

E3 alignment

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2025-10-08

This notebook analyzes alignment values using a Bayesian approach.

```
set.seed(15000)
```

Load the data.

```
data <- read_csv('../data/E3/alignment.csv', show_col_types = FALSE)
```

Check number of subjects per group.

```
length(unique(filter(data, Musician == 'Yes')$sub))
```

```
## [1] 49
```

```
length(unique(filter(data, Musician == 'No')$sub))
```

```
## [1] 46
```

Make sure non-musicians and musicians are labelled with different numbers.

```
data %>% mutate(sub = ifelse(Musician == 'Yes', sub, sub + 49))
```

Pivot the data longer.

```
data %>% pivot_longer(cols = -c(Musician, sub, scramble),
                        names_to = 'level', values_to = 'value')
```

Make group, scramble, and level into factors and set contrasts.

```
data %>% mutate(
  Musician = factor(Musician, levels = c('Yes', 'No')),
  scramble = factor(scramble, levels = c('Intact', '8B', '2B', '1B')),
  level = factor(level, levels = c(1,2,3,4,5,8,16), ordered = TRUE)
)

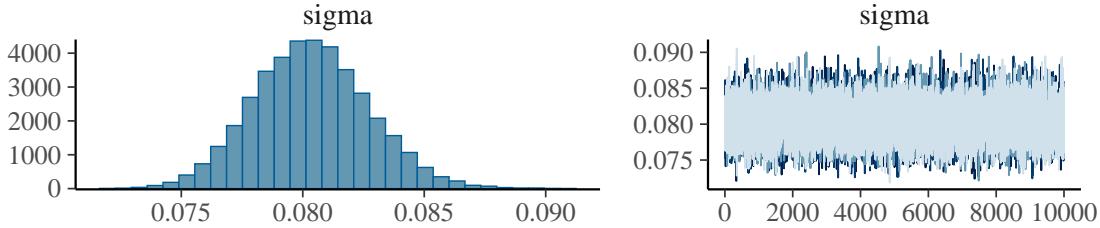
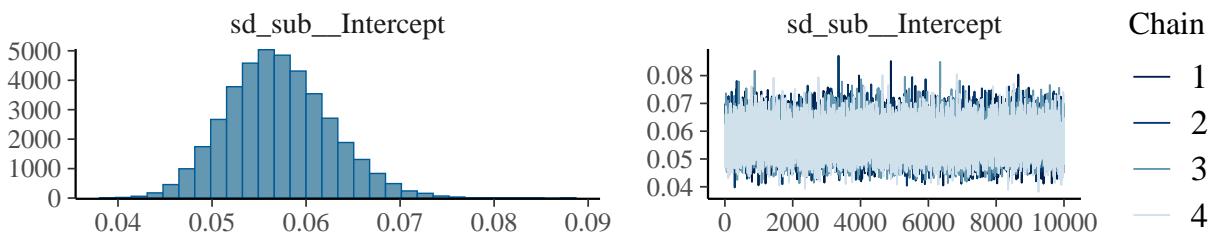
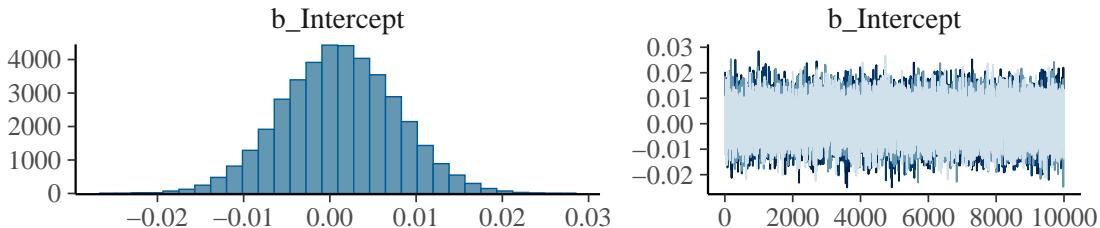
contrasts(data$scramble) <- contr.treatment(4) # Intact as reference
contrasts(data$level) <- contr.treatment(7, base = 6) # 8-bar as reference
contrasts(data$Musician) <- c(-1,1)
```

1B

```
data1B <- filter(data, scramble == '1B')

levels1B_null <- brm(value ~ 1 + (1|sub), data = data1B,
                      save_pars = save_pars(all = TRUE),
                      iter = 20000, refresh = 0,
                      file = 'models/E3_alignment_1B_null')

plot(levels1B_null)
```



```
print(summary(levels1B_null, robust = TRUE), digits = 4)
```

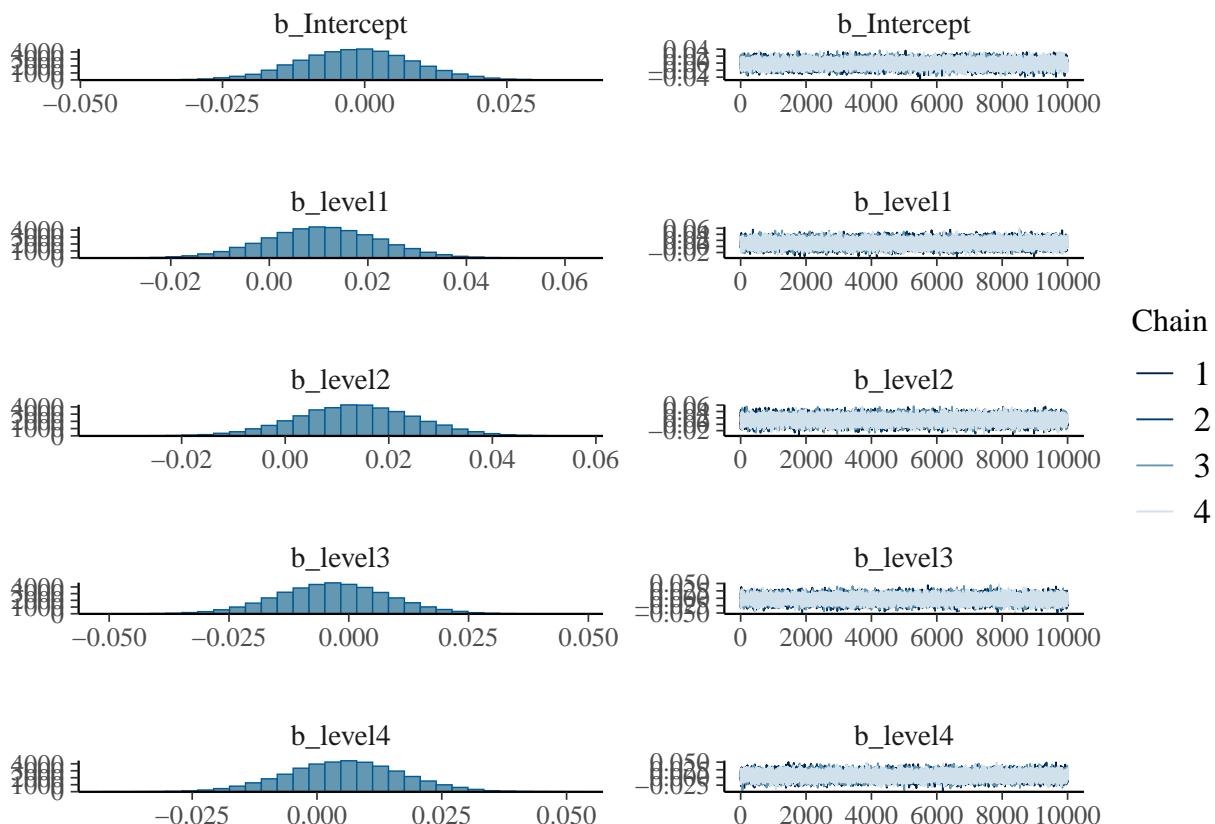
```
##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ 1 + (1 | sub)
##  Data: data1B (Number of observations: 665)
##  Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##          total post-warmup draws = 40000
##
##  Multilevel Hyperparameters:
##  ~sub (Number of levels: 95)
##                Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  sd(Intercept)   0.0568     0.0054    0.0471    0.0685 1.0001     13786    20106
## 
##  Regression Coefficients:
##                Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  Intercept      0.0011     0.0067   -0.0119    0.0141 1.0001     19091    25315
```

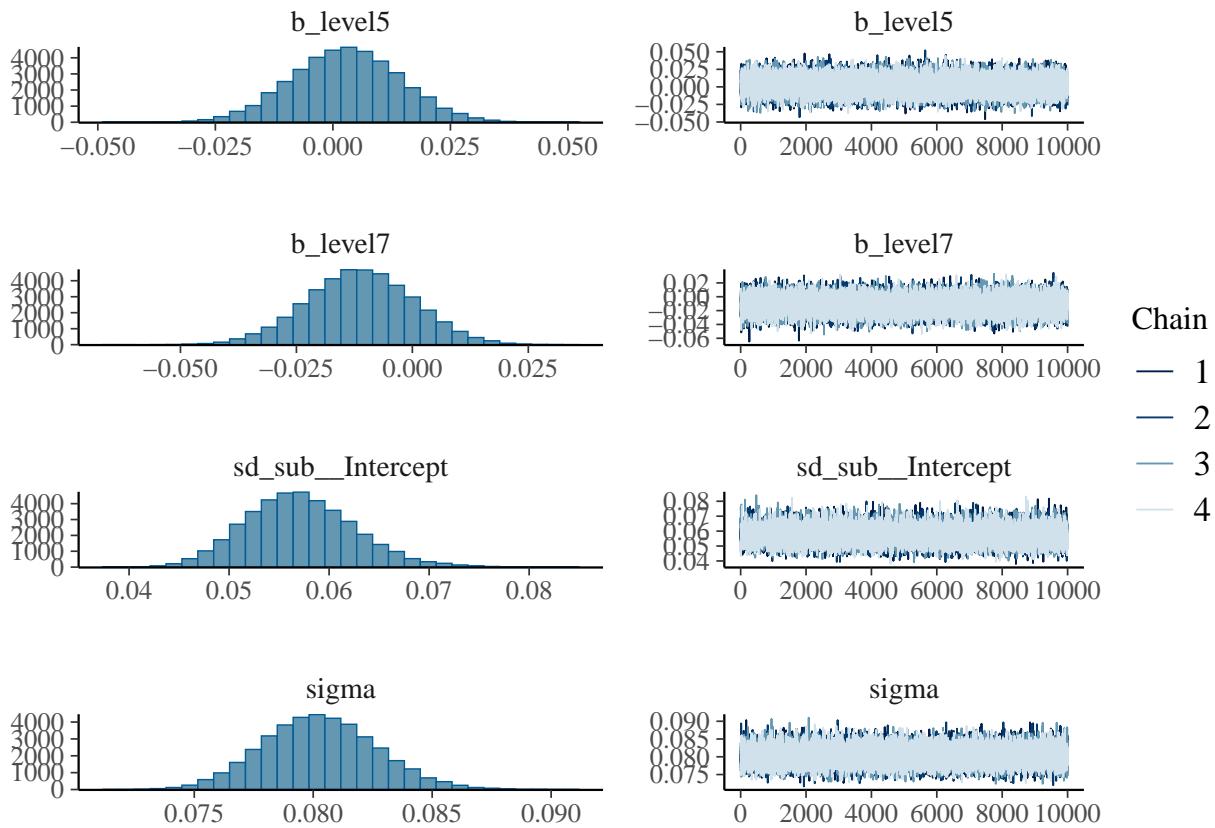
```

## Further Distributional Parameters:
## Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma    0.0803     0.0024    0.0759    0.0851 1.0001      52319     30089
##
## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
levels1B <- brm(value ~ level + (1|sub), data = data1B,
                  prior = c(
                    set_prior('normal(-0.2, 0.1)', coef = c('level1', 'level2', 'level3', 'level5')),
                    set_prior('normal(-0.1, 0.1)', coef = c('level4', 'level7')))
                  ),
                  save_pars = save_pars(all = TRUE), iter = 20000, refresh = 0,
                  file = 'models/E3_alignment_1B')

plot(levels1B)

```





```
print(summary(levels1B, robust = TRUE), digits = 4)
```

```
##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ level + (1 | sub)
##  Data: data1B (Number of observations: 665)
##  Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##          total post-warmup draws = 40000
##
## Multilevel Hyperparameters:
## ~sub (Number of levels: 95)
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sd(Intercept) 0.0568     0.0054   0.0471   0.0687 1.0002    14689    20381
##
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept -0.0015     0.0100  -0.0212   0.0182 1.0004    25534    27632
## level1    0.0107     0.0116  -0.0119   0.0331 1.0000    37154    33500
## level2    0.0136     0.0114  -0.0088   0.0360 1.0002    37210    34127
## level3   -0.0033     0.0115  -0.0259   0.0195 1.0000    37898    34044
## level4    0.0056     0.0114  -0.0168   0.0280 1.0001    36744    33742
## level5    0.0028     0.0116  -0.0199   0.0255 1.0001    37533    33898
## level7   -0.0112     0.0115  -0.0339   0.0112 1.0000    37200    34049
##
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma     0.0802     0.0024   0.0758   0.0851 1.0000    50356    32184
##
```

```

## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
BF_1B_level <- bayes_factor(levels1B, levels1B_null)

## Iteration: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4
## Iteration: 5
## Iteration: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4
## Iteration: 5

print(formatC(BF_1B_level$bf, format = 'e'))

```

```
## [1] "2.3674e-09"
```

There is very strong evidence against a main effect of level.

```

emm_1B <- emmeans(levels1B, specs = "level")
summary(emm_1B)

```

```

##   level    emmean lower.HPD upper.HPD
## 1      0.00923 -0.01047  0.02914
## 2      0.01205 -0.00776  0.03200
## 3     -0.00479 -0.02440  0.01518
## 4      0.00397 -0.01540  0.02412
## 5      0.00133 -0.01866  0.02118
## 8     -0.00148 -0.02113  0.01821
## 16     -0.01265 -0.03272  0.00685
##
## Point estimate displayed: median
## HPD interval probability: 0.95

```

All levels at chance.

```
contrast(emm_1B, method = "pairwise")
```

```

##   contrast      estimate lower.HPD upper.HPD
## 1 level1 - level2 -0.00288 -0.025488  0.0200
## 2 level1 - level3  0.01403 -0.008339  0.0372
## 3 level1 - level4  0.00521 -0.017642  0.0277
## 4 level1 - level5  0.00798 -0.014459  0.0311
## 5 level1 - level8  0.01074 -0.012155  0.0327
## 6 level1 - level16 0.02206 -0.000347  0.0451
## 7 level2 - level3  0.01691 -0.006175  0.0393
## 8 level2 - level4  0.00802 -0.014557  0.0307
## 9 level2 - level5  0.01091 -0.011918  0.0338
## 10 level2 - level8 0.01364 -0.007985  0.0367
## 11 level2 - level16 0.02486  0.002309  0.0473
## 12 level3 - level4 -0.00878 -0.031879  0.0136
## 13 level3 - level5 -0.00604 -0.028997  0.0169
## 14 level3 - level8 -0.00328 -0.025184  0.0201
## 15 level3 - level16 0.00791 -0.014254  0.0311

```

```
##  level4 - level5  0.00276 -0.020815  0.0247
##  level4 - level8  0.00560 -0.016437  0.0284
##  level4 - level16 0.01672 -0.005825  0.0393
##  level5 - level8  0.00280 -0.019834  0.0255
##  level5 - level16 0.01400 -0.008651  0.0367
##  level8 - level16 0.01119 -0.011244  0.0339
##
## Point estimate displayed: median
## HPD interval probability: 0.95
```

No differences between any levels.

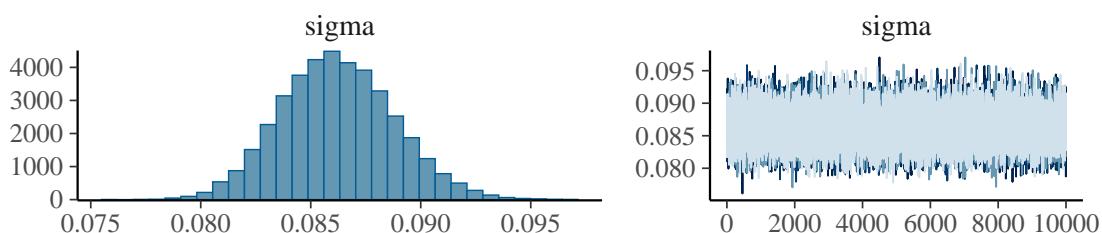
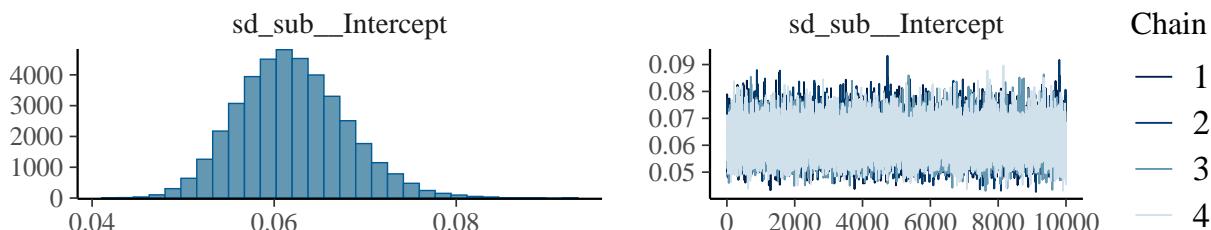
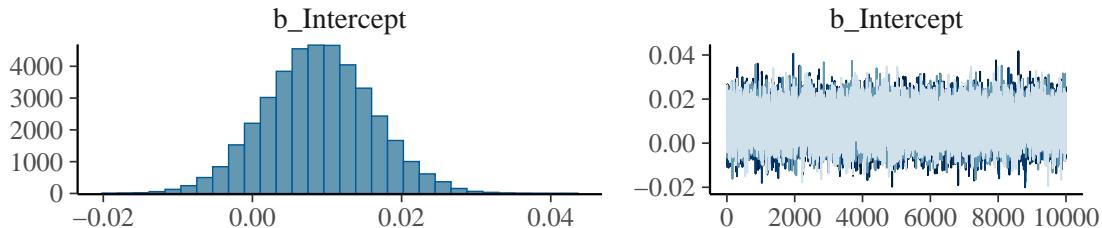
```
rm(levels1B)
rm(levels1B_null)
```

2B

```
data2B <- filter(data, scramble == '2B')

levels2B_null <- brm(value ~ 1 + (1|sub), data = data2B,
                      save_pars = save_pars(all = TRUE),
                      iter = 20000, refresh = 0,
                      file = 'models/E3_alignment_2B_null')

plot(levels2B_null)
```



```
print(summary(levels2B_null, robust = TRUE), digits = 4)
```

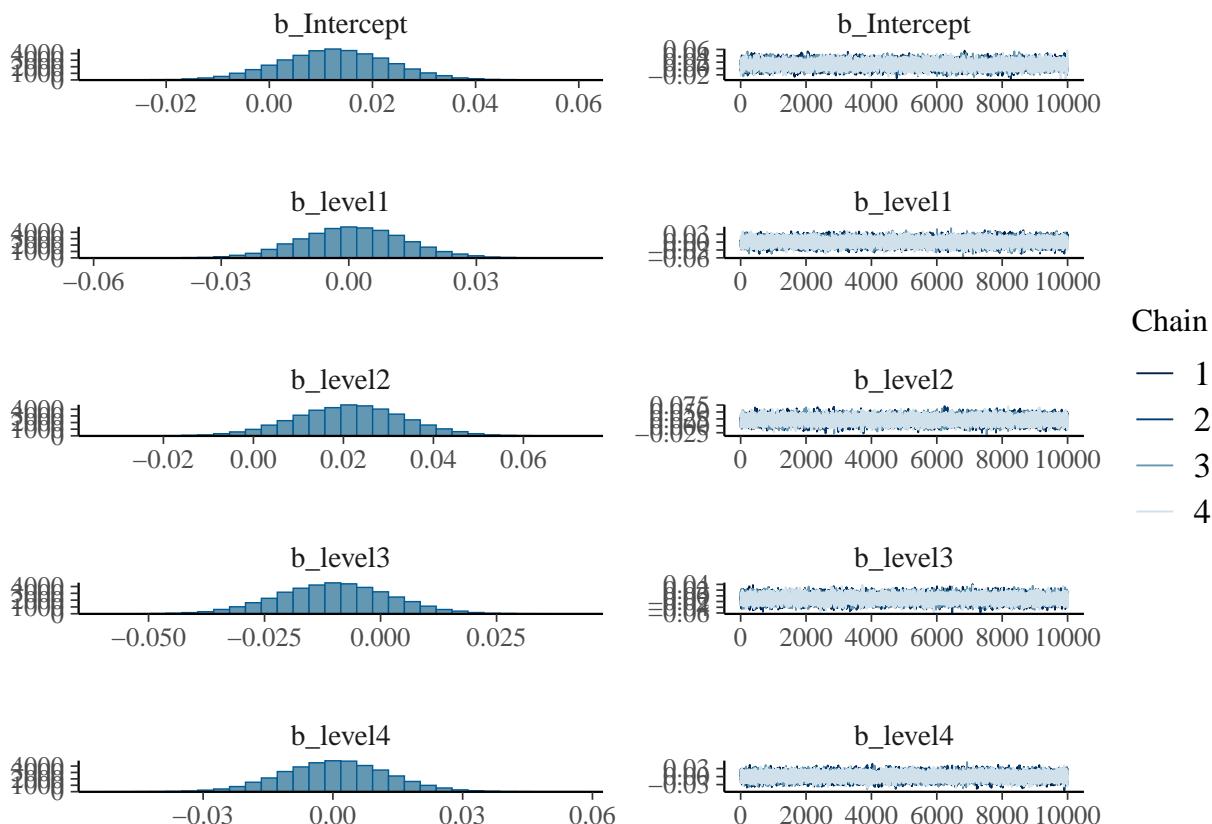
```
##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ 1 + (1 | sub)
##  Data: data2B (Number of observations: 665)
##  Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##        total post-warmup draws = 40000
##
##  Multilevel Hyperparameters:
##  ~sub (Number of levels: 95)
##                Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  sd(Intercept)   0.0617    0.0058   0.0513   0.0744 1.0006     14864    20449
## 
##  Regression Coefficients:
##                Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  Intercept      0.0089    0.0071  -0.0052   0.0232 1.0001     20214    25398
```

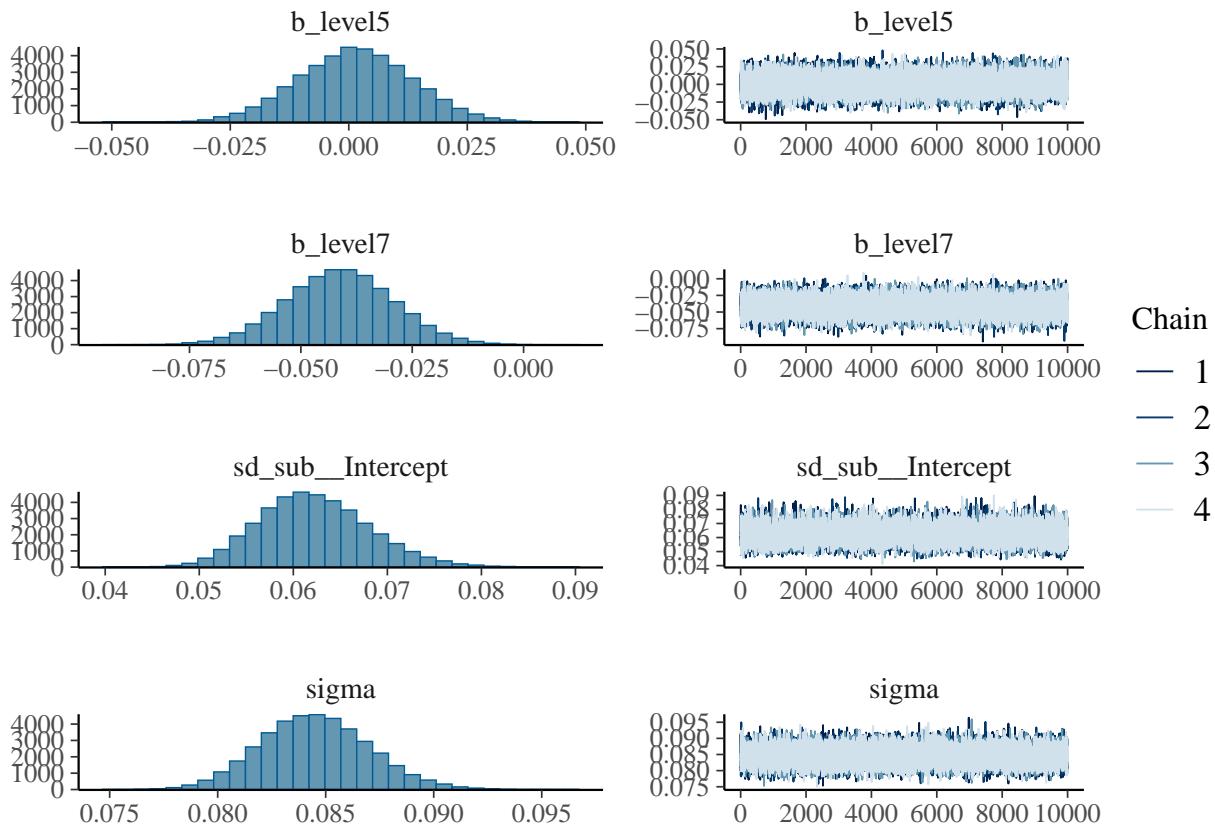
```

## Further Distributional Parameters:
##           Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma     0.0861     0.0026   0.0814   0.0914 1.0001      57672    30360
## 
## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
levels2B <- brm(value ~ level + (1|sub), data = data2B,
                  prior = c(
                    set_prior('normal(-0.2, 0.1)', coef = c('level1', 'level2', 'level3', 'level5')),
                    set_prior('normal(-0.1, 0.1)', coef = c('level4', 'level7'))
                  ),
                  save_pars = save_pars(all = TRUE), iter = 20000, refresh = 0,
                  file = 'models/E3_alignment_2B')

plot(levels2B)

```





```
print(summary(levels2B, robust = TRUE), digits = 4)
```

```
## Family: gaussian
## Links: mu = identity; sigma = identity
## Formula: value ~ level + (1 | sub)
## Data: data2B (Number of observations: 665)
## Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##         total post-warmup draws = 40000
##
## Multilevel Hyperparameters:
## ~sub (Number of levels: 95)
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sd(Intercept)  0.0619    0.0058   0.0517   0.0746 1.0002    14801    23527
## 
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept    0.0127    0.0106  -0.0082   0.0335 1.0000    20620    25959
## level1       0.0010    0.0122  -0.0225   0.0250 1.0000    36947    33313
## level2       0.0215    0.0121  -0.0025   0.0451 1.0000    36470    34014
## level3      -0.0100    0.0121  -0.0337   0.0138 1.0000    35805    32782
## level4       0.0006    0.0121  -0.0230   0.0243 1.0000    36433    33389
## level5       0.0014    0.0121  -0.0224   0.0251 1.0000    36274    33374
## level7      -0.0412    0.0120  -0.0650  -0.0175 1.0000    36856    34187
## 
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma        0.0845    0.0025   0.0798   0.0896 1.0001    53947    31187
## 
```

```
## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS  
## and Tail_ESS are effective sample size measures, and Rhat is the potential  
## scale reduction factor on split chains (at convergence, Rhat = 1).
```

```
BF_2B_level <- bayes_factor(levels2B, levels2B_null)
```

```
## Iteration: 1  
## Iteration: 2  
## Iteration: 3  
## Iteration: 4  
## Iteration: 5  
## Iteration: 1  
## Iteration: 2  
## Iteration: 3  
## Iteration: 4  
## Iteration: 5  
print(BF_2B_level)
```

```
## Estimated Bayes factor in favor of levels2B over levels2B_null: 0.00021
```

There is strong evidence against an effect of level.

```
emm_2B <- emmeans(levels2B, specs = "level")  
summary(emm_2B)
```

```
##   level    emmean lower.HPD upper.HPD  
## 1     0.01371 -0.00690  0.03566  
## 2     0.03409  0.01306  0.05543  
## 3     0.00266 -0.01778  0.02429  
## 4     0.01333 -0.00790  0.03447  
## 5     0.01408 -0.00740  0.03462  
## 8     0.01267 -0.00755  0.03409  
## 16    -0.02856 -0.04960 -0.00759  
##  
## Point estimate displayed: median  
## HPD interval probability: 0.95
```

Above chance: 2, 5 Below chance: 16 All others at chance

```
contrast(emm_2B, method = "pairwise")
```

```
##   contrast      estimate lower.HPD upper.HPD  
## 1 level1 - level2 -0.020363 -0.04481  0.00337  
## 2 level1 - level3  0.011007 -0.01277  0.03540  
## 3 level1 - level4  0.000434 -0.02333  0.02448  
## 4 level1 - level5 -0.000455 -0.02439  0.02399  
## 5 level1 - level8  0.000974 -0.02260  0.02493  
## 6 level1 - level16  0.042254  0.01862  0.06687  
## 7 level2 - level3  0.031413  0.00739  0.05561  
## 8 level2 - level4  0.020766 -0.00352  0.04415  
## 9 level2 - level5  0.020064 -0.00442  0.04379  
## 10 level2 - level8  0.021518 -0.00211  0.04544  
## 11 level2 - level16  0.062626  0.03911  0.08732  
## 12 level3 - level4 -0.010555 -0.03419  0.01300  
## 13 level3 - level5 -0.011340 -0.03602  0.01202  
## 14 level3 - level8 -0.009956 -0.03476  0.01257  
## 15 level3 - level16  0.031295  0.00745  0.05471
```

```
##  level4 - level5 -0.000724 -0.02563  0.02244
##  level4 - level8  0.000628 -0.02253  0.02467
##  level4 - level16 0.041843  0.01863  0.06585
##  level5 - level8  0.001425 -0.02243  0.02497
##  level5 - level16 0.042633  0.01926  0.06700
##  level8 - level16 0.041209  0.01739  0.06485
##
## Point estimate displayed: median
## HPD interval probability: 0.95
1 > 16, 2 > 16, 3 > 16, 4 > 16, 5 > 16, 8 > 16
2 > 3
rm(levels2B)
rm(levels2B_null)
```

8B

```

data8B <- filter(data, scramble == '8B')

levels8B_null <- brm(value ~ 1 + (1|sub), data = data8B,
                      save_pars = save_pars(all = TRUE),
                      iter = 20000, refresh = 0,
                      file = 'models/E3_alignment_8B_null')

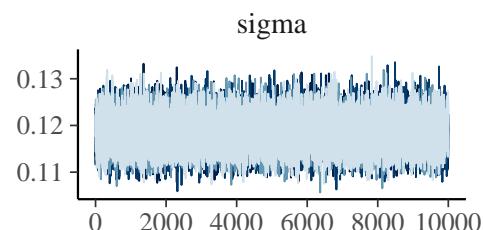
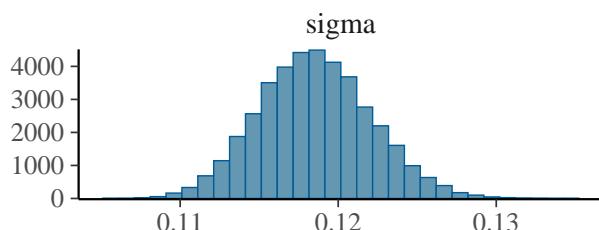
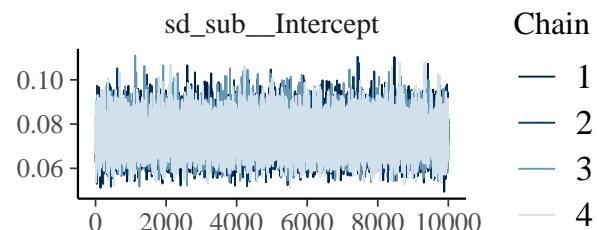
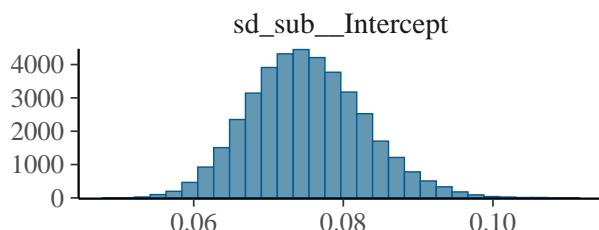
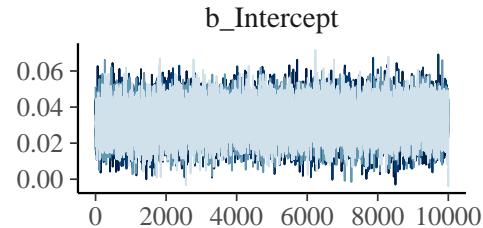
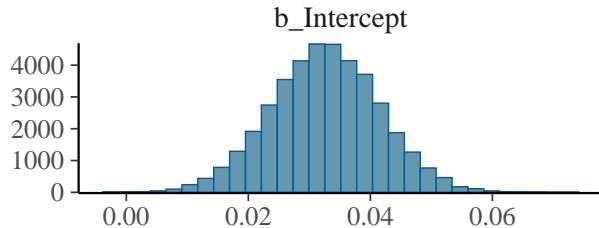
## Compiling Stan program...

## Trying to compile a simple C file

## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## using C compiler: 'Apple clang version 16.0.0 (clang-1600.0.26.6)'
## using SDK: 'MacOSX15.2.sdk'
## clang -arch arm64 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG -I"/Library/Frameworks/R.framework/Resources/include"
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeaders/include.hpp:30
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/Dense:102
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core/Block.h:42
##   679 | #include <cmath>
##       |         ^~~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(levels8B_null)

```



```

print(summary(levels8B_null, robust = TRUE), digits = 4)

## Family: gaussian
## Links: mu = identity; sigma = identity
## Formula: value ~ 1 + (1 | sub)
## Data: data8B (Number of observations: 665)
## Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##         total post-warmup draws = 40000
##
## Multilevel Hyperparameters:
## ~sub (Number of levels: 95)
##             Estimate Est.Error l-95% CI u-95% CI   Rhat Bulk_ESS Tail_ESS
## sd(Intercept)  0.0747    0.0076   0.0612   0.0911 1.0003    15098    19817
## 
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI   Rhat Bulk_ESS Tail_ESS
## Intercept    0.0326    0.0089   0.0149   0.0500 1.0001    26301    29058
## 
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI   Rhat Bulk_ESS Tail_ESS
## sigma       0.1184    0.0036   0.1118   0.1258 1.0002    51819    31632
## 
## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).

levels8B <- brm(value ~ level + (1|sub), data = data8B,
                  prior = c(
                    set_prior('normal(-0.2, 0.1)', coef = c('level1', 'level2', 'level3', 'level5')),
                    set_prior('normal(-0.1, 0.1)', coef = c('level4', 'level7'))
                  ),
                  save_pars = save_pars(all = TRUE), iter = 20000, refresh = 0,
                  file = 'models/E3_alignment_8B')

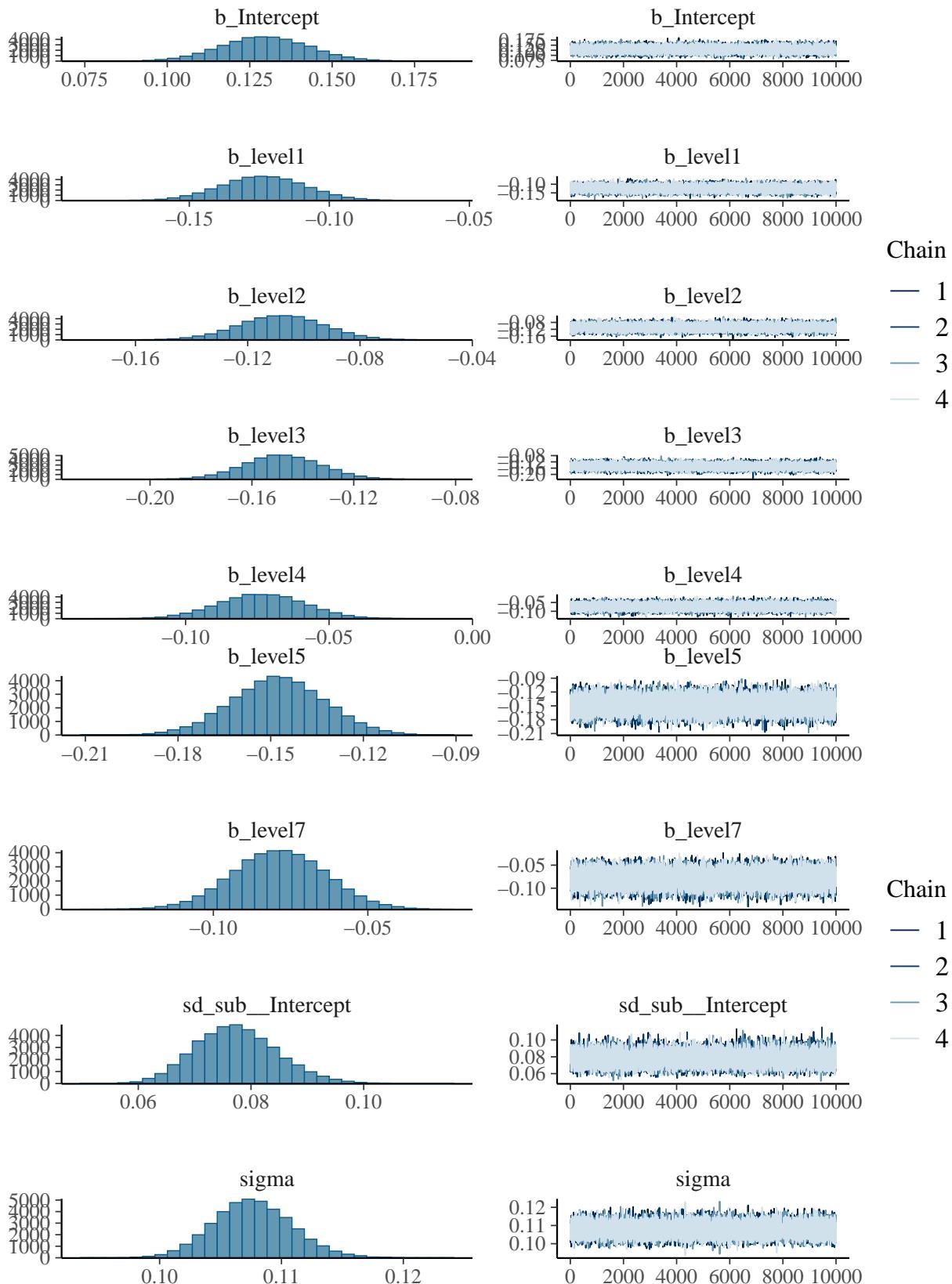
## Compiling Stan program...

## Trying to compile a simple C file

## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## using C compiler: 'Apple clang version 16.0.0 (clang-1600.0.26.6)'
## using SDK: 'MacOSX15.2.sdk'
## clang -arch arm64 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG -I"/Library/Frameworks/R.framework/Resources/include"
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeaders/include.hpp:10:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/RcppEigen.hpp:10:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/RcppEigen.hpp:10:
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core/DenseMatrix.h:679:1: #include <cmath>
## | ^~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(levels8B)

```



```
print(summary(levels8B, robust = TRUE), digits = 4)
```

```

## Family: gaussian
## Links: mu = identity; sigma = identity
## Formula: value ~ level + (1 | sub)
## Data: data8B (Number of observations: 665)
## Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##         total post-warmup draws = 40000
##
## Multilevel Hyperparameters:
## ~sub (Number of levels: 95)
##           Estimate Est.Error l-95% CI u-95% CI   Rhat Bulk_ESS Tail_ESS
## sd(Intercept)  0.0772    0.0073   0.0641   0.0928 1.0000    16030    23945
##
## Regression Coefficients:
##           Estimate Est.Error l-95% CI u-95% CI   Rhat Bulk_ESS Tail_ESS
## Intercept    0.1295    0.0133   0.1037   0.1557 1.0002    21689    27049
## level1     -0.1235    0.0151  -0.1532  -0.0938 1.0000    36191    33223
## level2     -0.1080    0.0151  -0.1381  -0.0783 1.0000    36593    32510
## level3     -0.1481    0.0151  -0.1777  -0.1184 1.0000    35500    30712
## level4     -0.0736    0.0152  -0.1032  -0.0442 1.0001    35547    33361
## level5     -0.1475    0.0150  -0.1776  -0.1179 1.0000    36678    33289
## level7     -0.0787    0.0152  -0.1085  -0.0492 1.0002    35907    33510
##
## Further Distributional Parameters:
##           Estimate Est.Error l-95% CI u-95% CI   Rhat Bulk_ESS Tail_ESS
## sigma      0.1076    0.0032   0.1016   0.1142 1.0000    55964    29895
##
## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
BF_8B_level <- bayes_factor(levels8B, levels8B_null)

```

```

## Iteration: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4
## Iteration: 5
## Iteration: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4
## Iteration: 5

```

```
print(BF_8B_level)
```

```
## Estimated Bayes factor in favor of levels8B over levels8B_null: 14534497896605048832.00000
```

There is very strong evidence for an effect of level.

```
emm_8B <- emmeans(levels8B, specs = "level")
summary(emm_8B)
```

```

##  level    emmean lower.HPD upper.HPD
##  1       0.00593  -0.0210   0.03211
##  2       0.02161  -0.0045   0.04853
##  3      -0.01827  -0.0449   0.00824
##  4       0.05593   0.0297   0.08313

```

```

##   5      -0.01794   -0.0440    0.00897
##   8       0.12954    0.1041    0.15616
##  16      0.05094    0.0248    0.07798
##
## Point estimate displayed: median
## HPD interval probability: 0.95

Above chance: 4, 8, 16 At chance: 1, 2, 3, 5
contrast(emm_8B, method = "pairwise")

## contrast           estimate lower.HPD upper.HPD
## level1 - level2 -0.015456 -0.04635  0.014604
## level1 - level3  0.024390 -0.00657  0.054604
## level1 - level4 -0.049957 -0.08087 -0.019744
## level1 - level5  0.023923 -0.00625  0.054564
## level1 - level8 -0.123524 -0.15335 -0.094034
## level1 - level16 -0.044861 -0.07455 -0.014366
## level2 - level3  0.039908  0.00992  0.070668
## level2 - level4 -0.034576 -0.06451 -0.003538
## level2 - level5  0.039508  0.00873  0.069696
## level2 - level8 -0.107991 -0.13858 -0.078853
## level2 - level16 -0.029423 -0.05997  0.000831
## level3 - level4 -0.074473 -0.10445 -0.044015
## level3 - level5 -0.000429 -0.02972  0.031336
## level3 - level8 -0.148066 -0.17782 -0.118551
## level3 - level16 -0.069260 -0.09898 -0.038299
## level4 - level5  0.073962  0.04361  0.104857
## level4 - level8 -0.073551 -0.10311 -0.044132
## level4 - level16  0.005130 -0.02607  0.035137
## level5 - level8 -0.147527 -0.17699 -0.117474
## level5 - level16 -0.068873 -0.09900 -0.038325
## level8 - level16  0.078670  0.04884  0.108138
##
## Point estimate displayed: median
## HPD interval probability: 0.95

```

2 > 3, 2 > 5

4 > 1, 4 > 2, 4 > 3, 4 > 5

8 > 1, 8 > 2, 8 > 3, 8 > 4, 8 > 5, 8 > 16

16 > 1, 16 > 3, 16 > 5

Phrase level greater than all others. Structurally relevant levels (2,4,8,16) are consistently greater than structurally irrelevant levels (3,5), BUT participants align to longer SRL (4,8) more than 2 - consistent with lower rate of response

```

rm(levels8B)
rm(levels8B_null)

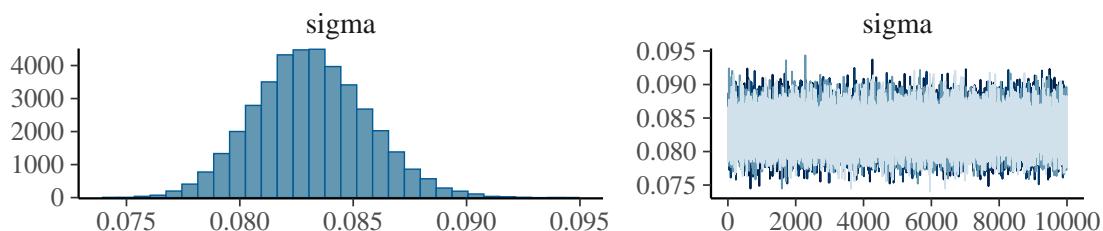
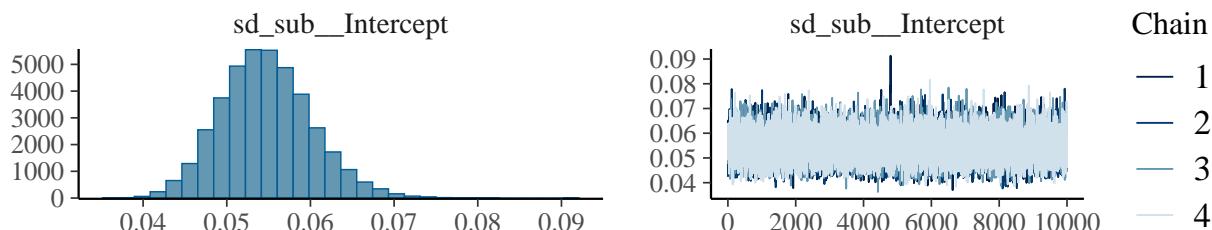
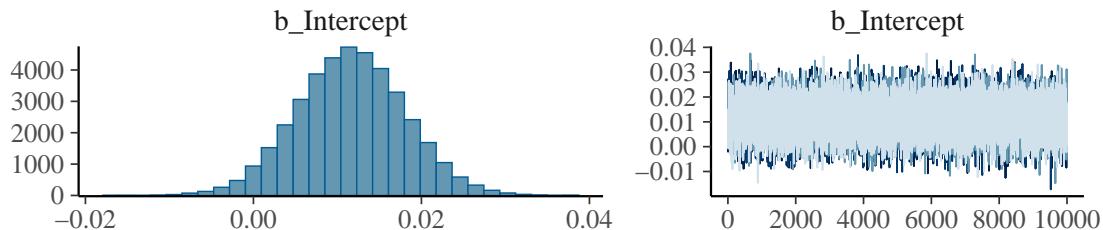
```

Intact

```
dataI <- filter(data, scramble == 'Intact')

levelsI_null <- brm(value ~ 1 + (1|sub), data = dataI,
                     save_pars = save_pars(all = TRUE),
                     iter = 20000, refresh = 0,
                     file = 'models/E3_alignment_Intact_null')

plot(levelsI_null)
```



```
print(summary(levelsI_null, robust = TRUE), digits = 4)
```

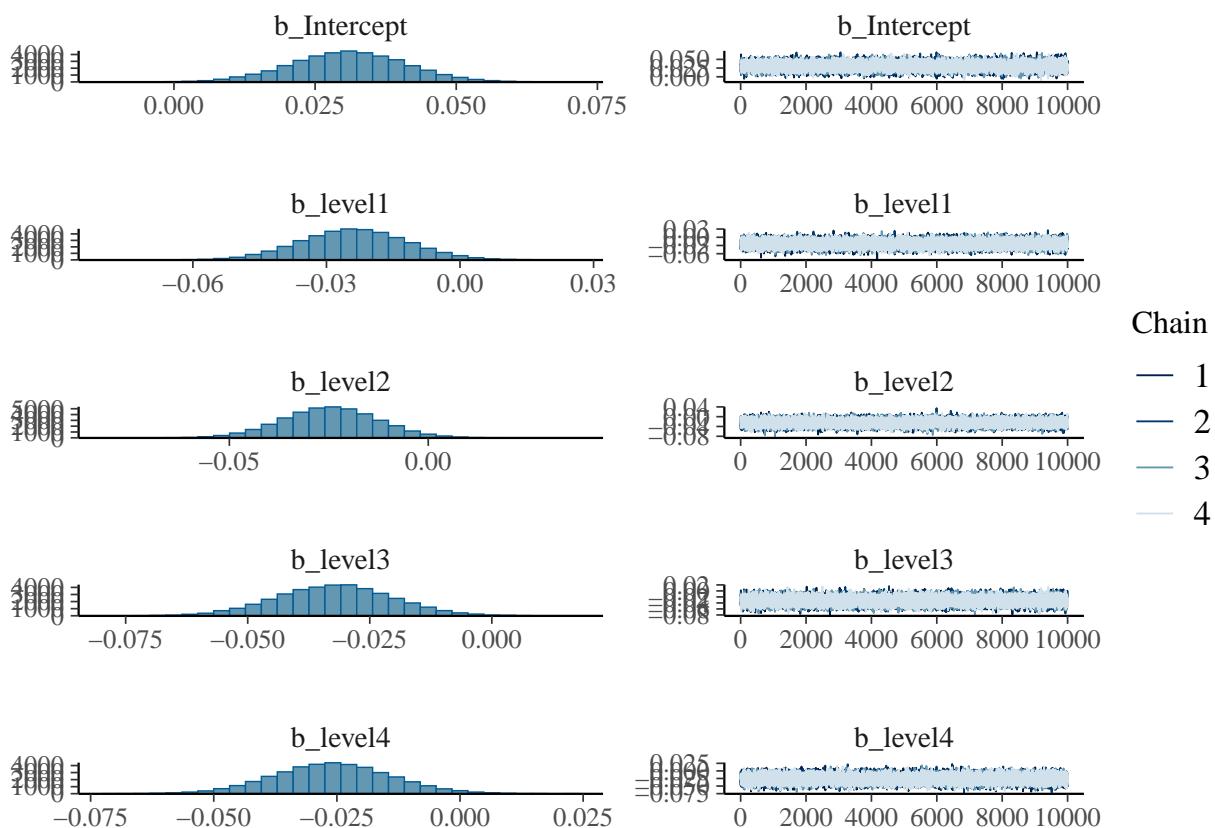
```
##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ 1 + (1 | sub)
##  Data: dataI (Number of observations: 665)
##  Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##          total post-warmup draws = 40000
##
##  Multilevel Hyperparameters:
##  ~sub (Number of levels: 95)
##              Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  sd(Intercept)  0.0545    0.0054   0.0447   0.0662 1.0001    14706   21105
## 
##  Regression Coefficients:
##              Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  Intercept     0.0116    0.0064  -0.0009   0.0242 1.0001    24997   28853
```

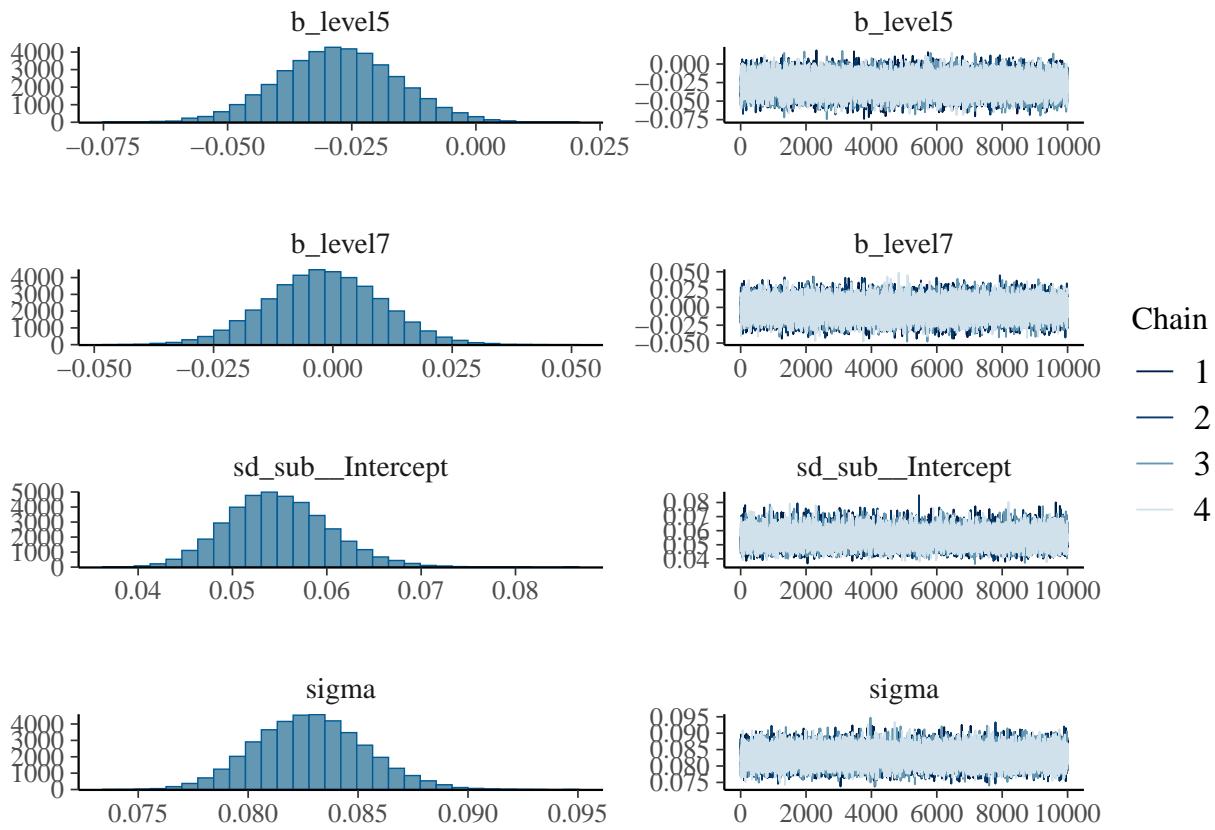
```

## Further Distributional Parameters:
## Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma    0.0831     0.0025    0.0785    0.0882 1.0000      51549     30613
##
## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
levelsI <- brm(value ~ level + (1|sub), data = dataI,
                 prior = c(
                   set_prior('normal(-0.2, 0.1)', coef = c('level1', 'level2', 'level3', 'level5')),
                   set_prior('normal(-0.1, 0.1)', coef = c('level4', 'level7'))
                 ),
                 save_pars = save_pars(all = TRUE), iter = 20000, refresh = 0,
                 file = 'models/E3_alignment_Intact')

```

```
plot(levelsI)
```





```
print(summary(levelsI, robust = TRUE), digits = 4)
```

```
##  Family: gaussian
##  Links: mu = identity; sigma = identity
##  Formula: value ~ level + (1 | sub)
##  Data: dataI (Number of observations: 665)
##  Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##          total post-warmup draws = 40000
##
##  Multilevel Hyperparameters:
##  ~sub (Number of levels: 95)
##              Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  sd(Intercept)  0.0546   0.0054   0.0449   0.0663 1.0002    14837    21276
## 
##  Regression Coefficients:
##              Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  Intercept     0.0309   0.0101   0.0110   0.0506 1.0000    27562    27488
##  level1      -0.0238   0.0119  -0.0469  -0.0006 1.0001    38193    34681
##  level2      -0.0246   0.0119  -0.0480  -0.0013 1.0000    39071    33514
##  level3      -0.0321   0.0119  -0.0555  -0.0090 1.0001    38381    32770
##  level4      -0.0259   0.0118  -0.0492  -0.0024 1.0001    38678    33801
##  level5      -0.0278   0.0118  -0.0509  -0.0043 1.0001    36688    33056
##  level7      -0.0019   0.0119  -0.0251   0.0214 1.0002    36749    32859
## 
##  Further Distributional Parameters:
##              Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  sigma       0.0828   0.0025   0.0781   0.0879 1.0002    53512    31017
## 
```

```

## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
BF_I_level <- bayes_factor(levelsI, levelsI_null)

## Iteration: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4
## Iteration: 5
## Iteration: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4

print(formatC(BF_I_level$bf, format = 'e'))

```

```
## [1] "1.5245e-07"
```

There is strong evidence against an effect of level.

```

emm_I <- emmeans(levelsI, specs = "level")
summary(emm_I)

```

	level	emmean	lower.HPD	upper.HPD
##	1	0.00712	-0.01348	0.0266
##	2	0.00633	-0.01377	0.0261
##	3	-0.00127	-0.02169	0.0183
##	4	0.00509	-0.01481	0.0251
##	5	0.00322	-0.01683	0.0232
##	8	0.03094	0.01125	0.0508
##	16	0.02907	0.00908	0.0489
##				

Point estimate displayed: median
HPD interval probability: 0.95

Only level above chance is 8-bar level.

```
contrast(emm_I, method = "pairwise")
```

	contrast	estimate	lower.HPD	upper.HPD
##	level1 - level2	0.000772	-0.0232	0.024057
##	level1 - level3	0.008325	-0.0156	0.031488
##	level1 - level4	0.002165	-0.0210	0.025924
##	level1 - level5	0.003908	-0.0196	0.027305
##	level1 - level8	-0.023841	-0.0471	-0.000813
##	level1 - level16	-0.021945	-0.0455	0.001648
##	level2 - level3	0.007547	-0.0169	0.030647
##	level2 - level4	0.001299	-0.0224	0.024770
##	level2 - level5	0.003129	-0.0200	0.027126
##	level2 - level8	-0.024612	-0.0478	-0.001198
##	level2 - level16	-0.022717	-0.0465	0.000516
##	level3 - level4	-0.006266	-0.0293	0.017759
##	level3 - level5	-0.004424	-0.0275	0.019434
##	level3 - level8	-0.032133	-0.0559	-0.009454
##	level3 - level16	-0.030243	-0.0540	-0.006783
##	level4 - level5	0.001850	-0.0218	0.025226

```
##  level4 - level8  -0.025933  -0.0496 -0.002940
##  level4 - level16 -0.024037  -0.0467 -0.000281
##  level5 - level8  -0.027771  -0.0509 -0.004279
##  level5 - level16 -0.025885  -0.0489 -0.001566
##  level8 - level16  0.001881  -0.0217  0.024686
##
## Point estimate displayed: median
## HPD interval probability: 0.95
8 > 3, 8 > 4, 8 > 5
rm(levelsI)
rm(levelsI_null)
```

8B vs Intact, 8 vs 16

```

data_longTS <- data %>%
  filter(scramble %in% c('Intact', '8B')) %>%
  filter(level %in% c('8', '16')) %>%
  mutate(scramble = factor(scramble, levels = c('Intact', '8B')),
         level = factor(level, levels = c('8', '16')))

contrasts(data_longTS$level) <- contr.treatment(2)

data_longTS_M <- filter(data_longTS, Musician == 'Yes')
data_longTS_NM <- filter(data_longTS, Musician == 'No')

longTS_M <- brm(value ~ scramble + level + (1|sub),
                  prior = set_prior('normal(0, 0.1)', class = 'b'),
                  save_pars = save_pars(all = TRUE), iter = 20000, refresh = 0,
                  file = 'models/E3_alignment_longTimescales_mus')

plot(longTS_M)

```

The figure consists of a 4x2 grid of plots. The columns represent different parameters: **b_Intercept**, **b_scramble8B**, **b_level2**, **sd_sub_Intercept**, and **sigma**. The rows show histograms of the posterior distributions for each parameter (left column) and trace plots showing the evolution of the parameters over 10,000 iterations for four chains (right column). The x-axis for the histograms ranges from -0.05 to 0.10 for **b_Intercept**, **b_scramble8B**, and **b_level2**; from 0.05 to 0.15 for **sd_sub_Intercept**; and from 0.125 to 0.175 for **sigma**. The y-axis for the histograms ranges from 0 to 5000. The x-axis for the trace plots ranges from 0 to 10,000. The legend on the right indicates that the four chains are represented by different colored lines: Chain 1 (black), Chain 2 (dark blue), Chain 3 (light blue), and Chain 4 (cyan).

```

print(summary(longTS_M, robust = TRUE), digits = 4)

## # Family: gaussian
## # Links: mu = identity; sigma = identity
## # Formula: value ~ scramble + level + (1 | sub)
## # Data: data_longTS_M (Number of observations: 196)
## # Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
## #         total post-warmup draws = 40000
## #

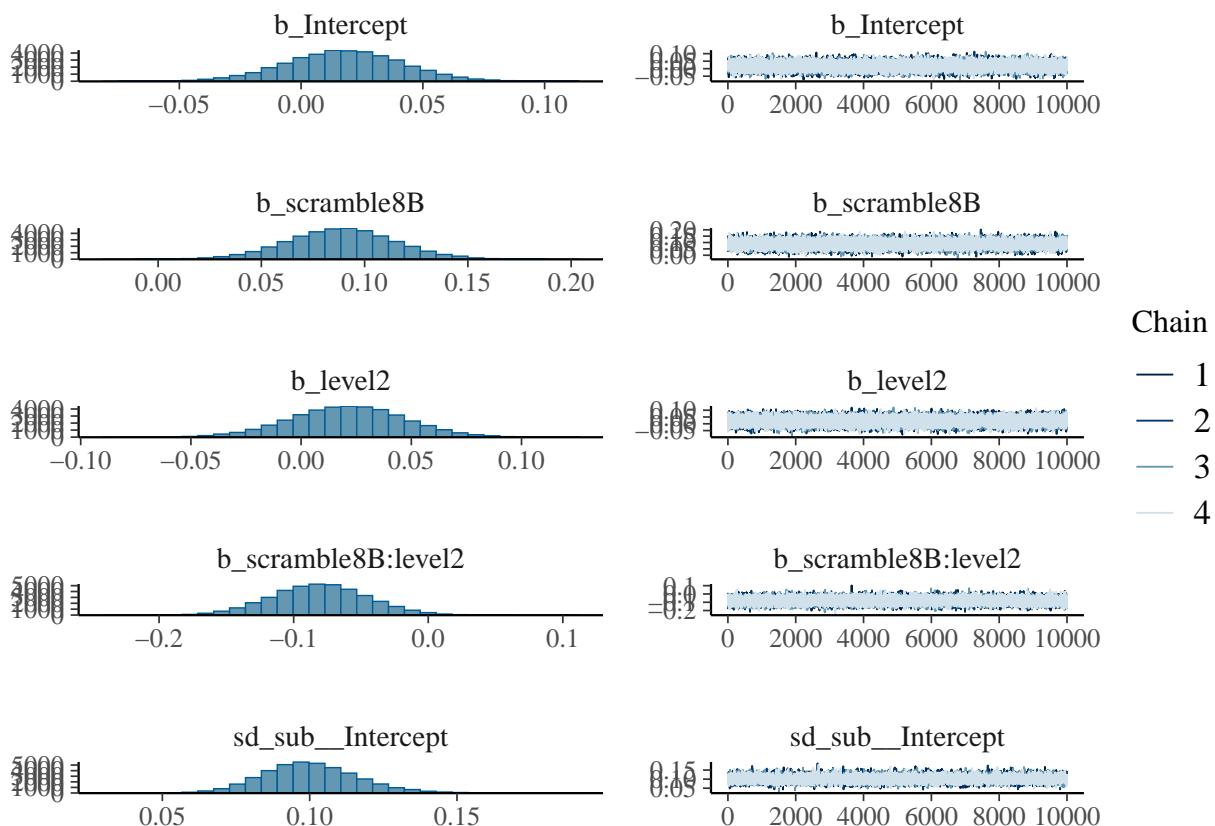
```

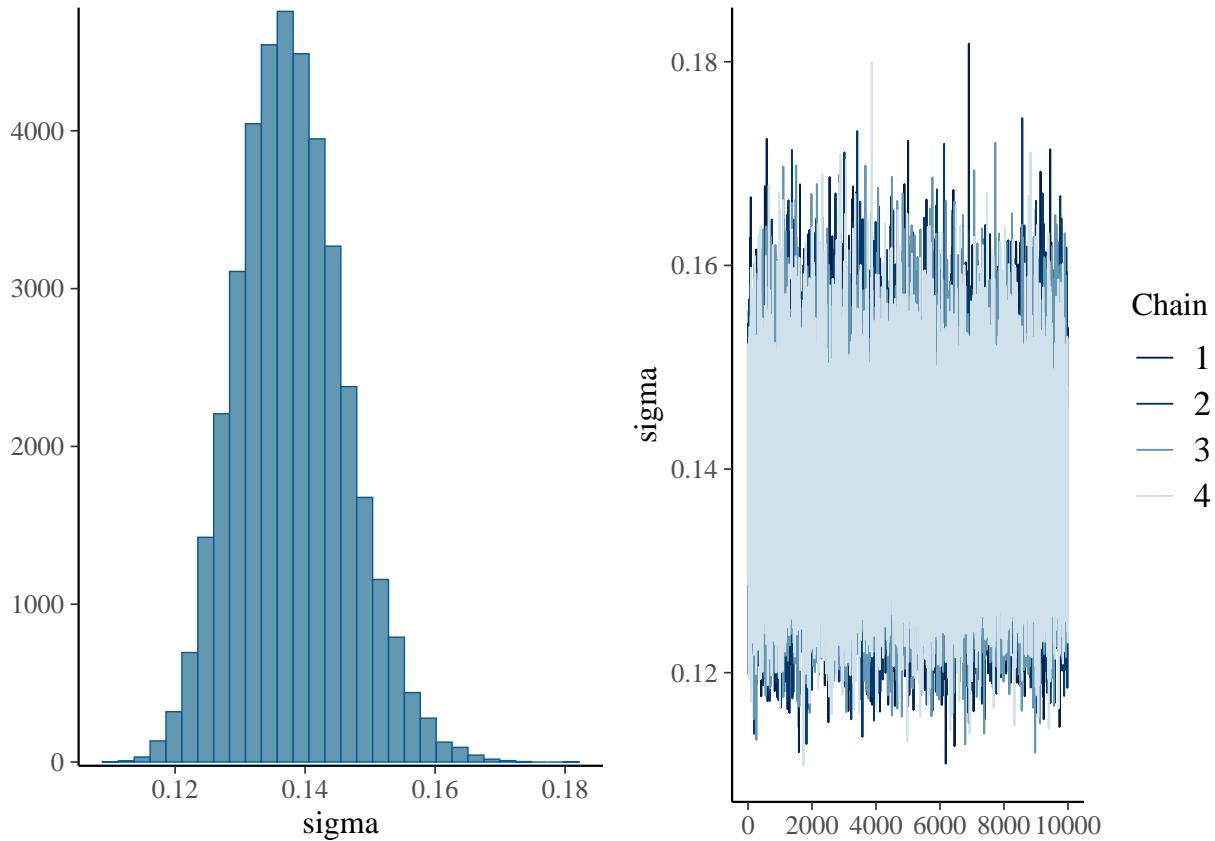
```

## Multilevel Hyperparameters:
## ~sub (Number of levels: 49)
##           Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sd(Intercept)  0.0986   0.0158   0.0696   0.1338 1.0002    13740   22074
##
## Regression Coefficients:
##           Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept     0.0365   0.0222  -0.0076   0.0803 1.0000    32119   30964
## scramble8B    0.0496   0.0198   0.0108   0.0887 1.0004    67166   28493
## level2       -0.0179   0.0196  -0.0563   0.0212 1.0001    64578   27674
##
## Further Distributional Parameters:
##           Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma        0.1401   0.0084   0.1253   0.1582 1.0001    29454   28965
##
## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
longTS_M_int <- brm(value ~ scramble*level + (1|sub), data = data_longTS_M,
                      prior = set_prior('normal(0, 0.1)', class = 'b'),
                      save_pars = save_pars(all = TRUE), iter = 20000, refresh = 0,
                      file = 'models/E3_alignment_longTimescales_musInt')

```

```
plot(longTS_M_int)
```





```

print(summary(longTS_M_int, robust = TRUE), digits = 4)

## Family: gaussian
## Links: mu = identity; sigma = identity
## Formula: value ~ scramble * level + (1 | sub)
## Data: data_longTS_M (Number of observations: 196)
## Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##         total post-warmup draws = 40000
##
## Multilevel Hyperparameters:
## ~sub (Number of levels: 49)
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sd(Intercept)  0.0995   0.0156   0.0710   0.1341 1.0001   14056   21346
## 
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept      0.0177   0.0237  -0.0291   0.0641 1.0000   27444   28965
## scramble8B     0.0890   0.0255   0.0379   0.1398 1.0000   40856   31831
## level2        0.0213   0.0257  -0.0304   0.0709 1.0000   41325   32392
## scramble8B:level2 -0.0807   0.0354  -0.1497  -0.0109 1.0000   36882   30790
## 
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma       0.1375   0.0082   0.1230   0.1553 1.0000   31339   30215
## 
## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential

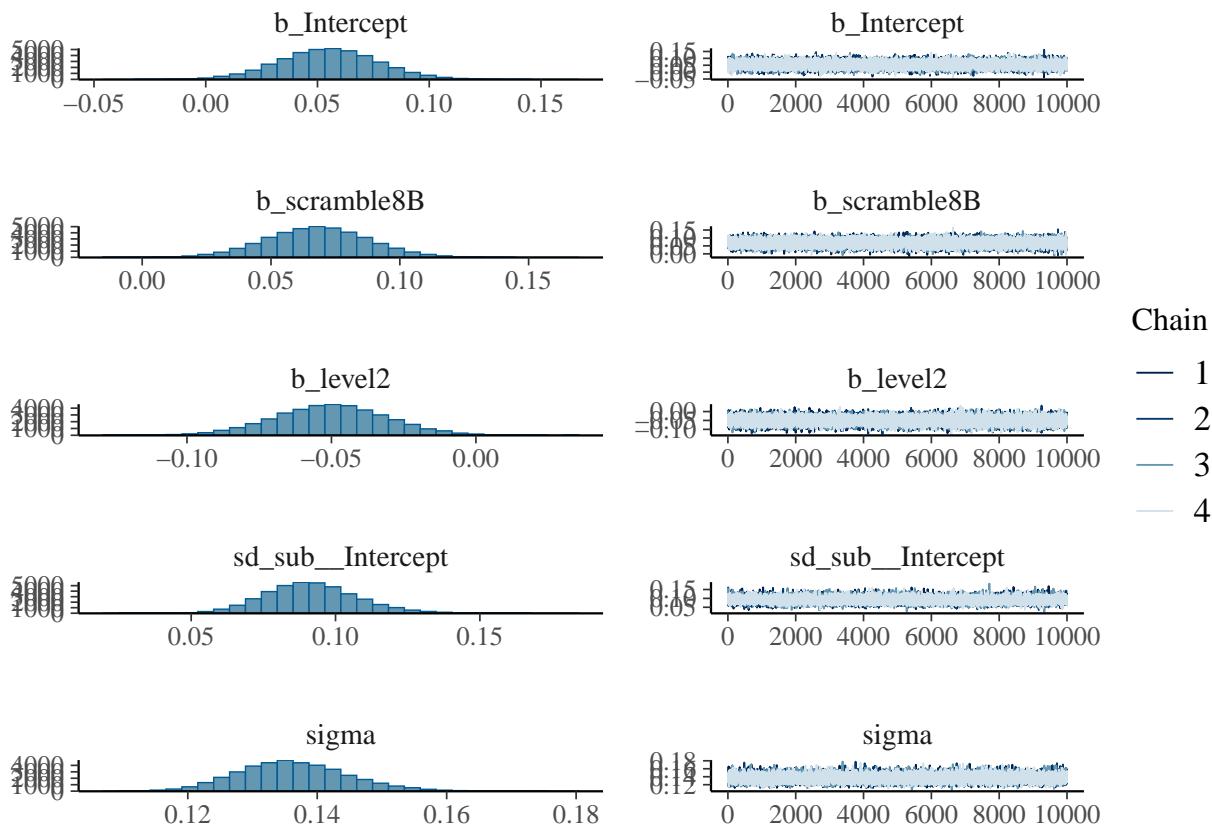
```

```
## scale reduction factor on split chains (at convergence, Rhat = 1).  
BF_longM <- bayes_factor(longTS_M_int, longTS_M)  
  
## Iteration: 1  
## Iteration: 2  
## Iteration: 3  
## Iteration: 4  
## Iteration: 5  
## Iteration: 1  
## Iteration: 2  
## Iteration: 3  
## Iteration: 4  
## Iteration: 5  
  
print(BF_longM)  
  
## Estimated Bayes factor in favor of longTS_M_int over longTS_M: 4.58391
```

There is weak evidence for an interaction for musicians.

```
longTS_NM <- brm(value ~ scramble + level + (1|sub), data = data_longTS_NM,
                    prior = set_prior('normal(0, 0.1)', class = 'b'),
                    save_pars = save_pars(all = TRUE), iter = 20000, refresh = 0,
                    file = 'models/E3_alignment_longTimescales_nonmus')
```

```
plot(longTS_NM)
```



```
print(summary(longTS_NM, robust = TRUE), digits = 4)
```

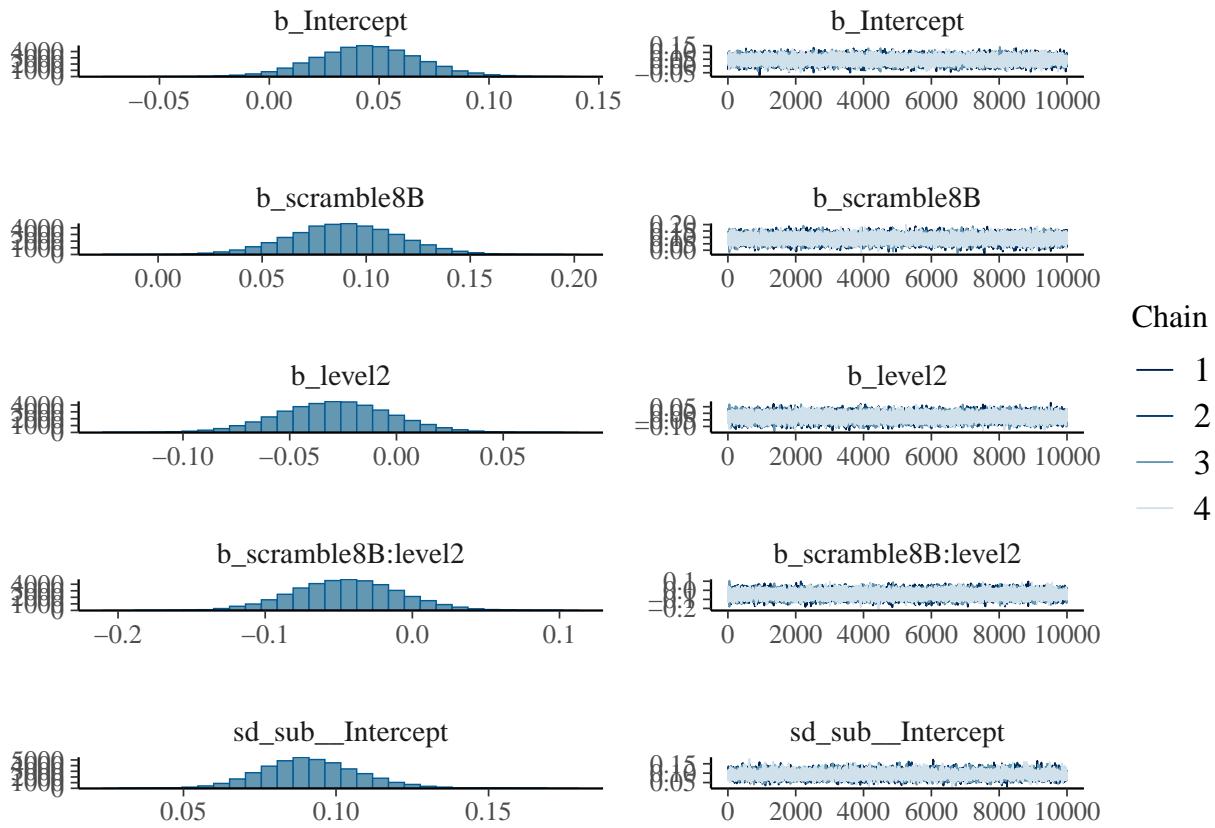
```
##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ scramble + level + (1 | sub)
##  Data: data_longTS_NM (Number of observations: 184)
##  Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##         total post-warmup draws = 40000
##
## Multilevel Hyperparameters:
## ~sub (Number of levels: 46)
##             Estimate Est.Error l-95% CI u-95% CI   Rhat Bulk_ESS Tail_ESS
## sd(Intercept)  0.0910    0.0155   0.0622   0.1257 1.0003    12666   19777
## 
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI   Rhat Bulk_ESS Tail_ESS
## Intercept     0.0549    0.0217   0.0117   0.0979 1.0001    24306   27818
## scramble8B    0.0680    0.0198   0.0293   0.1070 1.0000    52501   30293
## level2       -0.0501    0.0194  -0.0887  -0.0116 1.0000    52280   31227
## 
## Further Distributional Parameters:
```

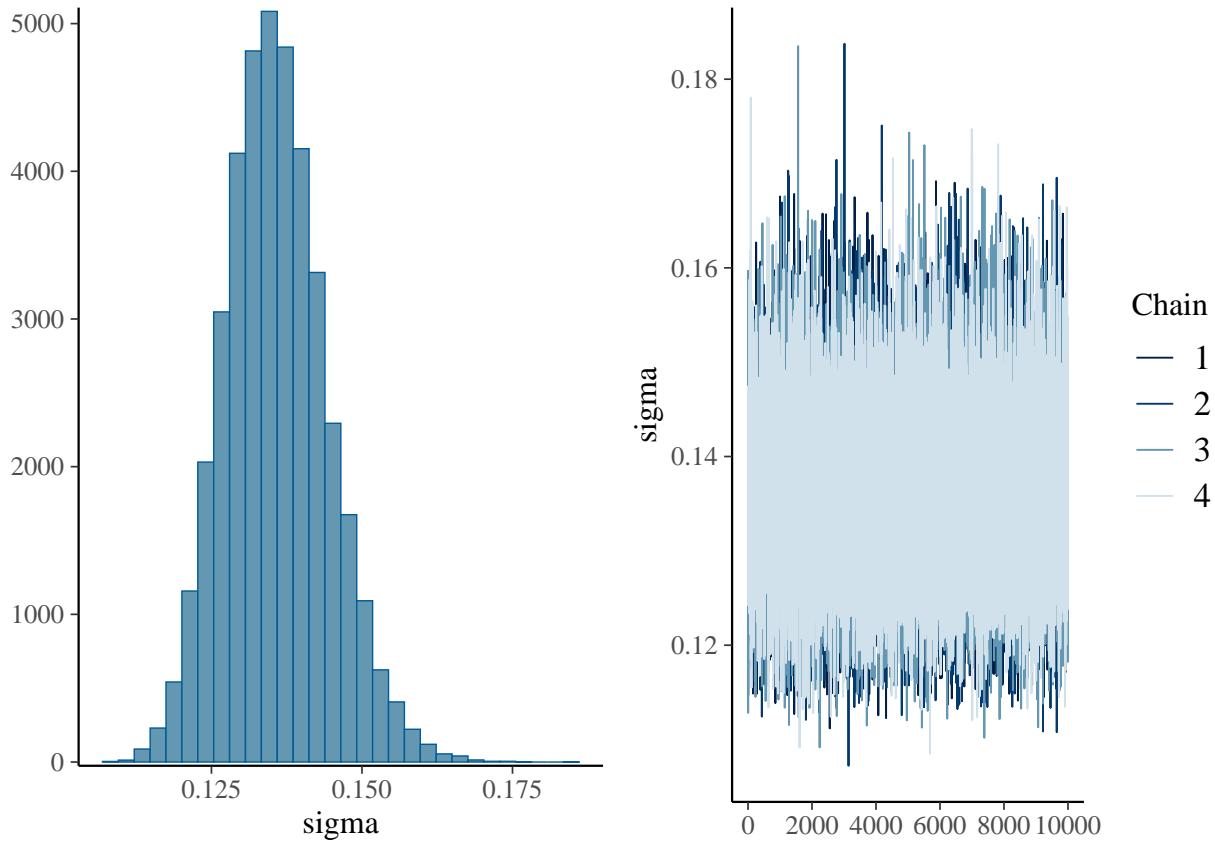
```

##      Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma    0.1359     0.0083   0.1210   0.1541 1.0001     26880     29635
##
## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
longTS_NM_int <- brm(value ~ scramble*level + (1|sub), data = data_longTS_NM,
                      prior = set_prior('normal(0, 0.1)', class = 'b'),
                      save_pars = save_pars(all = TRUE),
                      iter = 20000, refresh = 0,
                      file = 'models/E3_alignment_longTimescales_nonmusInt')

```

```
plot(longTS_NM_int)
```





```

print(summary(longTS_NM_int, robust = TRUE), digits = 4)

##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ scramble * level + (1 | sub)
##  Data: data_longTS_NM (Number of observations: 184)
##  Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##          total post-warmup draws = 40000
##
## Multilevel Hyperparameters:
## ~sub (Number of levels: 46)
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sd(Intercept)  0.0910    0.0156   0.0619   0.1256 1.0000    13591    19947
## 
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept      0.0446    0.0232  -0.0017   0.0912 1.0000    30098    27027
## scramble8B     0.0896    0.0261   0.0379   0.1407 1.0000    41226    30854
## level2        -0.0286    0.0263  -0.0805   0.0226 1.0000    41782    31645
## scramble8B:level2 -0.0448    0.0360  -0.1151   0.0262 1.0000    39655    30568
## 
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma       0.1354    0.0083   0.1205   0.1537 1.0000    29717    28386
## 
## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential

```

```
## scale reduction factor on split chains (at convergence, Rhat = 1).  
BF_longNM <- bayes_factor(longTS_NM_int, longTS_NM)  
  
## Iteration: 1  
## Iteration: 2  
## Iteration: 3  
## Iteration: 4  
## Iteration: 1  
## Iteration: 2  
## Iteration: 3  
## Iteration: 4  
## Iteration: 5  
  
print(BF_longNM)  
  
## Estimated Bayes factor in favor of longTS_NM_int over longTS_NM: 0.78118
```

There is weak evidence against an interaction for musicians.