M21 RT (Continuous Predictors)

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Contents

Setup

Load libraries

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1 Load Files and Format Files

1.1 Load Files

```
rt <- read_csv("rt_data_chrt1.csv",  show_col_types = FALSE)
frq_w <- read_csv("frq_cw.csv",  show_col_types = FALSE)
frq_nw <- read_csv("frq_nw.csv",  show_col_types = FALSE)
dmg <- read_csv("demo_lang_vsl_pca_hc.csv", show_col_types = FALSE)
```

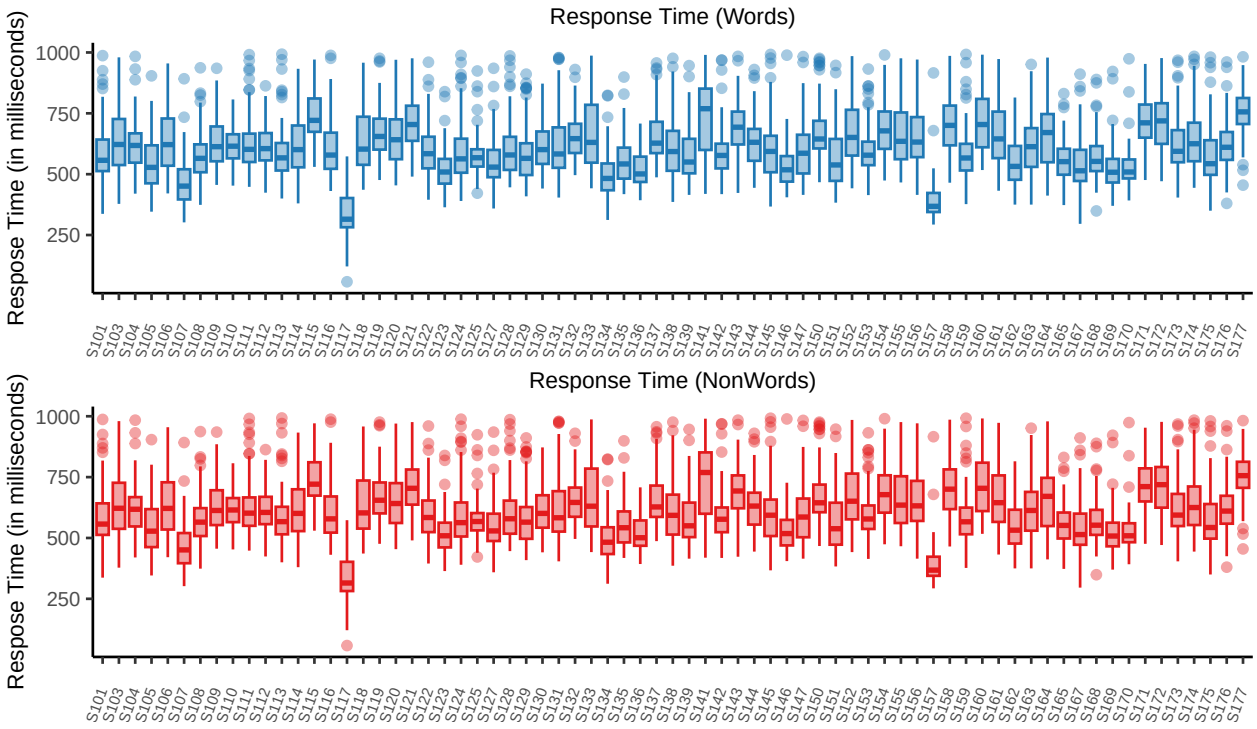
1.2 Format Files

```
# Concatenate datasets

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$BF_Split <- factor(rt_words_frq$BF_Split)
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)
```

1.3 Plot RT distributions

...



1.4 Test for Skewness

Response Time

```
# Words Skewness values
skewness(rt_words_frq$response_time, na.rm = TRUE)
```

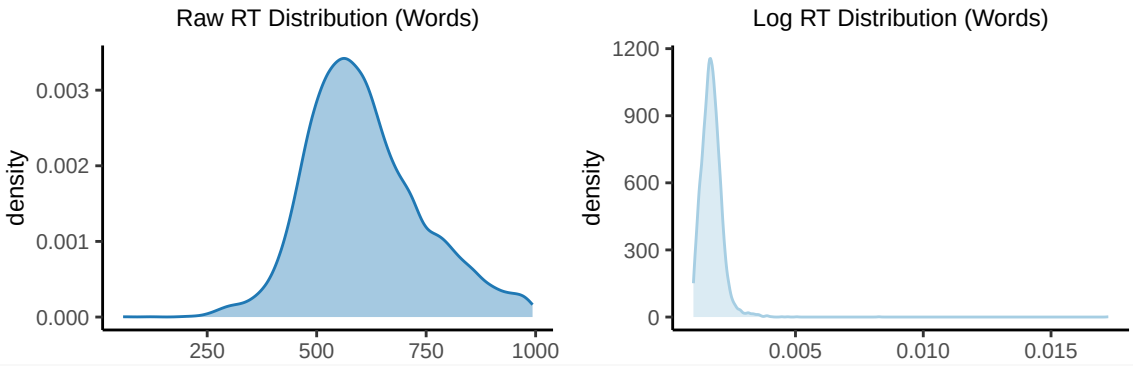
```
|| [1] 0.4868724
```

```
skewness(rt_words_frq$LogRT, na.rm = TRUE)
```

```
|| [1] -0.4362045
```

```
# Words Raw RT Distribution
p1 <- rt_words_frq |> ggplot(aes(x = response_time)) +
  geom_density(colour = "#1F78B4", fill = "#1F78B4", alpha = .4) +
  labs(title = "Raw RT Distribution (Words)") +
  theme( plot.title = element_text(size = 9, hjust = .5),
```

```
        legend.title = element_blank(),
        axis.title.x = element_blank(),
        axis.text.x = element_text(size = 8))

# Words Log RT Distribution
p2 <- rt_words_frq |> ggplot(aes(x = InvRT)) +
  geom_density(colour = "#A6CEE3", fill = "#A6CEE3", alpha = .4)  +
  labs(title = "Log RT Distribution (Words)") +
  theme( plot.title = element_text(size = 9, hjust = .5),
        legend.title = element_blank(),
        axis.title.x = element_blank(),
        axis.text.x = element_text(size = 8))
plot_grid(p1, p2, ncol = 2)
```



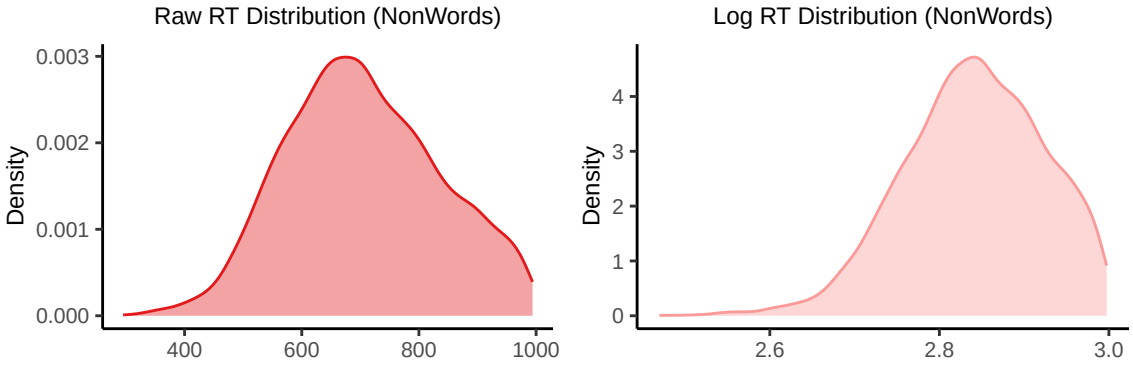

```
# NONWORDS
# Skewness values
skewness(rt_nwords_frq$response_time, na.rm = TRUE)
```

```
|| [1] 0.1000102
```

```
skewness(rt_nwords_frq$LogRT, na.rm = TRUE)
```

```
|| [1] -0.3817821
```

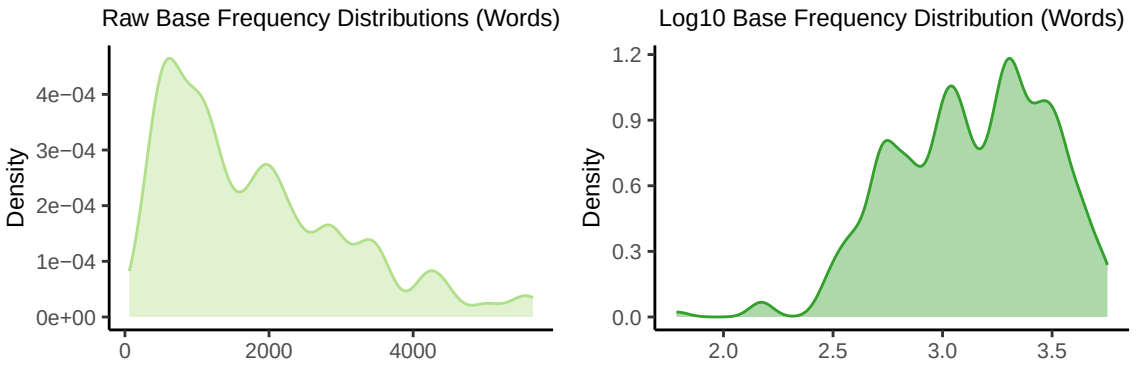
```
# Raw RT
p1 <- rt_nwords_frq |> ggplot(aes(x = response_time)) +
  geom_density(colour = "#E31A1C", fill = "#E31A1C", alpha = .4) +
  labs(y = "Density",title = "Raw RT Distribution (NonWords)") +
  theme( plot.title = element_text(size = 9, hjust = .5),
        legend.title = element_blank(),
        axis.title.x = element_blank(),
        axis.text.x = element_text(size = 8))
# LogRT
p2 <- rt_nwords_frq |> ggplot(aes(x = LogRT)) +
  geom_density(colour = "#FB9A99", fill = "#FB9A99", alpha = .4)  +
  labs(y = "Density", title = "Log RT Distribution (NonWords)") +
  theme( plot.title = element_text(size = 9, hjust = .5),
        legend.title = element_blank(),
        axis.title.x = element_blank(),
        axis.text.x = element_text(size = 8))
plot_grid(p1, p2, ncol = 2)
```




```
Base Frequency
```

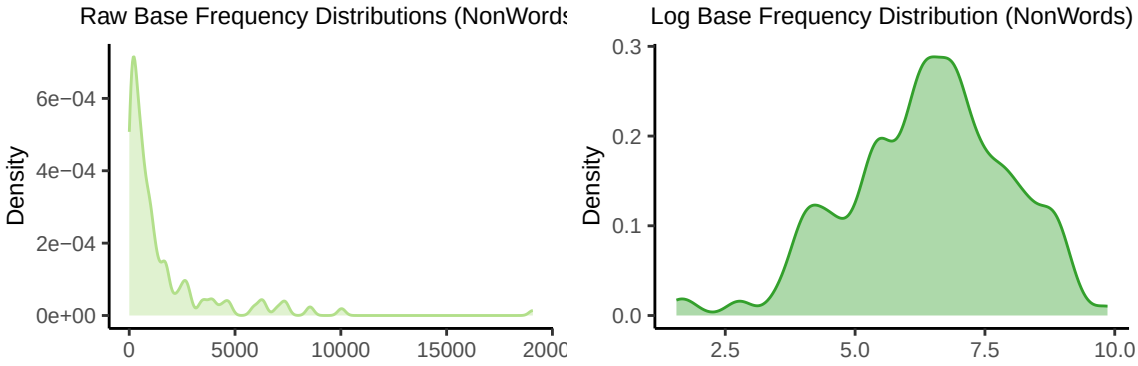
```
|| [1] 0.9870676
```

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




```
|| [1] 3.404106
```

```
|| [1] -0.3931931
```



Family Size

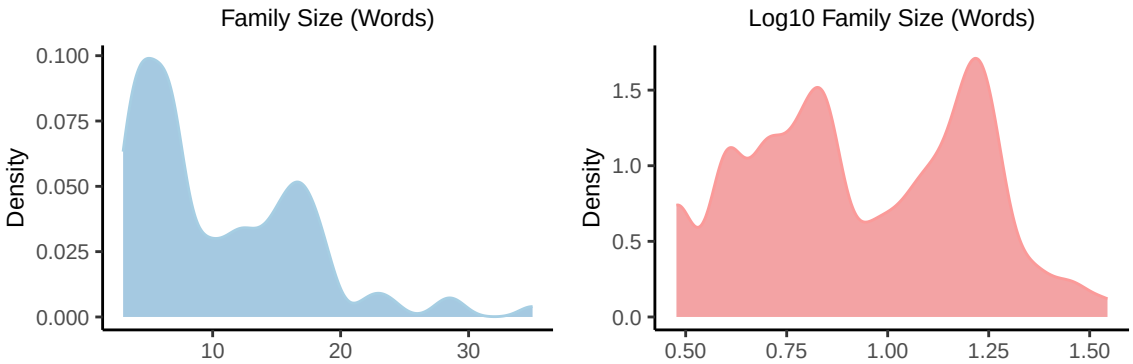
```
# Words
# Skewness values
rt_words_frq <- rt_words_frq |> mutate(Log10FS = log10(FS))
skewness(rt_words_frq$FS, na.rm = TRUE)
```

```
|| [1] 1.101473
```

```
skewness(rt_words_frq$Log10FS, na.rm = TRUE)
```

```
|| [1] 0.05781409
```

```
# Raw FS
p1 <- ggplot(rt_words_frq, aes(x = FS)) +
  geom_density(colour = "#A6CEE3", fill = "#1F78B4", alpha = .4) +
  labs(title = "Family Size (Words)", y = "Density") +
  theme( plot.title = element_text(size = 9, hjust = .5),
         legend.title = element_blank(),
         axis.title.x = element_blank(),
         axis.text.x = element_text(size = 8))
# Log10 FS
p2 <- ggplot(rt_words_frq, aes(x = Log10FS)) +
  geom_density(colour = "#FB9A99", fill = "#E31A1C", alpha = .4) +
  labs(title = "Log10 Family Size (Words)", y = "Density") +
  theme( plot.title = element_text(size = 9, hjust = .5),
         legend.title = element_blank(),
         axis.title.x = element_blank(),
         axis.text.x = element_text(size = 8))
plot_grid(p1, p2, ncol = 2)
```



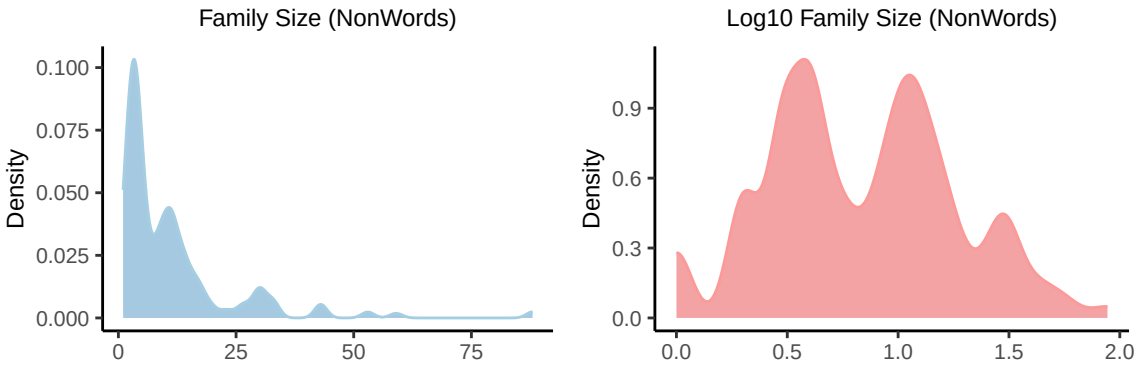

```
# NonWords
# Skewness values
rt_nwords_frq <- rt_nwords_frq |> mutate(Log10FS = log10(FS))
skewness(rt_nwords_frq$FS, na.rm = TRUE)
```

```
|| [1] 2.909422
```

```
skewness(rt_nwords_frq$Log10FS, na.rm = TRUE)
```

```
|| [1] 0.1536901
```

```
# Raw FS
p1 <- ggplot(rt_nwords_frq, aes(x = FS)) +
  geom_density(colour = "#A6CEE3", fill = "#1F78B4", alpha = .4) +
  labs(title = "Family Size (NonWords)", y = "Density") +
  theme( plot.title = element_text(size = 9, hjust = .5),
         legend.title = element_blank(),
         axis.title.x = element_blank(),
         axis.text.x = element_text(size = 8))
# Log10 FS
p2 <- ggplot(rt_nwords_frq, aes(x = Log10FS)) +
  geom_density(colour = "#FB9A99", fill = "#E31A1C", alpha = .4) +
  labs(title = "Log10 Family Size (NonWords)", y = "Density") +
  theme( plot.title = element_text(size = 9, hjust = .5),
         legend.title = element_blank(),
         axis.title.x = element_blank(),
         axis.text.x = element_text(size = 8))
plot_grid(p1, p2, ncol = 2)
```



1.5 ANOVA Words

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

Standardize the predictors

```
rt_words_cmpl$Log10BF_std <- as.numeric(scale(rt_words_cmpl$Log10BF, center = TRUE, scale = TRUE))
rt_words_cmpl$FS_std <- as.numeric(scale(rt_words_cmpl$FS, center = TRUE, scale = TRUE))
rt_words_cmpl$Log10WF_std <- as.numeric(scale(rt_words_cmpl$Log10WF, center = TRUE, scale = TRUE))
rt_words_cmpl$Log10FS_std <- as.numeric(scale(rt_words_cmpl$Log10FS, center = TRUE, scale = TRUE))
rt_words_cmpl$Dim.2_std <- as.numeric(scale(rt_words_cmpl$Dim.2, center = TRUE, scale = TRUE))
```

1.5.1 Anova with Continuous Log10BF and Continuous Log10FS

```
# Anova with Continuous Log10BF AND Continous FS
anova_model <- mixed(
  response_time ~ Log10BF_std * Log10FS_std * Orthographic_Sensitivity + (1  | SubjID),
```

```
  data = rt_words_cmpl,
  method = "KR"
)
anova_model
```

```
|| Mixed Model Anova Table (Type 3 tests, KR-method)
||
|| Model: response_time ~ Log10BF_std * Log10FS_std * Orthographic_Sensitivity +
|| Model:     (1 | SubjID)
|| Data: rt_words_cmpl
||                                          Effect         df         F p.value
|| 1                                  Log10BF_std 1, 5792.73 44.34 ***   <.001
|| 2                                  Log10FS_std 1, 5792.42 31.10 ***   <.001
|| 3                        Orthographic_Sensitivity   1, 64.04    3.48 +    .067
|| 4                         Log10BF_std:Log10FS_std 1, 5792.49      0.09    .764
|| 5            Log10BF_std:Orthographic_Sensitivity 1, 5792.73      1.80    .180
|| 6            Log10FS_std:Orthographic_Sensitivity 1, 5792.42      0.06    .804
|| 7 Log10BF_std:Log10FS_std:Orthographic_Sensitivity 1, 5792.49      1.00    .317
|| ---
|| Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1 ' ' 1
```

```
summary(anova_model)
```

```
|| Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
|| Formula: response_time ~ Log10BF_std * Log10FS_std * Orthographic_Sensitivity +      (1 | SubjID)
||    Data: data
||
|| REML criterion at convergence: 71992
||
|| Scaled residuals:
||     Min      1Q  Median      3Q     Max
|| -3.0178 -0.6874 -0.1449  0.5139  4.7355
||
|| Random effects:
||  Groups   Name        Variance Std.Dev.
||  SubjID   (Intercept)  5272     72.61
||  Residual             12136    110.16
|| Number of obs: 5864, groups:  SubjID, 66
||
|| Fixed effects:
||                                                Estimate Std. Error        df t value Pr(>|t|)
|| (Intercept)                                    610.6175     9.0723   63.8685  67.306  < 2e-16 ***
|| Log10BF_std                                    -10.1087     1.5181 5792.5608  -6.659 3.02e-11 ***
|| Log10FS_std                                     -8.1418     1.4599 5792.2546  -5.577 2.56e-08 ***
|| Orthographic_Sensitivity1                      -16.9147     9.0723   63.8685  -1.864   0.0669 .
|| Log10BF_std:Log10FS_std                          0.4676     1.5576 5792.3235   0.300   0.7640
|| Log10BF_std:Orthographic_Sensitivity1           -2.0361     1.5181 5792.5608  -1.341   0.1799
|| Log10FS_std:Orthographic_Sensitivity1            0.3628     1.4599 5792.2546   0.248   0.8038
|| Log10BF_std:Log10FS_std:Orthographic_Sensitivity1   -1.5574     1.5576 5792.3235  -1.000   0.3174
|| ---
|| Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
||
|| Correlation of Fixed Effects:
||                (Intr) Lg10BF_ Lg10FS_ Ort_S1 Lg10BF_:L10FS_ L10BF_:O L10FS_:
|| Log10BF_std    -0.005
|| Log10FS_std     0.002 -0.134
|| Orthgrph_S1    -0.060 -0.001   0.002
|| Lg10BF_:L10FS_ -0.018  0.298  -0.120   0.000
|| L10BF_:O_S1    -0.001 -0.017   0.000  -0.005  0.007
|| L10FS_:O_S1     0.002  0.000  -0.044   0.002 -0.005         -0.134
|| L10BF_:L10FS_:  0.000  0.007  -0.005  -0.018 -0.022          0.298   -0.120
```

```
eta_squared(anova_model, partial = TRUE)
```

```
|| # Effect Size for ANOVA (Type III)
||
|| Parameter                                   | Eta2 (partial) |       95% CI
|| ------------------------------------------------------------------------------
|| Log10BF_std                                 |       7.60e-03 | [0.00, 1.00]
|| Log10FS_std                                 |       5.34e-03 | [0.00, 1.00]
|| Orthographic_Sensitivity                    |           0.05 | [0.00, 1.00]
|| Log10BF_std:Log10FS_std                     |       1.56e-05 | [0.00, 1.00]
|| Log10BF_std:Orthographic_Sensitivity        |       3.10e-04 | [0.00, 1.00]
|| Log10FS_std:Orthographic_Sensitivity        |       1.07e-05 | [0.00, 1.00]
|| Log10BF_std:Log10FS_std:Orthographic_Sensitivity |       1.73e-04 | [0.00, 1.00]
||
|| - One-sided CIs: upper bound fixed at [1.00].
```

1.5.2 Effects

Effect	df	F	p.value
Log10BF_std	1, 5792.73	44.34 ***	<.001
Log10FS_std	1, 5792.42	31.10 ***	<.001
Orthographic_Sensitivity	1, 64.04	3.48 +	.067
Log10BF:FS:Ortho_Sensitivity	1, 5792.49	1.00	.317

Main Effect of Family Size, Orthographic Sensitivity, Base Frequency

```
emm_options(pbkrtest.limit = 5864)
emtrends(anova_model, ~1, var = "Log10FS_std")
```

```
||  1       Log10FS_std.trend   SE   df lower.CL upper.CL
||  overall             -8.14 1.46 5792      -11    -5.28
||
|| Results are averaged over the levels of: Orthographic_Sensitivity
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
```

```
emtrends(anova_model, ~1, var = "Log10BF_std")
```

```
||  1       Log10BF_std.trend   SE   df lower.CL upper.CL
||  overall             -10.1 1.52 5793    -13.1    -7.13
||
|| Results are averaged over the levels of: Orthographic_Sensitivity
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
```

```
emmeans_obj <- emmeans(anova_model, pairwise ~ Orthographic_Sensitivity)
cohensd_df <- as.data.frame(cohens_d(response_time ~ Orthographic_Sensitivity, data = rt_words_cmpl))
contrasts_df <- as.data.frame(emmeans_obj$contrasts)
(ortho_sens_contrasts <- bind_cols(contrasts_df,cohensd_df))
```

```
||  contrast                              estimate       SE    df t.ratio p.value   Cohens_d   CI     CI_low    CI_high
||  High Orthographic - Low Orthographic -33.82941 18.14466 64.04  -1.864  0.0668 -0.2458167 0.95 -0.2972398 -0.1943728
||
|| Degrees-of-freedom method: kenward-roger
```

```
(ortho_sens_means <-as.data.frame(emmeans_obj$emmeans))
```

```
||  Orthographic_Sensitivity   emmean       SE    df lower.CL upper.CL
||  High Orthographic        593.7028 12.43703 64.07 568.8575 618.5481
||  Low Orthographic         627.5322 13.21170 64.01 601.1388 653.9255
||
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
```

Base Frequency by Orthographic Sensitivity Interaction

```
# estimate simple slopes of base frequency by group:
emtrends(anova_model, ~ Orthographic_Sensitivity, var = "Log10BF_std")
```

```
||  Orthographic_Sensitivity Log10BF_std.trend   SE   df lower.CL upper.CL
||  High Orthographic                  -12.14 2.13 5793    -16.3    -7.97
||  Low Orthographic                    -8.07 2.17 5793    -12.3    -3.83
||
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
```

```
emtrends(anova_model, pairwise ~ Orthographic_Sensitivity, var = "Log10BF_std")
```

```
|| $emtrends
||  Orthographic_Sensitivity Log10BF_std.trend   SE   df lower.CL upper.CL
||  High Orthographic                  -12.14 2.13 5793    -16.3    -7.97
||  Low Orthographic                    -8.07 2.17 5793    -12.3    -3.83
||
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
||
|| $contrasts
||  contrast                              estimate   SE   df t.ratio p.value
||  High Orthographic - Low Orthographic    -4.07 3.04 5793  -1.341  0.1799
||
|| Degrees-of-freedom method: kenward-roger
```

```
# Estimate marginal means of RT at the mean of both predictors
emm <- emmeans(anova_model, ~ Orthographic_Sensitivity, at = list(Log10BF_std = 0, Log10FS_std = 0))
emm_df <- as.data.frame(emm)

print(emm_df)
```

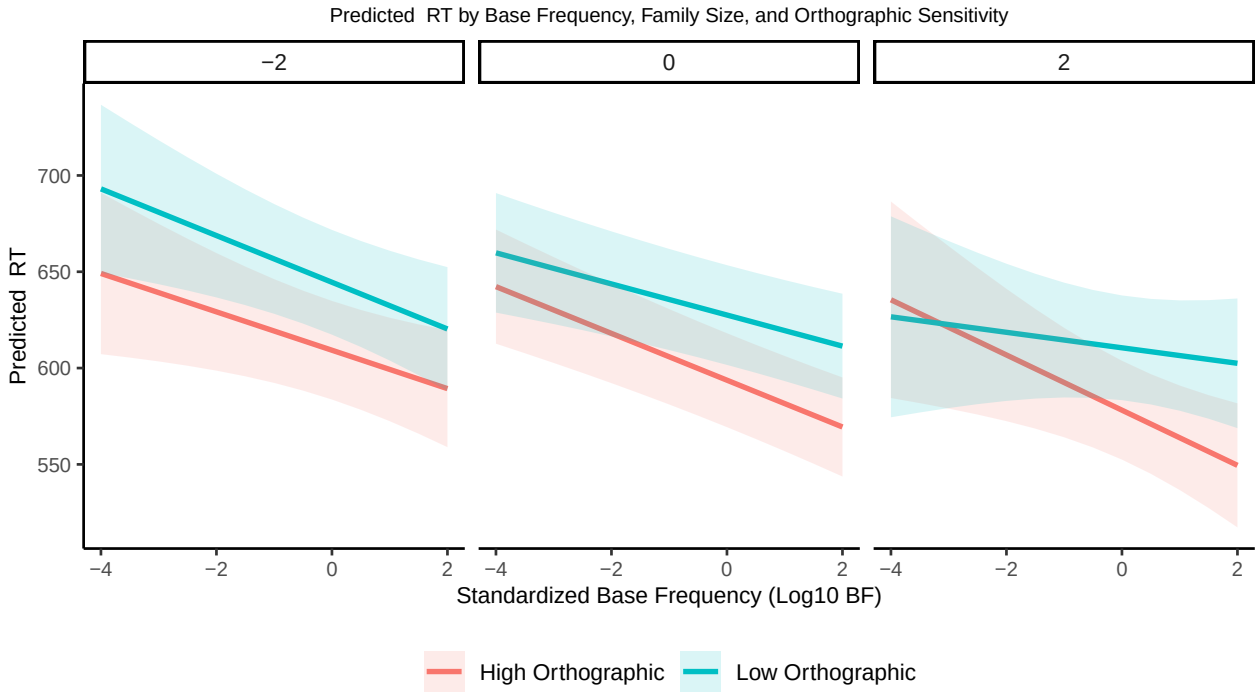
```
||  Orthographic_Sensitivity   emmean       SE    df lower.CL upper.CL
||  High Orthographic        593.7028 12.43703 64.07 568.8575 618.5481
```

```
||  Low Orthographic         627.5322 13.21170 64.01 601.1388 653.9255
||
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
```

1.5.3 Plots

Family Size x Base Frequency x Orthographic Sensitivity

```
# re-run anova with lmer to use `ggeffects`
anova_model_lmer <- lmer(response_time ~ Log10BF_std * Log10FS_std * Orthographic_Sensitivity + (1 | SubjID), data = rt_words_cmpl)
# Generate predicted values
preds <- ggpredict(anova_model_lmer, terms = c("Log10BF_std", "Orthographic_Sensitivity", "Log10FS_std [-2,0,2]"))

# Plot
ggplot(preds, aes(x = x, y = predicted, color = group, fill = group)) +
  geom_line(linewidth = 1) +
  geom_ribbon(aes(ymin = conf.low, ymax = conf.high), alpha = 0.15, color = NA) +
  facet_wrap(~facet, labeller = label_value) +
  labs(x = "Standardized Base Frequency (Log10 BF)",
       y = "Predicted  RT",
       color = "Family Size (Log10 FS)",
       fill = "Family Size (Log10 FS)",
       title = "Predicted  RT by Base Frequency, Family Size, and Orthographic Sensitivity")+
  theme( plot.title = element_text(size = 8, hjust = .5),
         legend.title = element_blank(),
         axis.text.x = element_text(size = 8))
```



1.6 ANOVA Non-Words

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

Standardize the predictors

```
rt_nwords_cmpl$Log10BF_std <- as.numeric(scale(rt_nwords_cmpl$Log10BF, center = TRUE, scale = TRUE))
rt_nwords_cmpl$FS_std <- as.numeric(scale(rt_nwords_cmpl$FS, center = TRUE, scale = TRUE))
rt_nwords_cmpl$Log10FS_std <- as.numeric(scale(rt_nwords_cmpl$Log10FS, center = TRUE, scale = TRUE))
rt_nwords_cmpl$BF_std <- as.numeric(scale(rt_nwords_cmpl$BF, center = TRUE, scale = TRUE))
rt_nwords_cmpl$Dim.2_std <- as.numeric(scale(rt_nwords_cmpl$Dim.2, center = TRUE, scale = TRUE))
rt_nwords_cmpl <- rt_nwords_cmpl |>  select(-complexity.x)
rt_nwords_cmpl <- rename(rt_nwords_cmpl, complexity = complexity.y)
```

Test Correlation between Base Frequency and Complexity

```
t.test(Log10BF ~ complexity, data = rt_nwords_cmpl)
```

```
||
||  Welch Two Sample t-test
```

```
||
|| data:  Log10BF by complexity
|| t = -0.7232, df = 4547.8, p-value = 0.4696
|| alternative hypothesis: true difference in means between group Complex and group Simple is not equal to 0
|| 95 percent confidence interval:
||  -0.05059200  0.02332506
|| sample estimates:
|| mean in group Complex  mean in group Simple
||              2.793225              2.806859
```

```
# Create a contingency table
table_data <- table(rt_nwords_cmpl$complexity, rt_nwords_cmpl$BF_Split)

# Run the chi-square test
chisq.test(table_data)
```

```
||
||  Pearson's Chi-squared test with Yates' continuity correction
||
|| data:  table_data
|| X-squared = 3.9314, df = 1, p-value = 0.04739
```

1.6.1 Anova with Continuous Log10BF and Categorical Complexity

```
anova_model_2 <- mixed(
  response_time ~ complexity * Log10FS_std * Orthographic_Sensitivity + (1  | SubjID),
  data = rt_nwords_cmpl,
  method = "KR"
)
anova_model_2
```

```
|| Mixed Model Anova Table (Type 3 tests, KR-method)
||
|| Model: response_time ~ complexity * Log10FS_std * Orthographic_Sensitivity +
|| Model:     (1 | SubjID)
|| Data: rt_nwords_cmpl
||                                         Effect         df          F p.value
|| 1                                   complexity 1, 4601.21 106.13 ***   <.001
|| 2                                 Log10FS_std 1, 4600.02       2.49    .115
|| 3                       Orthographic_Sensitivity   1, 64.11     5.32 *    .024
|| 4                         complexity:Log10FS_std 1, 4600.65     3.96 *    .047
|| 5            complexity:Orthographic_Sensitivity 1, 4601.21       0.68    .408
|| 6           Log10FS_std:Orthographic_Sensitivity 1, 4600.02       0.04    .846
|| 7 complexity:Log10FS_std:Orthographic_Sensitivity 1, 4600.65       0.29    .590
|| ---
|| 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: response_time ~ complexity * Log10FS_std * Orthographic_Sensitivity +      (1 | SubjID)
||    Data: data
||
|| REML criterion at convergence: 56995.5
||
|| Scaled residuals:
||     Min      1Q  Median      3Q     Max
|| -3.1330 -0.7114 -0.0816  0.6377  4.1120
||
|| Random effects:
||  Groups   Name        Variance Std.Dev.
||  SubjID   (Intercept)  7095     84.23
||  Residual             11145    105.57
|| Number of obs: 4671, groups:  SubjID, 66
||
|| Fixed effects:
||                                                Estimate Std. Error        df t value Pr(>|t|)
|| (Intercept)                                    715.6108    10.5228   62.5863  68.006   <2e-16 ***
|| complexity1                                     16.2736     1.5797 4599.6974  10.302   <2e-16 ***
|| Log10FS_std                                      2.5006     1.5854 4598.4808   1.577   0.1148
|| Orthographic_Sensitivity1                      -24.2792    10.5228   62.5863  -2.307   0.0244 *
|| complexity1:Log10FS_std                          3.1569     1.5870 4599.1311   1.989   0.0467 *
|| complexity1:Orthographic_Sensitivity1           -1.3060     1.5797 4599.6974  -0.827   0.4084
|| Log10FS_std:Orthographic_Sensitivity1            0.3085     1.5854 4598.4808   0.195   0.8457
|| complexity1:Log10FS_std:Orthographic_Sensitivity1    0.8552     1.5870 4599.1311   0.539   0.5900
|| ---
|| Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
||
|| Correlation of Fixed Effects:
||             (Intr) cmplx1 Lg10FS_ Ort_S1 cm1:L10FS_ c1:O_S L10FS_:
|| complexity1  0.025
```

```
|| Log10FS_std  0.003  0.031
|| Orthgrph_S1 -0.064 -0.006 -0.004
|| cmp1:L10FS_  0.005  0.014  0.178  -0.002
|| cmplx1:O_S1 -0.006 -0.123 -0.014   0.025 -0.022
|| L10FS_:O_S1 -0.004 -0.014 -0.125   0.003 -0.024      0.031
|| c1:L10FS_:O -0.002 -0.022 -0.024   0.005 -0.126      0.014  0.178
```

1.6.2 Effects

Effect	df	F	p.value
complexity	1, 4600.75	106.13 ***	<.001
Orthographic_Sensitivity	1, 64.11	5.32 *	.024
complexity:Log10FS_std	1, 4600.65	3.96 *	.047

```
# Complexity
emmeans_obj <- emmeans(anova_model_2, pairwise ~ complexity)
cohensd_df <- as.data.frame(cohens_d(response_time ~ complexity, data = rt_nwords_cmpl))
contrasts_df <- as.data.frame(emmeans_obj$contrasts)
(complexity_df <- bind_cols(contrasts_df,cohensd_df))
```

```
||  contrast         estimate       SE      df t.ratio p.value Cohens_d   CI    CI_low   CI_high
||  Complex - Simple 32.54719 3.159352 4601.21  10.302  <.0001  0.21345 0.95 0.1552988 0.2715784
||
|| Results are averaged over the levels of: Orthographic_Sensitivity
|| Degrees-of-freedom method: kenward-roger
```

```
(complexity_means <-as.data.frame(emmeans_obj$emmeans))
```

```
||  complexity   emmean       SE    df lower.CL upper.CL
||  Complex    731.8844 10.67933 68.01 710.5742 753.1947
||  Simple     699.3372 10.60207 66.07 678.1699 720.5045
||
|| Results are averaged over the levels of: Orthographic_Sensitivity
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
```

```
# Orthographic_Sensitivity
emmeans_obj <- emmeans(anova_model_2, pairwise ~ Orthographic_Sensitivity)
cohensd_df <- as.data.frame(cohens_d(response_time ~ Orthographic_Sensitivity, data = rt_nwords_cmpl))
contrasts_df <- as.data.frame(emmeans_obj$contrasts)
(ortho_sens_df <- bind_cols(contrasts_df,cohensd_df))
```

```
||  contrast                              estimate       SE    df t.ratio p.value   Cohens_d   CI     CI_low    CI_high
||  High Orthographic - Low Orthographic -48.55848 21.04573 64.11  -2.307  0.0243 -0.2542169 0.95 -0.3121916 -0.1962152
||
|| Results are averaged over the levels of: complexity
|| Degrees-of-freedom method: kenward-roger
```

```
(ortho_sens_means <-as.data.frame(emmeans_obj$emmeans))
```

```
||  Orthographic_Sensitivity   emmean       SE    df lower.CL upper.CL
||  High Orthographic        691.3316 14.40093 63.72 662.5600 720.1031
||  Low Orthographic         739.8901 15.34718 64.46 709.2348 770.5454
||
|| Results are averaged over the levels of: complexity
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
```

```
# Estimate the effect of complexity at low, mean, and high FS
em_complexity <- emmeans(anova_model_2, ~ complexity | Log10FS_std, at = list(Log10FS_std = c(-1, 0, 1)))
summary(em_complexity)
```

```
|| Log10FS_std = -1:
||  complexity emmean   SE   df lower.CL upper.CL
||  Complex       726 10.9 74.6      704      748
||  Simple        700 10.8 71.2      678      722
||
|| Log10FS_std =  0:
||  complexity emmean   SE   df lower.CL upper.CL
||  Complex       732 10.7 68.0      711      753
||  Simple        699 10.6 66.1      678      721
||
|| Log10FS_std =  1:
||  complexity emmean   SE   df lower.CL upper.CL
||  Complex       738 11.0 75.9      716      759
||  Simple        699 10.8 70.8      677      720
||
|| Results are averaged over the levels of: Orthographic_Sensitivity
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
```

```r
# Estimate the slope of Log10FS within each complexity level
em_trends <- emtrends(anova_model_2, ~ complexity, var = "Log10FS_std")
summary(em_trends)
```

```
||  complexity Log10FS_std.trend   SE   df lower.CL upper.CL
||  Complex                5.657 2.43 4601    0.885    10.43
||  Simple                -0.656 2.03 4600   -4.644     3.33
||
|| Results are averaged over the levels of: Orthographic_Sensitivity
|| Degrees-of-freedom method: kenward-roger
|| Confidence level used: 0.95
```

1.6.3 Plots

...

```r
# Plot

# Refit the model using lmer()
anova_model_lmer <- lmer(
  response_time ~ complexity * Log10FS_std * Orthographic_Sensitivity + (1 | SubjID),
  data = rt_nwords_cmpl,
  REML = FALSE
)

# Get predicted values
preds <- ggpredict(anova_model_lmer, terms = c("Log10FS_std", "complexity"))

# Plot
ggplot(preds, aes(x = x, y = predicted, color = group, fill = group)) +
  geom_line(linewidth = 1) +
  geom_ribbon(aes(ymin = conf.low, ymax = conf.high), alpha = 0.2, color = NA) +
  labs(x = "Standardized Log Family Size",
       y = "Predicted RT (ms)",
       color = "Complexity",
       fill = "Complexity",
       title = "Interaction of Morphological Complexity and Family Size on RT") +
  theme( plot.title = element_text(size = 8, hjust = .5),
         legend.title = element_blank(),
         axis.text.x = element_text(size = 8))
```