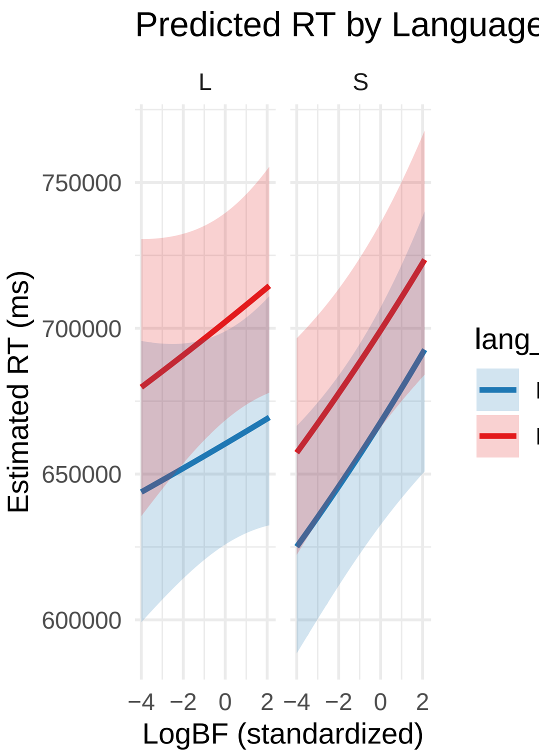


Option 1: Collapsed across Family Size



Option 2: LogBR x Language Type as a function of FS





Option 3: LogBR x Language Type as a function of FS (Faceted Plot)