

E3 alignment

R. Cassano-Coleman

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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)
)

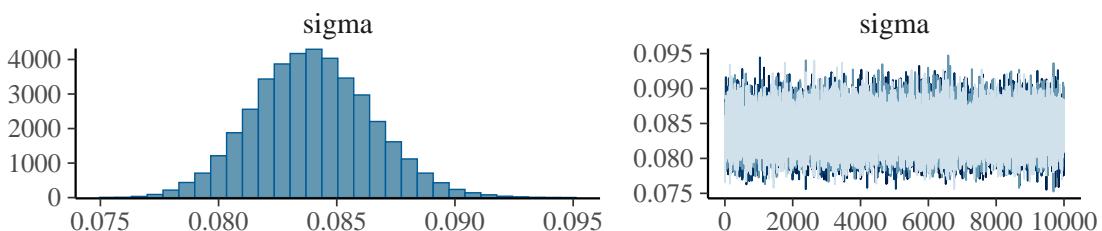
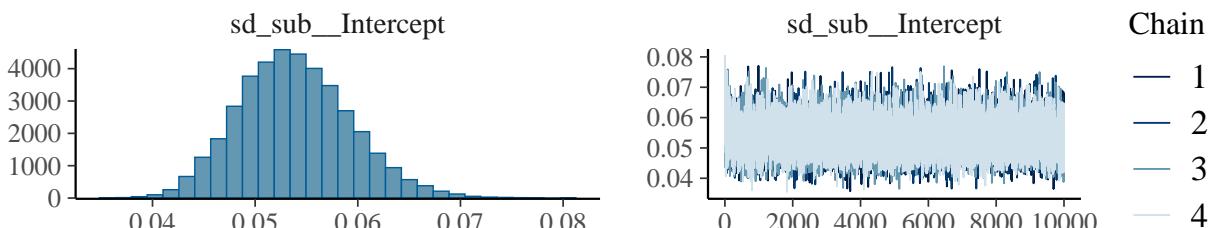
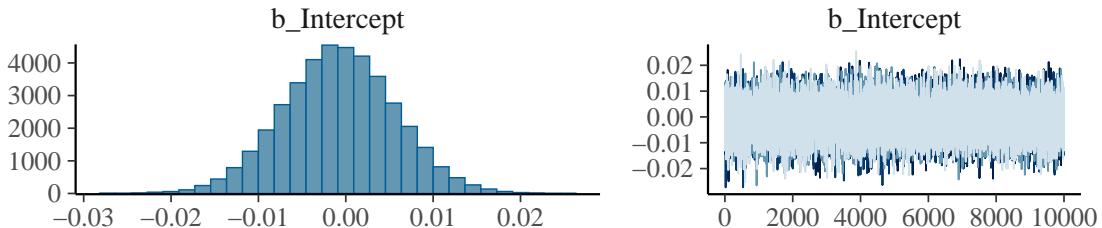
contrasts(data$scramble) <- contr.treatment(4) # Intact as reference
contrasts(data$level) <- contr.treatment(7, base = 6) # 8-bar as reference
contrasts(data$Musician) <- c(-1,1)
```

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)
```

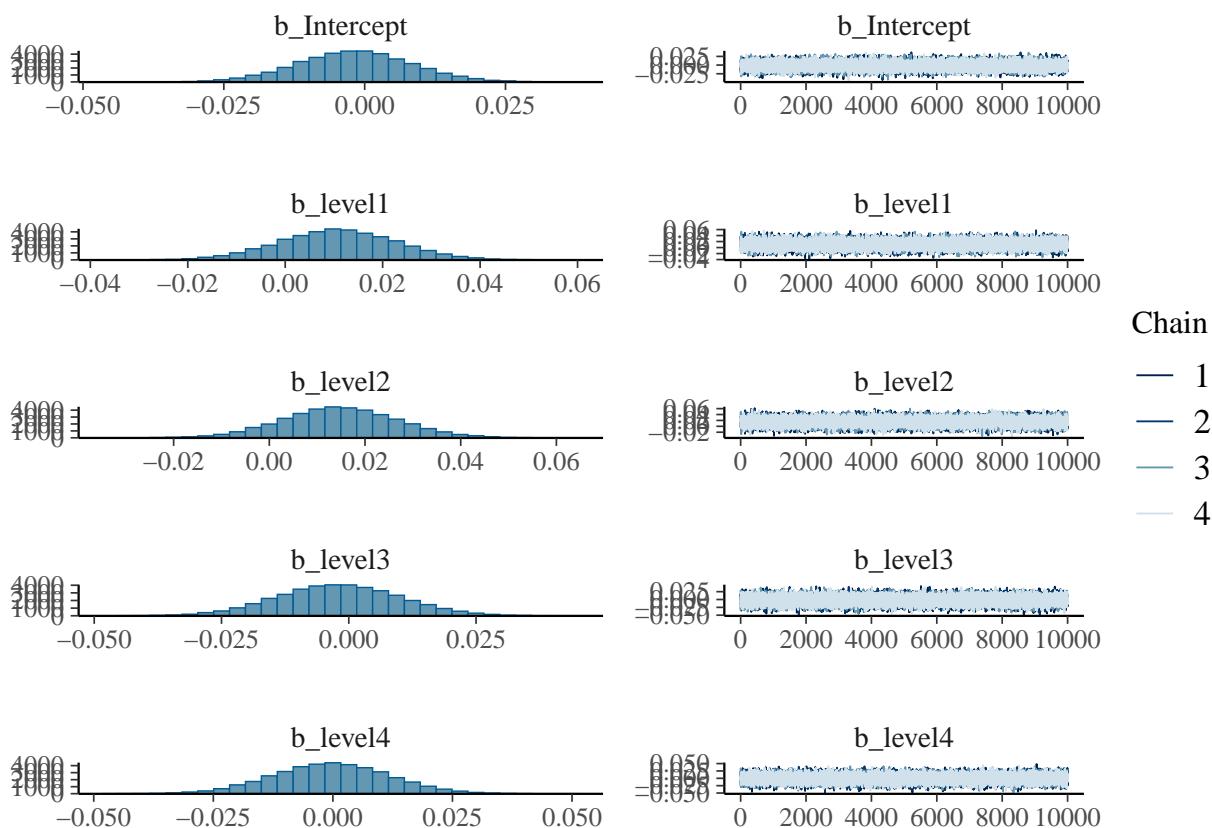
```
##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ 1 + (1 | sub)
##  Data: data1B (Number of observations: 665)
##  Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##          total post-warmup draws = 40000
##
##  Multilevel Hyperparameters:
##  ~sub (Number of levels: 95)
##                Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  sd(Intercept)   0.0536    0.0054    0.0440    0.0653 1.0002     13842    19478
## 
##  Regression Coefficients:
##                Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  Intercept     -0.0008    0.0063   -0.0133    0.0118 1.0001     24705    28001
```

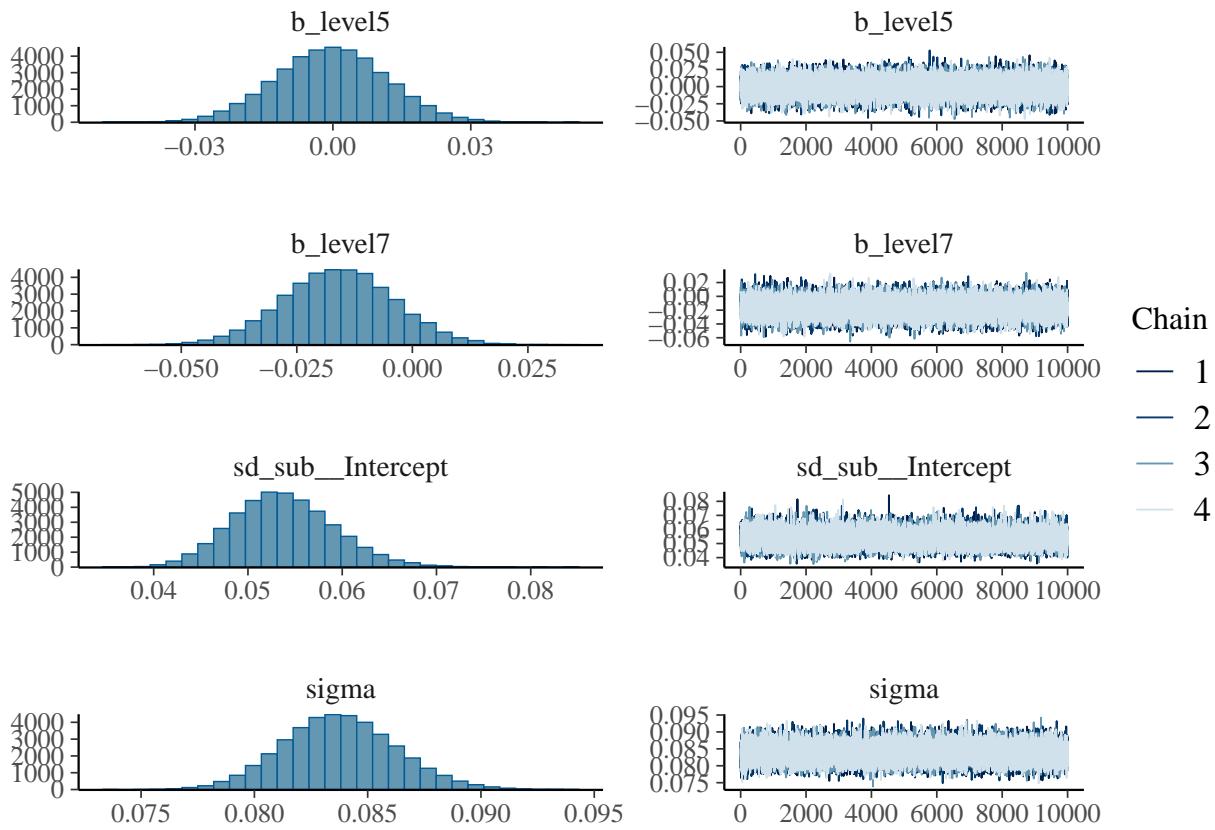
```

## Further Distributional Parameters:
## Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma    0.0839     0.0025    0.0792    0.0890 1.0001      47338    29980
##
## 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) 0.0535     0.0054   0.0440   0.0651 1.0000     14788    19610
##
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept -0.0018     0.0100  -0.0215   0.0181 1.0000     29177    28273
## level1    0.0108     0.0121  -0.0127   0.0343 1.0001     36876    33621
## level2    0.0147     0.0119  -0.0086   0.0383 1.0001     38090    33468
## level3   -0.0020     0.0121  -0.0254   0.0215 1.0000     37772    32725
## level4   -0.0004     0.0121  -0.0240   0.0230 1.0001     37984    33845
## level5   -0.0003     0.0120  -0.0240   0.0231 1.0000     38109    33796
## level7   -0.0159     0.0119  -0.0395   0.0075 1.0001     37846    33624
##
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma     0.0837     0.0025   0.0790   0.0888 1.0001     46232    28704
##
```

```

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

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

```

[1] "7.0935e-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      0.00911 -0.01069  0.02912
## 2      0.01294 -0.00724  0.03260
## 3     -0.00377 -0.02369  0.01620
## 4     -0.00209 -0.02189  0.01811
## 5     -0.00215 -0.02166  0.01846
## 8     -0.00177 -0.02169  0.01786
## 16    -0.01771 -0.03773  0.00238
##
## Point estimate displayed: median
## HPD interval probability: 0.95

```

All levels at chance.

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

```

##   contrast      estimate lower.HPD upper.HPD
## level1 - level2 -4.00e-03 -0.02717  0.0203
## level1 - level3 1.28e-02 -0.01076  0.0366
## level1 - level4 1.12e-02 -0.01233  0.0355
## level1 - level5 1.12e-02 -0.01269  0.0347
## level1 - level8 1.08e-02 -0.01242  0.0346
## level1 - level16 2.68e-02  0.00274  0.0506
## level2 - level3 1.67e-02 -0.00678  0.0403
## level2 - level4 1.51e-02 -0.00863  0.0389
## level2 - level5 1.51e-02 -0.00885  0.0389
## level2 - level8 1.47e-02 -0.00853  0.0383
## level2 - level16 3.08e-02  0.00644  0.0538
## level3 - level4 -1.52e-03 -0.02569  0.0219
## level3 - level5 -1.60e-03 -0.02465  0.0228
## level3 - level8 -1.99e-03 -0.02521  0.0217
## level3 - level16 1.40e-02 -0.00970  0.0378
## level4 - level5 7.04e-06 -0.02377  0.0241
## level4 - level8 -3.89e-04 -0.02341  0.0235

```

```
##  level4 - level16  1.55e-02  -0.00812   0.0395
##  level5 - level8  -3.46e-04  -0.02363   0.0234
##  level5 - level16  1.55e-02  -0.00824   0.0393
##  level8 - level16  1.59e-02  -0.00806   0.0387
##
## Point estimate displayed: median
## HPD interval probability: 0.95
```

No differences between any levels.

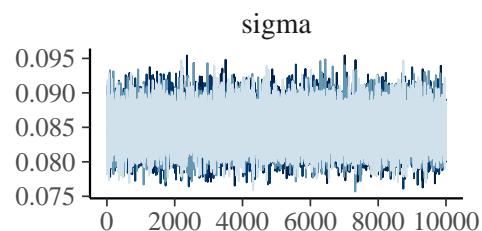
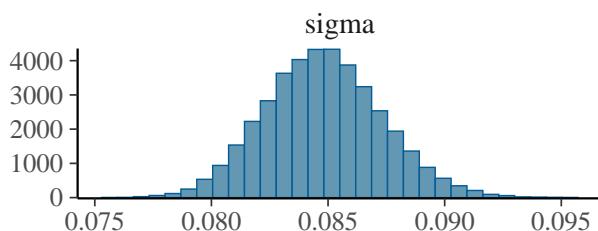
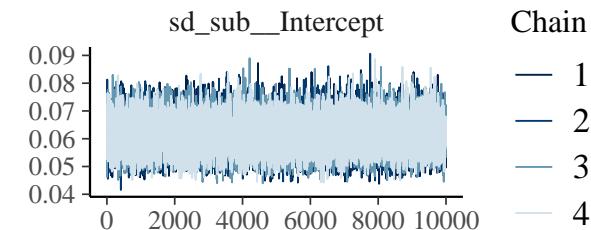
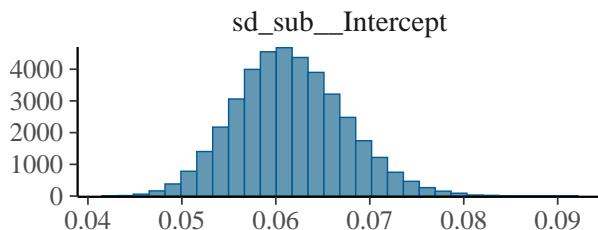
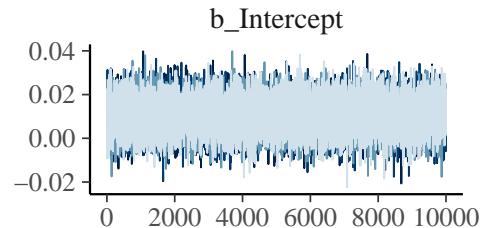
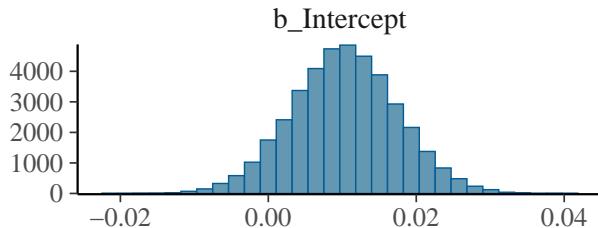
```
rm(levels1B)
rm(levels1B_null)
```

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)
```

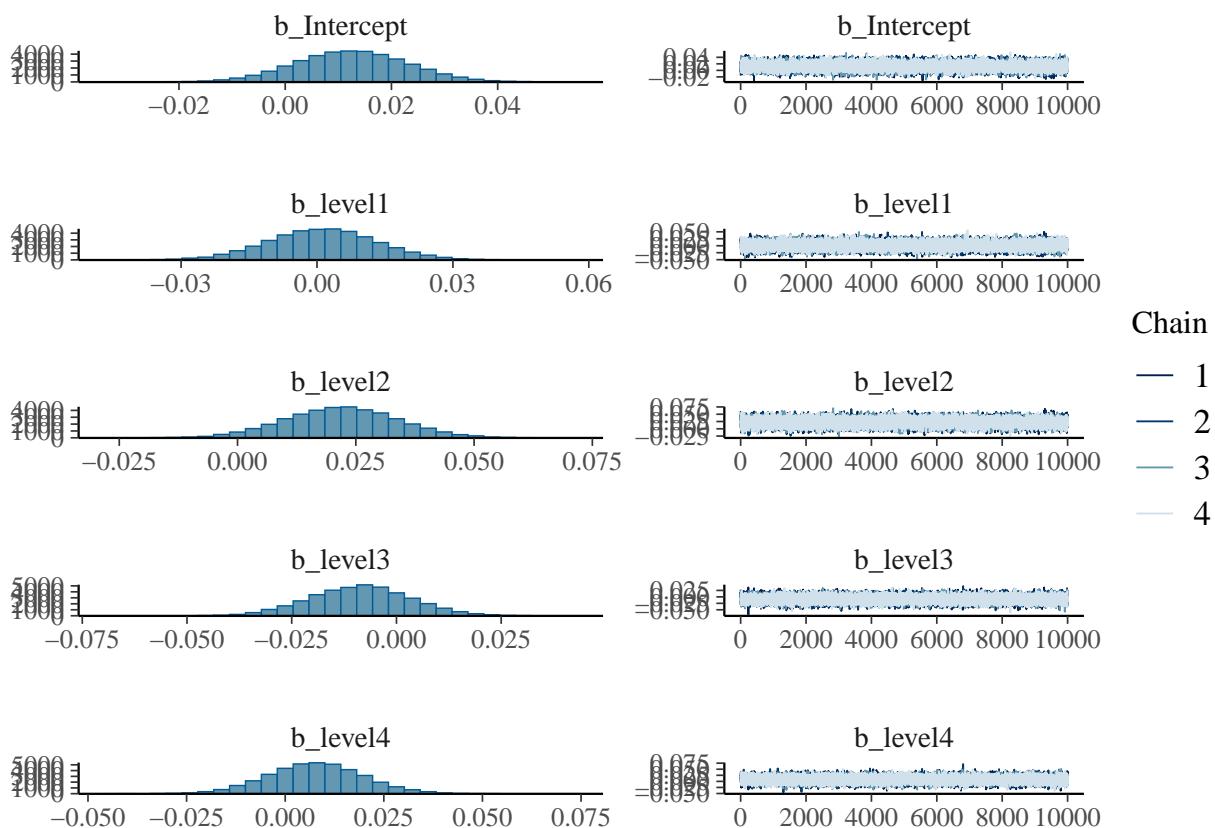
```
##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ 1 + (1 | sub)
##  Data: data2B (Number of observations: 665)
##  Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##          total post-warmup draws = 40000
##
##  Multilevel Hyperparameters:
##  ~sub (Number of levels: 95)
##                  Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  sd(Intercept)   0.0613    0.0058   0.0509    0.0737 1.0002    14116   19606
## 
##  Regression Coefficients:
##                  Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  Intercept      0.0103    0.0071  -0.0038    0.0244 1.0003    19549   25877
```

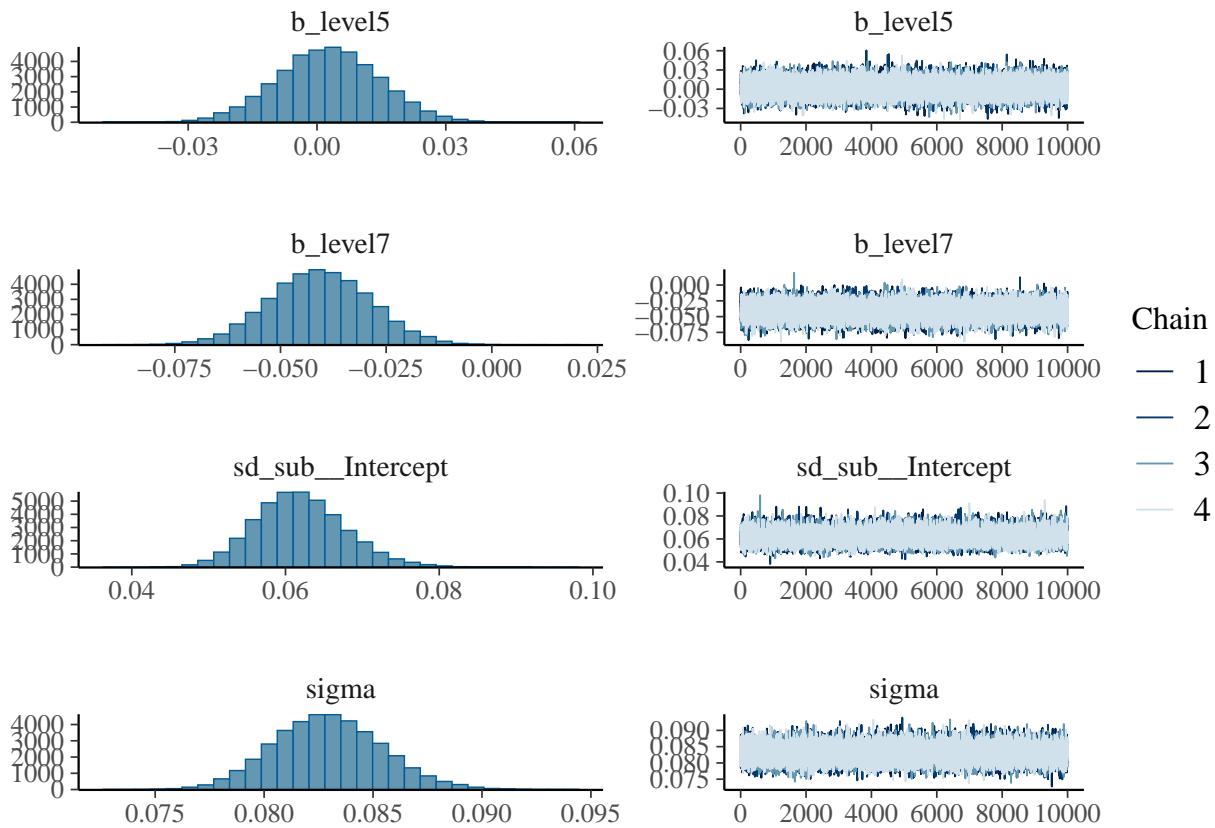
```

## Further Distributional Parameters:
## Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma    0.0847     0.0025    0.0801    0.0899 1.0000      52634     32151
##
## 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)  0.0617    0.0057   0.0514   0.0744 1.0008     14201    21939
## 
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept    0.0125    0.0105  -0.0079   0.0329 1.0001     20700    26283
## level1       0.0012    0.0118  -0.0220   0.0244 1.0002     36052    33296
## level2       0.0220    0.0119  -0.0013   0.0452 1.0001     37003    34312
## level3      -0.0085    0.0119  -0.0319   0.0147 1.0002     34120    33031
## level4       0.0076    0.0118  -0.0155   0.0313 1.0002     36019    32470
## level5       0.0027    0.0119  -0.0208   0.0260 1.0001     36701    32884
## level7      -0.0407    0.0120  -0.0640  -0.0174 1.0001     35793    32765
## 
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma        0.0829    0.0025   0.0783   0.0880 1.0001     49675    30619
## 
```

```
## 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
```

```
print(BF_2B_level)
```

```
## Estimated Bayes factor in favor of levels2B over levels2B_null: 0.00060
```

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     0.01370 -0.006348  0.03520  
## 2     0.03452  0.013819  0.05568  
## 3     0.00386 -0.016642  0.02500  
## 4     0.02020 -0.000256  0.04138  
## 5     0.01517 -0.005593  0.03647  
## 8     0.01254 -0.007210  0.03361  
## 16    -0.02821 -0.048925 -0.00741  
##
```

```
## 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 -0.02079 -0.04485  0.00274  
## 2 level1 - level3  0.00989 -0.01362  0.03370  
## 3 level1 - level4 -0.00650 -0.03013  0.01688  
## 4 level1 - level5 -0.00153 -0.02493  0.02246  
## 5 level1 - level8  0.00123 -0.02243  0.02398  
## 6 level1 - level16  0.04192  0.01856  0.06534  
## 7 level2 - level3  0.03064  0.00778  0.05468  
## 8 level2 - level4  0.01431 -0.00849  0.03850  
## 9 level2 - level5  0.01929 -0.00478  0.04267  
## 10 level2 - level8  0.02202 -0.00174  0.04471  
## 11 level2 - level16  0.06276  0.03872  0.08604  
## 12 level3 - level4 -0.01629 -0.03978  0.00719  
## 13 level3 - level5 -0.01135 -0.03523  0.01198  
## 14 level3 - level8 -0.00848 -0.03211  0.01439  
## 15 level3 - level16  0.03210  0.00888  0.05568  
## 16 level4 - level5  0.00497 -0.01916  0.02814
```

```
##  level4 - level8  0.00765 -0.01537  0.03135
##  level4 - level16 0.04842  0.02514  0.07180
##  level5 - level8  0.00265 -0.02102  0.02562
##  level5 - level16 0.04335  0.01988  0.06712
##  level8 - level16 0.04073  0.01733  0.06389
##
## Point estimate displayed: median
## HPD interval probability: 0.95

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

2 > 3

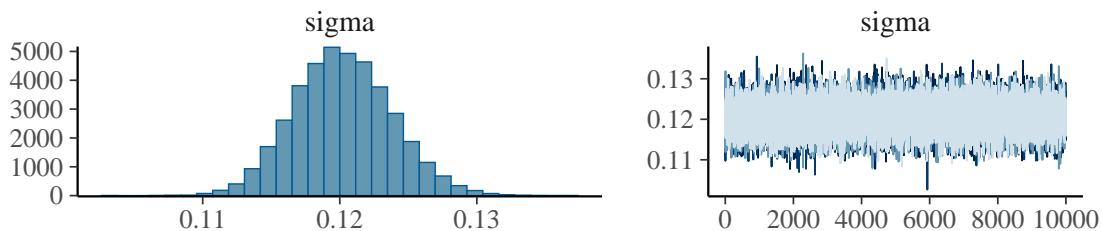
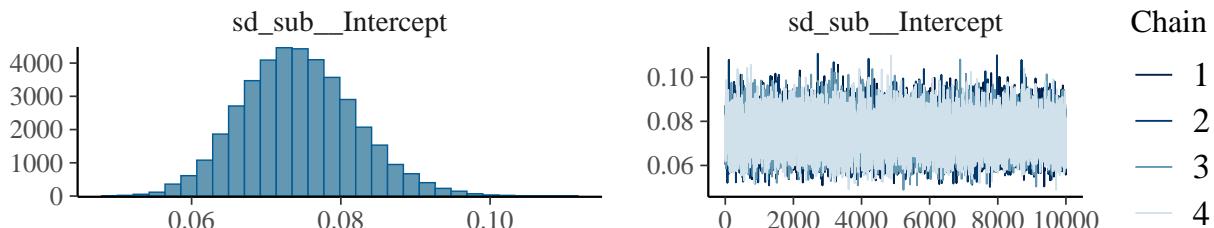
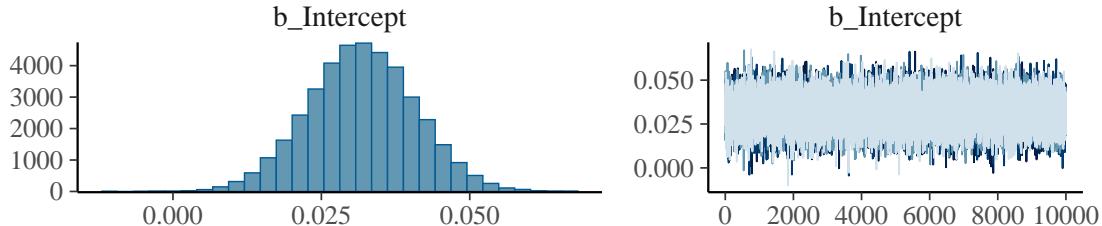
rm(levels2B)
rm(levels2B_null)
```

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')

plot(levels8B_null)
```



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

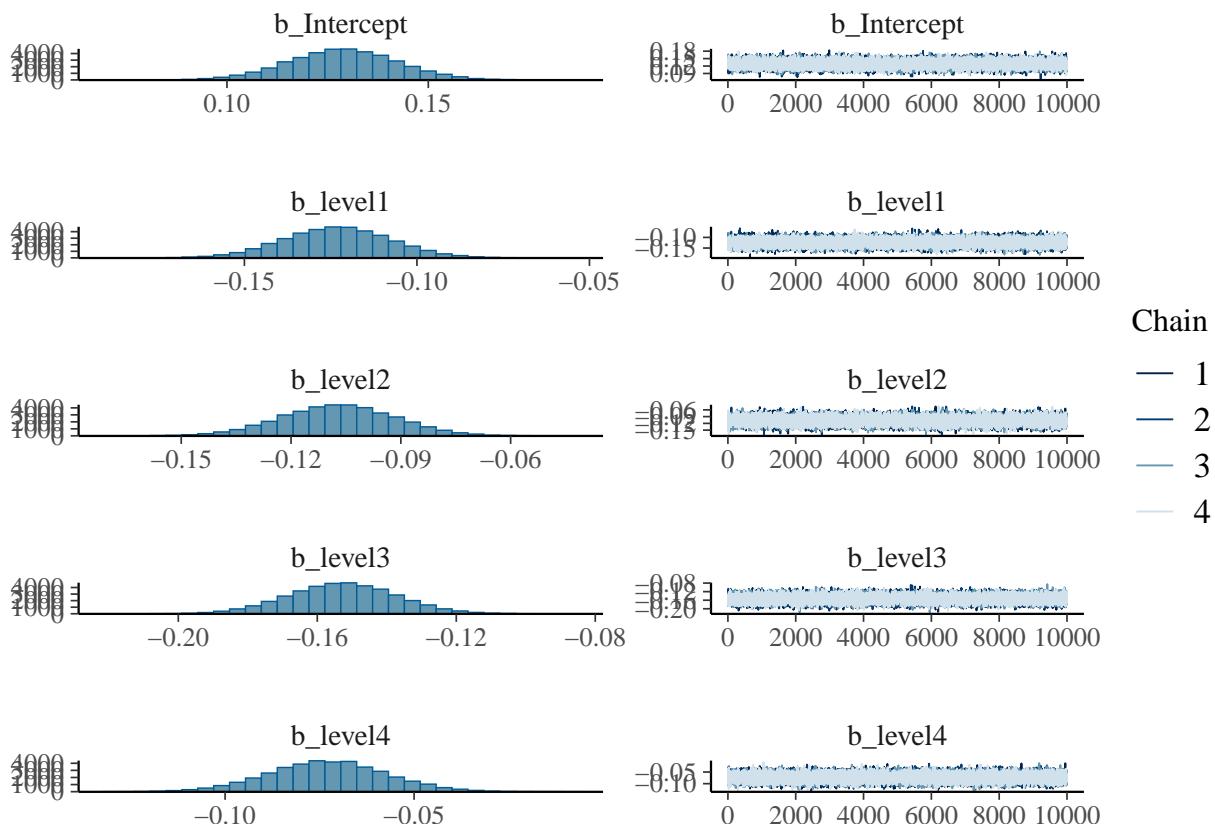
##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ 1 + (1 | sub)
##  Data: data8B (Number of observations: 665)
##  Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##        total post-warmup draws = 40000
##
##  Multilevel Hyperparameters:
##  ~sub (Number of levels: 95)
##          Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  sd(Intercept)  0.0740    0.0076   0.0602   0.0902 1.0002     13631    19391
## 
##  Regression Coefficients:
##          Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  Intercept    0.0318    0.0090   0.0142   0.0494 1.0001     18764    24668
```

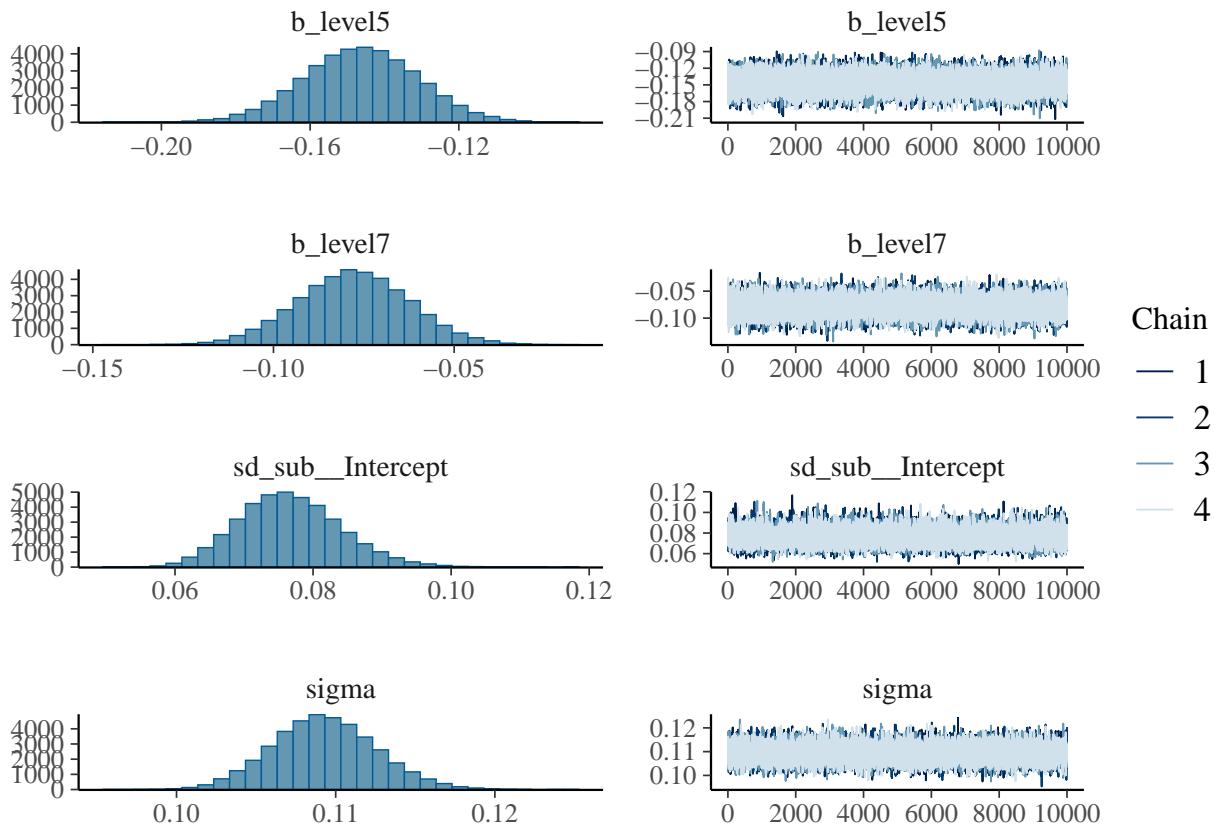
```

## Further Distributional Parameters:
## Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma    0.1201     0.0036    0.1135    0.1274 1.0000     41378    27412
##
## 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')

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)  0.0763     0.0073   0.0632   0.0923 1.0001    14835    20942
##
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept   0.1288     0.0134   0.1025   0.1550 1.0000    26609    28818
## level1     -0.1231     0.0155  -0.1535  -0.0928 1.0001    37215    33290
## level2     -0.1071     0.0156  -0.1379  -0.0770 1.0000    39226    32496
## level3     -0.1527     0.0155  -0.1829  -0.1226 1.0000    36762    34176
## level4     -0.0730     0.0154  -0.1033  -0.0426 1.0000    38365    34147
## level5     -0.1463     0.0154  -0.1766  -0.1163 1.0000    39055    34695
## level7     -0.0778     0.0155  -0.1083  -0.0473 1.0001    36724    32606
##
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma      0.1092     0.0032   0.1031   0.1159 1.0000    51548    30505
##
```

```

## 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

print(BF_8B_level)

## Estimated Bayes factor in favor of levels8B over levels8B_null: 11460703792892999680.00000

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      0.00574 -0.02108  0.03213
## 2      0.02175 -0.00535  0.04852
## 3     -0.02395 -0.05057  0.00272
## 4      0.05588  0.02841  0.08174
## 5     -0.01766 -0.04416  0.00919
## 8      0.12882  0.10279  0.15525
## 16     0.05093  0.02492  0.07801
##
## 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
## 1 level1 - level2 -0.01597 -0.04686  0.01442
## 2 level1 - level3  0.02970 -0.00101  0.06067
## 3 level1 - level4 -0.05009 -0.08061 -0.01861
## 4 level1 - level5  0.02326 -0.00646  0.05485
## 5 level1 - level8 -0.12307 -0.15399 -0.09342
## 6 level1 - level16 -0.04531 -0.07610 -0.01459
## 7 level2 - level3  0.04574  0.01512  0.07677
## 8 level2 - level4 -0.03424 -0.06585 -0.00370
## 9 level2 - level5  0.03923  0.00789  0.06976
## 10 level2 - level8 -0.10705 -0.13791 -0.07710
## 11 level2 - level16 -0.02923 -0.05968  0.00221
## 12 level3 - level4 -0.07975 -0.11056 -0.04923
## 13 level3 - level5 -0.00642 -0.03734  0.02364
## 14 level3 - level8 -0.15275 -0.18325 -0.12303
## 15 level3 - level16 -0.07499 -0.10617 -0.04459
## 16 level4 - level5  0.07344  0.04248  0.10386

```

```

##  level4 - level8 -0.07303 -0.10406 -0.04342
##  level4 - level16  0.00494 -0.02621  0.03550
##  level5 - level8 -0.14627 -0.17667 -0.11638
##  level5 - level16 -0.06848 -0.09980 -0.03787
##  level8 - level16  0.07779  0.04686  0.10770
##
## 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)

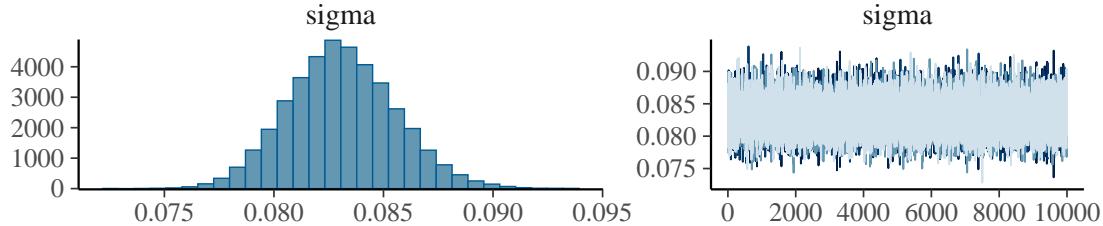
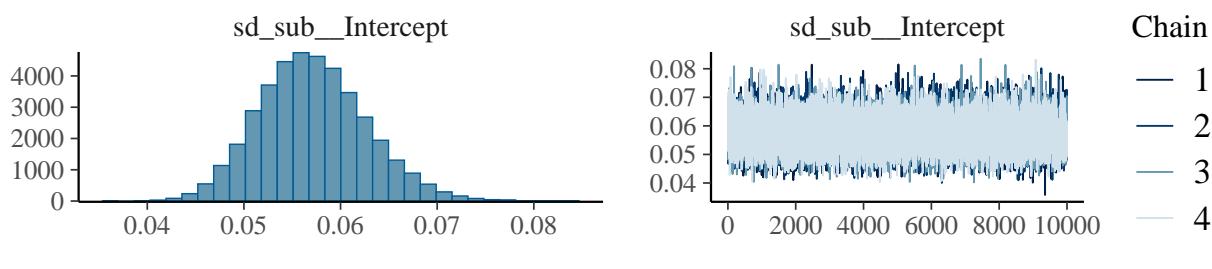
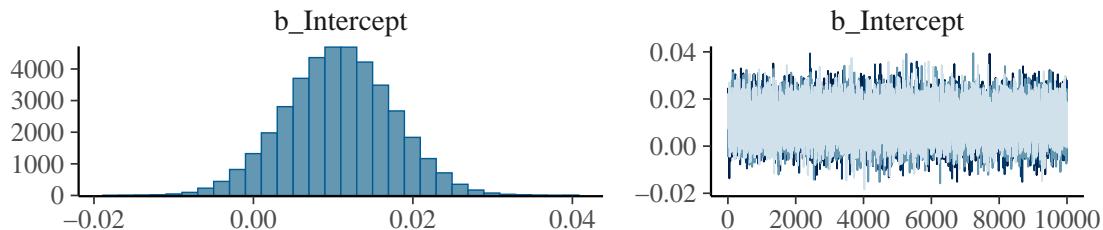
```

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)
```

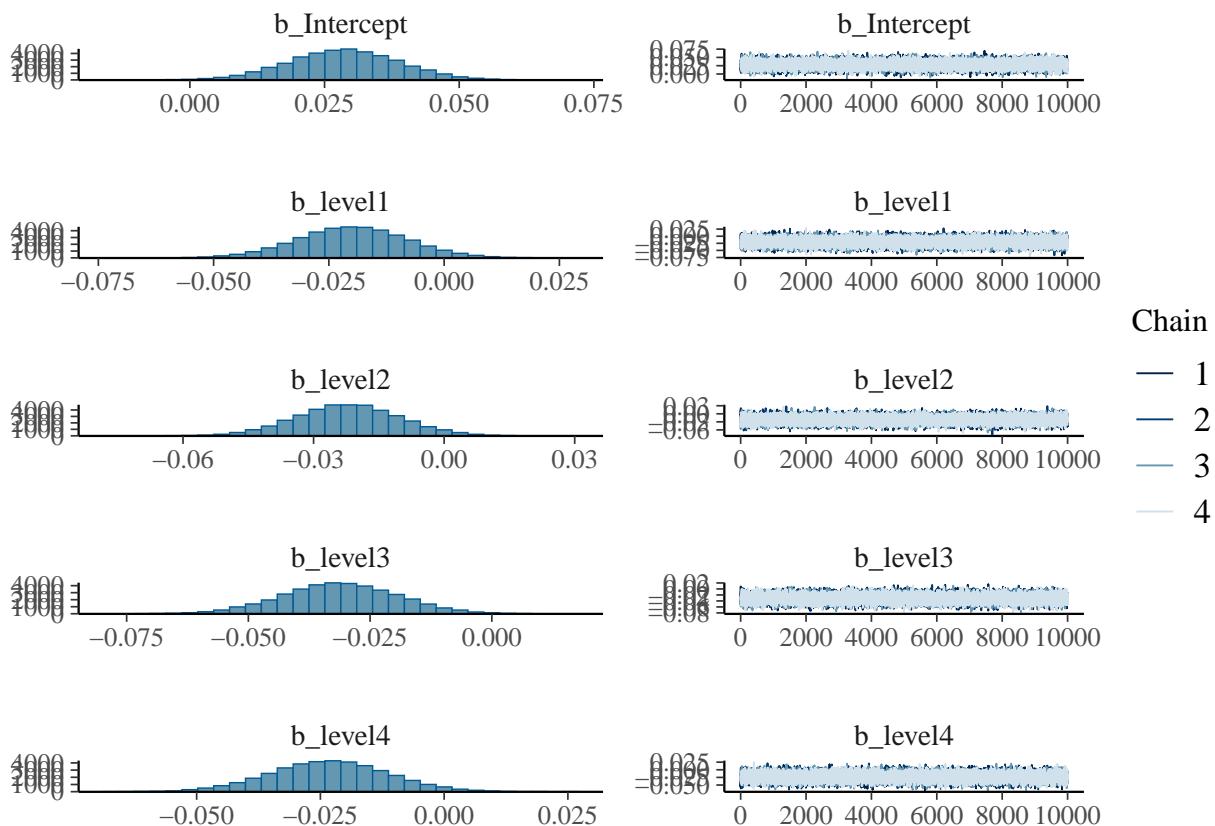
```
##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ 1 + (1 | sub)
##  Data: dataI (Number of observations: 665)
##  Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##         total post-warmup draws = 40000
##
##  Multilevel Hyperparameters:
##  ~sub (Number of levels: 95)
##                Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  sd(Intercept)   0.0569    0.0055   0.0471   0.0687 1.0002    15965    24689
## 
##  Regression Coefficients:
##                Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
##  Intercept     0.0107    0.0067  -0.0025   0.0238 1.0000    20993    26820
```

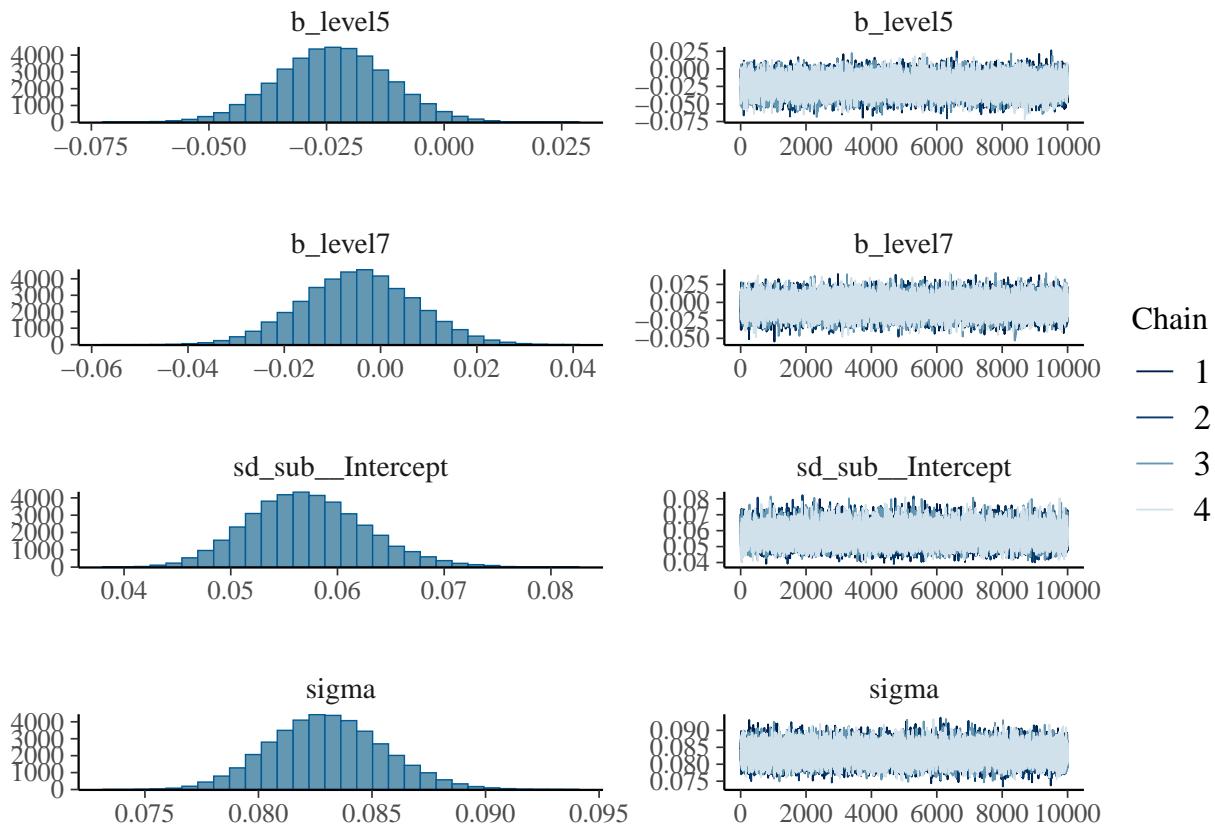
```

## Further Distributional Parameters:
## Estimate Est.Error l-95% CI u-95% CI   Rhat Bulk_ESS Tail_ESS
## sigma    0.0830    0.0024    0.0785    0.0881 1.0000     53387    28541
##
## 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)  0.0569    0.0055   0.0471   0.0690 1.0007    14656   23553
## 
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept    0.0286    0.0102   0.0087   0.0483 1.0001    23557   27596
## level1     -0.0199    0.0119  -0.0432   0.0031 1.0000    36120   32617
## level2     -0.0221    0.0118  -0.0454   0.0014 1.0000    35561   33522
## level3     -0.0312    0.0118  -0.0545  -0.0080 1.0002    34993   32092
## level4     -0.0232    0.0118  -0.0466  -0.0001 1.0001    36475   33614
## level5     -0.0236    0.0118  -0.0468  -0.0003 1.0001    36080   34194
## level7     -0.0046    0.0118  -0.0277   0.0184 1.0000    35732   29919
## 
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma      0.0830    0.0025   0.0783   0.0881 1.0000    55508   31110
## 
```

```

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

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

```

```
## [1] "2.5956e-08"
```

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	0.00870	-0.01174	0.0288
##	2	0.00656	-0.01366	0.0270
##	3	-0.00257	-0.02239	0.0178
##	4	0.00528	-0.01457	0.0257
##	5	0.00507	-0.01537	0.0253
##	8	0.02861	0.00911	0.0487
##	16	0.02394	0.00335	0.0440
##				

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	0.002115	-0.0221	0.024992
##	level1 - level3	0.011240	-0.0131	0.034247
##	level1 - level4	0.003382	-0.0199	0.027108
##	level1 - level5	0.003587	-0.0199	0.027536
##	level1 - level8	-0.019896	-0.0433	0.003079
##	level1 - level16	-0.015268	-0.0394	0.007639
##	level2 - level3	0.009095	-0.0142	0.032892
##	level2 - level4	0.001211	-0.0236	0.023713
##	level2 - level5	0.001426	-0.0217	0.025192
##	level2 - level8	-0.022141	-0.0451	0.001579
##	level2 - level16	-0.017423	-0.0413	0.006081
##	level3 - level4	-0.007942	-0.0313	0.015893
##	level3 - level5	-0.007689	-0.0317	0.014717
##	level3 - level8	-0.031209	-0.0546	-0.008264
##	level3 - level16	-0.026514	-0.0502	-0.003290
##	level4 - level5	0.000335	-0.0237	0.023102

```
##  level4 - level8  -0.023199  -0.0468 -0.000308
##  level4 - level16 -0.018517  -0.0419  0.004778
##  level5 - level8  -0.023562  -0.0464 -0.000123
##  level5 - level16 -0.018907  -0.0422  0.004751
##  level8 - level16  0.004650  -0.0185  0.027670
##
## 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

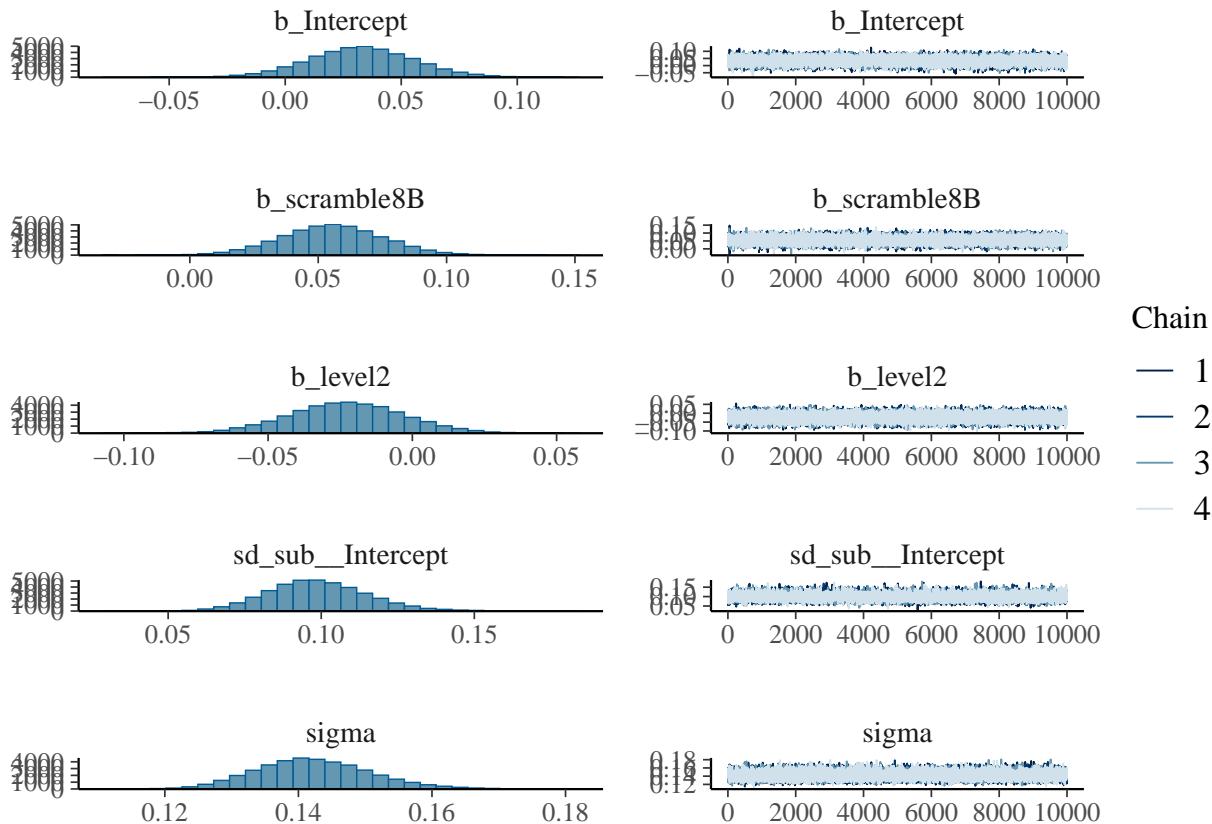
```
data_longTS <- data %>%
  filter(scramble %in% c('Intact', '8B')) %>%
  filter(level %in% c('8', '16')) %>%
  mutate(scramble = factor(scramble, levels = c('Intact', '8B')),
         level = factor(level, levels = c('8', '16')))
```

```
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)
```



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

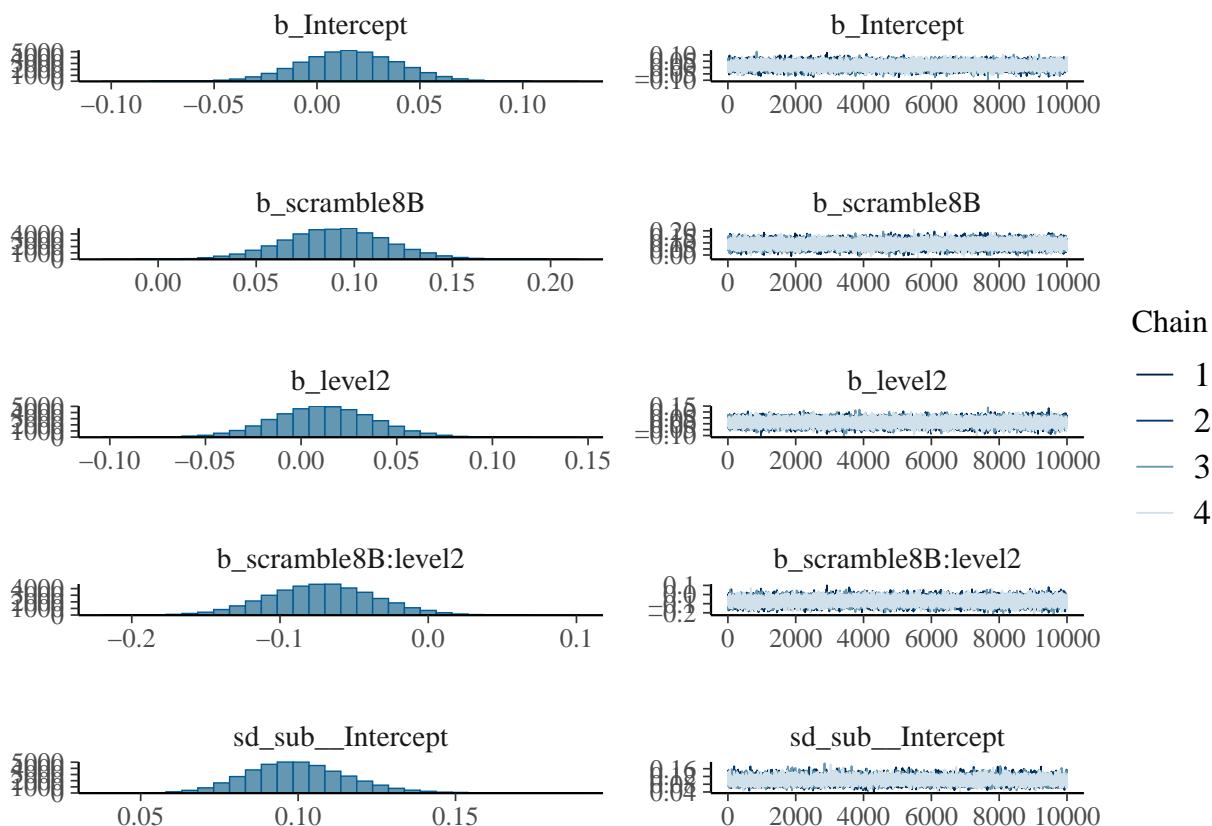
```
##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ scramble + level + (1 | sub)
##   Data: data_longTS_M (Number of observations: 196)
##   Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##          total post-warmup draws = 40000
##
```

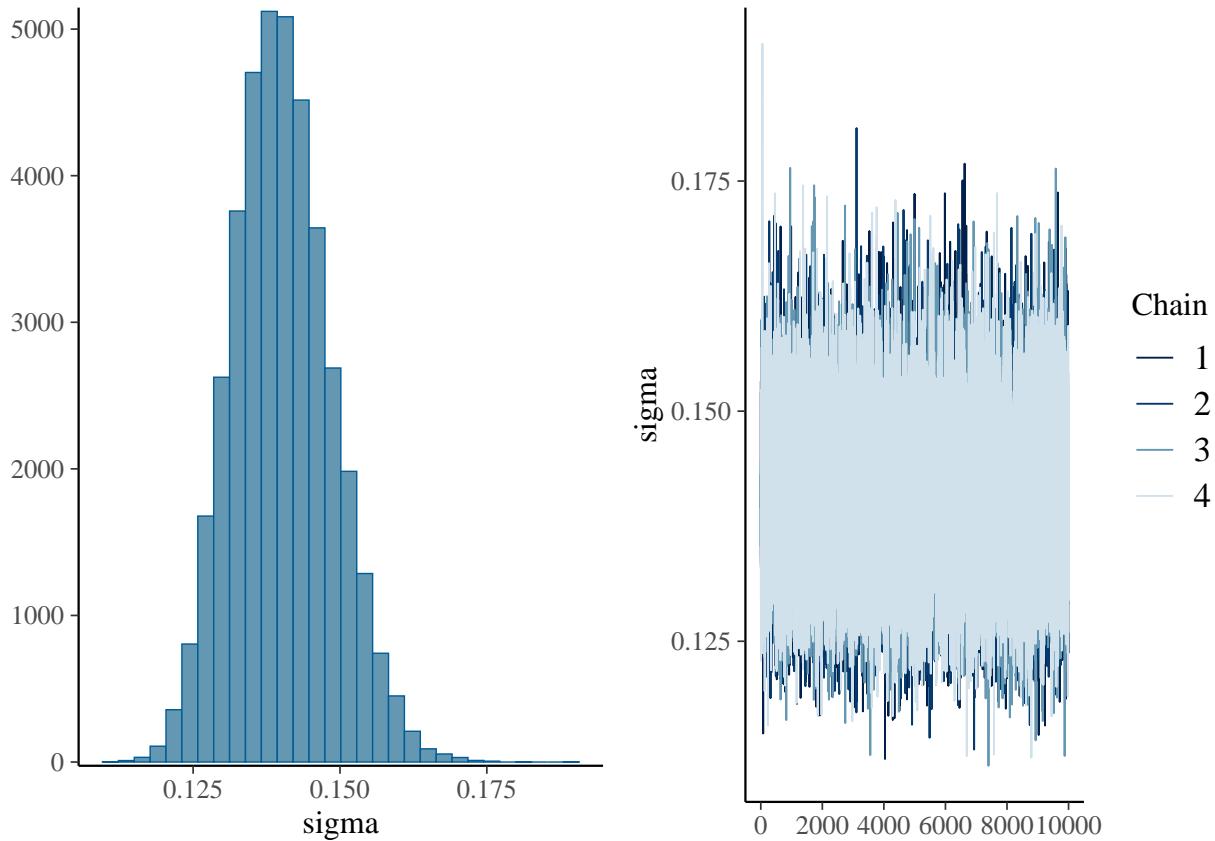
```

## Multilevel Hyperparameters:
## ~sub (Number of levels: 49)
##           Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sd(Intercept)  0.0982   0.0159   0.0687   0.1331 1.0003    13707   20213
##
## Regression Coefficients:
##           Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept     0.0328   0.0223  -0.0114   0.0772 1.0002    30831   30179
## scramble8B    0.0554   0.0196   0.0166   0.0943 1.0001    64410   28505
## level2       -0.0228   0.0197  -0.0615   0.0161 1.0000    63845   29581
##
## Further Distributional Parameters:
##           Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma        0.1419   0.0085   0.1268   0.1603 1.0003    28535   30095
##
## 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)  0.0992    0.0158   0.0704   0.1341 1.0000    13106    20922
## 
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept      0.0158    0.0237  -0.0304   0.0624 1.0002    26794    29039
## scramble8B     0.0904    0.0261   0.0382   0.1417 1.0000    39650    32523
## level2        0.0118    0.0260  -0.0395   0.0636 1.0002    39444    32025
## scramble8B:level2 -0.0718    0.0362  -0.1422  -0.0008 1.0001    36081    30394
## 
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma       0.1397    0.0083   0.1251   0.1576 1.0001    28915    29023
## 
## 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: 1  
## Iteration: 2  
## Iteration: 3  
## Iteration: 4  
## Iteration: 5  
## Iteration: 6  
  
print(BF_longM)  
  
## Estimated Bayes factor in favor of longTS_M_int over longTS_M: 2.58284
```

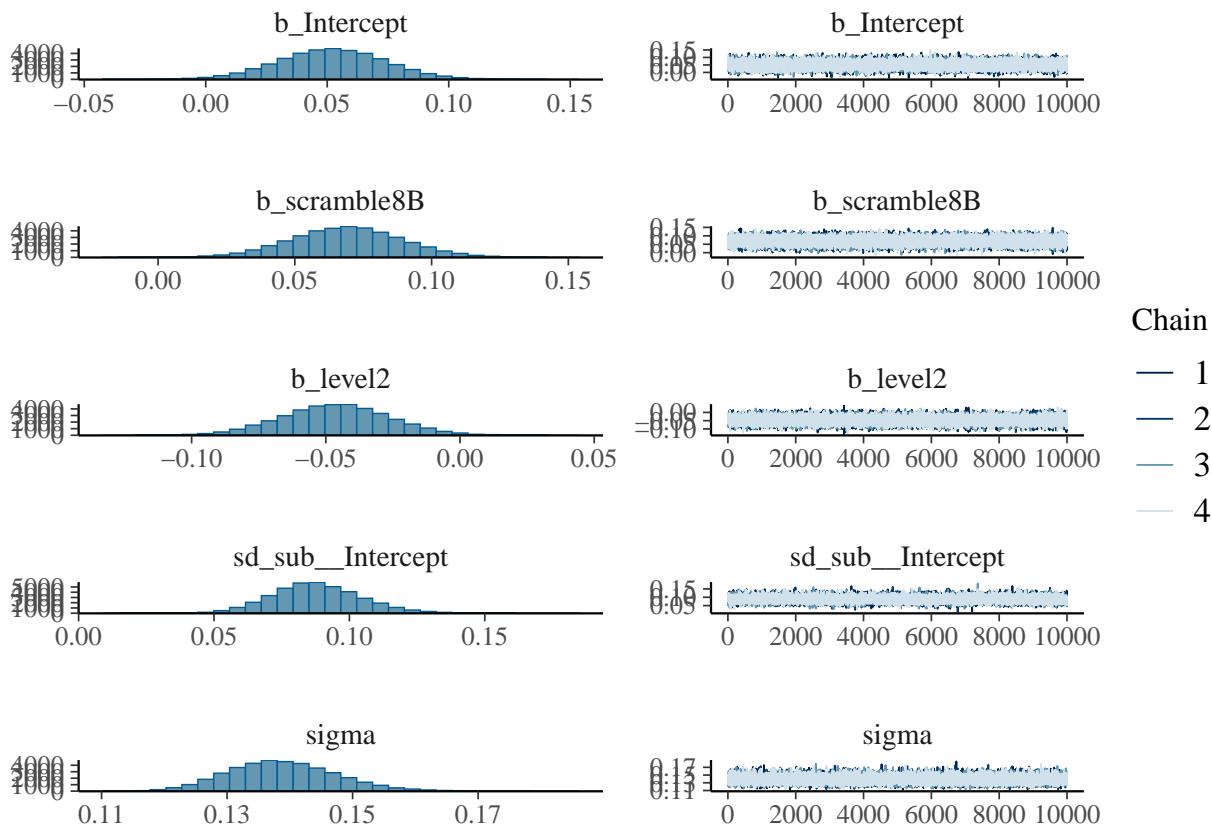
There is weak evidence for an interaction for musicians.

```

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)  0.0872    0.0160   0.0574   0.1221 1.0001    13293   20333
## 
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI   Rhat Bulk_ESS Tail_ESS
## Intercept     0.0521    0.0219   0.0087   0.0948 1.0000    25734   27165
## scramble8B    0.0690    0.0201   0.0292   0.1085 1.0000    55497   30021
## level2      -0.0463    0.0199  -0.0857  -0.0071 1.0002    52562   29603
## 
## Further Distributional Parameters:

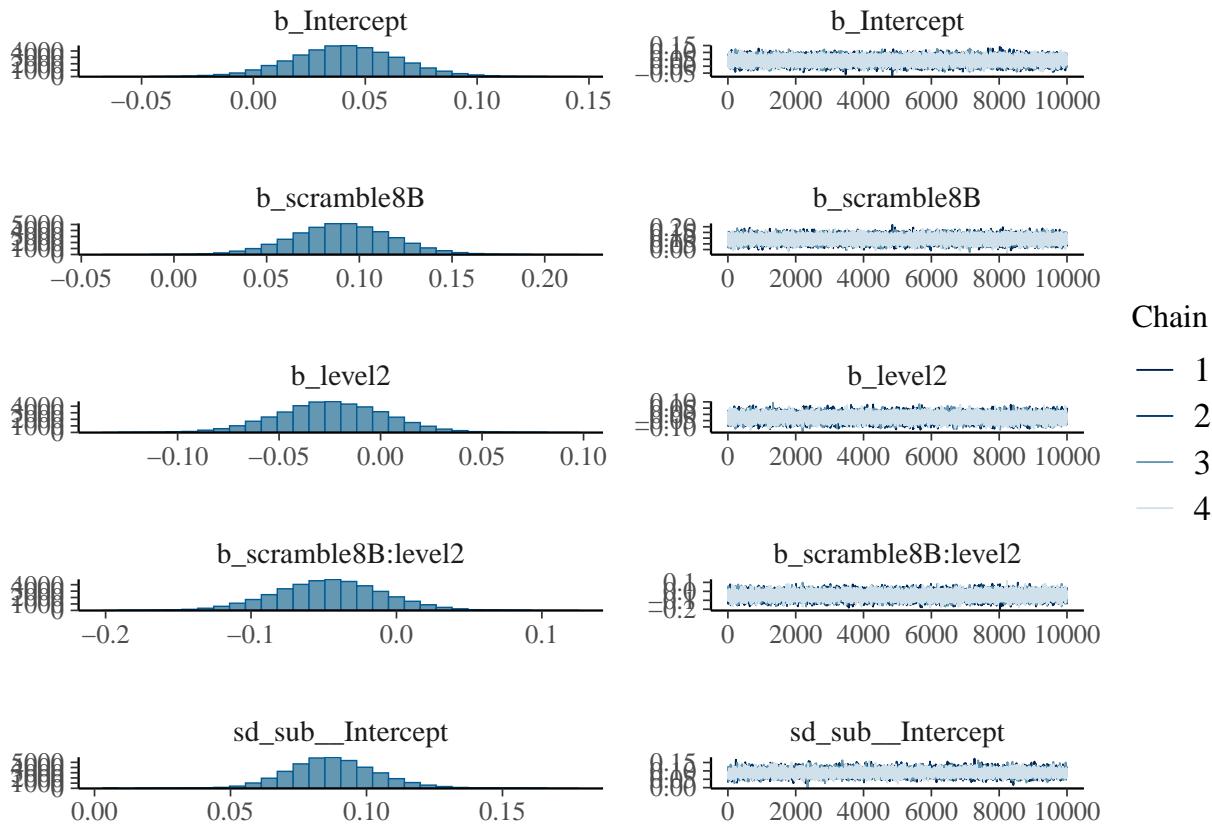
```

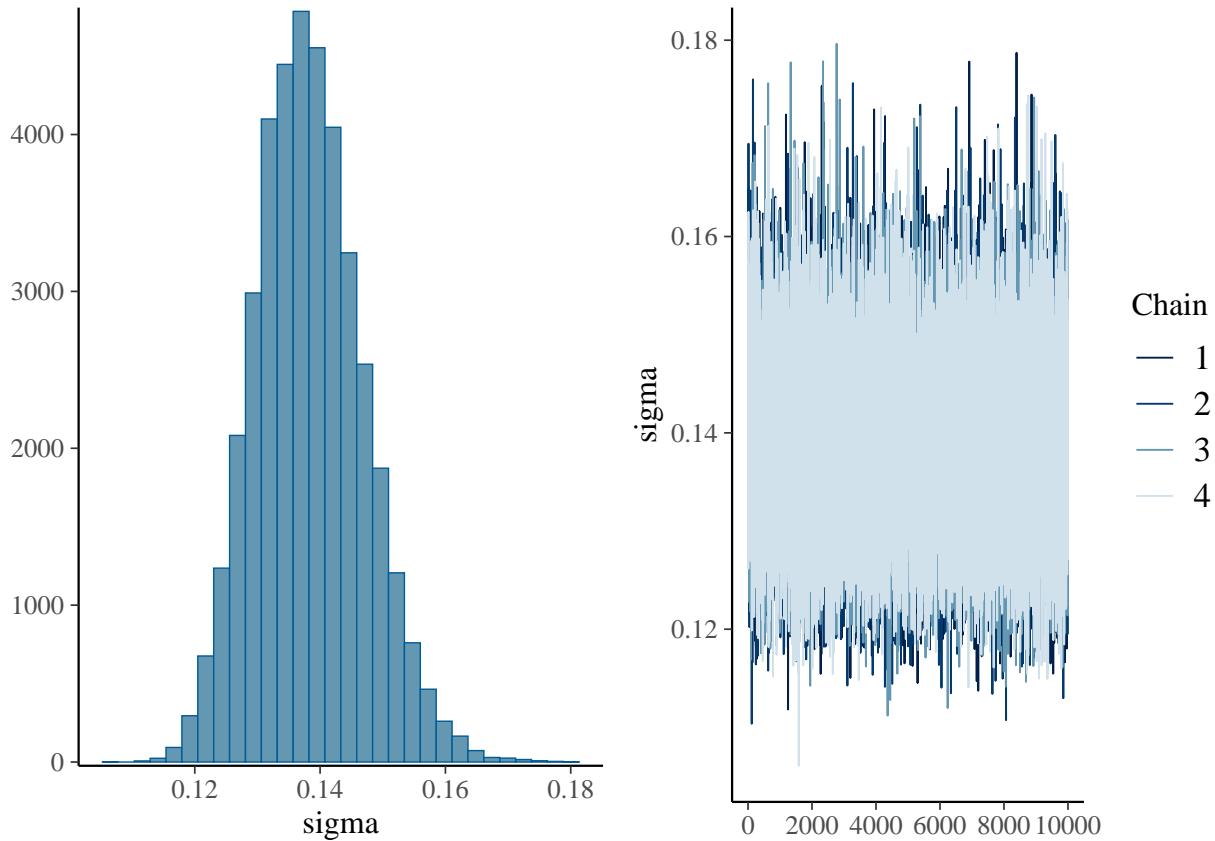
```

##      Estimate Est.Error 1-95% CI u-95% CI     Rhat Bulk_ESS Tail_ESS
## sigma    0.1384    0.0085   0.1232   0.1567 1.0000    25721    29526
##
## 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)  0.0871   0.0155   0.0575   0.1217 1.0007   12811   20948
## 
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept      0.0411   0.0233  -0.0050   0.0876 1.0000   36338   31740
## scramble8B     0.0909   0.0263   0.0385   0.1438 1.0000   49667   32719
## level2        -0.0242   0.0264  -0.0768   0.0275 1.0000   49281   34238
## scramble8B:level2 -0.0460   0.0365  -0.1184   0.0259 1.0000   47734   29413
## 
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma       0.1379   0.0085   0.1227   0.1562 1.0001   28917   28628
## 
## 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: 5  
## 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: 0.81943
```

There is weak evidence against an interaction for musicians.