

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')
```

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.

```

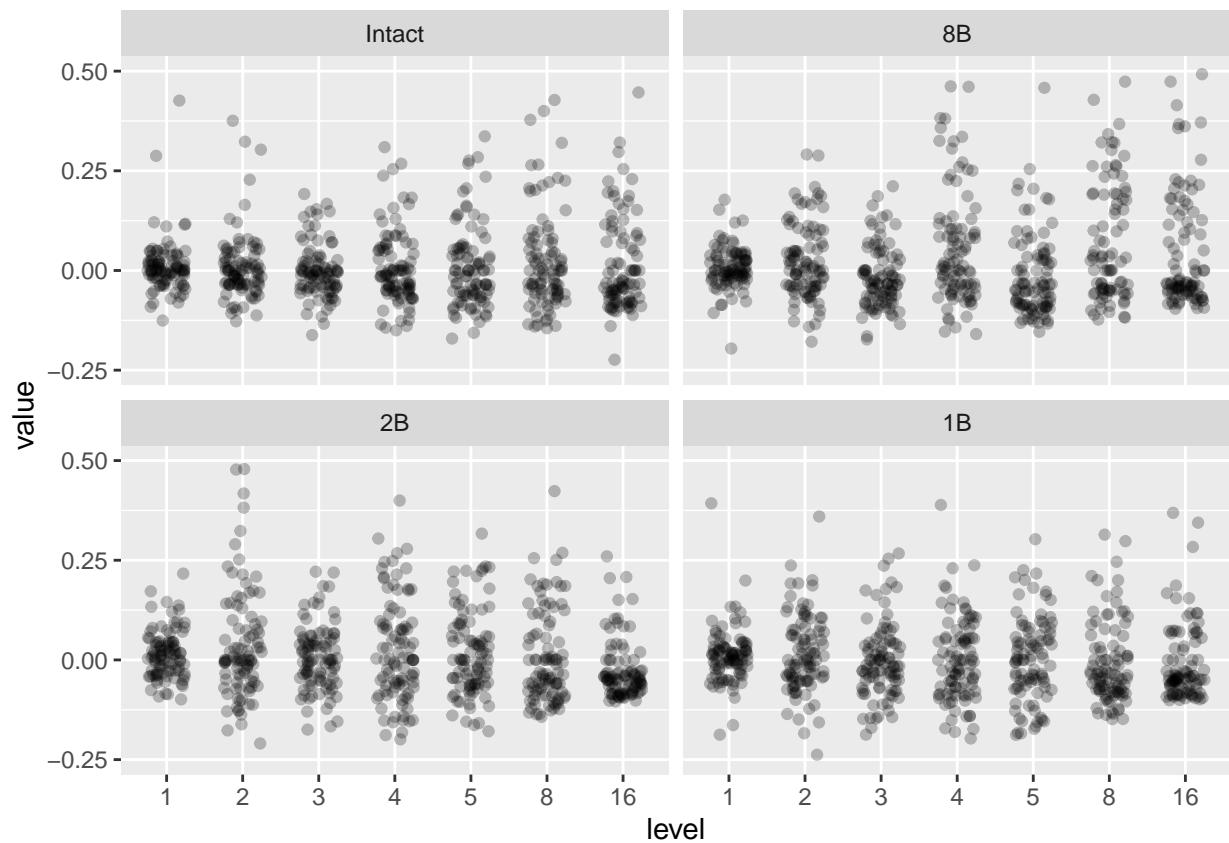
data %>%
  ggplot(aes(x = level, y = value)) +
  geom_jitter(width = 0.25, alpha = 0.25) +
  facet_wrap(vars(scramble)) +
  ylim(-0.25, 0.5)

```

```

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

```



Main analysis

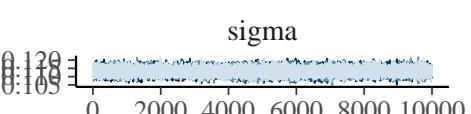
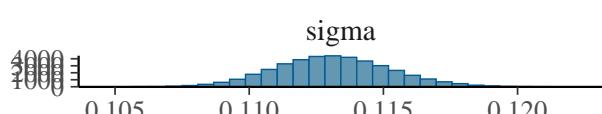
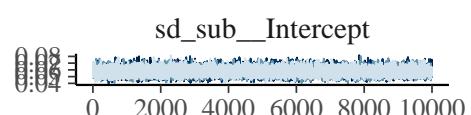
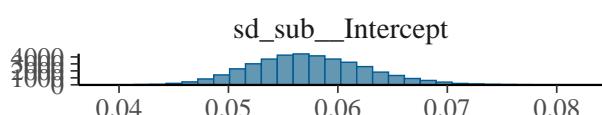
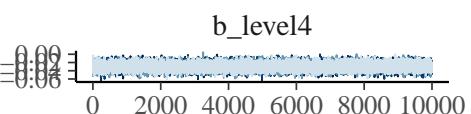
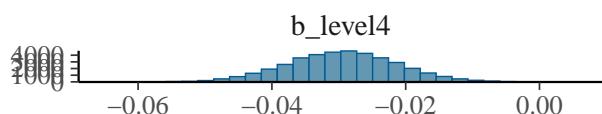
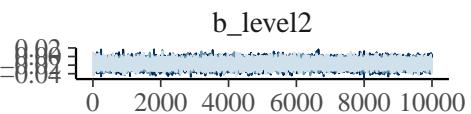
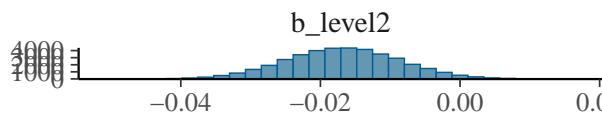
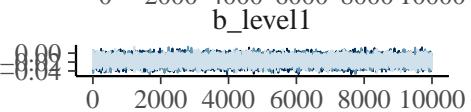
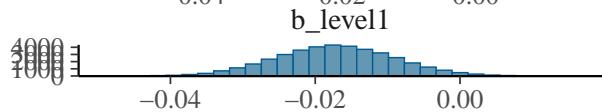
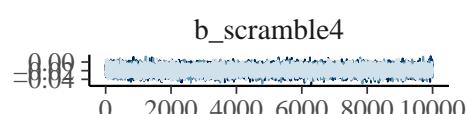
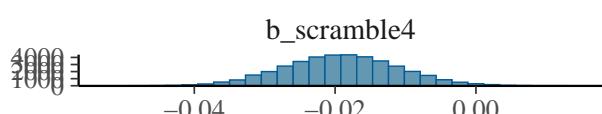
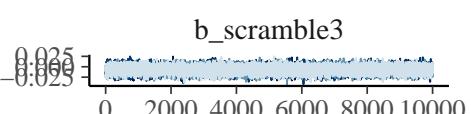
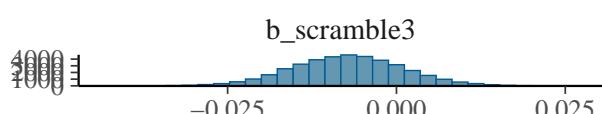
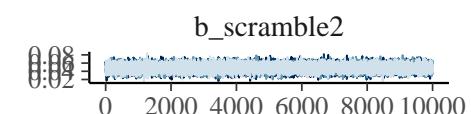
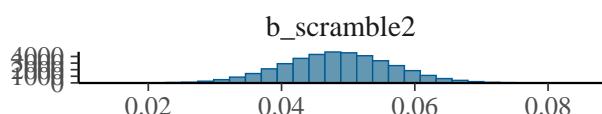
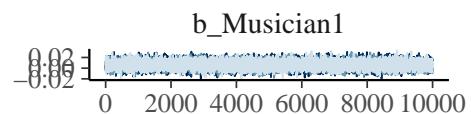
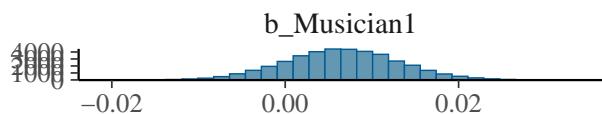
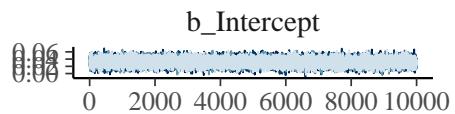
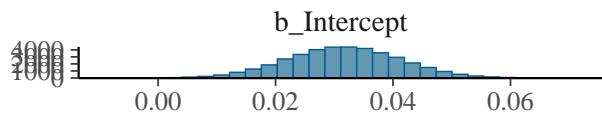
```
nested_3way <- brm(value ~ Musician + scramble + level + (1|sub), data = data_nested,
                     prior = c(
                       set_prior('normal(-0.1, 0.1)', coef = 'Musician1'),
                       set_prior('normal(0.1, 0.1)', coef = 'scramble2'),
                       set_prior('normal(-0.1, 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')

## 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/Versions/4.3-arm64/Resources/library/StanHeaders/include"
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeaders/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
##   679 | #include <cmath>
##       |           ^
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(nested_3way)
```



```
print(summary(nested_3way), 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)  0.0574    0.0054   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    0.0096   0.0128   0.0504 1.0001    29539    30139
## Musician1    0.0065    0.0066  -0.0063   0.0195 1.0000    18013    24808
## scramble2    0.0484    0.0082   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    0.0081  -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')

## 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/Versions/4.3-arm64/Resources/library/StanHeaders/include"
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeaders/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
##   679 | #include <cmath>
##       |           ^~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling

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')

## 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/Versions/4.3-arm64/Resources/library/StanHeaders/include"
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeaders/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
##   679 | #include <cmath>
##       |           ^~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

```

```

## Start sampling
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')

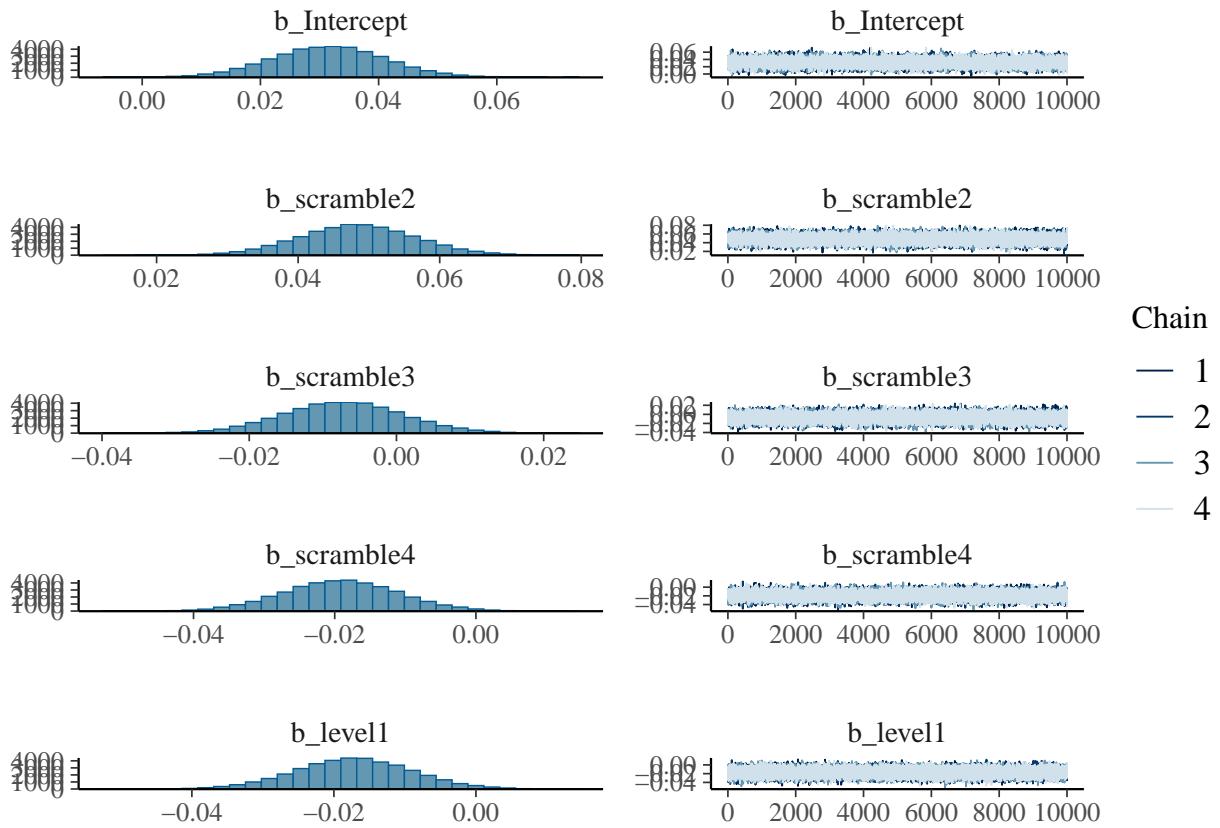
## Compiling Stan program...
## Trying to compile a simple C file
## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## using C compiler: 'Apple clang version 16.0.0 (clang-1600.0.26.6)'
## using SDK: 'MacOSX15.2.sdk'
## clang -arch arm64 -I"/Library/Frameworks/R.framework/Resources/include"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

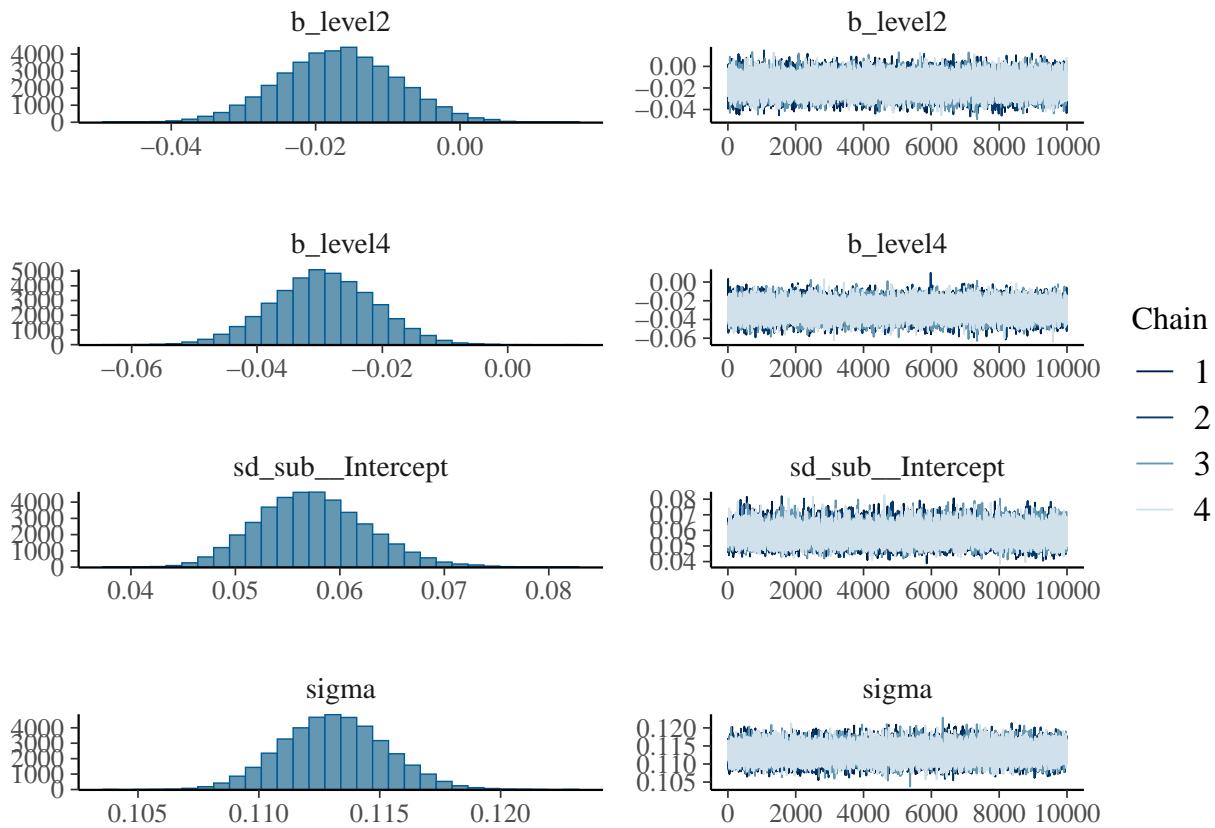
## Start sampling

```

Model without group:

```
plot(nested_noMus)
```





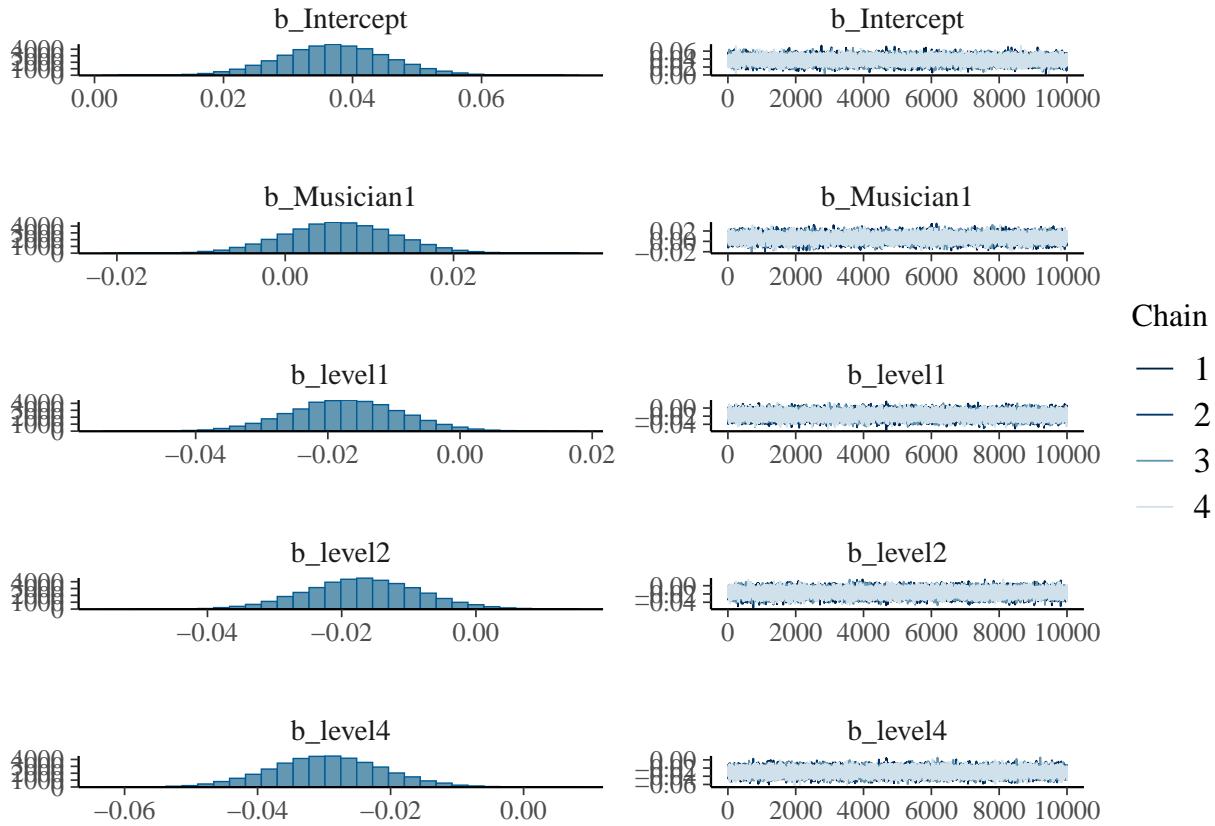
```
print(summary(nested_noMus), digits = 4)
```

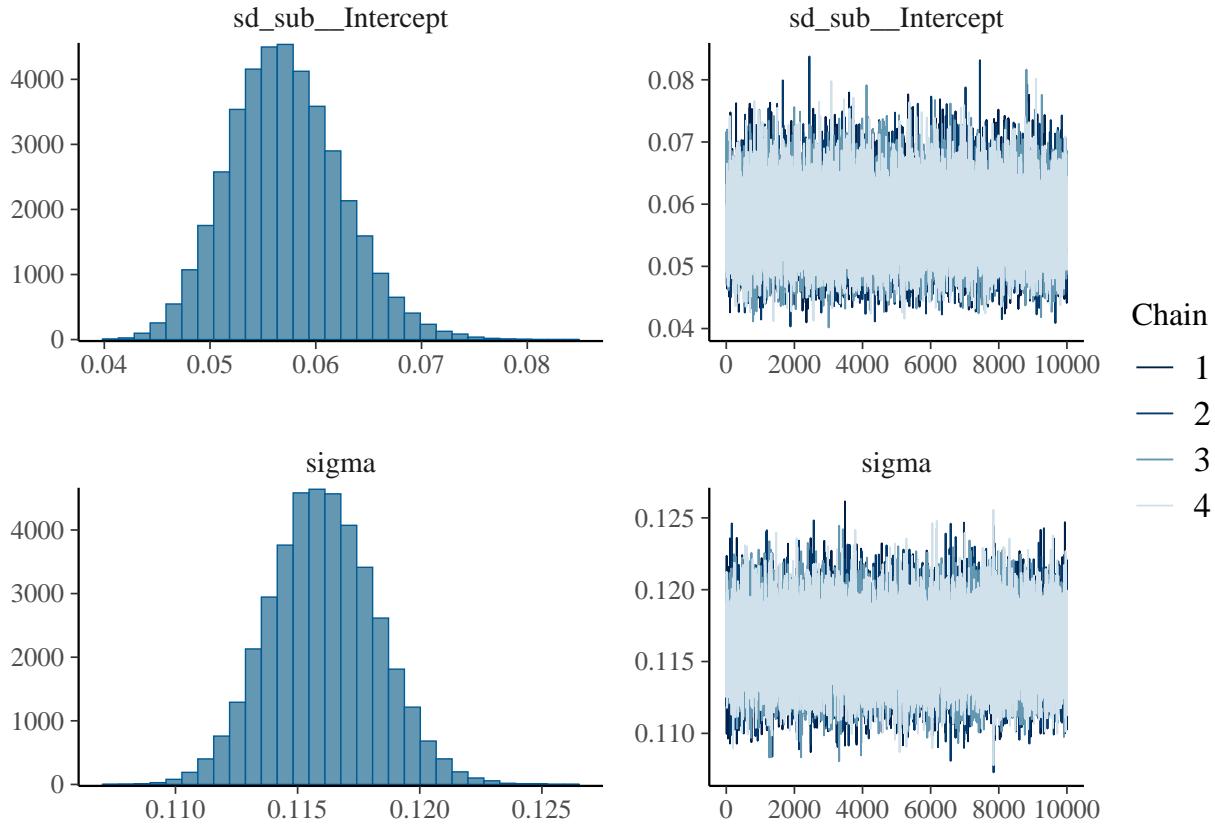
```
## Family: gaussian
##   Links: mu = identity; sigma = identity
## Formula: value ~ scramble + level + (1 | sub)
##   Data: data_nested (Number of observations: 1520)
##   Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##          total post-warmup draws = 40000
##
## Multilevel Hyperparameters:
## ~sub (Number of levels: 95)
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sd(Intercept)  0.0574    0.0053   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    0.0315    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    0.0082  -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     -0.0294    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), digits = 4)

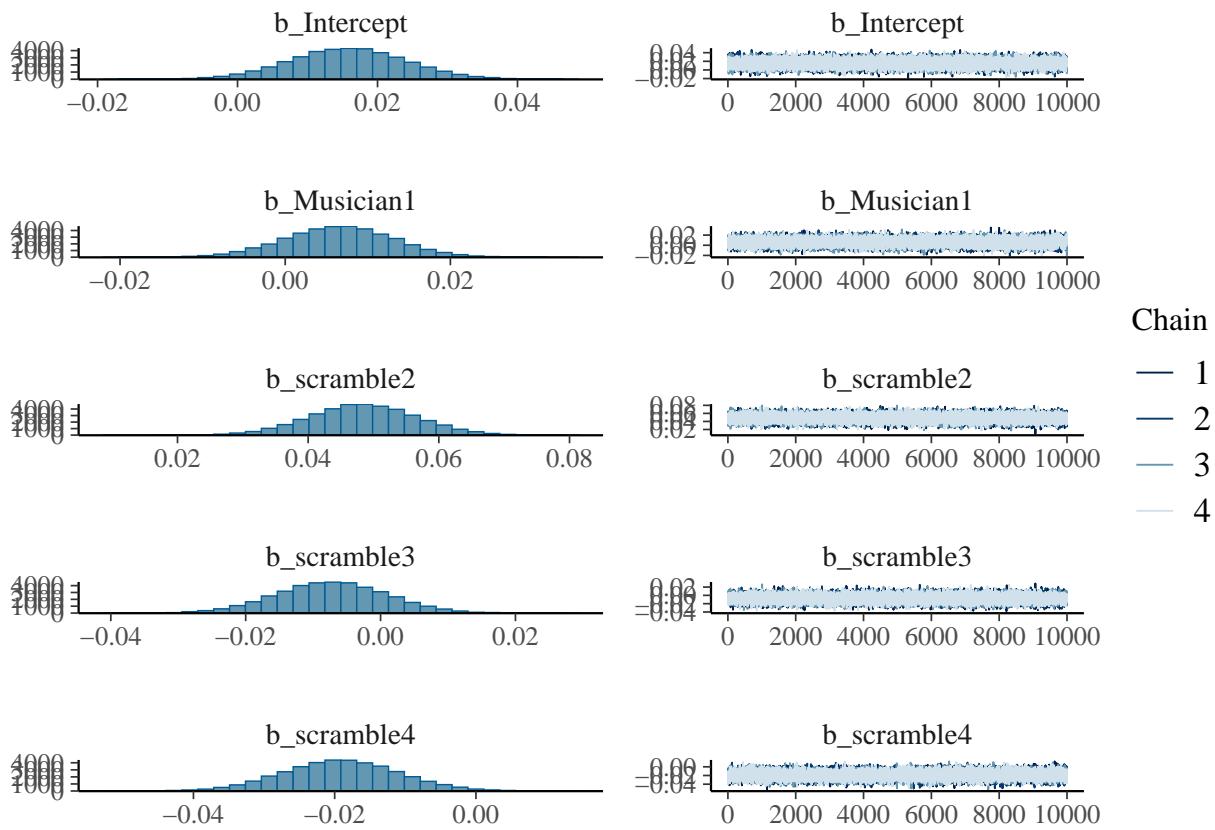
##  Family: gaussian
##  Links: mu = identity; sigma = identity
## Formula: value ~ Musician + level + (1 | sub)
##  Data: data_nested (Number of observations: 1520)
##  Draws: 4 chains, each with iter = 20000; warmup = 10000; thin = 1;
##          total post-warmup draws = 40000
##
## Multilevel Hyperparameters:
## ~sub (Number of levels: 95)
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sd(Intercept)  0.0571    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    0.0083   0.0209   0.0538 1.0002    26107   29163
## Musician1    0.0065    0.0066  -0.0064   0.0194 1.0004    19945   25600
## level1     -0.0172    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

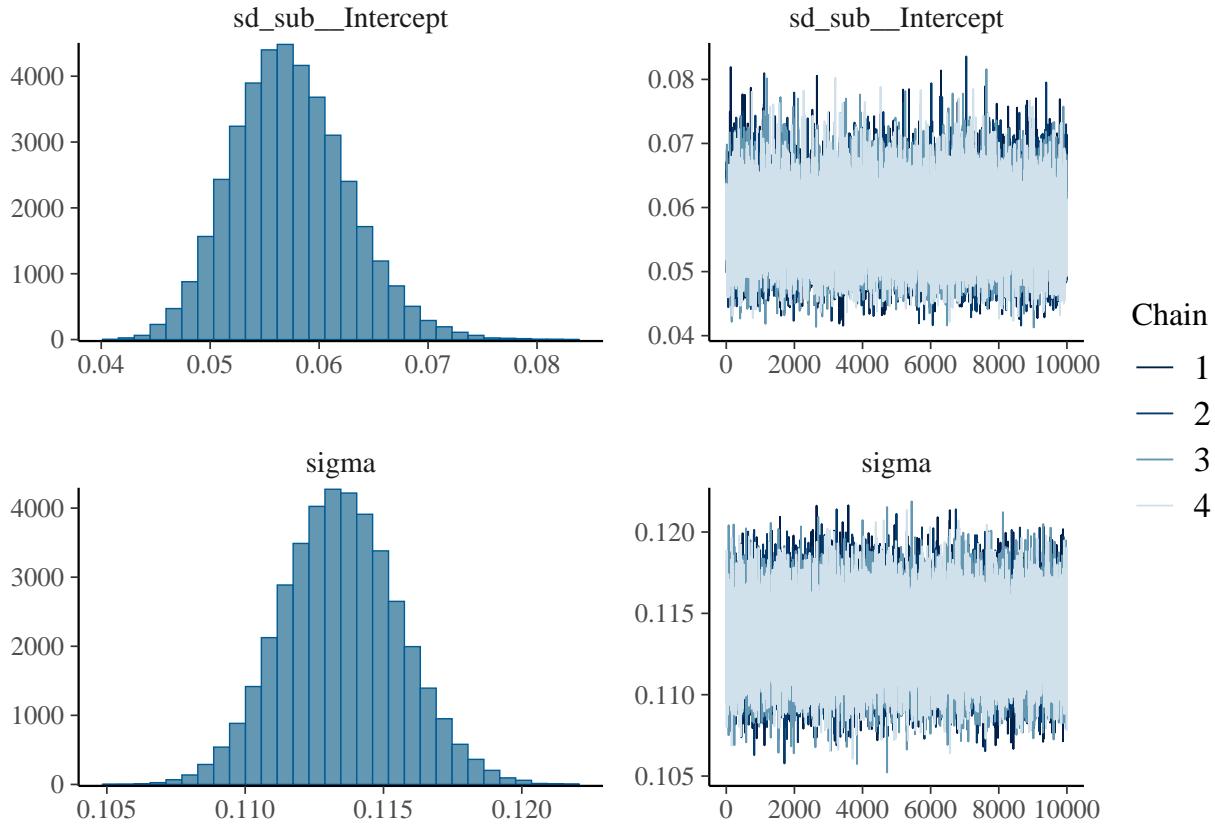
```

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

Model without level:

```
plot(nested_noLevel)
```





```

print(summary(nested_noLevel), 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)  0.0573    0.0053   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    0.0065    0.0066  -0.0065   0.0192 1.0003    19328   26198
## scramble2    0.0484    0.0082   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      0.1135    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 for the estimate.

```

```
## 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
## Iteration: 5

print(BF_nested_mus)

## Estimated Bayes factor in favor of nested_3way over nested_noMus: 0.06465
```

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

print(BF_nested_scram)

## Estimated Bayes factor in favor of nested_3way over nested_noScram: 4294871943947.75879
```

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
## Iteration: 5

print(BF_nested_level)

## Estimated Bayes factor in favor of nested_3way over nested_noLevel: 0.01407
```

Moderate evidence against a main effect of level.

Interactions

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

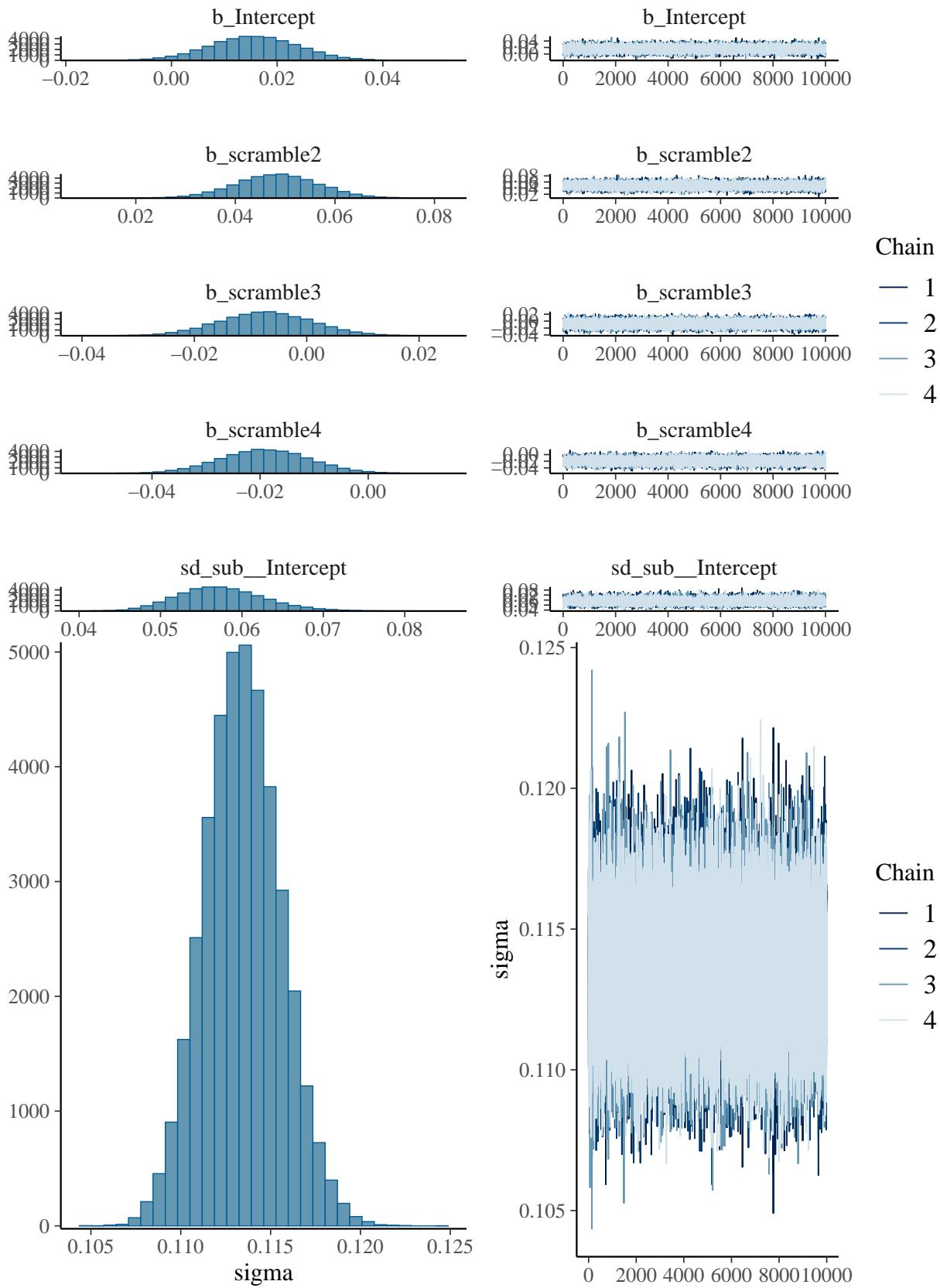
```
nested_justScram <- brm(value ~ scramble + (1|sub), data = data_nested,
  prior = c(
    set_prior('normal(0.1, 0.1)', coef = 'scramble2'),
    set_prior('normal(-0.1, 0.1)', coef = 'scramble3'),
    set_prior('normal(-0.1, 0.1)', coef = 'scramble4')
  ),
  save_pars = save_pars(all = TRUE),
  iter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

## 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/Frame
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeade
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
##   679 | #include <cmath>
##       |           ^~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(nested_justScram)
```



```

print(summary(nested_justScram), 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)  0.0575   0.0053   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   0.0082  -0.0233   0.0089 1.0001    53426   33896
## scramble4   -0.0191   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')

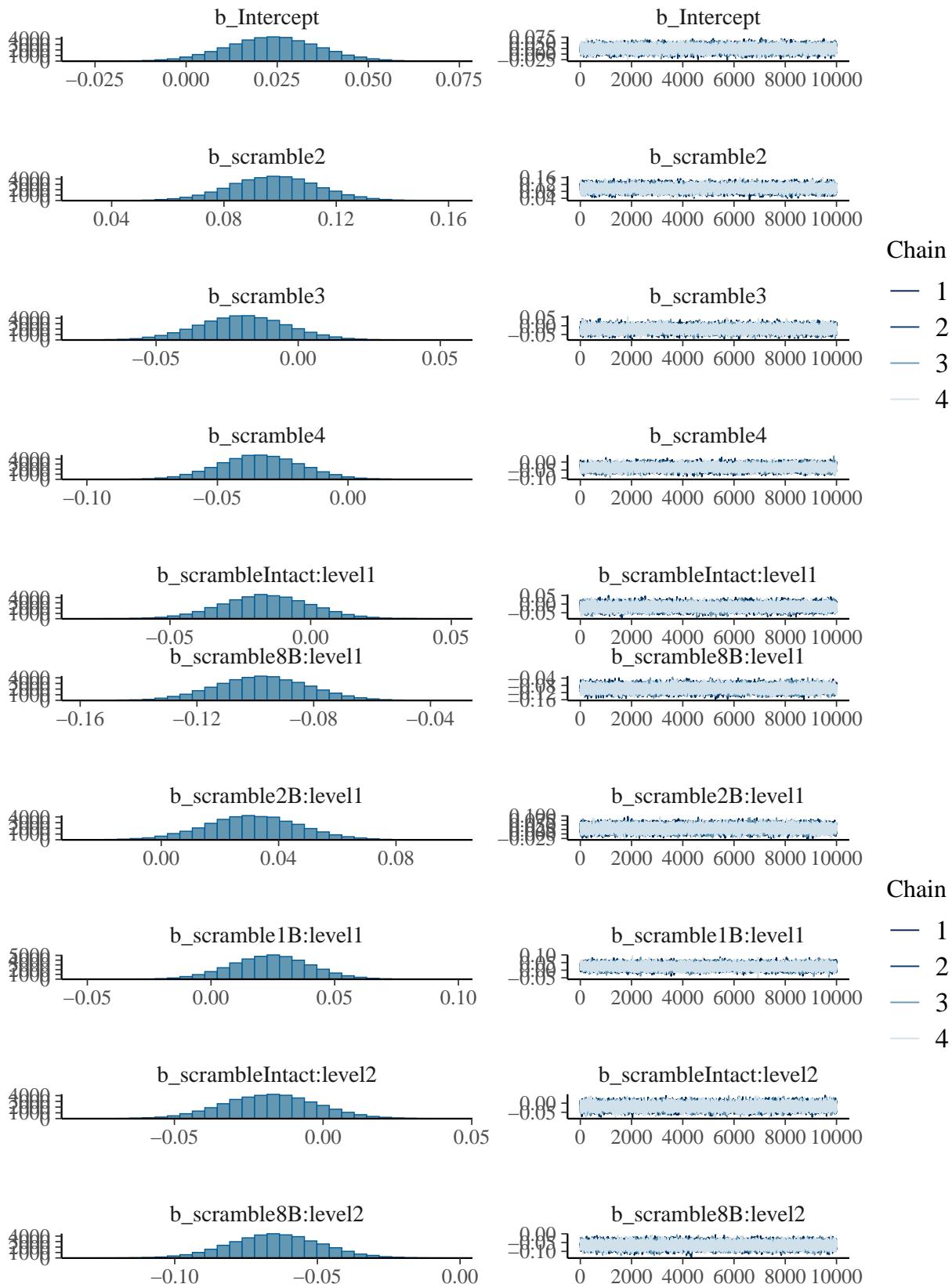
## Compiling Stan program...

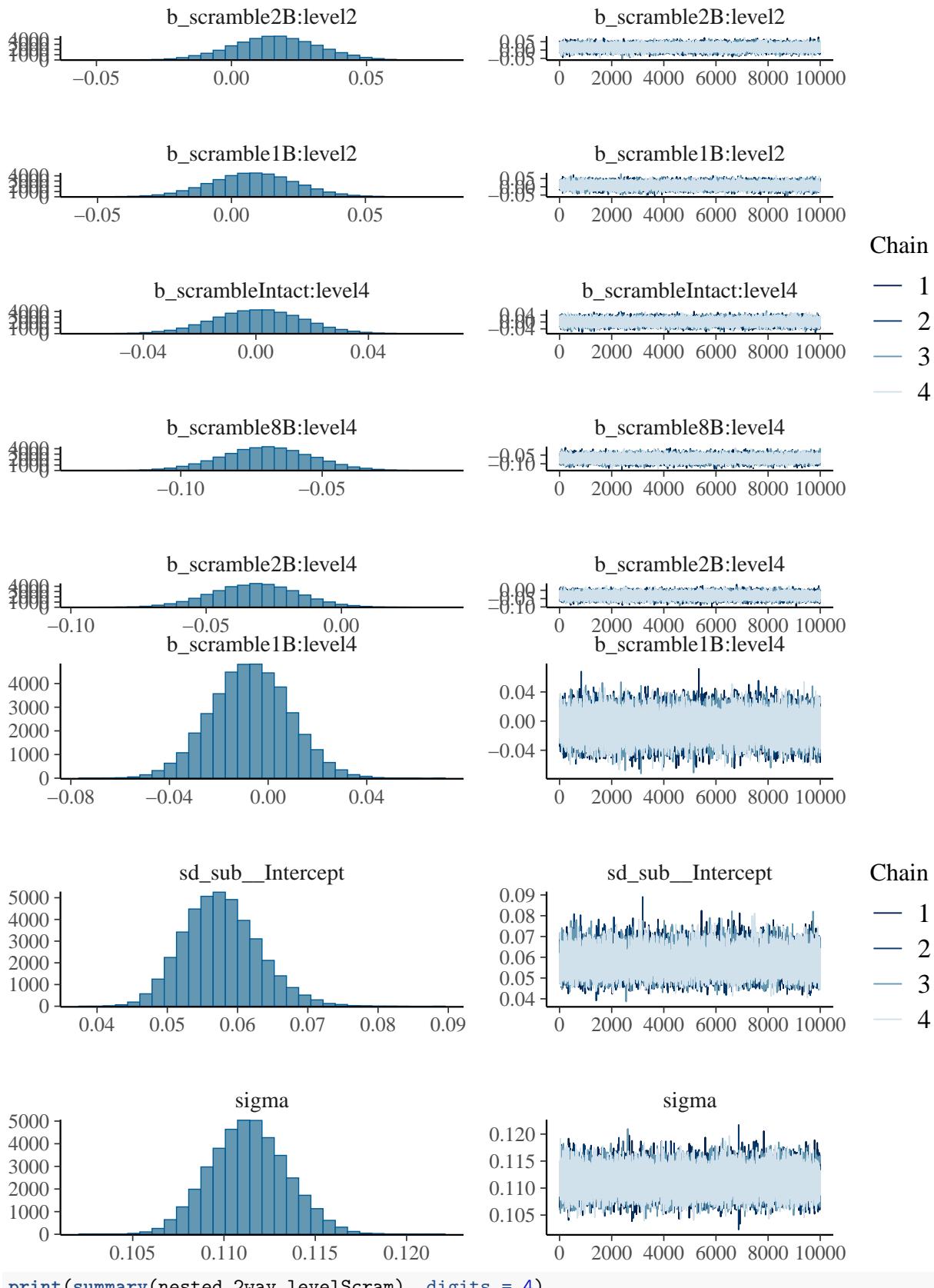
## Trying to compile a simple C file

## 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/Versions/4.3-arm64/Resources/library/StanHeaders/include"
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeaders/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
##   679 | #include <cmath>
##       |           ^
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(nested_2way_levelScram)

```





```

##  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)  0.0577   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        0.0238   0.0125  -0.0008   0.0484 1.0001    18167
## scramble2        0.0980   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  0.0312   0.0159   0.0000   0.0624 1.0002    38589
## scramble1B:level1  0.0242   0.0159  -0.0071   0.0553 1.0001    39710
## scrambleIntact:level2 -0.0177   0.0157  -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   0.0159  -0.0229   0.0395 1.0001    39545
## scrambleIntact:level4  0.0008   0.0157  -0.0303   0.0317 1.0001    30499
## scramble8B:level4  -0.0695   0.0159  -0.1007  -0.0383 1.0001    39050
## scramble2B:level4  -0.0320   0.0158  -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

print(BF_nested_2way_levelScram)

## Estimated Bayes factor in favor of nested_2way_levelScram over nested_justScram: 5216.33397
```

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')

## 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/Versions/4.3-arm64/Resources/library/StanHeaders/include"
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeaders/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
##   679 | #include <cmath>
##       |      ^~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling

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')

## 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/Versions/4.3-arm64/Resources/library/StanHeaders/include"
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeaders/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
##   679 | #include <cmath>
##       |      ^~~~~~
## 1 error generated.
```

```

## make: *** [foo.o] Error 1

## Start sampling

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')

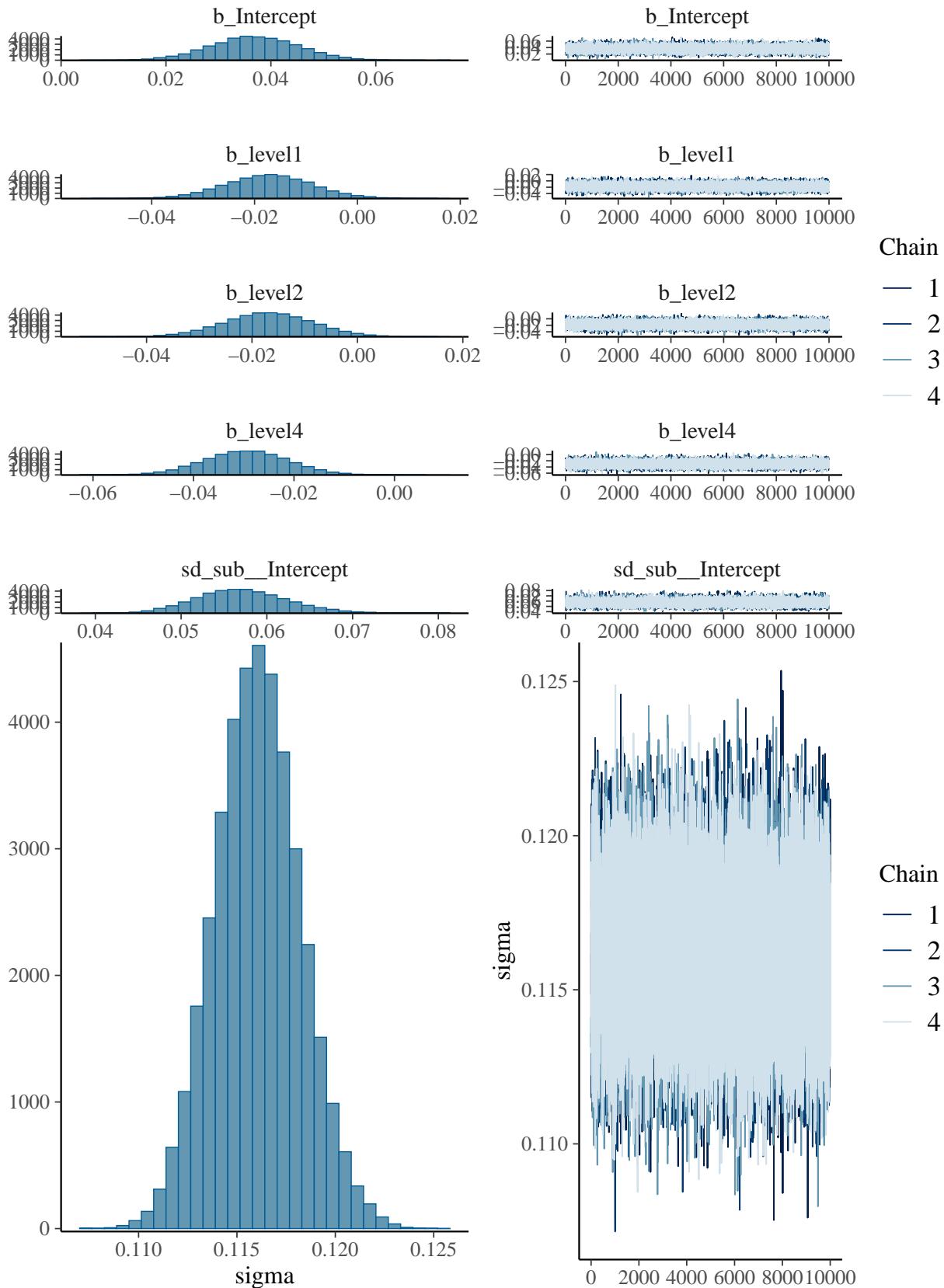
## Compiling Stan program...
## Trying to compile a simple C file

## 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
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
##   679 | #include <cmath>
##       |           ^
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling

```

```
plot(nested_justLevel)
```



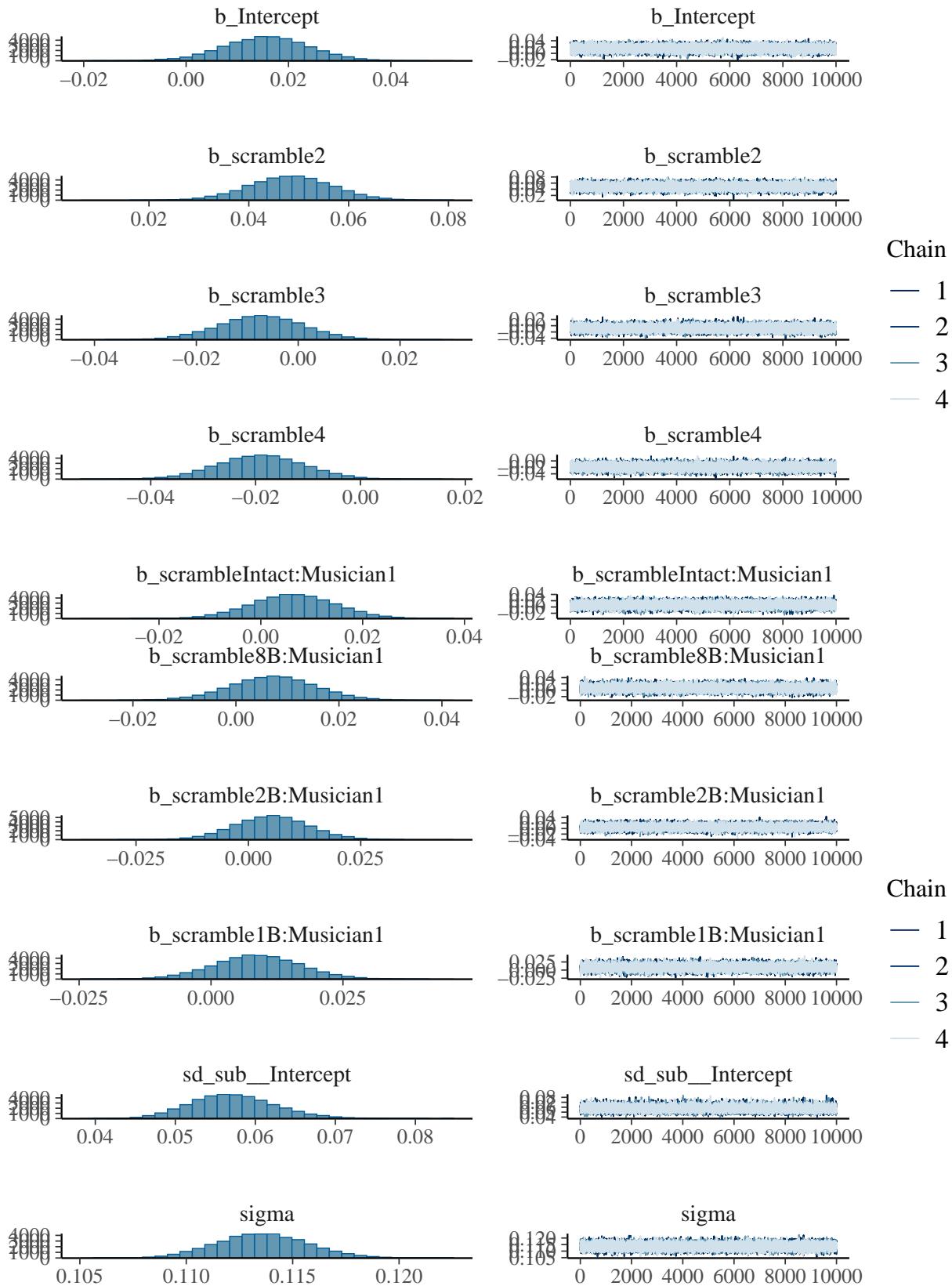
```

print(summary(nested_justLevel), 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)  0.0572   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    -0.0173   0.0084  -0.0338  -0.0007 1.0000    56382   32750
## level2    -0.0169   0.0084  -0.0334  -0.0005 1.0001    56795   33001
## level4    -0.0295   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     0.1161   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)
```



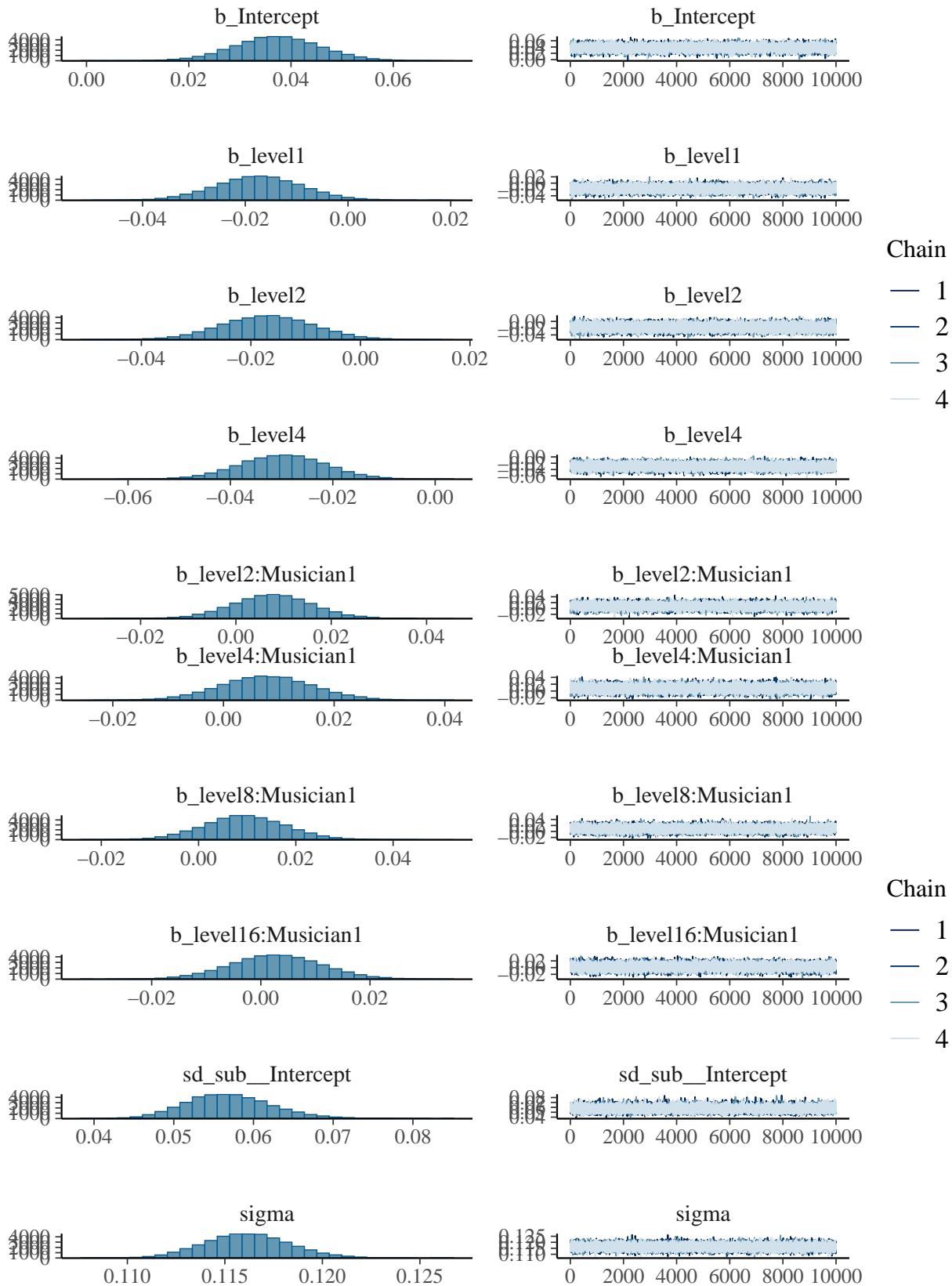
```

print(summary(nested_2way_musScram), 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)  0.0573    0.0053   0.0477   0.0684 1.0006    15560    24067
##
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI   Rhat Bulk_ESS
## Intercept        0.0157    0.0082  -0.0006   0.0318 1.0001    23104
## scramble2         0.0484    0.0083   0.0322   0.0647 1.0001    57338
## scramble3        -0.0073    0.0082  -0.0235   0.0088 1.0000    57081
## scramble4        -0.0190    0.0082  -0.0351  -0.0029 1.0001    56251
## scrambleIntact:Musician1  0.0064    0.0083  -0.0097   0.0226 1.0001    19188
## scramble8B:Musician1    0.0072    0.0083  -0.0092   0.0233 1.0000    19167
## scramble2B:Musician1    0.0052    0.0082  -0.0108   0.0215 1.0000    18961
## scramble1B:Musician1    0.0087    0.0082  -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), 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)  0.0570    0.0054   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    0.0084   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        -0.0298    0.0083  -0.0461  -0.0134 0.9999    55734    34544
## level2:Musician1  0.0077    0.0083  -0.0085   0.0242 1.0002    21043    27783
## level4:Musician1  0.0078    0.0084  -0.0086   0.0243 1.0000    20169    28079
## level8:Musician1  0.0095    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     0.1162    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: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4

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: 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.

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')

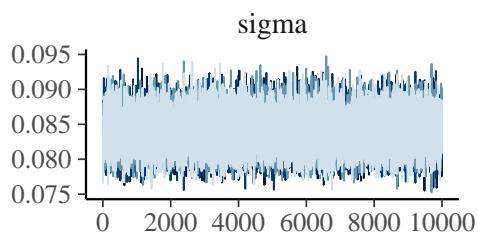
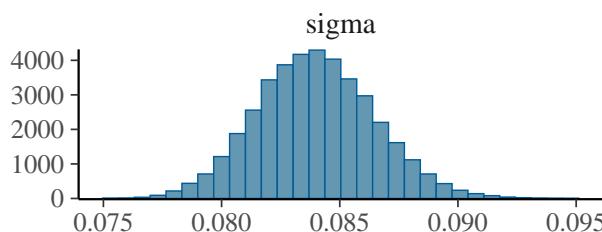
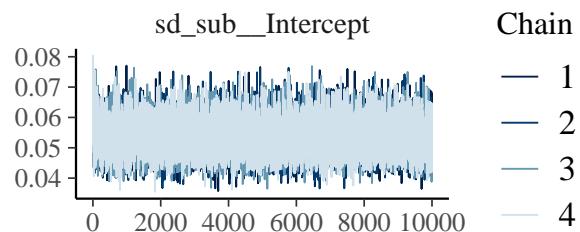
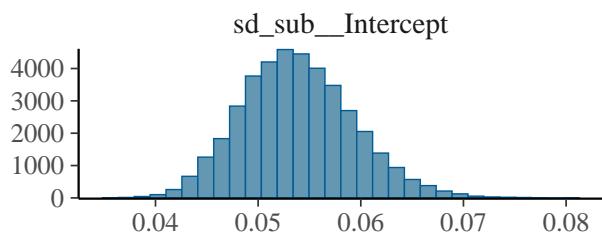
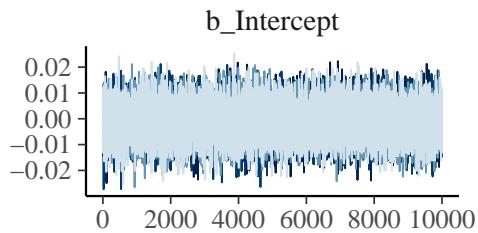
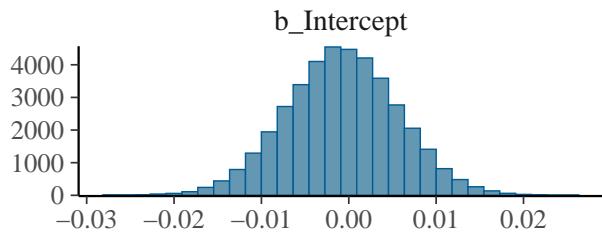
## Compiling Stan program...

## 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/Versions/4.3-arm64/Resources/library/StanHeaders/include"
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeaders/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core/Cor
##   679 | #include <cmath>
##       |           ^~~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(levels1B_null)

```



```

print(summary(levels1B_null), 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)  0.0538     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     0.0064  -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       0.0840     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')

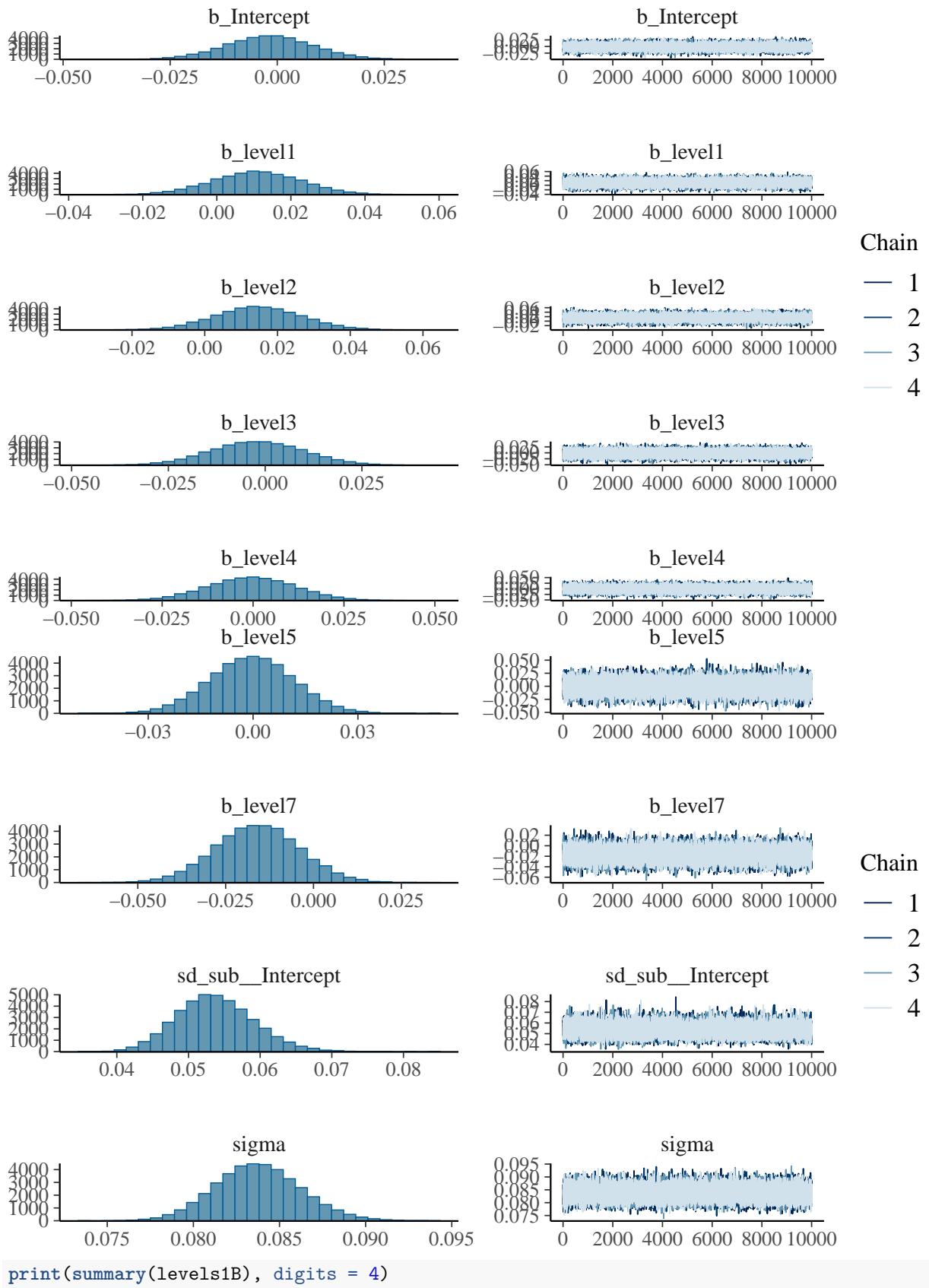
## Compiling Stan program...

## 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/Eigen/Dense:10,
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core/DenseBase.h:10
##   679 | #include <cmath>
##       |           ^~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(levels1B)

```



```

## 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)  0.0538     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     0.0101   -0.0215    0.0181 1.0000     29177    28273
## level1    0.0109     0.0120   -0.0127    0.0343 1.0001     36876    33621
## level2    0.0148     0.0120   -0.0086    0.0383 1.0001     38090    33468
## level3   -0.0020     0.0120   -0.0254    0.0215 1.0000     37772    32725
## level4   -0.0004     0.0120   -0.0240    0.0230 1.0001     37984    33845
## level5   -0.0004     0.0121   -0.0240    0.0231 1.0000     38109    33796
## level7   -0.0160     0.0120   -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     0.0838     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: 5
## Iteration: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4

```

```
print(BF_1B_level)
```

```
## Estimated Bayes factor in favor of levels1B over levels1B_null: 0.00000
```

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.

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')

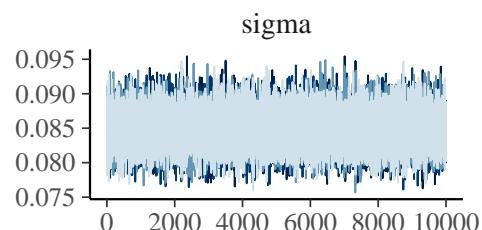
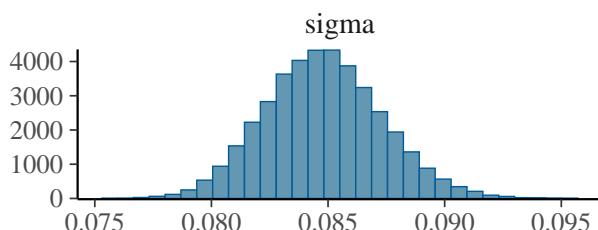
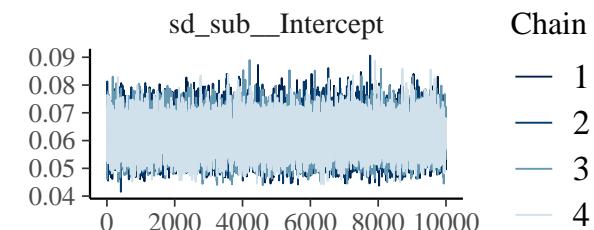
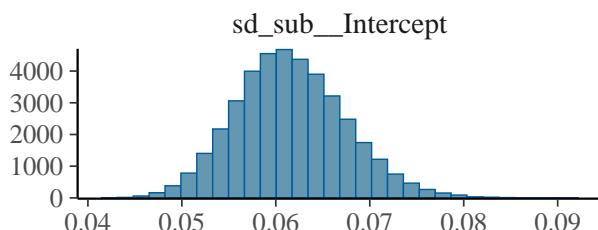
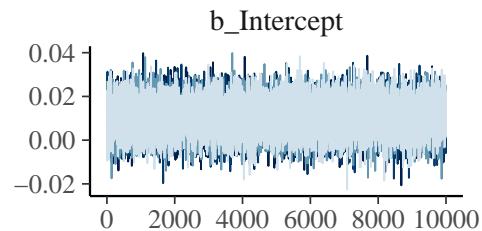
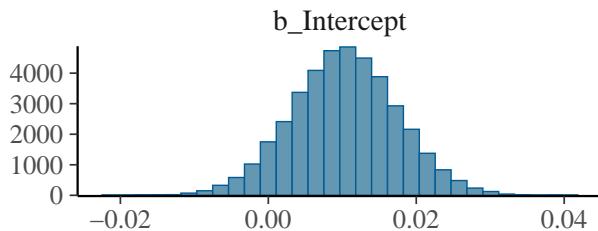
## Compiling Stan program...

## 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/PlainObject.h:102
##   679 | #include <cmath>
##       |           ^~~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(levels2B_null)

```



```

print(summary(levels2B_null), 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)  0.0616   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       0.0848   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')

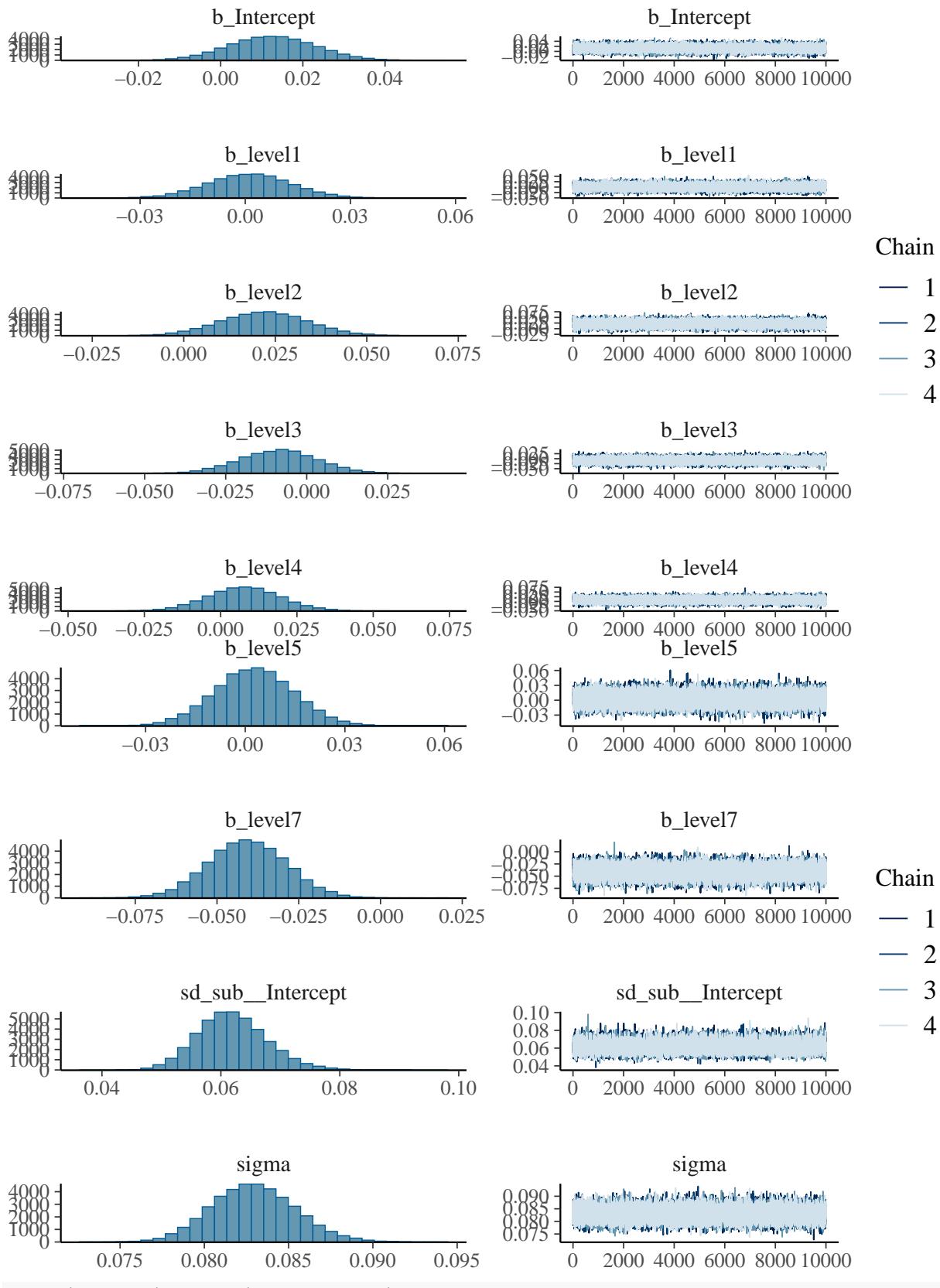
## Compiling Stan program...

## 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:10,
##   679 | #include <cmath>
##     |      ^~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(levels2B)

```



```

## 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)  0.0620     0.0058   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     0.0119  -0.0220   0.0244 1.0002     36052    33296
## level2       0.0220     0.0119  -0.0013   0.0452 1.0001     37003    34312
## level3      -0.0086     0.0119  -0.0319   0.0147 1.0002     34120    33031
## level4       0.0077     0.0119  -0.0155   0.0313 1.0002     36019    32470
## level5       0.0027     0.0119  -0.0208   0.0260 1.0001     36701    32884
## level7      -0.0407     0.0119  -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
## Iteration: 5

```

```
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
## level1 - level2 -0.02079 -0.04485  0.00274
## level1 - level3  0.00989 -0.01362  0.03370
## level1 - level4 -0.00650 -0.03013  0.01688
## level1 - level5 -0.00153 -0.02493  0.02246
## level1 - level8  0.00123 -0.02243  0.02398
## level1 - level16 0.04192  0.01856  0.06534
## level2 - level3  0.03064  0.00778  0.05468
## level2 - level4  0.01431 -0.00849  0.03850
## level2 - level5  0.01929 -0.00478  0.04267
## level2 - level8  0.02202 -0.00174  0.04471
## level2 - level16 0.06276  0.03872  0.08604
## level3 - level4 -0.01629 -0.03978  0.00719
## level3 - level5 -0.01135 -0.03523  0.01198
## level3 - level8 -0.00848 -0.03211  0.01439
## level3 - level16 0.03210  0.00888  0.05568
## 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

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')

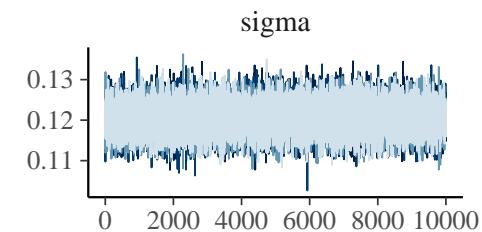
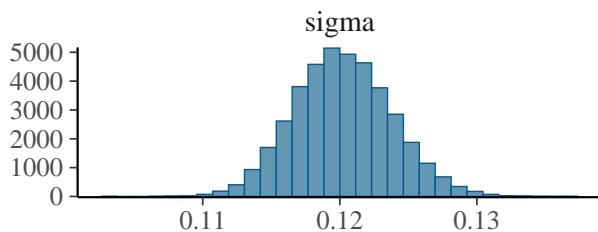
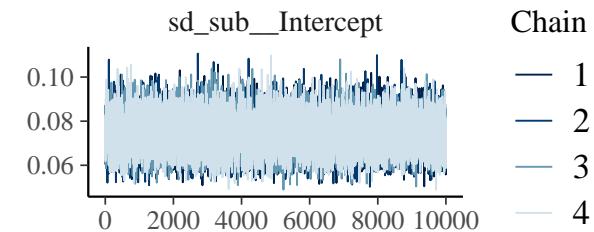
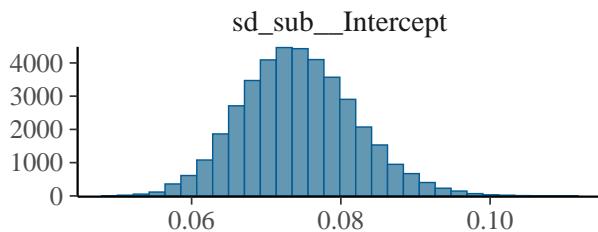
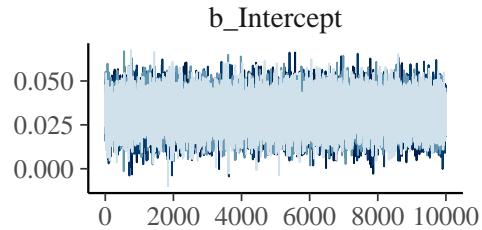
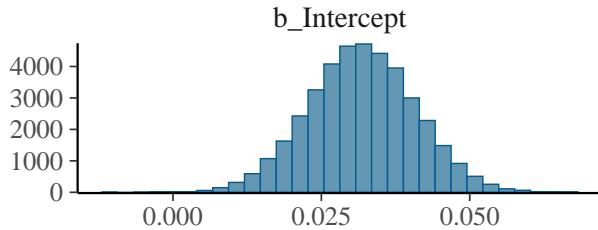
## Compiling Stan program...

## 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/Versions/4.3-arm64/Resources/library/StanHeaders/include"
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeaders/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core/Cor
##   679 | #include <cmath>
##       |           ^~~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(levels8B_null)

```



```

print(summary(levels8B_null), 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)  0.0743   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       0.1202   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')

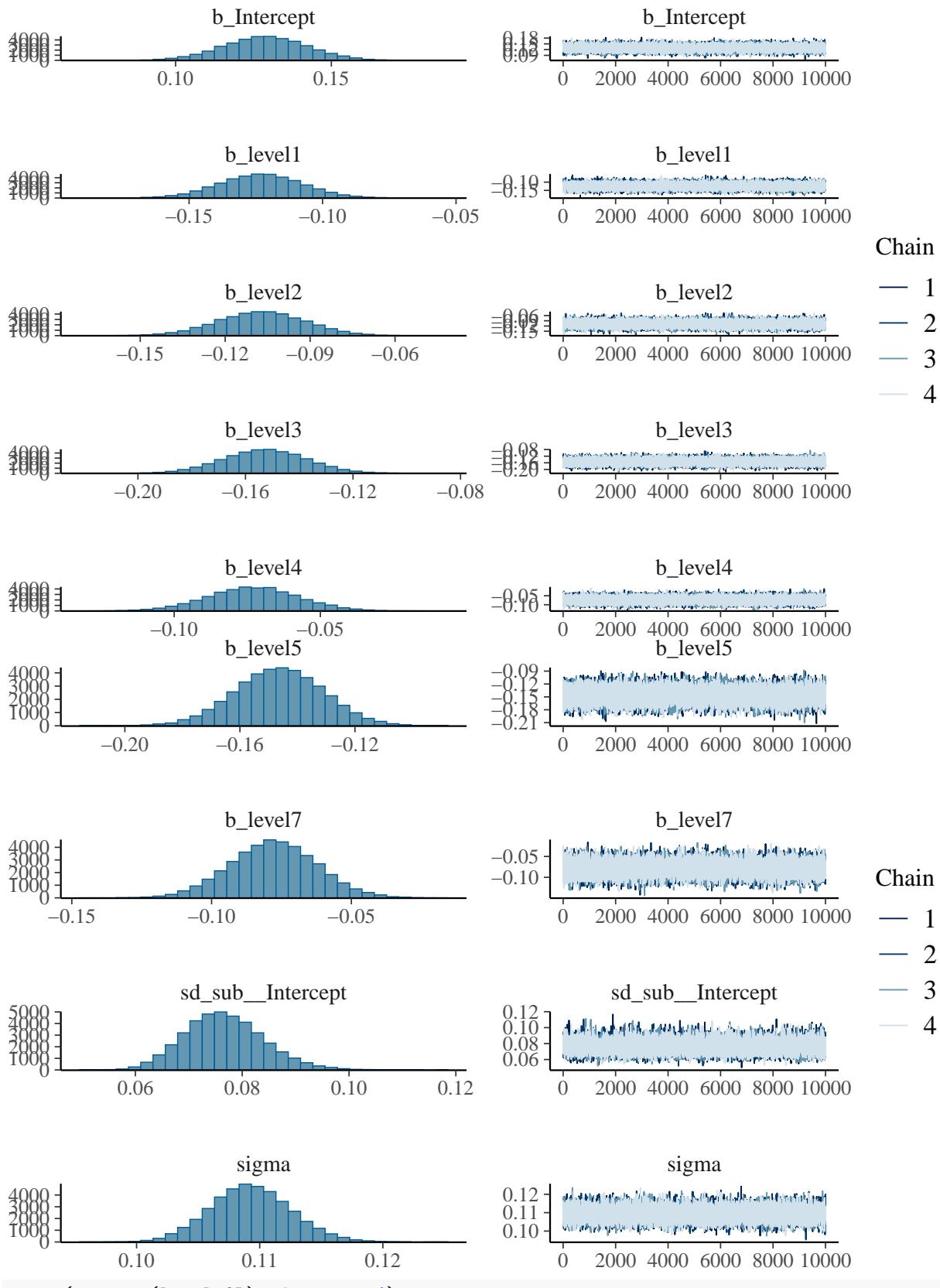
## Compiling Stan program...

## 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/Eigen/Dense:10,
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core/DenseBase.h:10
##   679 | #include <cmath>
##       |           ^~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(levels8B)

```



```

## 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)  0.0767    0.0074   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     -0.1528    0.0154  -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     -0.0779    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      0.1093    0.0033   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
## Iteration: 5
```

```
print(BF_8B_level)
```

```
## Estimated Bayes factor in favor of levels8B over levels8B_null: 11442676595268884480.00000
```

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
## level1 - level2 -0.01597 -0.04686  0.01442
## level1 - level3  0.02970 -0.00101  0.06067
## level1 - level4 -0.05009 -0.08061 -0.01861
## level1 - level5  0.02326 -0.00646  0.05485
## level1 - level8 -0.12307 -0.15399 -0.09342
## level1 - level16 -0.04531 -0.07610 -0.01459
## level2 - level3  0.04574  0.01512  0.07677
## level2 - level4 -0.03424 -0.06585 -0.00370
## level2 - level5  0.03923  0.00789  0.06976
## level2 - level8 -0.10705 -0.13791 -0.07710
## level2 - level16 -0.02923 -0.05968  0.00221
## level3 - level4 -0.07975 -0.11056 -0.04923
## level3 - level5 -0.00642 -0.03734  0.02364
## level3 - level8 -0.15275 -0.18325 -0.12303
## level3 - level16 -0.07499 -0.10617 -0.04459
## 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

Intact

```

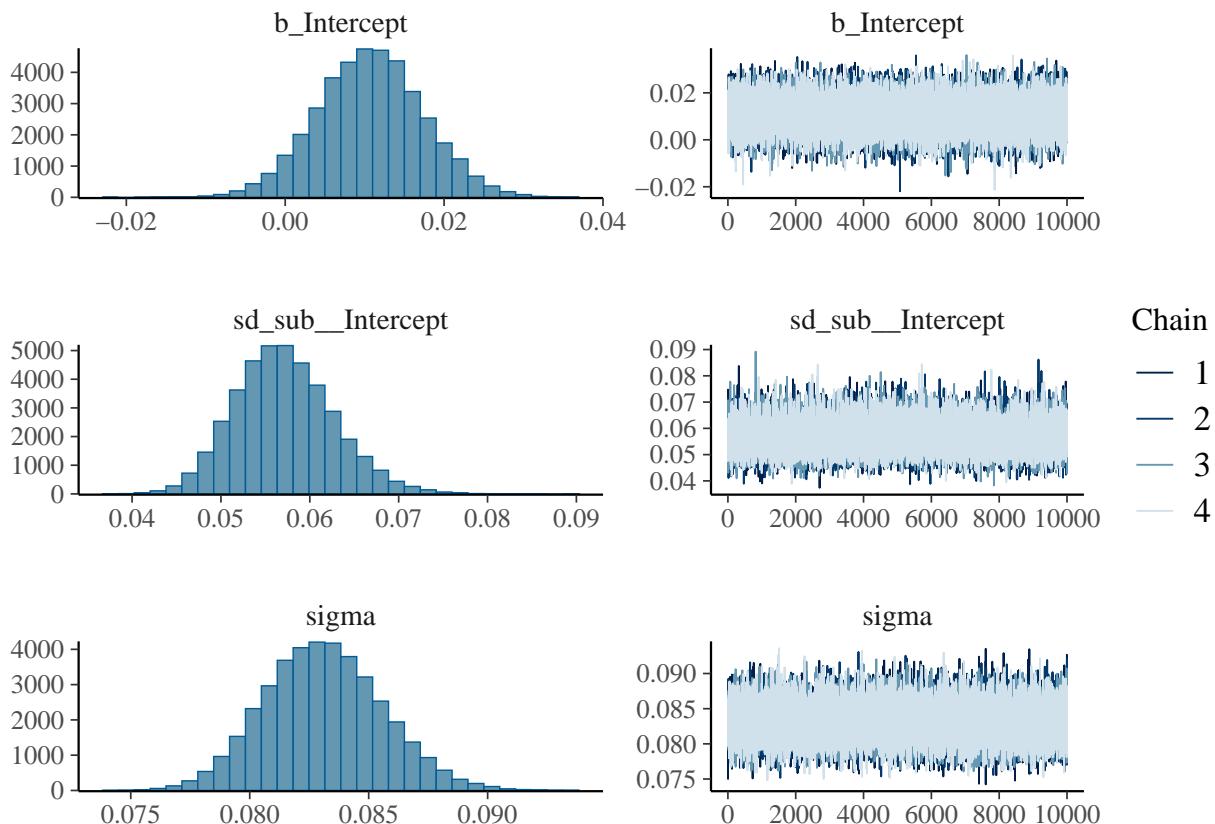
dataI <- filter(data, scramble == 'Intact')

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')

## 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
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
##   679 | #include <cmath>
##       |           ^~~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(levelsI_null)

```



```

print(summary(levelsI_null), 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)  0.0571    0.0056   0.0471   0.0688 1.0002     13491    19402
##
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept    0.0107    0.0067  -0.0024   0.0240 1.0001     22859    27259
##
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma       0.0831    0.0025   0.0785   0.0881 1.0000     45816    29371
##
## 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')

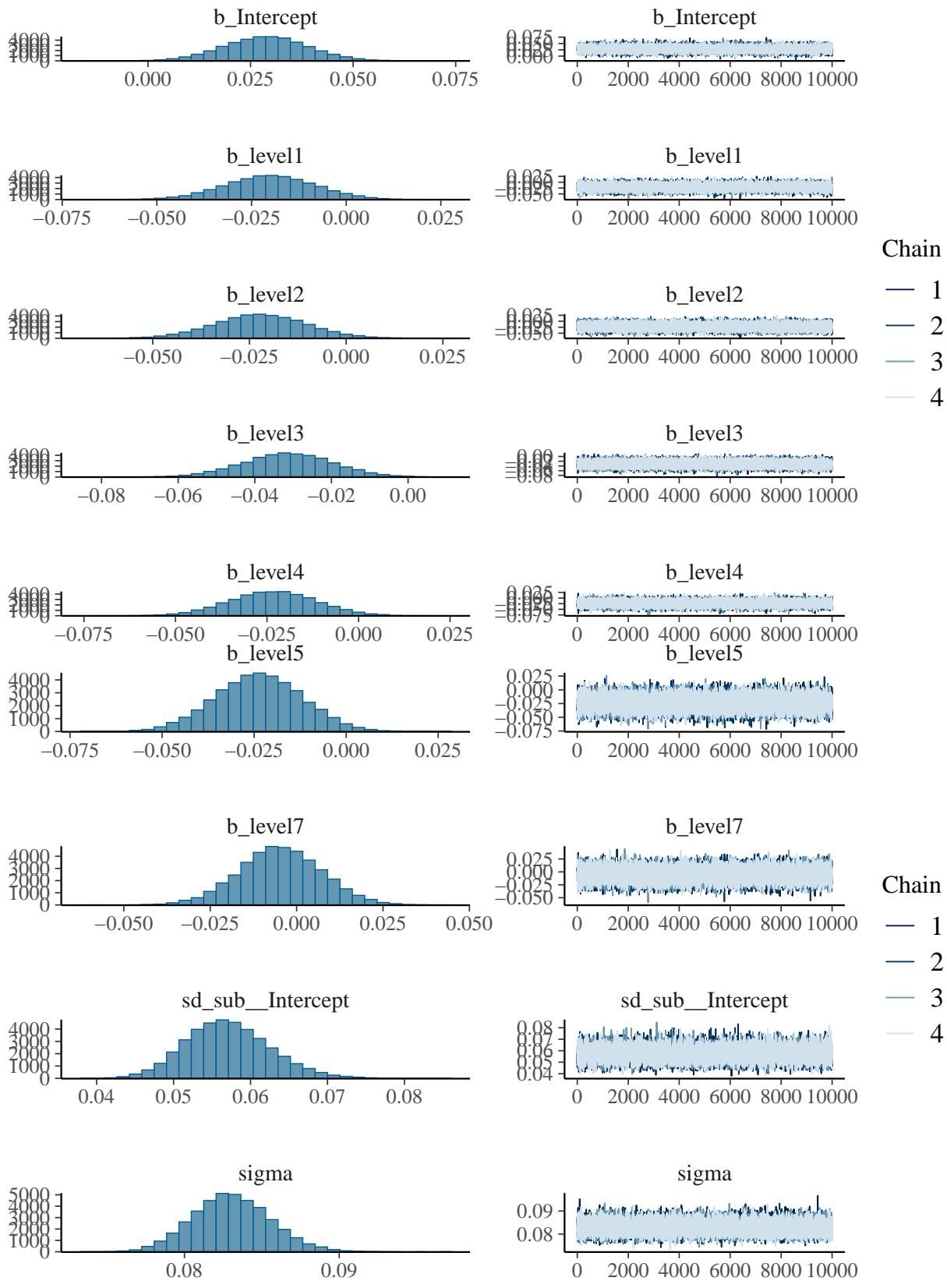
## Compiling Stan program...

## 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:
##   679 | #include <cmath>
##       |           ^~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(levelsI)

```



```

## 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)  0.0571     0.0055   0.0470   0.0686 1.0001    16483    24530
##
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept    0.0287     0.0101   0.0090   0.0486 1.0002    21430    26526
## level1      -0.0201     0.0119  -0.0435   0.0030 1.0001    34902    33115
## level2      -0.0221     0.0118  -0.0454   0.0011 1.0000    33771    32632
## level3      -0.0314     0.0117  -0.0543  -0.0085 1.0000    33742    33028
## level4      -0.0234     0.0118  -0.0465  -0.0004 1.0000    33771    33903
## level5      -0.0237     0.0118  -0.0469  -0.0008 1.0001    34093    32950
## level7      -0.0048     0.0119  -0.0281   0.0187 1.0001    34380    32816
##
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma       0.0831     0.0025   0.0784   0.0881 1.0000    52638    31380
##
## 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(BF_I_level)
```

```
## Estimated Bayes factor in favor of levelsI over levelsI_null: 0.00000
```

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      0.00875 -0.01188   0.0286
## 2      0.00658 -0.01306   0.0269
## 3     -0.00262 -0.02306   0.0172
## 4      0.00538 -0.01471   0.0257
## 5      0.00502 -0.01481   0.0256
```

```

##   8      0.02878  0.00899  0.0486
##  16      0.02400  0.00421  0.0445
##
## 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  0.002124 -0.0214  0.025758
##  level1 - level3  0.011208 -0.0122  0.034370
##  level1 - level4  0.003335 -0.0206  0.026338
##  level1 - level5  0.003684 -0.0191  0.027825
##  level1 - level8 -0.020041 -0.0431  0.003344
##  level1 - level16 -0.015306 -0.0386  0.008082
##  level2 - level3  0.009150 -0.0142  0.032447
##  level2 - level4  0.001274 -0.0223  0.024561
##  level2 - level5  0.001653 -0.0220  0.024733
##  level2 - level8 -0.022139 -0.0456  0.000796
##  level2 - level16 -0.017403 -0.0413  0.005508
##  level3 - level4 -0.007961 -0.0312  0.015237
##  level3 - level5 -0.007571 -0.0321  0.015001
##  level3 - level8 -0.031343 -0.0542 -0.008407
##  level3 - level16 -0.026570 -0.0501 -0.003310
##  level4 - level5  0.000354 -0.0234  0.023698
##  level4 - level8 -0.023344 -0.0465 -0.000403
##  level4 - level16 -0.018663 -0.0430  0.004178
##  level5 - level8 -0.023710 -0.0466 -0.000577
##  level5 - level16 -0.018913 -0.0426  0.004479
##  level8 - level16  0.004820 -0.0194  0.027409
##
## Point estimate displayed: median
## HPD interval probability: 0.95

```

8 > 3, 8 > 4, 8 > 5

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')

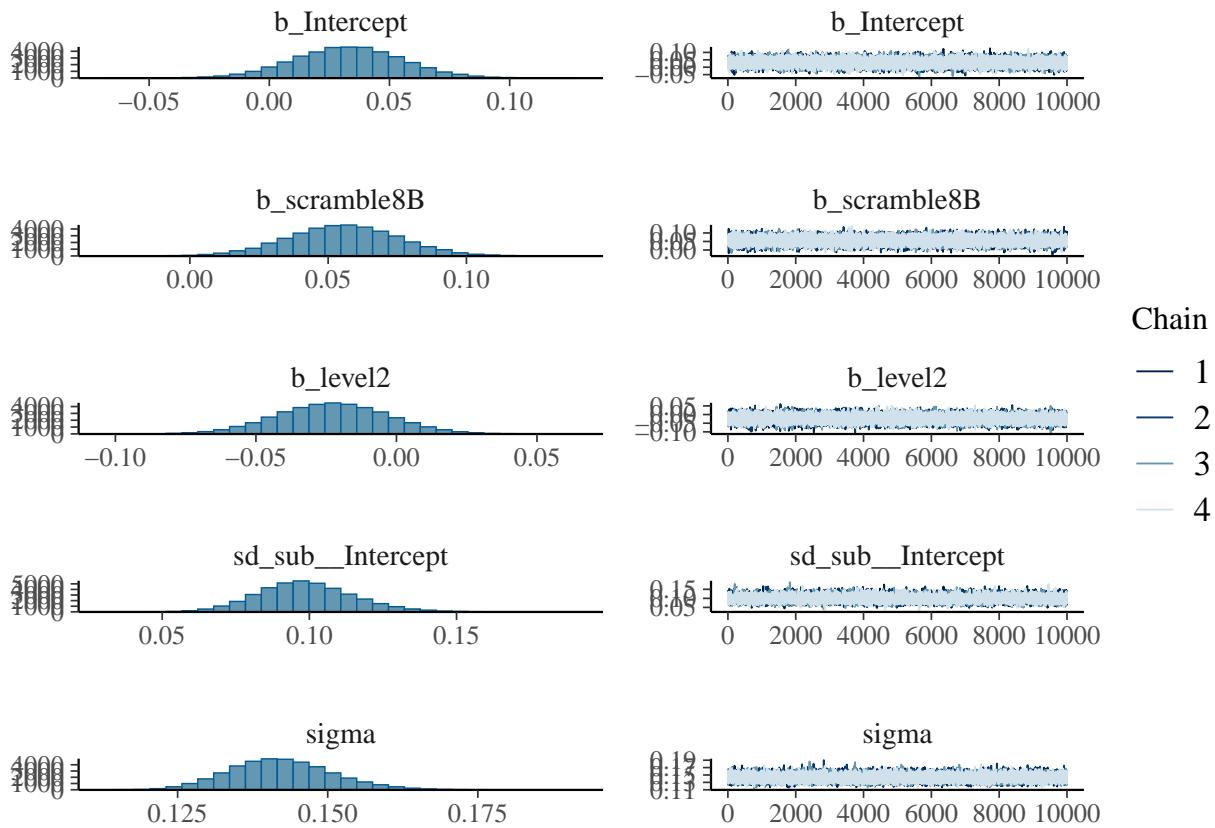
longTS_M <- brm(value ~ scramble + level + (1|sub), data = data_longTS_M,
                  prior = set_prior('normal(0, 0.1)', class = 'b'),
                  save_pars = save_pars(all = TRUE), iter = 20000, refresh = 0,
                  file = 'models/E3_alignment_longTimescales_mus')

## 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/Frame
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeader
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
##   679 | #include <cmath>
##       |           ^~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(longTS_M)
```



```
print(summary(longTS_M), 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)  0.0989   0.0162   0.0688   0.1332 1.0000   14256   21996
##
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept     0.0327   0.0224  -0.0112   0.0768 1.0001   31988   30097
## scramble8B    0.0556   0.0199   0.0164   0.0944 1.0001   62644   28889
## level2       -0.0228   0.0197  -0.0614   0.0159 1.0000   62946   28848
##
## Further Distributional Parameters:
##             Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma        0.1422   0.0085   0.1267   0.1600 1.0000   31059   30483
##
## 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')

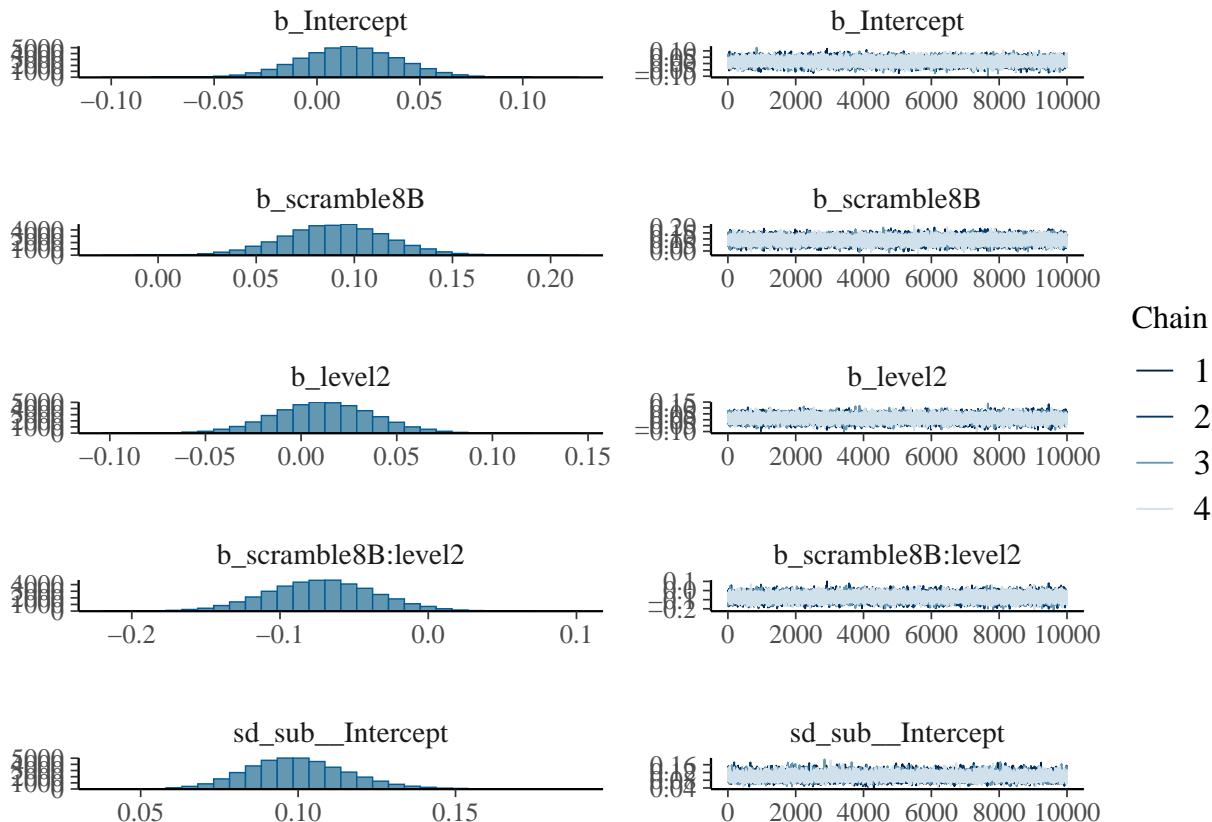
## Compiling Stan program...

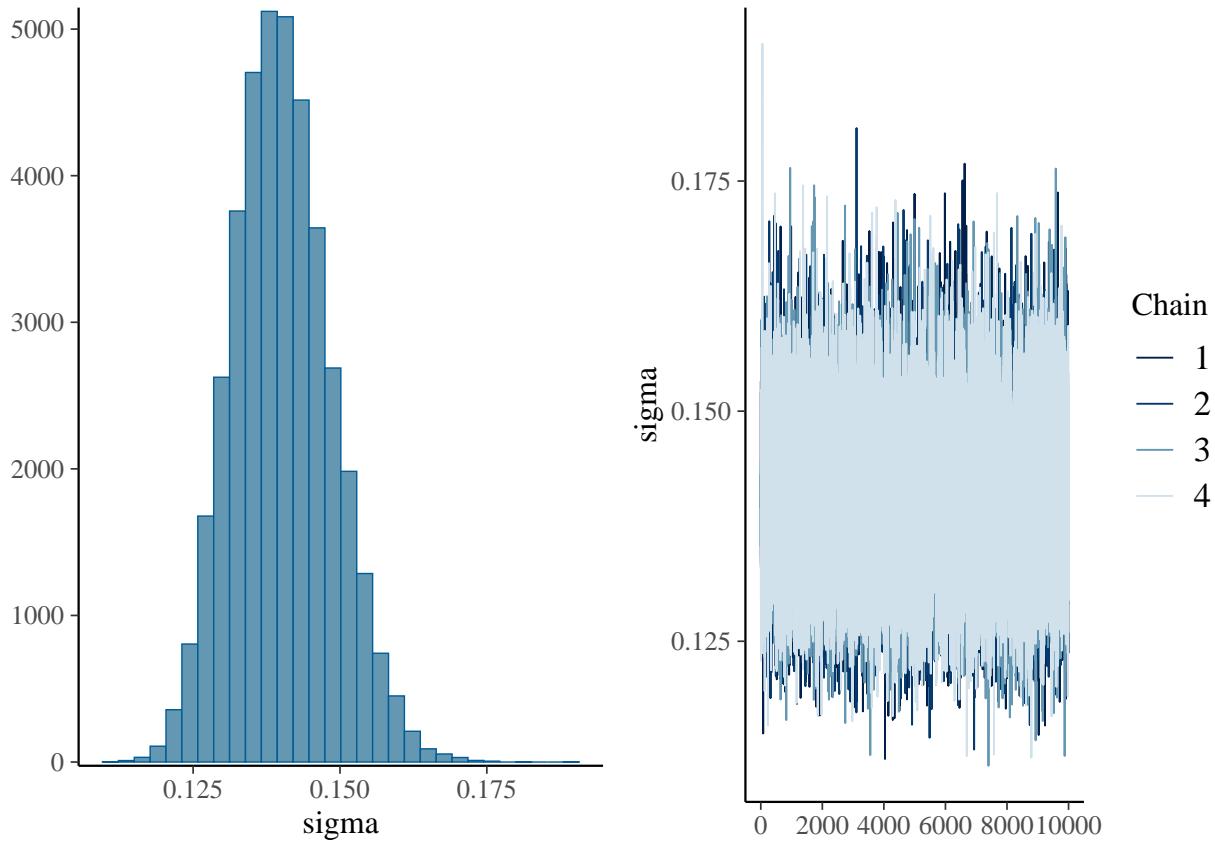
## Trying to compile a simple C file

## 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/PlainObject.h:42:
##   679 | #include <cmath>
##       |         ~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(longTS_M_int)

```





```

print(summary(longTS_M_int), 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)  0.1000    0.0162   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     0.0902    0.0263   0.0382   0.1417 1.0000    39650    32523
## level2        0.0119    0.0261  -0.0395   0.0636 1.0002    39444    32025
## scramble8B:level2 -0.0720    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       0.1401    0.0084   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: 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: 2.62951
```

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')

## 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/c++/v1"
## 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/Eigen/Dense:10
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/SolverBase:10
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core/PlainObject.h:679 | #include <cmath>
##           |          ~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling
plot(longTS_NM)

```

The figure consists of eight subplots arranged in a 4x2 grid. The left column contains histograms representing the posterior distributions of parameters: **b_Intercept**, **b_scramble8B**, **b_level2**, and **sd_sub_Intercept**. The right column contains trace plots showing the evolution of these parameters over 10,000 MCMC iterations for each of the four chains (Chain 1, Chain 2, Chain 3, Chain 4).

```

b_Intercept
sd_sub_Intercept
sigma
b_scramble8B
b_level2

```

```

print(summary(longTS_NM), digits = 4)

## Family: gaussian

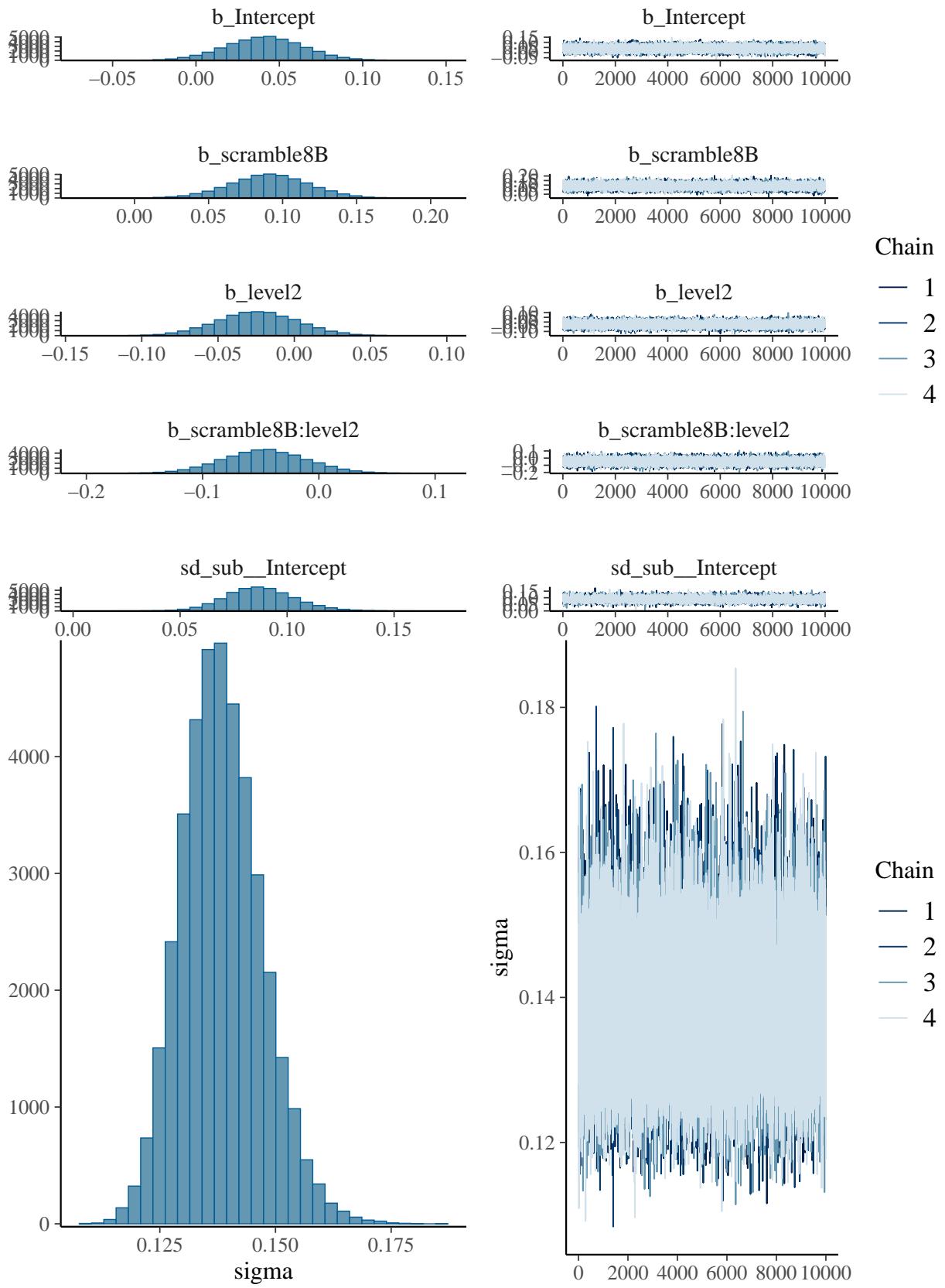
```

```

##   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)  0.0879    0.0164   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     0.0519    0.0219   0.0087   0.0948 1.0000    25734    27165
## scramble8B    0.0689    0.0201   0.0292   0.1085 1.0000    55497    30021
## level2       -0.0464    0.0201  -0.0857  -0.0071 1.0002    52562    29603
##
## Further Distributional Parameters:
##           Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma      0.1389    0.0086   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')

## 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
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
##   679 | #include <cmath>
##       |         ^~~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1
## Start sampling
plot(longTS_NM_int)

```



```

print(summary(longTS_NM_int), 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)  0.0876    0.0164   0.0569   0.1214 1.0001     13739    21154
##
## Regression Coefficients:
##           Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## Intercept      0.0410    0.0234  -0.0051   0.0868 1.0001     32996    30303
## scramble8B     0.0911    0.0265   0.0386   0.1427 1.0001     44190    31955
## level2        -0.0241    0.0266  -0.0763   0.0286 1.0001     45030    33790
## scramble8B:level2 -0.0462    0.0365  -0.1174   0.0257 1.0001     41509    30219
##
## Further Distributional Parameters:
##           Estimate Est.Error l-95% CI u-95% CI    Rhat Bulk_ESS Tail_ESS
## sigma     0.1384    0.0087   0.1228   0.1566 1.0000     27196    29174
##
## 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: 0.79956

```

There is weak evidence against an interaction for musicians.