

E3 alignment

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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')
```

For comparisons across levels, look at nested structure only (levels 2, 4, 8, 16).

```
data_nested <- data %>%
  filter(!level %in% c(1,3,5))
```

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)

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

```

contrasts(data_nested$scramble) <- contr.treatment(4) # Intact as reference
contrasts(data_nested$level) <- contr.treatment(4, base = 3) # 8-bar as reference
contrasts(data_nested$Musician) <- c(-1,1)

```

Check normality of the data.

```

data %>%
  group_by(scramble, level) %>%
  shapiro_test(value)

```

```

## # A tibble: 28 x 5
##   scramble level variable statistic      p
##   <fct>    <ord> <chr>     <dbl>    <dbl>
## 1 Intact    1     value     0.735 8.46e-12
## 2 Intact    2     value     0.811 1.06e- 9
## 3 Intact    3     value     0.946 6.96e- 4
## 4 Intact    4     value     0.925 4.15e- 5
## 5 Intact    5     value     0.919 2.10e- 5
## 6 Intact    8     value     0.889 7.44e- 7
## 7 Intact   16     value     0.816 1.56e- 9
## 8 8B        1     value     0.945 5.79e- 4
## 9 8B        2     value     0.964 1.02e- 2
## 10 8B       3     value     0.901 2.52e- 6
## # i 18 more rows

```

Visualize.

```

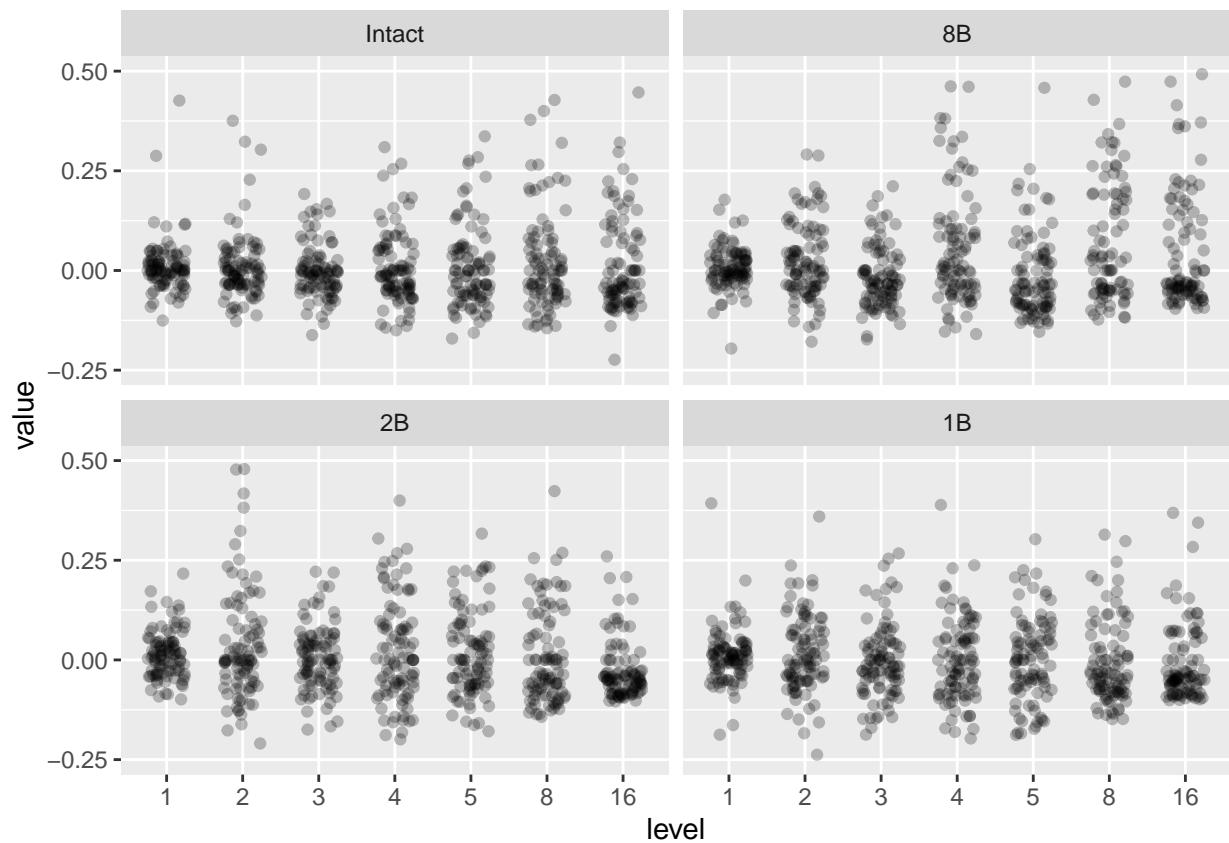
data %>%
  ggplot(aes(x = level, y = value)) +
  geom_jitter(width = 0.25, alpha = 0.25) +
  facet_wrap(vars(scramble)) +
  ylim(-0.25, 0.5)

```

```

## Warning: Removed 15 rows containing missing values or values outside the scale range
## (`geom_point()`).

```



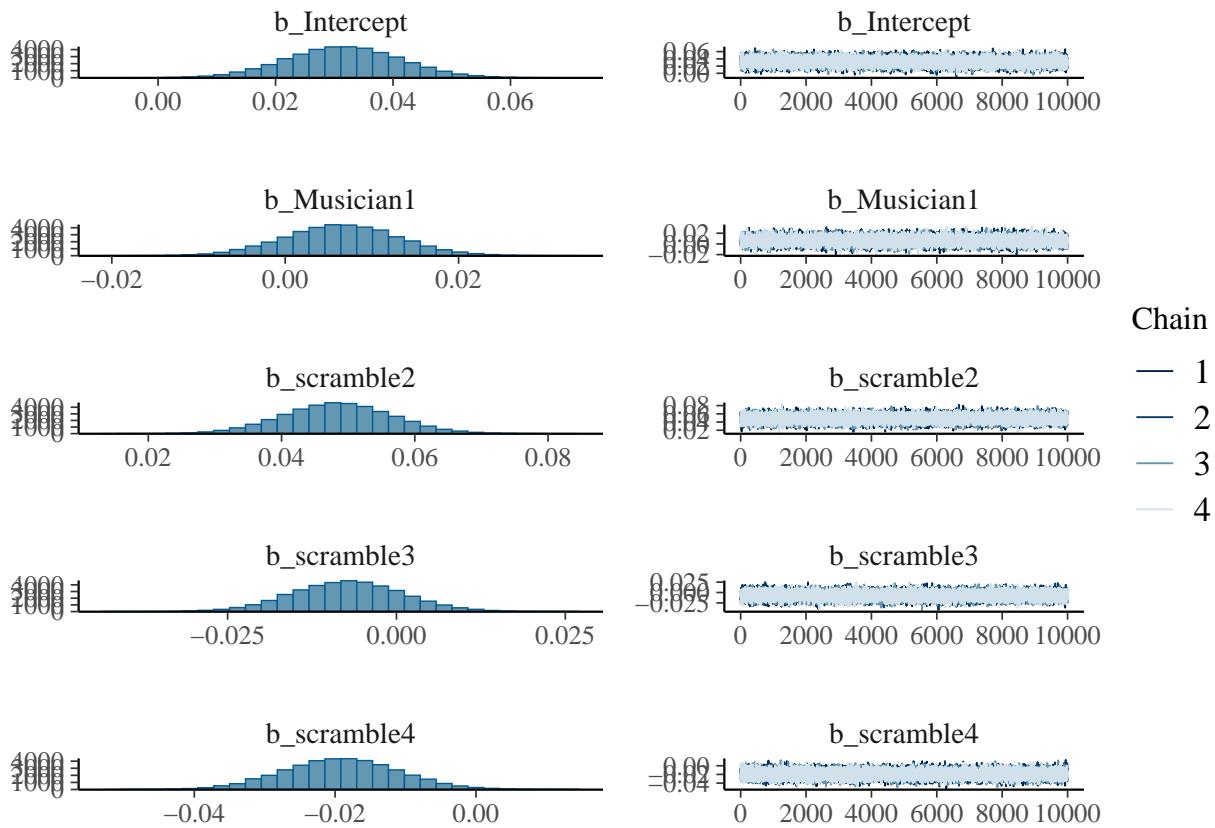
Main analysis

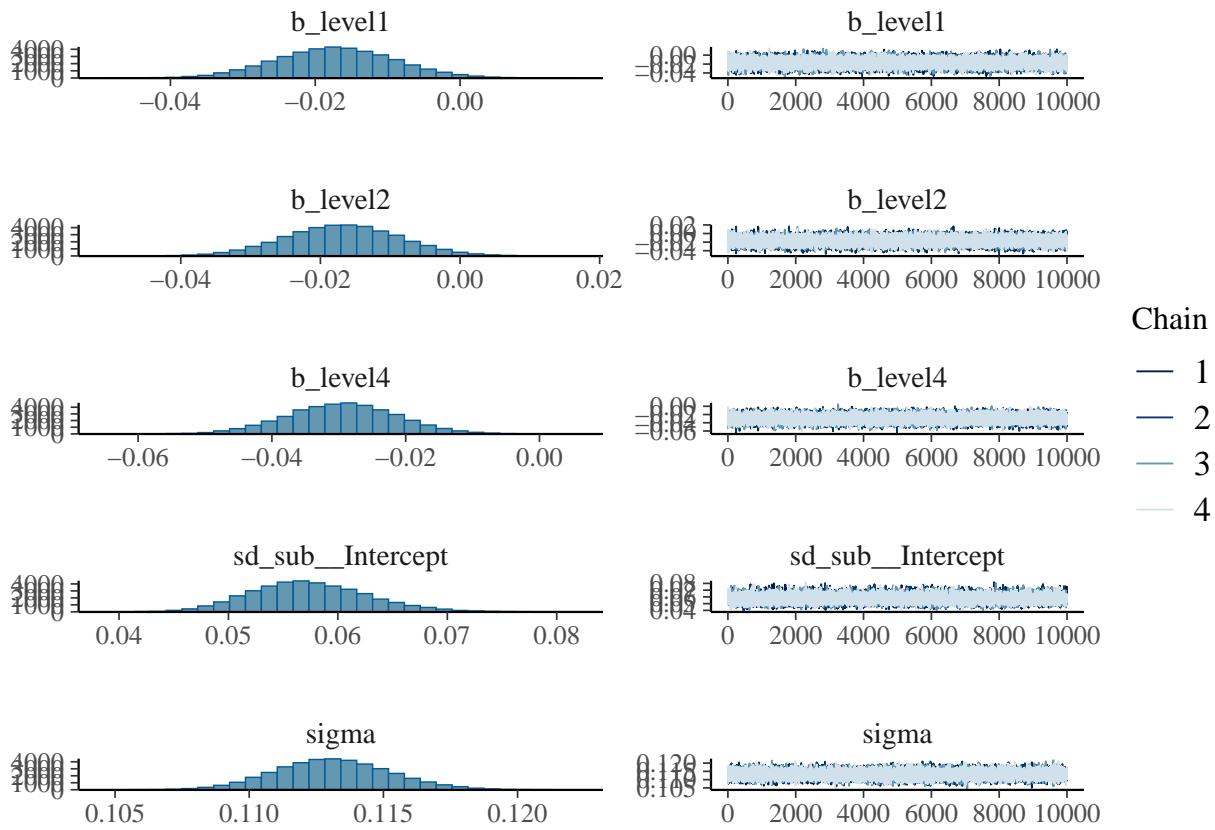
```

nested_3way <- brm(value ~ Musician + scramble + level + (1|sub), data = data_nested,
                     prior = c(
                       set_prior('normal(-0.1, 0.1)', coef = 'Musician1'),
                       set_prior('normal(0.1, 0.1)', coef = 'scramble2'),
                       set_prior('normal(-0.1, 0.1)', coef = 'scramble3'),
                       set_prior('normal(-0.1, 0.1)', coef = 'scramble4'),
                       set_prior('normal(-0.2, 0.1)', coef = 'level1'),
                       set_prior('normal(-0.1, 0.1)', coef = c('level2', 'level4'))
                     ),
                     save_pars = save_pars(all = TRUE), iter = 20000, refresh = 0,
                     file = 'models/E3_alignment_3way_noInt')

plot(nested_3way)

```





```
print(summary(nested_3way, robust = TRUE), digits = 4)
```

```
##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ Musician + scramble + level + (1 | sub)
##  Data: data_nested (Number of observations: 1520)
##  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)  0.0571    0.0053   0.0477   0.0687 1.0003    14994   22761
## 
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept    0.0316    0.0097   0.0128   0.0504 1.0001    29539   30139
## Musician1    0.0065    0.0065  -0.0063   0.0195 1.0000    18013   24808
## scramble2    0.0484    0.0081   0.0325   0.0644 1.0000    58669   33877
## scramble3   -0.0072    0.0082  -0.0232   0.0088 1.0000    57439   33776
## scramble4   -0.0191    0.0081  -0.0350  -0.0032 1.0000    58476   33964
## level1     -0.0172    0.0082  -0.0331  -0.0012 1.0000    57068   33720
## level2     -0.0168    0.0082  -0.0327  -0.0010 1.0000    57535   34218
## level4     -0.0295    0.0082  -0.0456  -0.0135 1.0001    55528   34146
## 
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma      0.1131    0.0021   0.1091   0.1174 1.0001    74547   31040
```

```
##  
## 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).
```

```

nested_noMus <- brm(value ~ scramble + level + (1|sub), data = data_nested,
                     prior = c(
                       set_prior('normal(0.1, 0.1)', coef = 'scramble2'),
                       set_prior('normal(-0.1, 0.1)', coef = 'scramble3'),
                       set_prior('normal(-0.1, 0.1)', coef = 'scramble4'),
                       set_prior('normal(-0.2, 0.1)', coef = 'level1'),
                       set_prior('normal(-0.1, 0.1)', coef = c('level2', 'level4'))
                     ),
                     save_pars = save_pars(all = TRUE), iter = 20000, refresh = 0,
                     file = 'models/E3_alignment_2way_noMus')

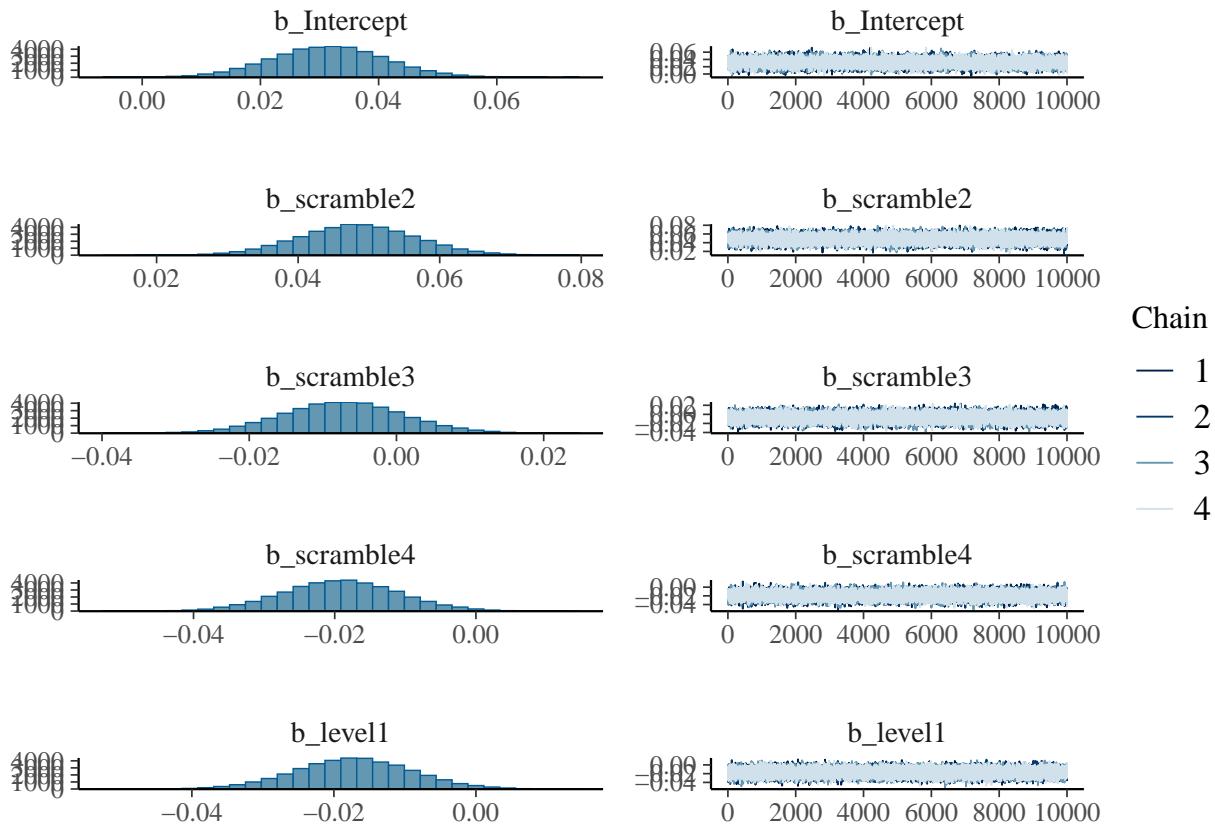
nested_noScram <- brm(value ~ Musician + level + (1|sub), data = data_nested,
                        prior = c(
                          set_prior('normal(-0.1, 0.1)', coef = 'Musician1'),
                          set_prior('normal(-0.2, 0.1)', coef = 'level1'),
                          set_prior('normal(-0.1, 0.1)', coef = c('level2', 'level4'))
                        ),
                        save_pars = save_pars(all = TRUE), iter = 20000, refresh = 0,
                        file = 'models/E3_alignment_2way_noScram')

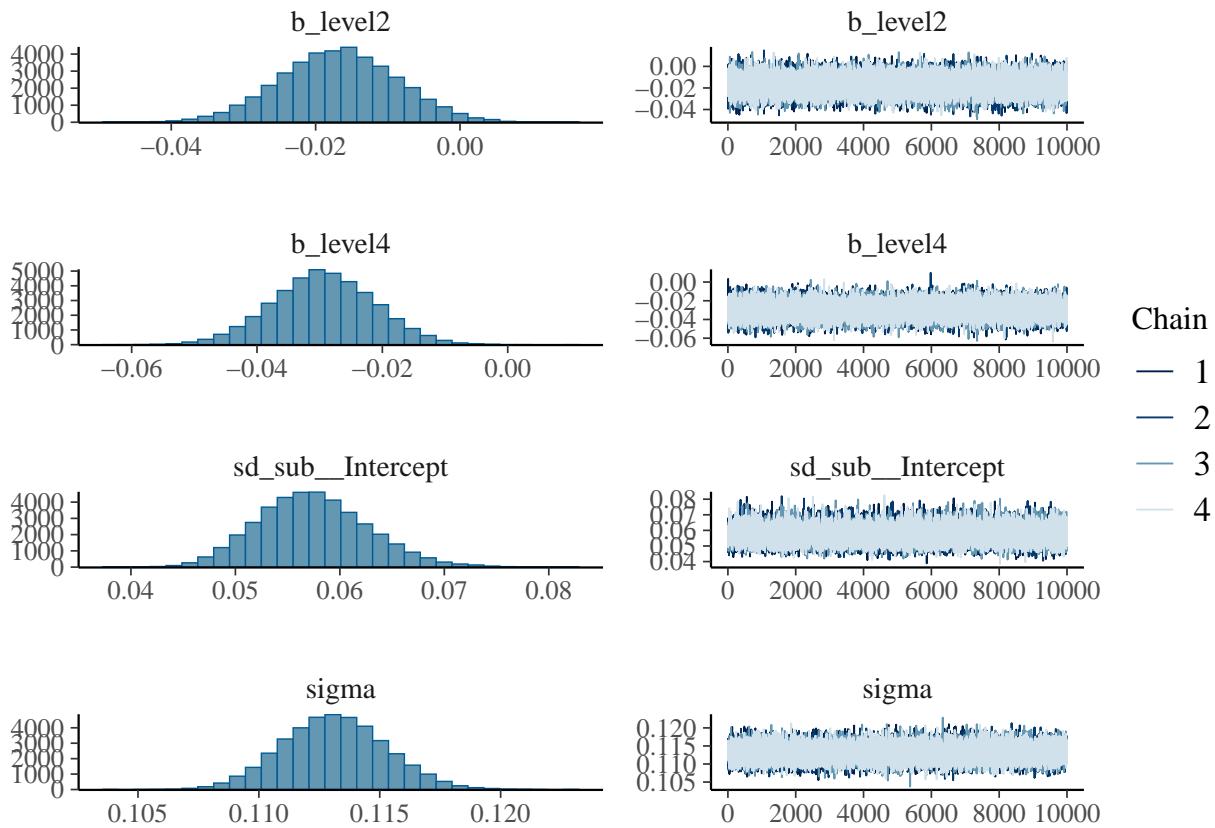
nested_noLevel <- brm(value ~ Musician + scramble + (1|sub), data = data_nested,
                        prior = c(
                          set_prior('normal(-0.1, 0.1)', coef = 'Musician1'),
                          set_prior('normal(0.1, 0.1)', coef = 'scramble2'),
                          set_prior('normal(-0.1, 0.1)', coef = 'scramble3'),
                          set_prior('normal(-0.1, 0.1)', coef = 'scramble4')
                        ),
                        save_pars = save_pars(all = TRUE), iter = 20000, refresh = 0,
                        file = 'models/E3_alignment_2way_noLevel')

```

Model without group:

```
plot(nested_noMus)
```





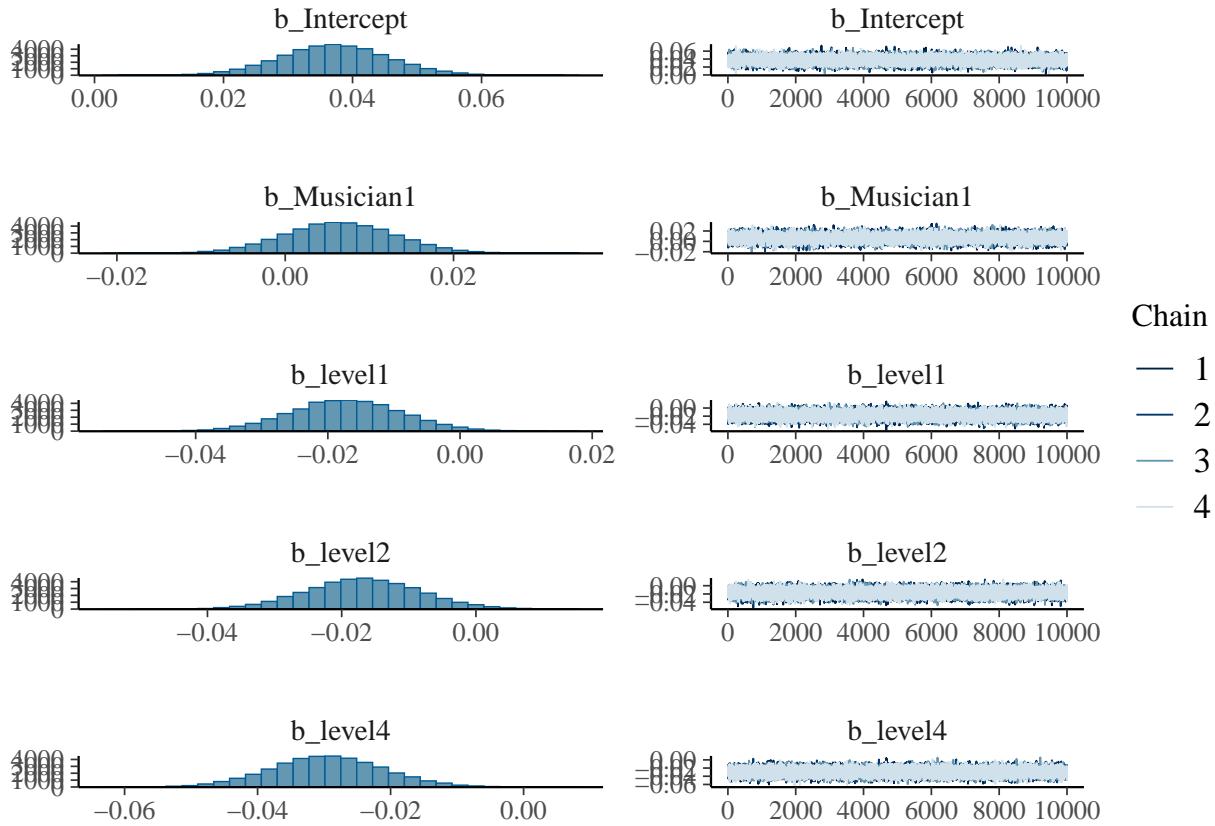
```
print(summary(nested_noMus, robust = TRUE), digits = 4)
```

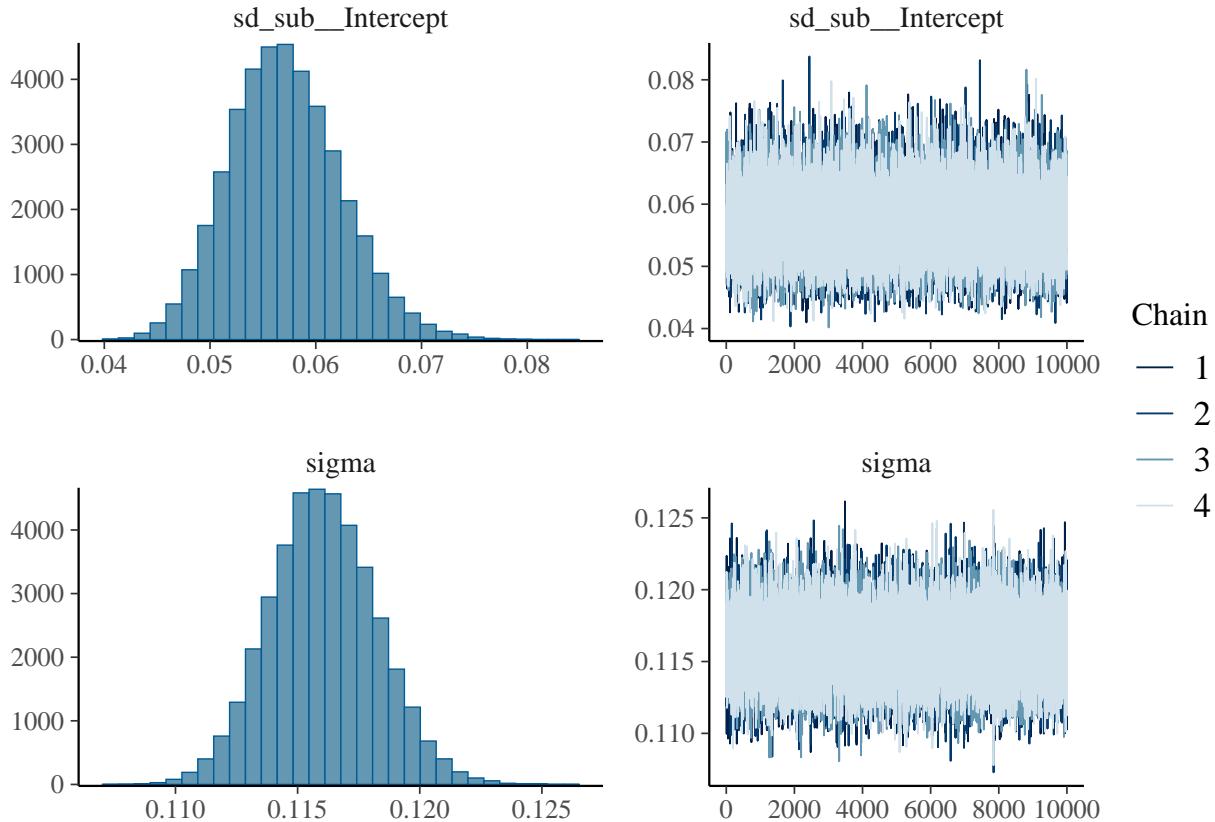
```
##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ scramble + level + (1 | sub)
##  Data: data_nested (Number of observations: 1520)
##  Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##          total post-warmup draws = 40000
##
## Multilevel Hyperparameters:
## ~sub (Number of levels: 95)
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sd(Intercept)  0.0572    0.0052   0.0479   0.0685 1.0001    14777   22644
##
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept    0.0316    0.0096   0.0126   0.0504 1.0000    28339   29606
## scramble2    0.0484    0.0082   0.0325   0.0646 0.9999    56716   33800
## scramble3   -0.0072    0.0081  -0.0232   0.0089 1.0000    57048   33653
## scramble4   -0.0191    0.0082  -0.0351  -0.0029 1.0002    53622   33980
## level1     -0.0172    0.0082  -0.0333  -0.0012 1.0001    55562   33642
## level2     -0.0168    0.0081  -0.0327  -0.0010 0.9999    54656   34281
## level4     -0.0295    0.0081  -0.0455  -0.0136 1.0000    54295   33265
##
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma      0.1131    0.0021   0.1091   0.1173 1.0002    68120   30151
##
```

```
## 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).
```

Model without condition:

```
plot(nested_noScram)
```





```

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

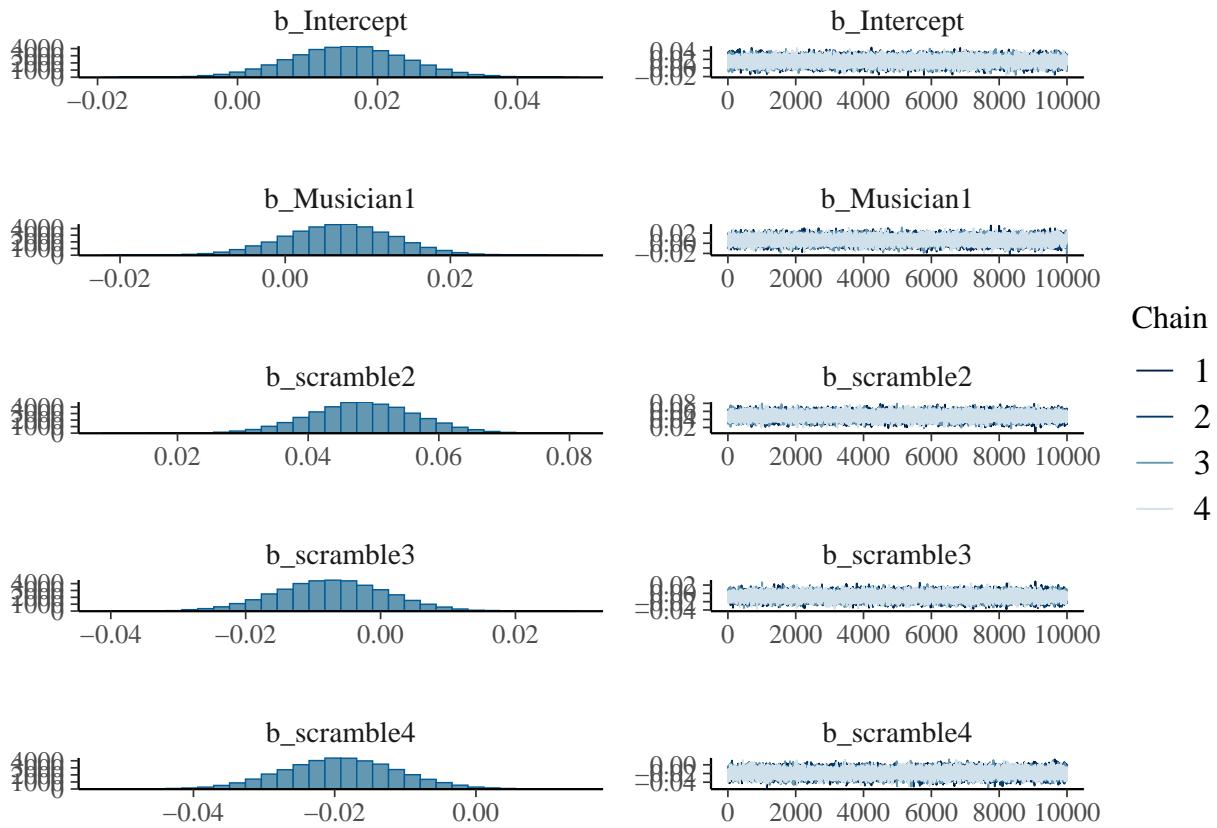
## Family: gaussian
## Links: mu = identity; sigma = identity
## Formula: value ~ Musician + level + (1 | sub)
## Data: data_nested (Number of observations: 1520)
## Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##         total post-warmup draws = 40000
##
## Multilevel Hyperparameters:
## ~sub (Number of levels: 95)
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sd(Intercept) 0.0568     0.0053   0.0474   0.0682 1.0002    15247    23123
## 
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept  0.0372     0.0082   0.0209   0.0538 1.0002    26107    29163
## Musician1  0.0064     0.0066  -0.0064   0.0194 1.0004    19945    25600
## level1    -0.0173     0.0084  -0.0337  -0.0007 1.0000    55520    33044
## level2    -0.0168     0.0084  -0.0333  -0.0002 1.0001    55497    33057
## level4    -0.0295     0.0084  -0.0459  -0.0129 1.0001    57368    33554
## 
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma      0.1160     0.0022   0.1118   0.1204 1.0001    70630    29237
## 
## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential

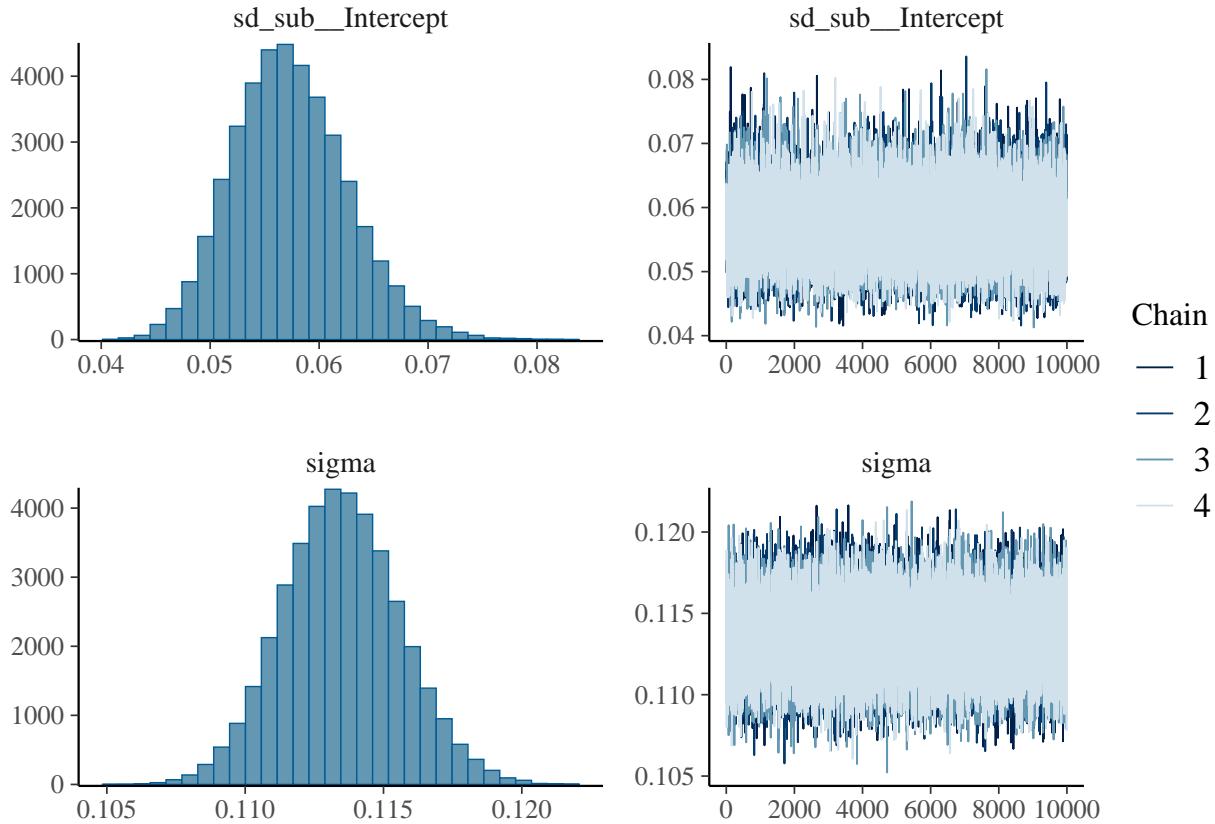
```

```
## scale reduction factor on split chains (at convergence, Rhat = 1).
```

Model without level:

```
plot(nested_noLevel)
```





```

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

##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ Musician + scramble + (1 | sub)
##  Data: data_nested (Number of observations: 1520)
##  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) 0.0571     0.0052   0.0478   0.0684 1.0000    15636   22926
## 
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept  0.0158     0.0083 -0.0004   0.0320 1.0002    24589   28115
## Musician1  0.0066     0.0066 -0.0065   0.0192 1.0003    19328   26198
## scramble2  0.0484     0.0081  0.0324   0.0644 1.0002    57484   34263
## scramble3 -0.0073     0.0082 -0.0235   0.0086 1.0003    57235   33470
## scramble4 -0.0191     0.0082 -0.0350  -0.0031 1.0002    56509   34385
## 
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma      0.1134     0.0021   0.1094   0.1178 1.0002    70679   28821
## 
## 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).
```

Main effect of group

```
BF_nested_mus <- bayes_factor(nested_3way, nested_noMus)

## Iteration: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4
## Iteration: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4
print(BF_nested_mus)

## Estimated Bayes factor in favor of nested_3way over nested_noMus: 0.06464
```

Strong evidence against a main effect of group.

Main effect of condition

```
BF_nested_scram <- bayes_factor(nested_3way, nested_noScram)

## Iteration: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4
## Iteration: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4
print(BF_nested_scram)

## Estimated Bayes factor in favor of nested_3way over nested_noScram: 4294718640616.28076
```

Very strong evidence for a main effect of condition.

Main effect of level

```
BF_nested_level <- bayes_factor(nested_3way, nested_noLevel)

## Iteration: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4
## Iteration: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4
print(BF_nested_level)

## Estimated Bayes factor in favor of nested_3way over nested_noLevel: 0.01391
```

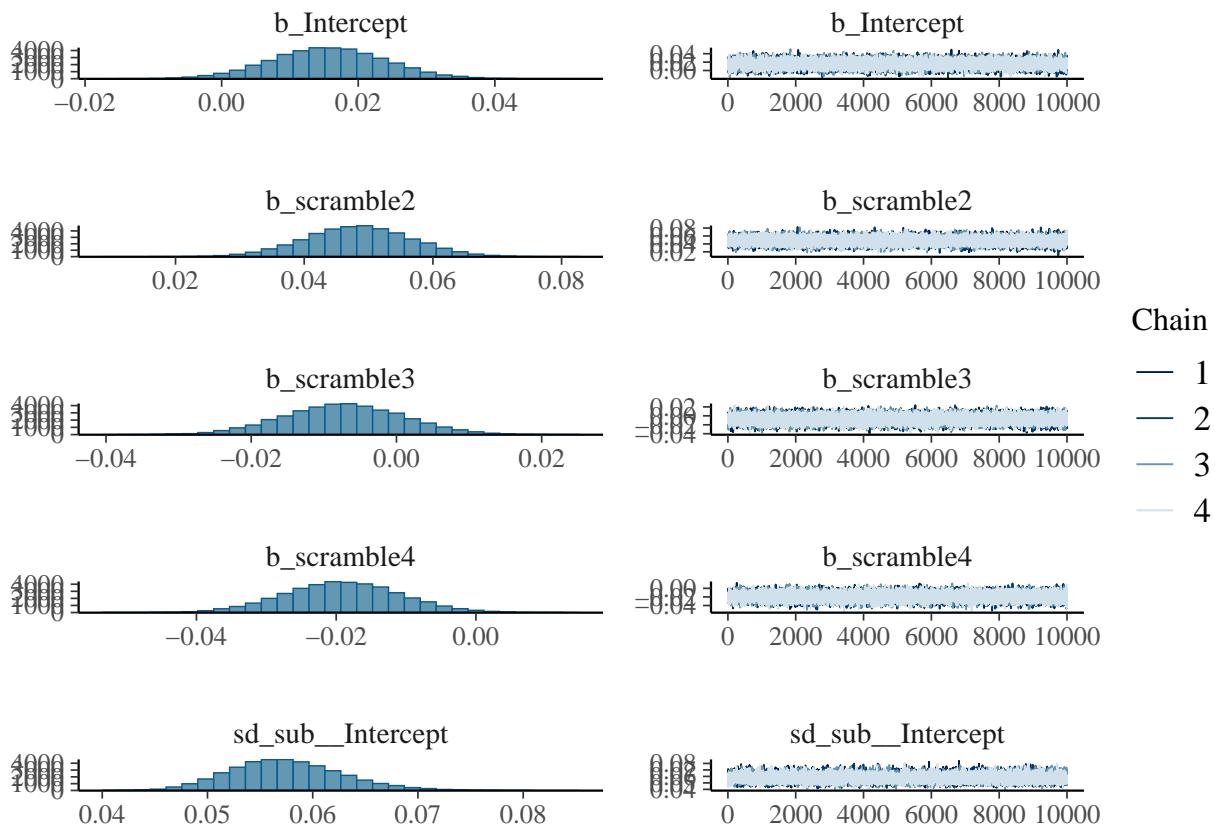
Moderate evidence against a main effect of level.

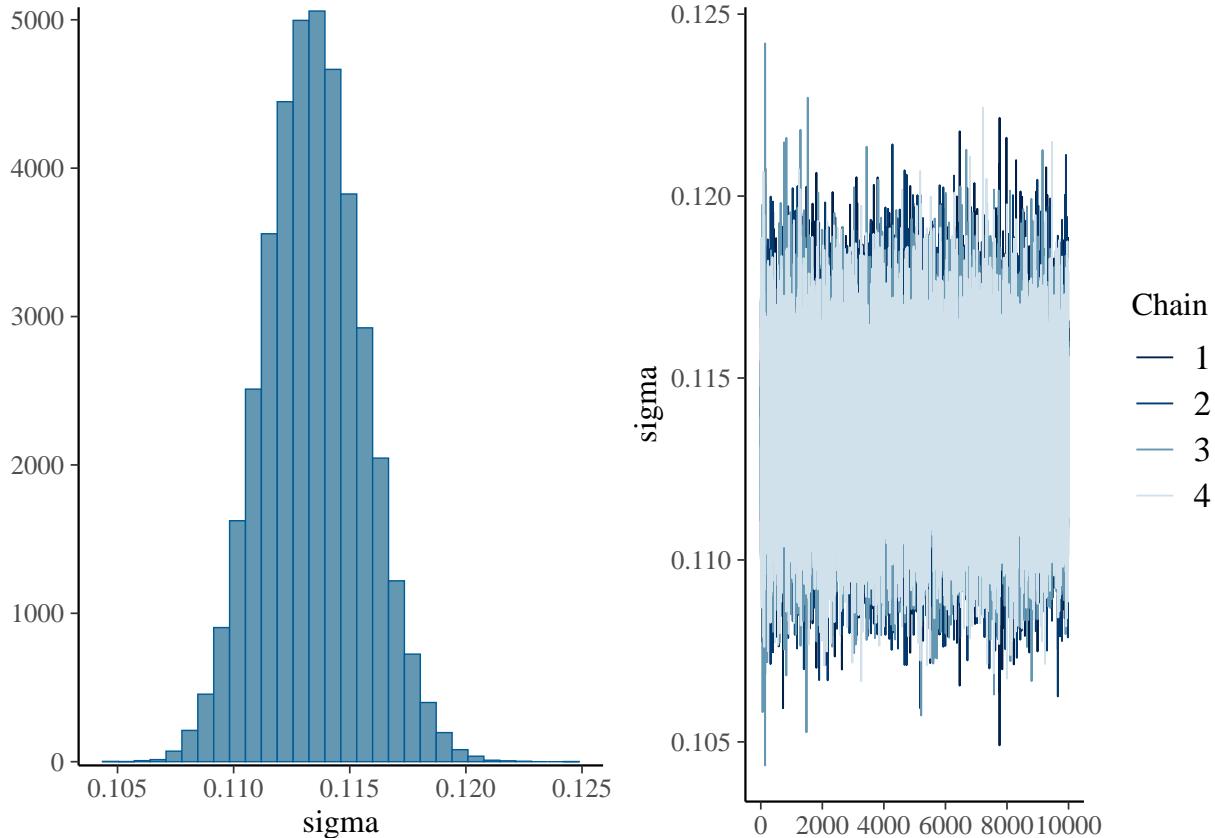
Interactions

Does adding an interaction between condition and level improve the model? (Without group)

```
nested_justScram <- brm(value ~ scramble + (1|sub), data = data_nested,
                         prior = c(
                           set_prior('normal(0.1, 0.1)', coef = 'scramble2'),
                           set_prior('normal(-0.1, 0.1)', coef = 'scramble3'),
                           set_prior('normal(-0.1, 0.1)', coef = 'scramble4')
                         ),
                         save_pars = save_pars(all = TRUE),
                         iter = 20000, refresh = 0,
                         file = 'models/E3_alignment_justScram')
```

```
plot(nested_justScram)
```





```

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

##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ scramble + (1 | sub)
##  Data: data_nested (Number of observations: 1520)
##  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)  0.0572    0.0052   0.0479   0.0688 1.0002    14763   23619
## 
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept    0.0156    0.0083  -0.0006   0.0320 1.0001    21700   28402
## scramble2    0.0484    0.0082   0.0324   0.0644 1.0001    56190   35149
## scramble3   -0.0073    0.0083  -0.0233   0.0089 1.0001    53426   33896
## scramble4   -0.0192    0.0083  -0.0353  -0.0029 1.0002    57056   33584
## 
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma       0.1134    0.0021   0.1094   0.1177 1.0000    75951   27324
## 
## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential

```

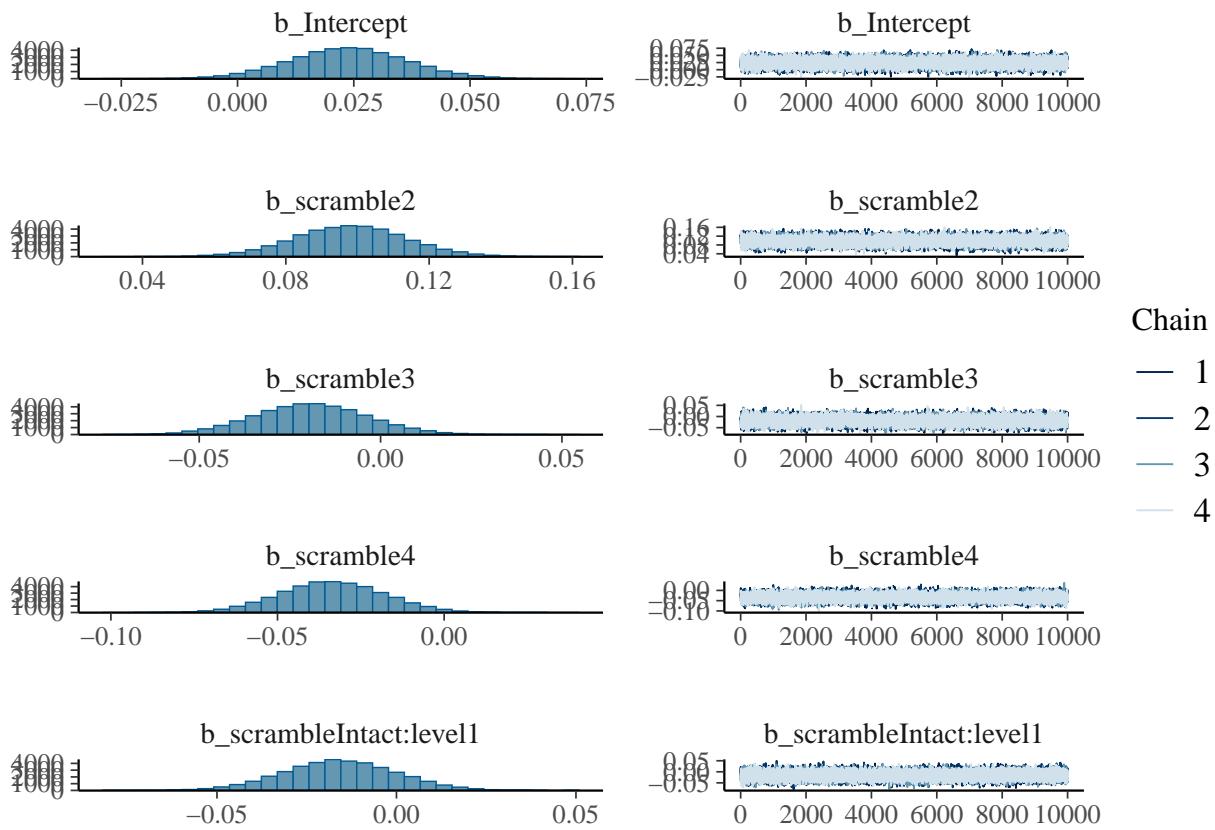
```
## scale reduction factor on split chains (at convergence, Rhat = 1).
```

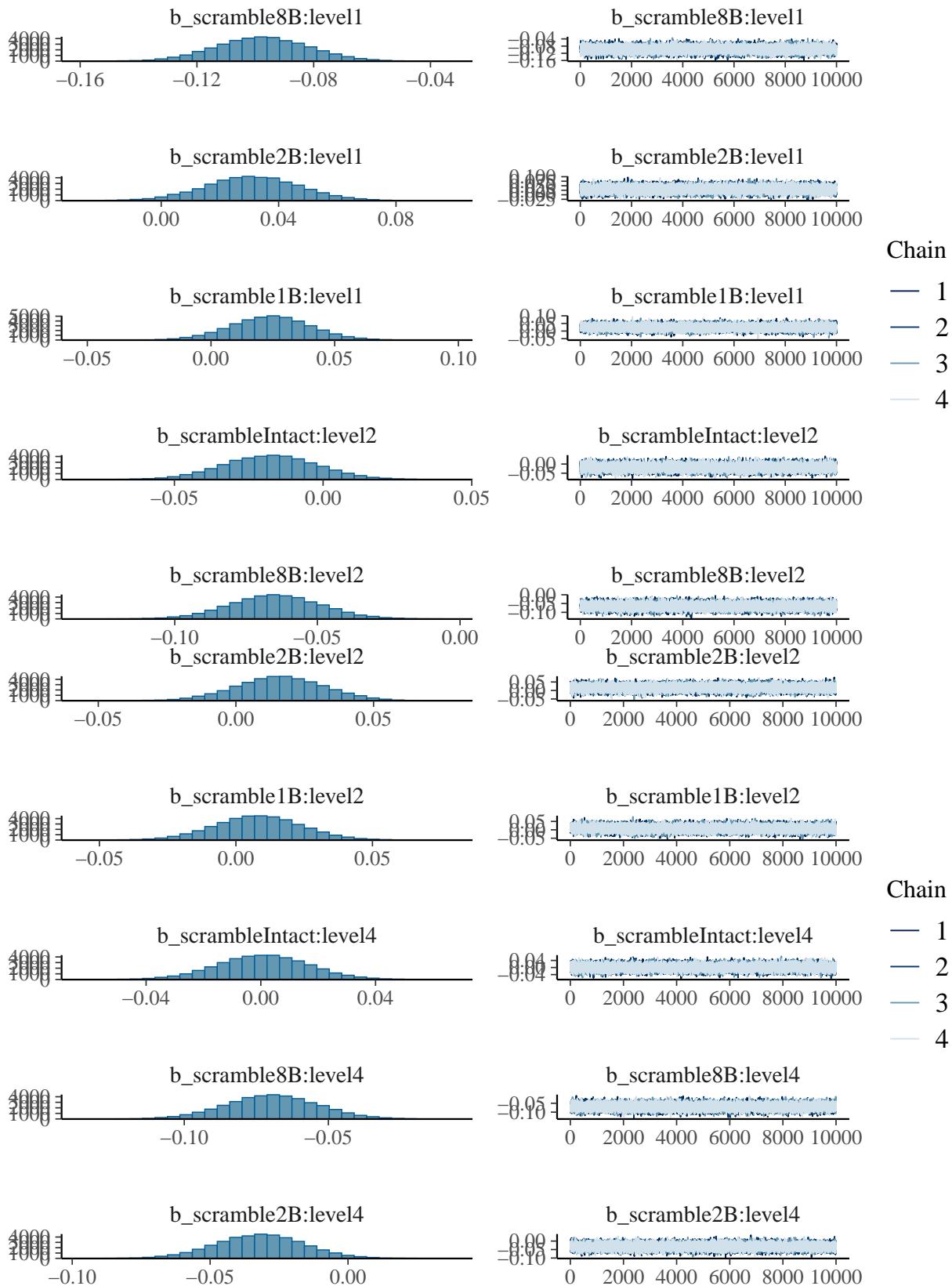
```

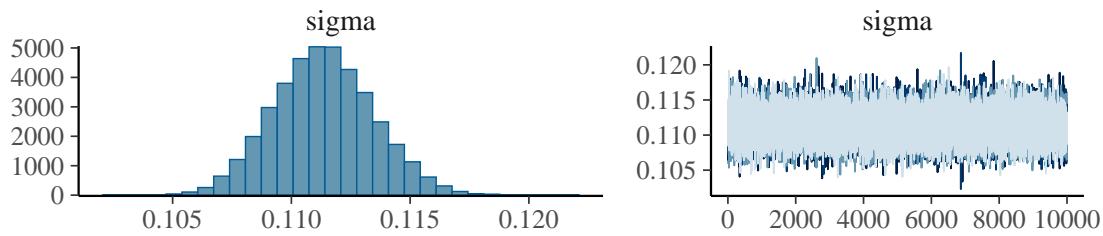
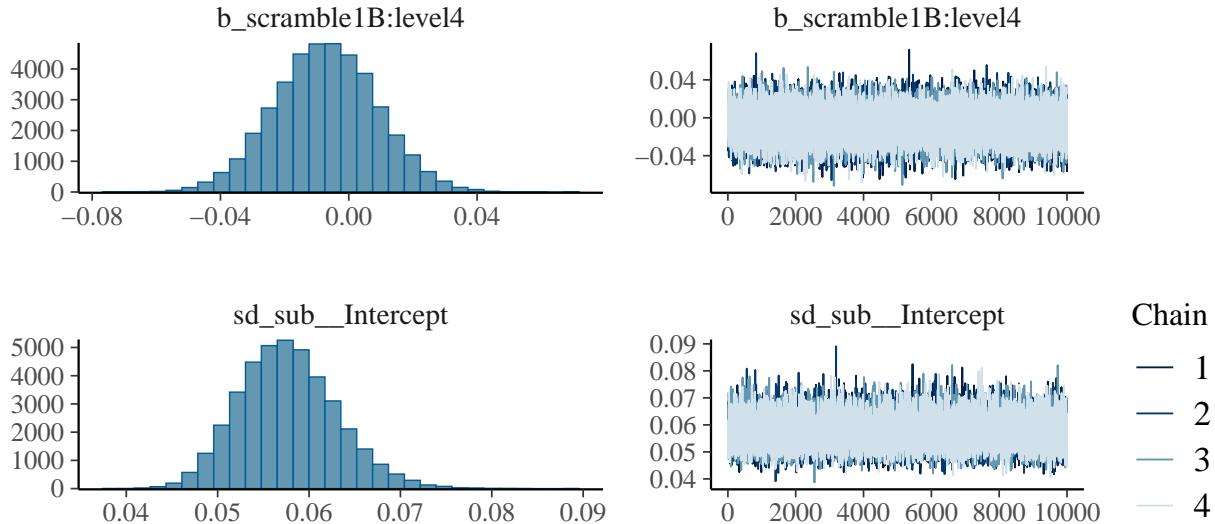
nested_2way_levelScram <- brm(value ~ scramble + scramble:level + (1|sub), data = data_nested,
                                prior = c(
                                    set_prior('normal(0, 0.1)', class = 'b'), # all interactions
                                    set_prior('normal(0.1, 0.1)', coef = 'scramble2'),
                                    set_prior('normal(-0.1, 0.1)', coef = 'scramble3'),
                                    set_prior('normal(-0.1, 0.1)', coef = 'scramble4')
                                ),
                                save_pars = save_pars(all = TRUE),
                                iter = 20000, refresh = 0,
                                file = 'models/E3_alignment_2way_levelScramInt')

```

```
plot(nested_2way_levelScram)
```







```
print(summary(nested_2way_levelScram, robust = TRUE), digits = 4)
```

```
## Family: gaussian
##   Links: mu = identity; sigma = identity
## Formula: value ~ scramble + scramble:level + (1 | sub)
##   Data: data_nested (Number of observations: 1520)
##   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) 0.0574    0.0053   0.0481   0.0689 1.0004    13524   20912
##
## Regression Coefficients:
##                               Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS
## Intercept                  0.0239    0.0125  -0.0008   0.0484 1.0001    18167
## scramble2                   0.0981    0.0156   0.0673   0.1288 1.0003    21965
## scramble3                  -0.0193    0.0156  -0.0498   0.0115 1.0002    22489
## scramble4                  -0.0336    0.0156  -0.0640  -0.0030 1.0001    22200
## scrambleIntact:level1     -0.0158    0.0157  -0.0466   0.0151 1.0001    30061
## scramble8B:level1        -0.0975    0.0159  -0.1283  -0.0664 1.0002    38195
## scramble2B:level1         0.0311    0.0159   0.0000   0.0624 1.0002    38589
## scramble1B:level1         0.0242    0.0158  -0.0071   0.0553 1.0001    39710
## scrambleIntact:level2     -0.0176    0.0158  -0.0482   0.0131 1.0001    30884
## scramble8B:level2        -0.0647    0.0158  -0.0955  -0.0335 1.0000    37966
## scramble2B:level2         0.0162    0.0158  -0.0149   0.0471 1.0000    38131
## scramble1B:level2         0.0082    0.0158  -0.0229   0.0395 1.0001    39545
```

```

## scrambleIntact:level4    0.0009    0.0158   -0.0303    0.0317 1.0001    30499
## scramble8B:level4      -0.0696    0.0158   -0.1007   -0.0383 1.0001    39050
## scramble2B:level4      -0.0318    0.0159   -0.0634   -0.0013 1.0001    38335
## scramble1B:level4      -0.0072    0.0159   -0.0383    0.0238 1.0000    40644
##
##                                     Tail_ESS
## Intercept                          25370
## scramble2                           27376
## scramble3                           27060
## scramble4                           27896
## scrambleIntact:level1              31864
## scramble8B:level1                 33855
## scramble2B:level1                 33125
## scramble1B:level1                 33137
## scrambleIntact:level2              30445
## scramble8B:level2                 32618
## scramble2B:level2                 32536
## scramble1B:level2                 32819
## scrambleIntact:level4              31967
## scramble8B:level4                 33207
## scramble2B:level4                 33986
## scramble1B:level4                 33290
##
## Further Distributional Parameters:
##           Estimate Est.Error l-95% CI u-95% CI   Rhat Bulk_ESS Tail_ESS
## sigma     0.1113    0.0021    0.1073    0.1156 1.0000    63302    30034
##
## 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_nested_2way_levelScram <- bayes_factor(nested_2way_levelScram, nested_justScram)

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

print(BF_nested_2way_levelScram)

## Estimated Bayes factor in favor of nested_2way_levelScram over nested_justScram: 5229.35960
Strong evidence for an interaction between condition and level.

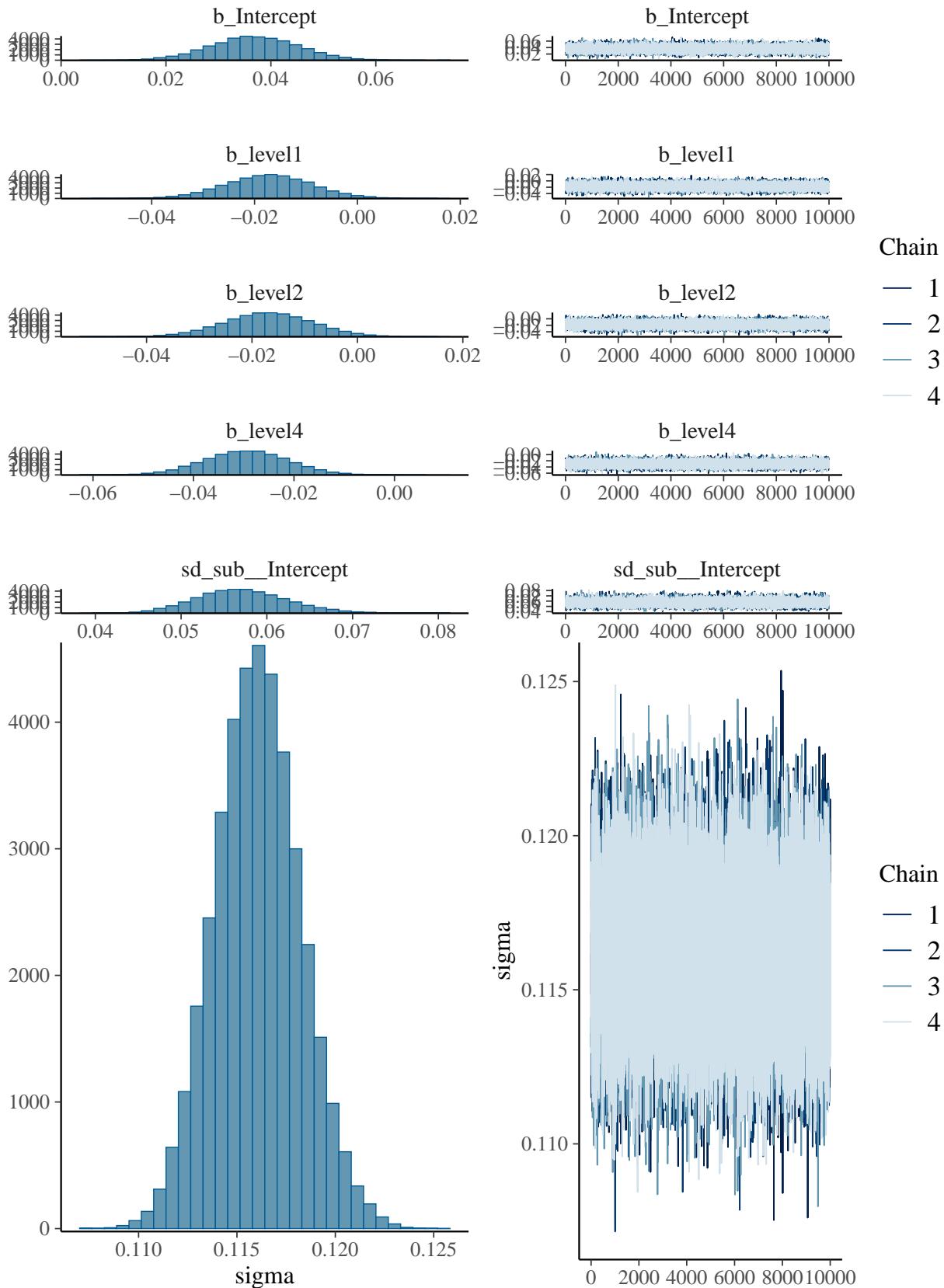
```

Check the other interactions.

```
nested_justLevel <- brm(value ~ level + (1|sub), data = data_nested,
                         prior = c(
                           set_prior('normal(-0.2, 0.1)', coef = 'level1'),
                           set_prior('normal(-0.1, 0.1)', coef = c('level2', 'level4'))
                         ),
                         save_pars = save_pars(all = TRUE),
                         iter = 20000, refresh = 0,
                         file = 'models/E3_alignment_justLevel')

nested_2way_musScram <- brm(value ~ scramble + scramble:Musician + (1|sub), data = data_nested,
                               prior = c(
                                 set_prior('normal(0, 0.1)', class = 'b'), # all interactions
                                 set_prior('normal(0.1, 0.1)', coef = 'scramble2'),
                                 set_prior('normal(-0.1, 0.1)', coef = 'scramble3'),
                                 set_prior('normal(-0.1, 0.1)', coef = 'scramble4')
                               ),
                               save_pars = save_pars(all = TRUE),
                               iter = 20000, refresh = 0,
                               file = 'models/E3_alignment_2way_musScramInt')
nested_2way_musLevel <- brm(value ~ level + level:Musician + (1|sub), data = data_nested,
                             prior = c(
                               set_prior('normal(0, 0.1)', class = 'b'), # all interactions
                               set_prior('normal(-0.2, 0.1)', coef = 'level1'),
                               set_prior('normal(-0.1, 0.1)', coef = c('level2', 'level4'))
                             ),
                             save_pars = save_pars(all = TRUE),
                             iter = 20000, refresh = 0,
                             file = 'models/E3_alignment_2way_musLevelInt')
```

```
plot(nested_justLevel)
```



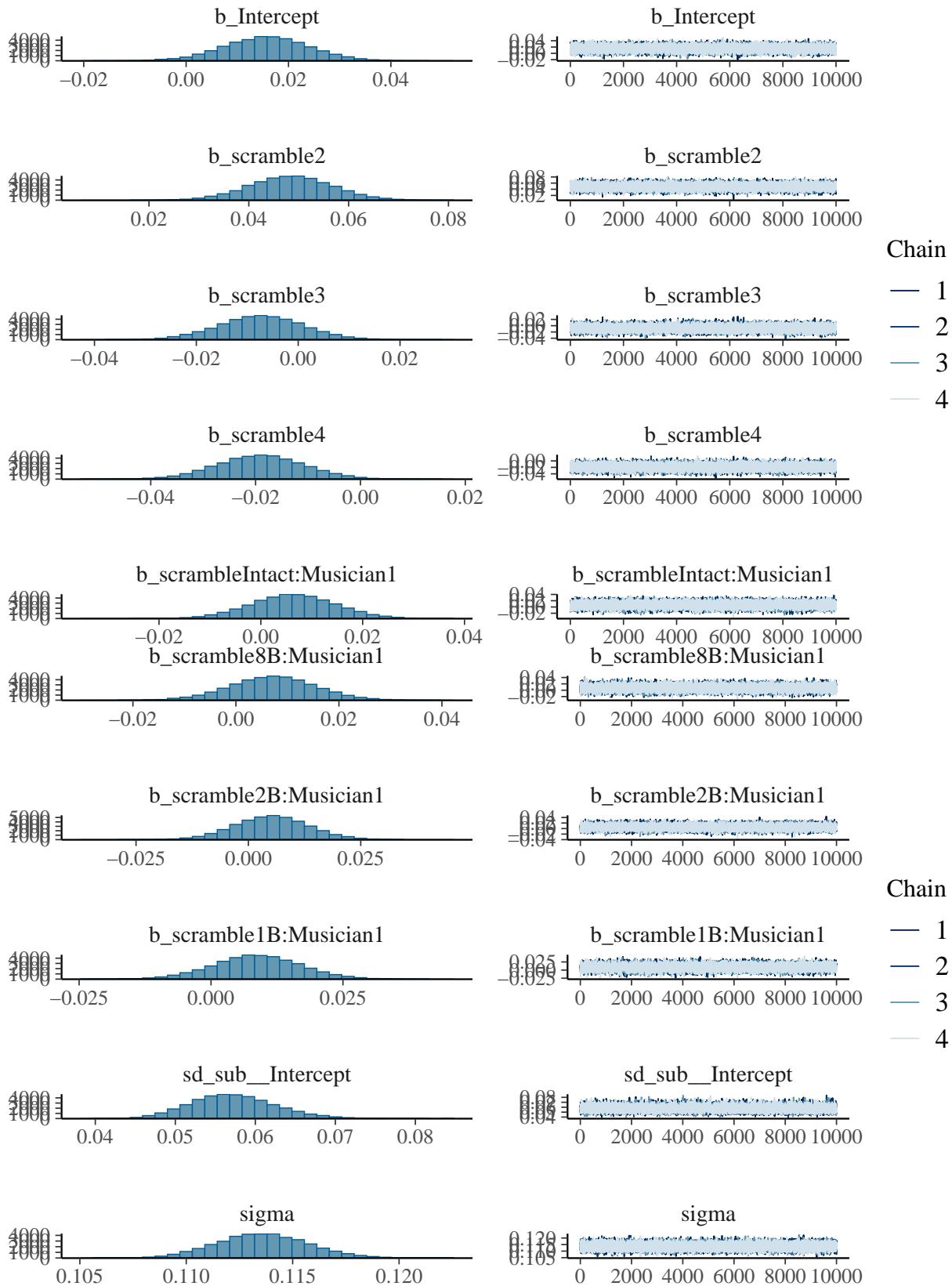
```

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

## Family: gaussian
## Links: mu = identity; sigma = identity
## Formula: value ~ level + (1 | sub)
## Data: data_nested (Number of observations: 1520)
## 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    0.0053   0.0474   0.0683 1.0002     14635    22034
##
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept    0.0369    0.0083   0.0205   0.0533 1.0000     27693    27391
## level1      -0.0172    0.0084  -0.0338  -0.0007 1.0000     56382    32750
## level2      -0.0169    0.0083  -0.0334  -0.0005 1.0001     56795    33001
## level4      -0.0294    0.0084  -0.0459  -0.0132 1.0000     57636    33885
##
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma       0.1160    0.0022   0.1119   0.1204 1.0000     63774    29137
##
## 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).

```

```
plot(nested_2way_musScram)
```



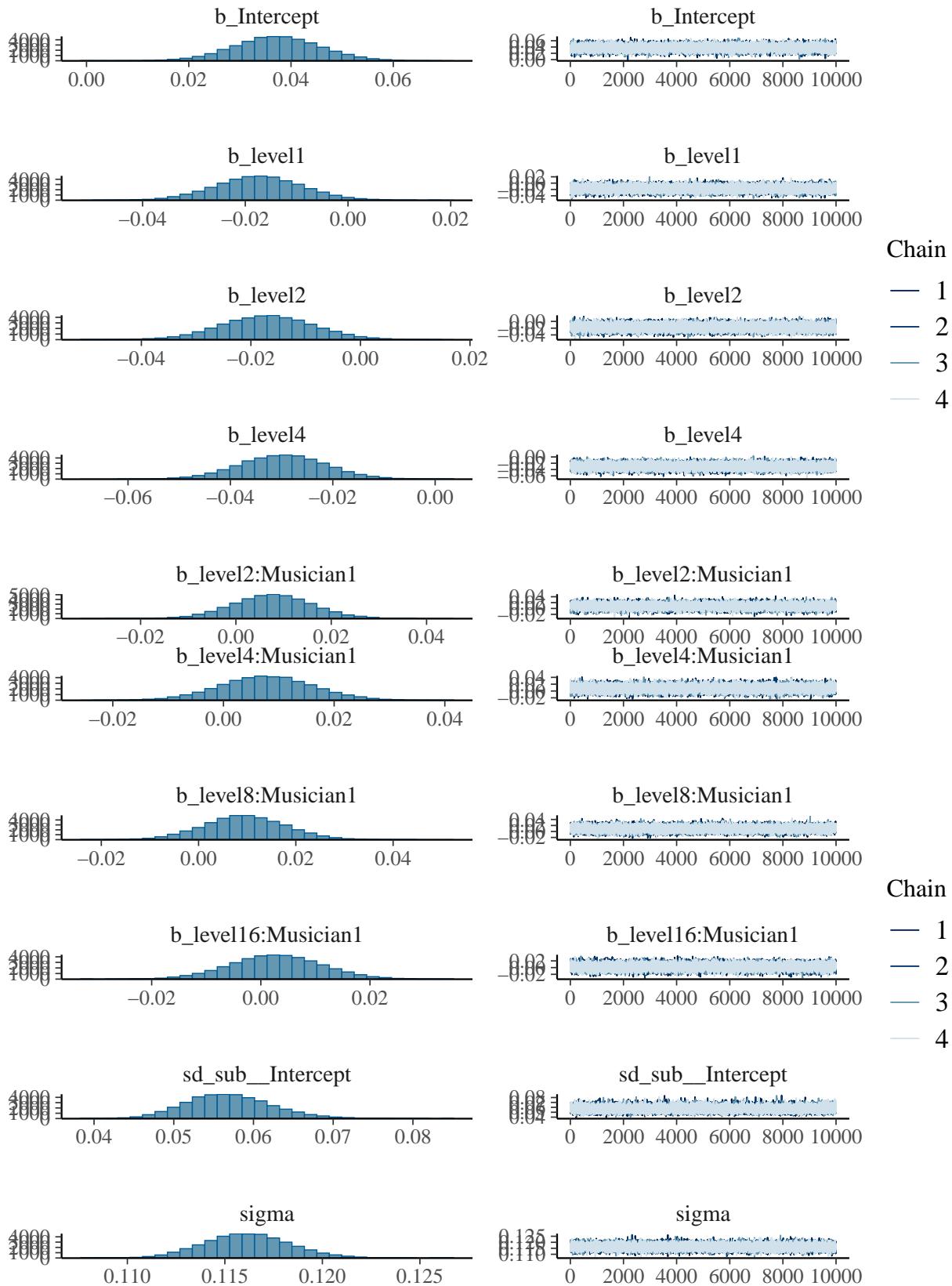
```

print(summary(nested_2way_musScram, robust = TRUE), digits = 4)

##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ scramble + scramble:Musician + (1 | sub)
##   Data: data_nested (Number of observations: 1520)
##   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)  0.0570    0.0052   0.0477   0.0684 1.0006    15560    24067
##
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS
## Intercept        0.0158    0.0082  -0.0006   0.0318 1.0001    23104
## scramble2         0.0485    0.0082   0.0322   0.0647 1.0001    57338
## scramble3        -0.0072    0.0082  -0.0235   0.0088 1.0000    57081
## scramble4        -0.0191    0.0082  -0.0351  -0.0029 1.0001    56251
## scrambleIntact:Musician1  0.0064    0.0082  -0.0097   0.0226 1.0001    19188
## scramble8B:Musician1     0.0072    0.0082  -0.0092   0.0233 1.0000    19167
## scramble2B:Musician1     0.0052    0.0082  -0.0108   0.0215 1.0000    18961
## scramble1B:Musician1     0.0086    0.0081  -0.0074   0.0248 1.0000    18718
##
##             Tail_ESS
## Intercept        28356
## scramble2         35026
## scramble3         34806
## scramble4         35712
## scrambleIntact:Musician1  27686
## scramble8B:Musician1     27655
## scramble2B:Musician1     27076
## scramble1B:Musician1     26565
##
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma      0.1136    0.0021   0.1095   0.1178 1.0002    73840    29398
##
## 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).

```

```
plot(nested_2way_musLevel)
```



```

print(summary(nested_2way_musLevel, robust = TRUE), digits = 4)

##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ level + level:Musician + (1 | sub)
##   Data: data_nested (Number of observations: 1520)
##   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)  0.0567    0.0053   0.0473   0.0684 1.0000    14595    20171
##
## Regression Coefficients:
##           Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept      0.0373    0.0083   0.0209   0.0537 1.0000    23622    29207
## level1        -0.0173    0.0083  -0.0337  -0.0009 1.0000    55667    34202
## level2        -0.0170    0.0084  -0.0332  -0.0006 1.0002    54350    33966
## level4        -0.0297    0.0084  -0.0461  -0.0134 0.9999    55734    34544
## level2:Musician1  0.0077    0.0082  -0.0085   0.0242 1.0002    21043    27783
## level4:Musician1  0.0078    0.0083  -0.0086   0.0243 1.0000    20169    28079
## level8:Musician1  0.0094    0.0083  -0.0067   0.0258 1.0000    20670    27308
## level16:Musician1 0.0028    0.0083  -0.0136   0.0191 1.0000    20661    27778
##
## Further Distributional Parameters:
##           Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma     0.1161    0.0022   0.1120   0.1206 1.0001    70253    30414
##
## 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_nested_2way_musScram <- bayes_factor(nested_2way_musScram, nested_justScram)

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

print(BF_nested_2way_musScram)

## Estimated Bayes factor in favor of nested_2way_musScram over nested_justScram: 0.00005
BF_nested_2way_musLevel <- bayes_factor(nested_2way_musLevel, nested_justLevel)

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

print(BF_nested_2way_musLevel)

## Estimated Bayes factor in favor of nested_2way_musLevel over nested_justLevel: 0.00007

```

Very strong evidence against interactions between group and condition and group and level.