Bayesian Analyses for CircleTime

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Contents

1 About the Study

1.1 Introduction to Circle-Time

Circle-time is a group activity based on Applied Behavior Analysis (ABA) for children with Autism Spectrum Disorder (ASD) to prepare them for attending in traditional classroom activities alongside neurotically developed children. In circle-time, children sit together semicircular, and an instructor give them group instruction activities such as dance, yoga, labeling animals, finding objects, etc. The goal of circle-time is to improve children's learning behaviors, which are:

- Affect
- Communication
- Engagement
- Performance

In this study, we evaluate the efficacy of a social robot in delivering group instruction activities to children with ASD. Throughout the six month of experiment, Six children participants received 10 sessions of group instructions from a human instructor and 10 sessions from a Pepper humanoid social robot as a within-subject study design. To compare children learning behaviors between the human and the robot instructor conditions their activities were video recorded and coded for the sessions 1, 4, 7, and 10.

1.2 Research Questions

In this research, we address the following research questions:

1. How learning behaviors (Affect, Communication, Engagement, Performance) differ between conditions (Human, Robot)?
2. How is the interaction between learning behaviors (Affect, Communication, Engagement, Performance) and time (Session Number)?

3. How is the interaction between different learning behaviors (Affect, Communication, Engagement, Performance)?
4. Between the Affect, Communication, and Engagement learning behaviors, which one is more effective on the Performance learning behavior (increasing performance is considered as the main objective)?

1.3 Study Design

For this longitudinal within-subject study with 6 participants we defined the following variables:

1.3.0.1 Independent Variables

- Instructor Conditions:
  - Human ~ 1
  - Robot ~ 2
- Time
  - Session 1 ~ 1
  - Session 4 ~ 2
  - Session 7 ~ 3
  - Session 10 ~ 4

1.3.0.2 Dependent Variables

- Affect
- Communication
- Engagement
- Performance

1.3.1 Data Collection

The evaluation of the learning behavior is based on the following metrics:

1.3.1.1 Affect children's happiness level was defined as:

- Positive
- Negative
- Neutral

A video was divided into 10 seconds intervals, and a human coder, focusing on one child in the group, labeled that interval as Positive if the child was happy, Negative if they was sad, and Neutral if they was neither happy or sad. Percentage of each measurement is used for analysis.

1.3.1.2 Communication Communication of the children was coded into 4 categories. Communication with:

- Instructor
- Instructor-Prompted
- Behavior Therapist (BT) or peers
- Indeterminate

1.3.1.3 Engagement

Engagement was coded into 3 categories. Engagement with:

- Instructor or screen (On Target)
- BT or peers
- Off Target

1.3.1.4 Performance

Children's performance was coded into two categories:

- Positive
- Negative

1.3.1.5 Inter-observer Agreement (IoA)

At the beginning of the coding procedure, coders' understanding of the metrics had to be on the same page. We used Cohen's Kappa score to evaluate the IoA on the coding procedure. An individual coder was allowed to code independently only if their Cohen's Kappa IioA score was higher than 80%. All session ones and tens were double coded as well as the 30% of the session fours and sevens. For the sessions with lower than 80% agreement, coders went through coding together and came up with 100% agreement. We considered this conservative approach since we were looking into the highest reliability of data on our 6 participants.

2 Data Analysis

In order to investigate the research questions, we analyze the data from children's learning behaviors as follows:

2.1 Affect

We use Bayesian Model to analyze the Affect metric.For all analyses condition 1 indicates the human instructor while condition 2 indicates the robot instructor.

2.1.1 Positive Affect

```
library(readr)
library(brms)
```

```
## Loading required package: Rcpp
```

```
## Loading 'brms' package (version 2.20.4). Useful instructions
## can be found by typing help('brms'). A more detailed introduction
## to the package is available through vignette('brms_overview').
```

```
##
## Attaching package: 'brms'
```

```
## The following object is masked from 'package:stats':
##
##     ar
```

```r
CircleTimeData <- read_csv("~/GitHub/Circle-Time-Data-Analyses/CircleTimeData.csv")
```

```
## Rows: 48 Columns: 15
```

```
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## dbl (15): Subject, Condition, time, Affect_Positive, Affect_Negative, Affect...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```r
bmodel <- brm(Affect_Positive ~ Condition * time + (1 | Subject), data = CircleTimeData)
```

```
## Compiling Stan program...
## Start sampling
```

```
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 2.8e-05 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.28 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 1:
## Chain 1:  Elapsed Time: 0.197 seconds (Warm-up)
## Chain 1:                0.098 seconds (Sampling)
## Chain 1:                0.295 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 9e-06 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.09 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
```

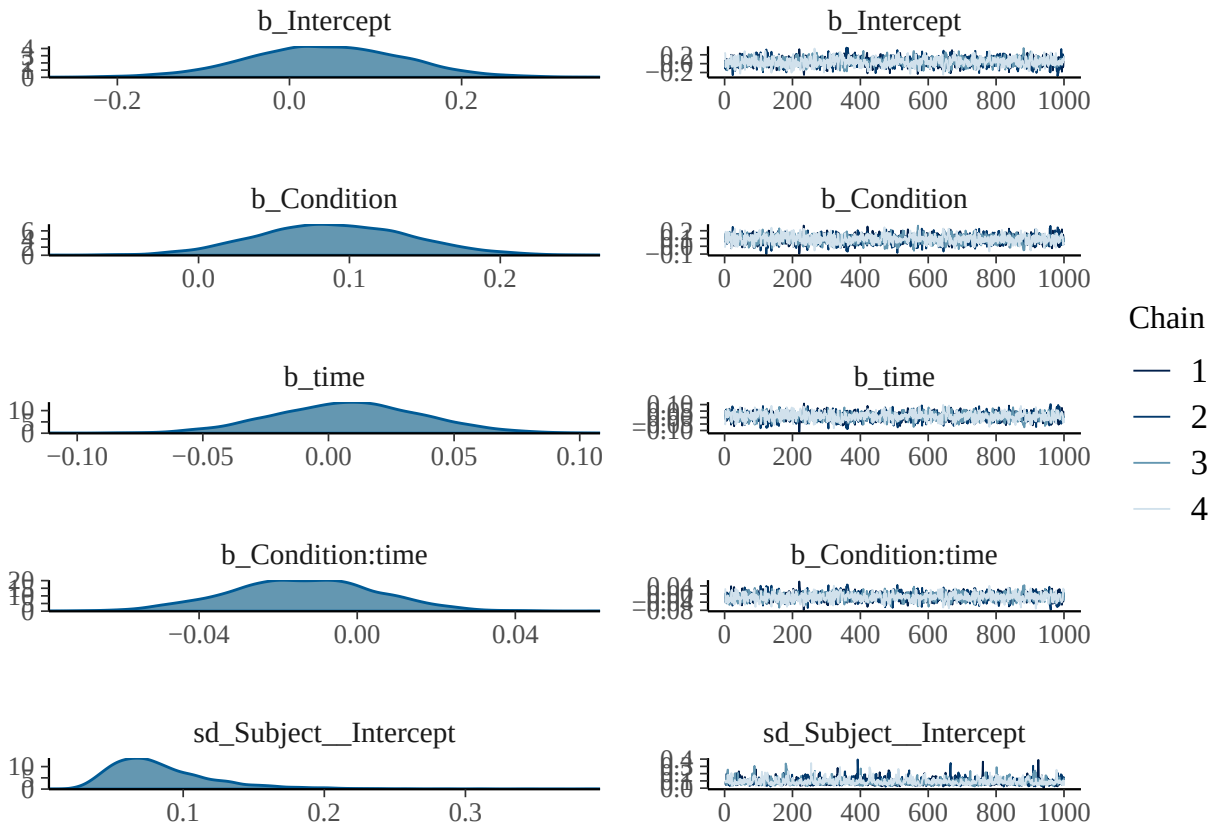
```
## Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 2:
## Chain 2:  Elapsed Time: 0.212 seconds (Warm-up)
## Chain 2:                0.103 seconds (Sampling)
## Chain 2:                0.315 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 1e-05 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.1 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 3:
## Chain 3:  Elapsed Time: 0.244 seconds (Warm-up)
## Chain 3:                0.096 seconds (Sampling)
## Chain 3:                0.34 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 1e-05 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.1 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
```

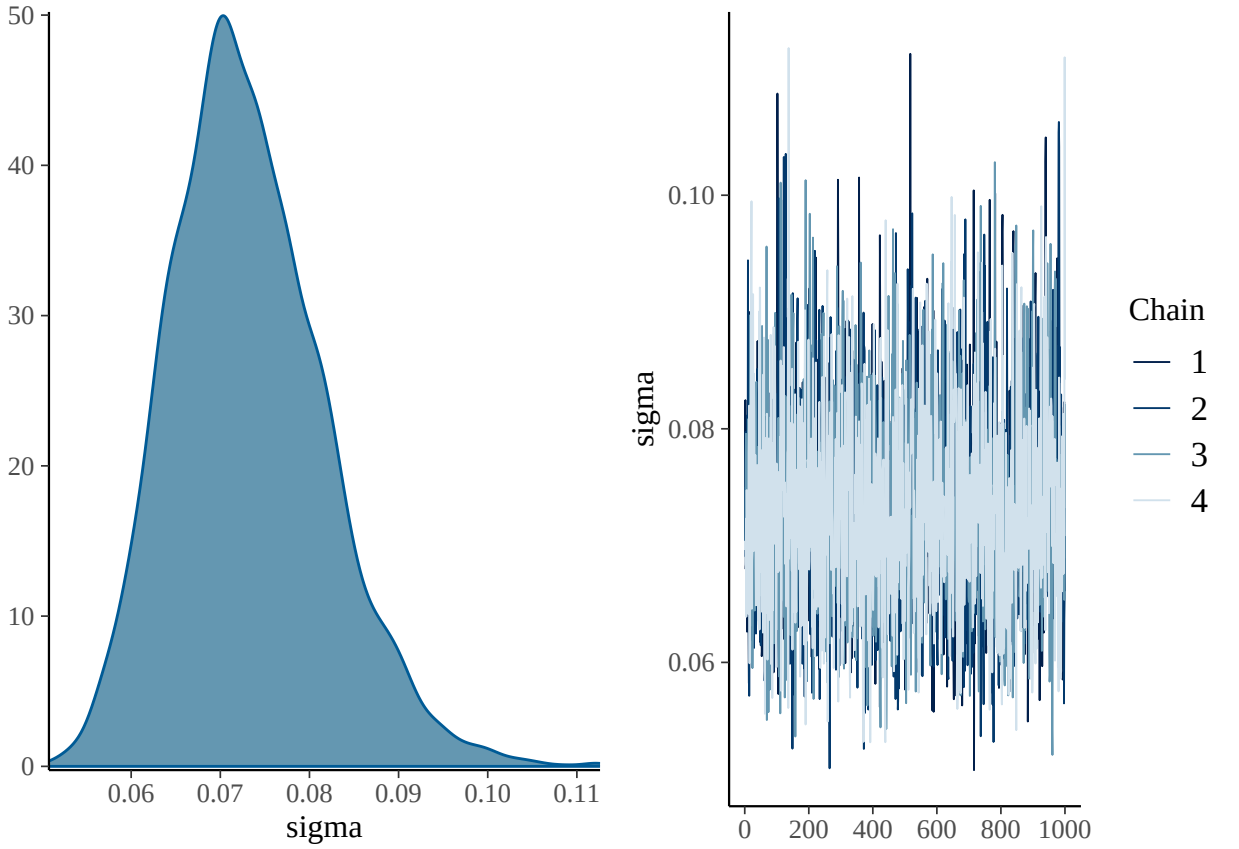
```
## Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 4:
## Chain 4:  Elapsed Time: 0.208 seconds (Warm-up)
## Chain 4:                0.108 seconds (Sampling)
## Chain 4:                0.316 seconds (Total)
## Chain 4:
```

```
summary(bmodel)
```

```
##  Family: gaussian
##   Links: mu = identity; sigma = identity
## Formula: Affect_Positive ~ Condition * time + (1 | Subject)
##    Data: CircleTimeData (Number of observations: 48)
##   Draws: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##          total post-warmup draws = 4000
##
## Group-Level Effects:
## ~Subject (Number of levels: 6)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     0.09      0.04     0.04     0.19 1.00     1136     1810
##
## Population-Level Effects:
##                Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.04      0.09    -0.14     0.22 1.00     1678     1912
## Condition          0.09      0.05    -0.01     0.19 1.00     1909     2120
## time               0.01      0.03    -0.05     0.07 1.00     1804     1996
## Condition:time    -0.01      0.02    -0.05     0.02 1.00     1774     1911
##
## Family Specific Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.07      0.01     0.06     0.09 1.00     2655     2586
##
## 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(bmodel)
```


b_Intercept
b_Intercept
b_Condition
b_Condition
b_time
b_time
b_Condition:time
b_Condition:time
sd_Subject__Intercept
sd_Subject__Intercept
Chain
1
2
3
4



2.1.1.1 Reporting Affect Positive Our Bayesian analysis of Affect_Positive explores the emotional responses of children in conditions involving human (Condition 1) versus robot instructors (Condition 2) across four pivotal sessions, representing sessions 1, 4, 7, and 10 in the context of a comprehensive longitudinal study spanning six months. The estimated standard deviation of intercepts across subjects is 0.08 (95% CI: 0.04, 0.20), indicating moderate variability in baseline levels of Affect_Positive among individuals. Examining population-level effects, the intercept is estimated at 0.04 (95% CI: -0.14, 0.21), representing the expected value of Affect_Positive when both Condition and time are zero. Positive effect sizes were observed for both Condition (0.09, 95% CI: -0.01, 0.20) and time (0.01, 95% CI: -0.05, 0.07), suggesting an increase in Affect_Positive during sessions with robot instructors compared to human instructors and a gradual rise over time. Interestingly, the interaction effect, represented by Condition:time, showed a slight decrease in the effect of Condition over time (-0.01, 95% CI: -0.05, 0.02). The estimated standard deviation of the residuals (sigma) was 0.07 (95% CI: 0.06, 0.09), capturing variability not explained by the fixed effects. These findings offer valuable insights into the nuanced emotional experiences of children, revealing the intricate interplay between experimental conditions and the temporal dimension of our six-month longitudinal study. The reliable convergence of our Bayesian model and adequate effective sample sizes underscore the robustness of these intriguing results.

2.1.2 Negative Affect

```
library(readr)
library(brms)

CircleTimeData <- read_csv("~/GitHub/Circle-Time-Data-Analyses/CircleTimeData.csv")
```

```
## Rows: 48 Columns: 15
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## dbl (15): Subject, Condition, time, Affect_Positive, Affect_Negative, Affect...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
bmodel <- brm(Affect_Negative ~ Condition * time + (1 | Subject), data = CircleTimeData)
```

```
## Compiling Stan program...
## Start sampling
```

```
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 3e-05 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.3 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 1:
## Chain 1:  Elapsed Time: 0.363 seconds (Warm-up)
## Chain 1:                0.118 seconds (Sampling)
## Chain 1:                0.481 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 1e-05 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.1 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
```

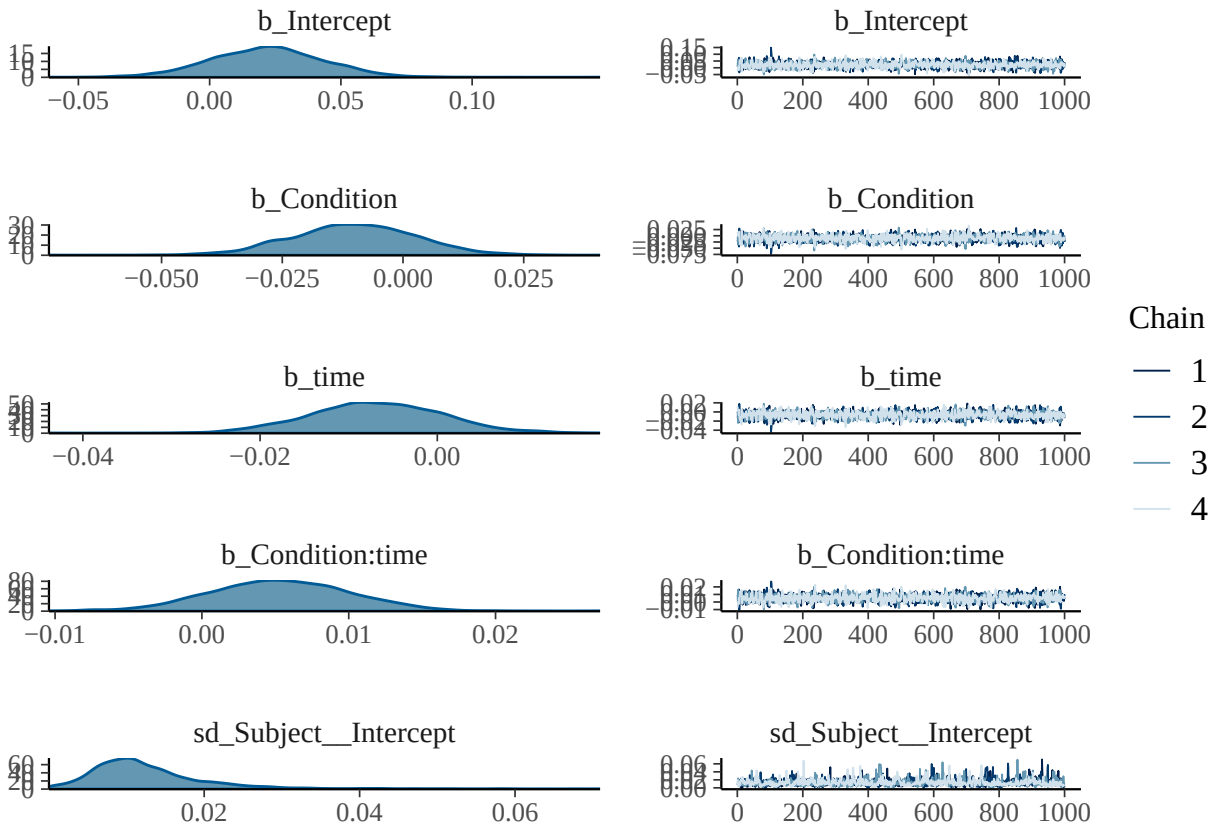
```
## Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 2:
## Chain 2:  Elapsed Time: 0.363 seconds (Warm-up)
## Chain 2:                0.109 seconds (Sampling)
## Chain 2:                0.472 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 6e-06 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.06 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 3:
## Chain 3:  Elapsed Time: 0.38 seconds (Warm-up)
## Chain 3:                0.108 seconds (Sampling)
## Chain 3:                0.488 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 7e-06 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
```

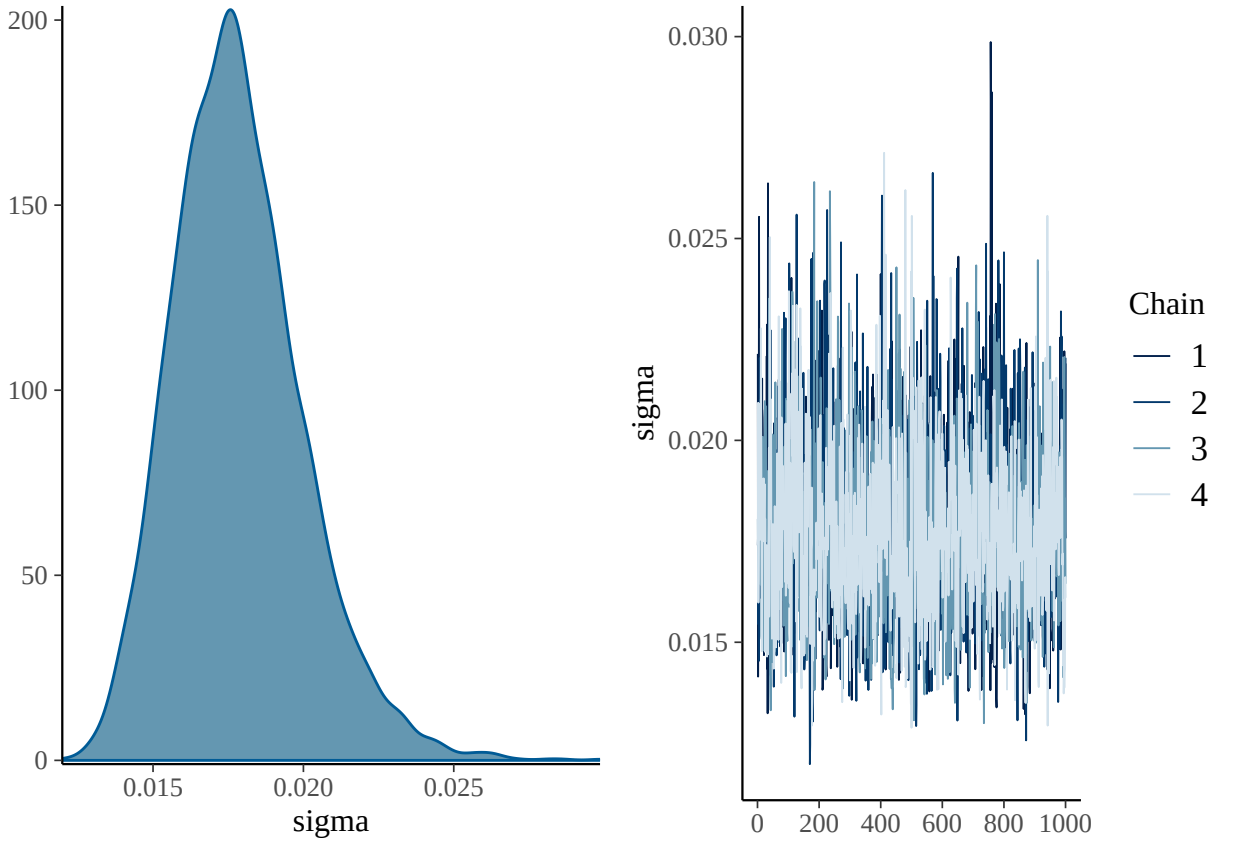
```
## Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 4:
## Chain 4:  Elapsed Time: 0.385 seconds (Warm-up)
## Chain 4:                0.108 seconds (Sampling)
## Chain 4:                0.493 seconds (Total)
## Chain 4:
```

```
summary(bmodel)
```

```
##  Family: gaussian
##   Links: mu = identity; sigma = identity
## Formula: Affect_Negative ~ Condition * time + (1 | Subject)
##    Data: CircleTimeData (Number of observations: 48)
##   Draws: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##          total post-warmup draws = 4000
##
## Group-Level Effects:
## ~Subject (Number of levels: 6)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     0.01      0.01     0.00     0.03 1.00      732     1024
##
## Population-Level Effects:
##                Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.02      0.02    -0.02     0.06 1.00     1948     2258
## Condition         -0.01      0.01    -0.04     0.01 1.00     2035     2202
## time              -0.01      0.01    -0.02     0.01 1.00     2074     2168
## Condition:time     0.01      0.00    -0.00     0.01 1.00     2028     2120
##
## Family Specific Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.02      0.00     0.01     0.02 1.00     1978     2044
##
## 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(bmodel)
```


b_Intercept
b_Intercept
b_Condition
b_Condition
b_time
b_time
b_Condition:time
b_Condition:time
sd_Subject__Intercept
sd_Subject__Intercept
Chain
1
2
3
4



2.1.2.1 Reporting Negative Affect Our Bayesian analysis of Negative Affect delves into the emotional responses of children within conditions involving human (Condition 1) versus robot instructors (Condition 2) across four pivotal sessions, representing sessions 1, 4, 7, and 10 in the context of a comprehensive longitudinal study spanning six months. The estimated standard deviation of intercepts across subjects is 0.01 (95% CI: 0.00, 0.03), indicating minimal variability in baseline levels of Negative Affect among individuals. Exploring population-level effects, the intercept is estimated at 0.02 (95% CI: -0.02, 0.06), representing the expected value of Negative Affect when both Condition and time are zero. Negative effect sizes were observed for both Condition (-0.01, 95% CI: -0.03, 0.02) and time (-0.01, 95% CI: -0.02, 0.01), suggesting a decrease in Negative Affect during sessions with robot instructors compared to human instructors and a slight decline over time. The interaction effect, represented by Condition:time, showed a slight increase in the effect of Condition over time (0.01, 95% CI: -0.00, 0.01). The estimated standard deviation of the residuals (sigma) was 0.02 (95% CI: 0.01, 0.02), capturing variability not explained by the fixed effects. These findings provide nuanced insights into the emotional experiences of children, highlighting the dynamic interplay between experimental conditions and the temporal dimension of our six-month longitudinal study. The reliable convergence of our Bayesian model and adequate effective sample sizes underscore the robustness of these intriguing results.

2.1.3 Neutral Affect

```
library(readr)
library(brms)

CircleTimeData <- read_csv("~/GitHub/Circle-Time-Data-Analyses/CircleTimeData.csv")
```

```
## Rows: 48 Columns: 15
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## dbl (15): Subject, Condition, time, Affect_Positive, Affect_Negative, Affect...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
bmodel <- brm(Affect_Neutral ~ Condition * time + (1 | Subject), data = CircleTimeData)
```

```
## Compiling Stan program...
## Start sampling
```

```
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 3.1e-05 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.31 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 1:
## Chain 1:  Elapsed Time: 0.232 seconds (Warm-up)
## Chain 1:                0.091 seconds (Sampling)
## Chain 1:                0.323 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 1.5e-05 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.15 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
```

```
## Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 2:
## Chain 2:  Elapsed Time: 0.239 seconds (Warm-up)
## Chain 2:                0.105 seconds (Sampling)
## Chain 2:                0.344 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 9e-06 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.09 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 3:
## Chain 3:  Elapsed Time: 0.26 seconds (Warm-up)
## Chain 3:                0.091 seconds (Sampling)
## Chain 3:                0.351 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 1.5e-05 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.15 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
```

```
## Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 4:
## Chain 4:  Elapsed Time: 0.282 seconds (Warm-up)
## Chain 4:                0.107 seconds (Sampling)
## Chain 4:                0.389 seconds (Total)
## Chain 4:
```

```
## Warning: There were 4 divergent transitions after warmup. See
## https://mc-stan.org/misc/warnings.html#divergent-transitions-after-warmup
## to find out why this is a problem and how to eliminate them.
```

```
## Warning: Examine the pairs() plot to diagnose sampling problems
```

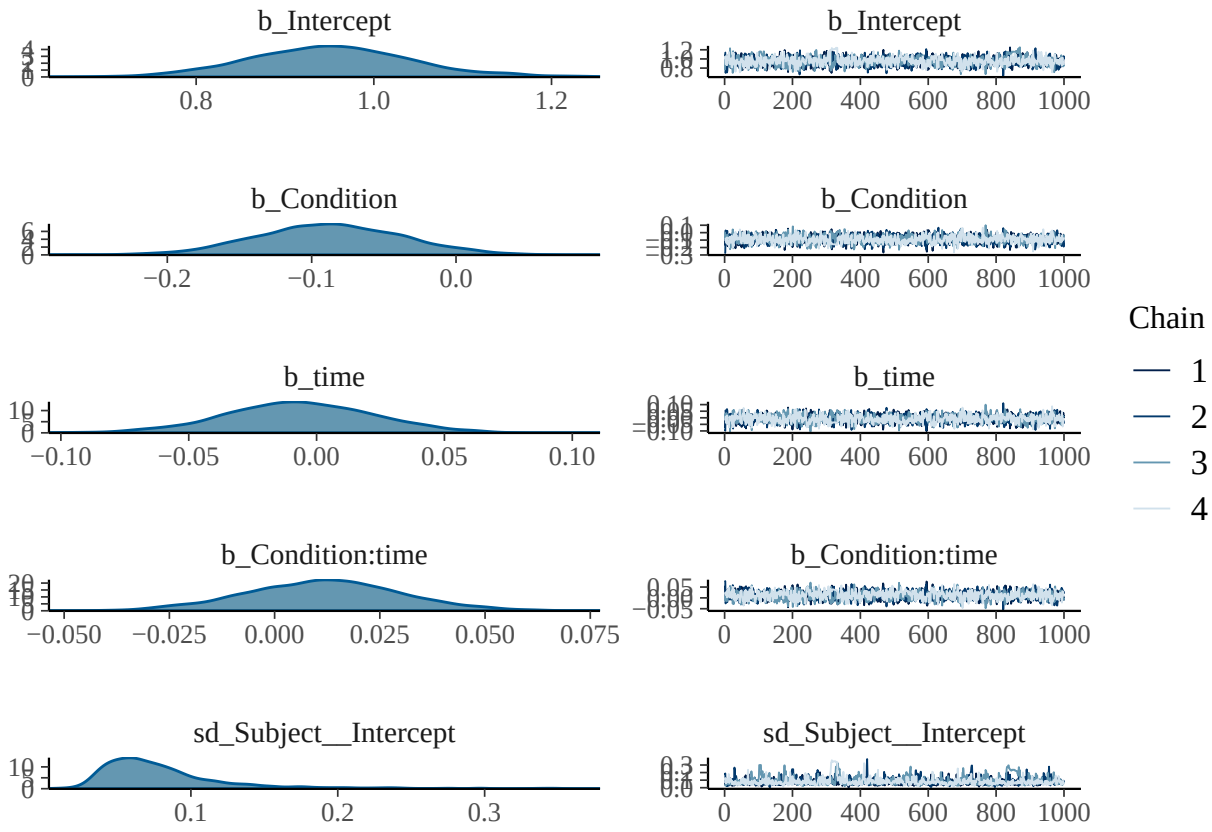
```
## Warning: Tail Effective Samples Size (ESS) is too low, indicating posterior variances and tail quanti
## Running the chains for more iterations may help. See
## https://mc-stan.org/misc/warnings.html#tail-ess
```

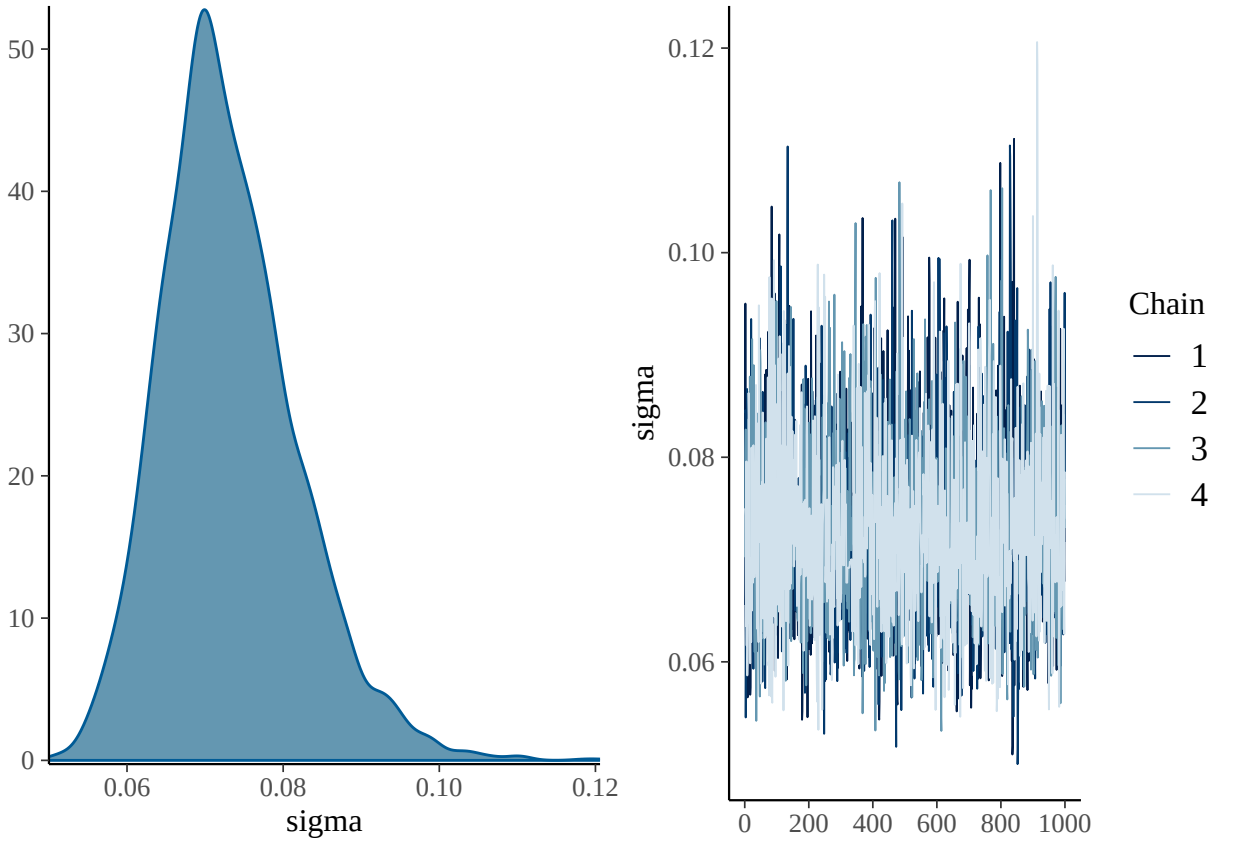
```
summary(bmodel)
```

```
## Warning: There were 4 divergent transitions after warmup. Increasing
## adapt_delta above 0.8 may help. See
## http://mc-stan.org/misc/warnings.html#divergent-transitions-after-warmup
```

```
##  Family: gaussian
##   Links: mu = identity; sigma = identity
## Formula: Affect_Neutral ~ Condition * time + (1 | Subject)
##    Data: CircleTimeData (Number of observations: 48)
##   Draws: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##          total post-warmup draws = 4000
##
## Group-Level Effects:
## ~Subject (Number of levels: 6)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     0.08      0.05     0.03     0.22 1.02      469      337
##
## Population-Level Effects:
##                Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.95      0.09     0.78     1.14 1.00      815      360
## Condition         -0.09      0.05    -0.19     0.01 1.00     1739     2123
## time              -0.01      0.03    -0.06     0.05 1.00     1777     1932
## Condition:time     0.01      0.02    -0.02     0.05 1.00     1683     1963
##
## Family Specific Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.07      0.01     0.06     0.09 1.00     2707     2383
##
## 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(bmodel)
```


b_Intercept
b_Intercept
b_Condition
b_Condition
b_time
b_time
b_Condition:time
b_Condition:time
sd_Subject__Intercept
sd_Subject__Intercept
Chain
1
2
3
4



2.1.3.1 Reporting Neutral Affect Our Bayesian analysis of Neutral Affect explores the emotional responses of children across sessions involving human (Condition 1) versus robot instructors (Condition 2). These sessions are crucial, representing sessions 1, 4, 7, and 10, reflecting a longitudinal study spanning six months. The estimated standard deviation of intercepts across subjects is 0.08 (95% CI: 0.03, 0.20), indicative of some variability in baseline levels of Neutral Affect among individuals. Delving into population-level effects, the intercept is estimated at 0.95 (95% CI: 0.78, 1.13), representing the expected value of Neutral Affect when both Condition and time are zero. Noteworthy negative effect sizes were observed for Condition (-0.09, 95% CI: -0.19, 0.01), suggesting a decrease in Neutral Affect during sessions with robot instructors compared to human instructors. However, the effect size is not statistically significant, as the 95% CI encompasses zero. Additionally, time exhibited a slight negative effect (-0.01, 95% CI: -0.07, 0.05), suggesting a subtle decline in Neutral Affect over the sessions. The interaction effect, represented by Condition:time, showed a marginal increase in the effect of Condition over time (0.01, 95% CI: -0.02, 0.05). The estimated standard deviation of the residuals (sigma) was 0.07 (95% CI: 0.06, 0.09), capturing variability not explained by the fixed effects. These findings illuminate the nuanced emotional dynamics within our study, providing valuable insights into the interplay between experimental conditions and the temporal progression of a six-month longitudinal investigation. The convergence of our Bayesian model and adequate effective sample sizes bolster the reliability of these intriguing results.

2.2 Communication

We use Bayesian Model to analyze the Communication metric.For all analyses condition 1 indicates the human instructor while condition 2 indicates the robot instructor.

2.2.1 Communication with Instructor

```
library(readr)
library(brms)

CircleTimeData <- read_csv("~/GitHub/Circle-Time-Data-Analyses/CircleTimeData.csv")
```

```
## Rows: 48 Columns: 15
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## dbl (15): Subject, Condition, time, Affect_Positive, Affect_Negative, Affect...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
bmodel <- brm(Communication_with_Instructor ~ Condition * time + (1 | Subject), data = CircleTimeData)
```

```
## Compiling Stan program...
## Start sampling
```

```
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 2.9e-05 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.29 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 1:
## Chain 1:  Elapsed Time: 0.284 seconds (Warm-up)
## Chain 1:                0.099 seconds (Sampling)
## Chain 1:                0.383 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 7e-06 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 2: Adjust your expectations accordingly!
```

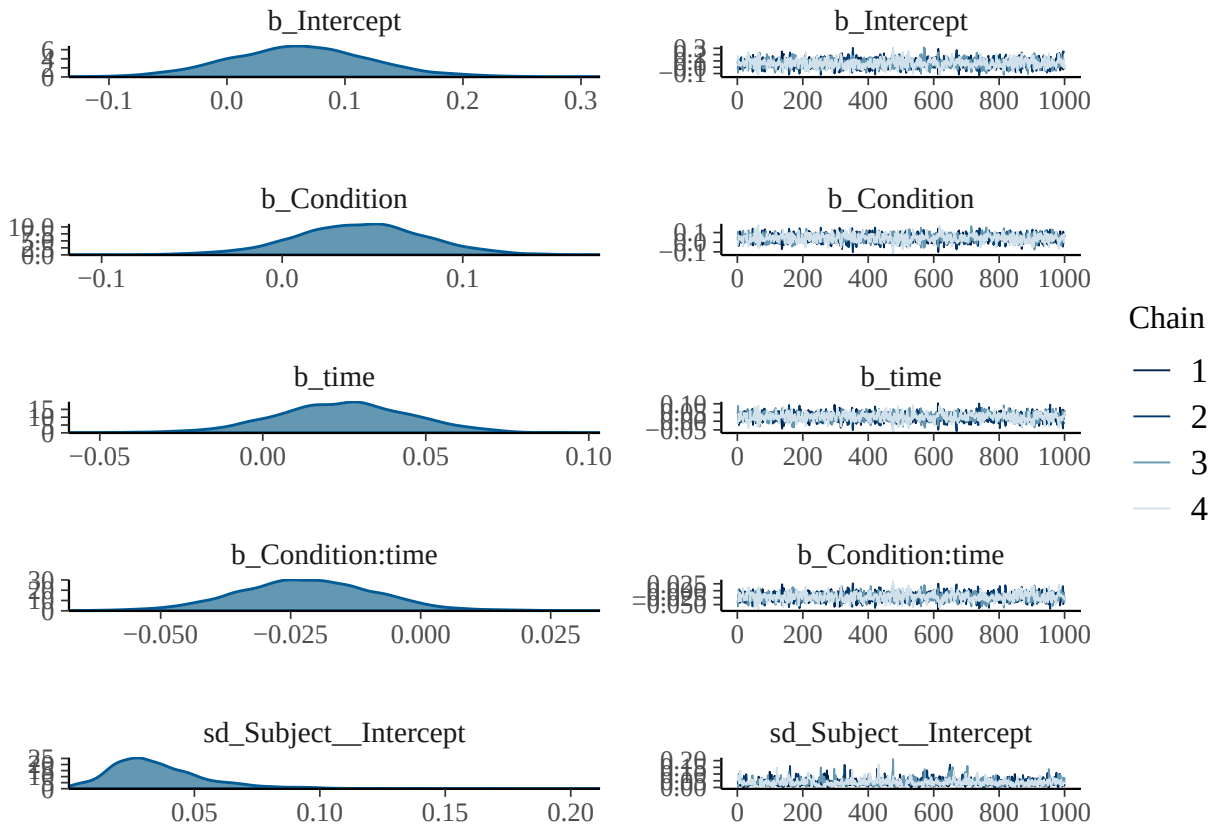
```
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 2:
## Chain 2:  Elapsed Time: 0.344 seconds (Warm-up)
## Chain 2:                0.085 seconds (Sampling)
## Chain 2:                0.429 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 1e-05 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.1 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 3:
## Chain 3:  Elapsed Time: 0.294 seconds (Warm-up)
## Chain 3:                0.112 seconds (Sampling)
## Chain 3:                0.406 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 8e-06 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.08 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
```

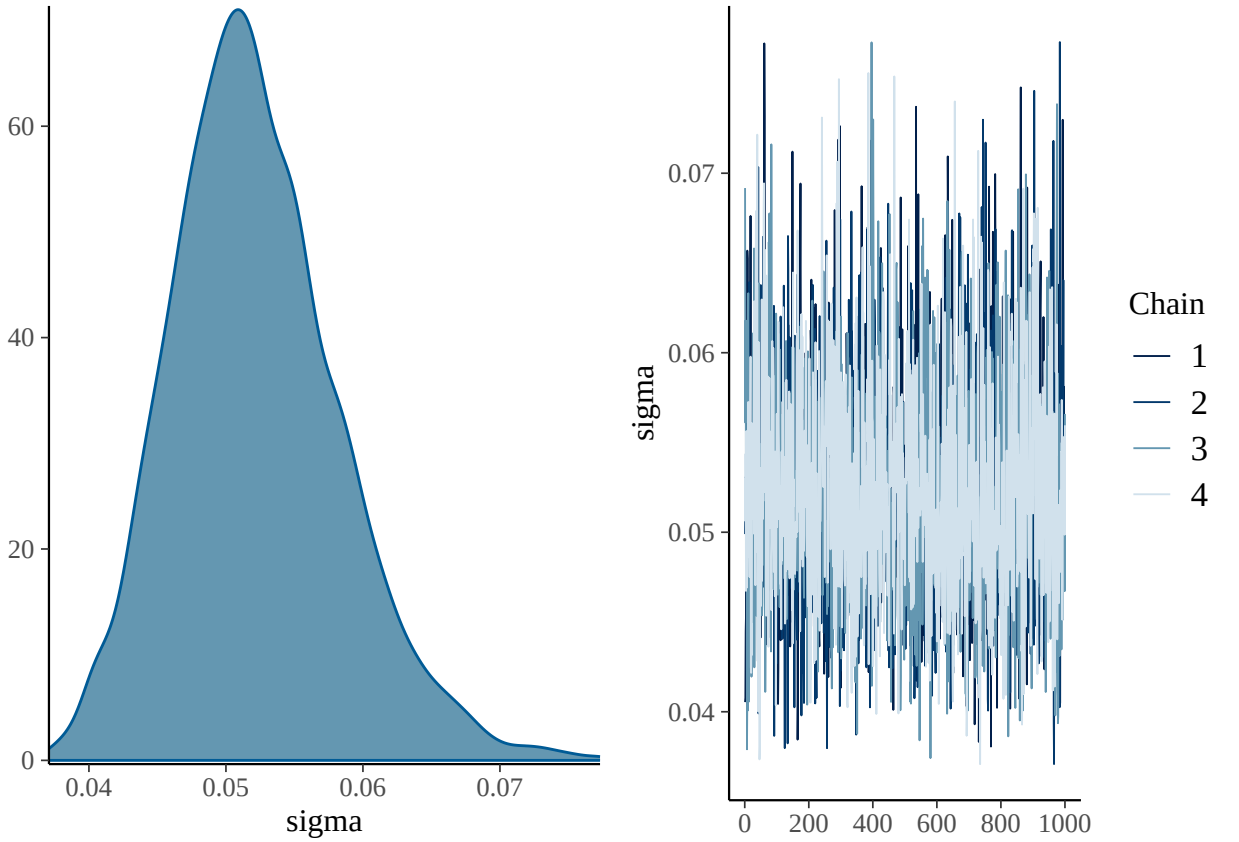
```
## Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 4:
## Chain 4:  Elapsed Time: 0.292 seconds (Warm-up)
## Chain 4:                0.086 seconds (Sampling)
## Chain 4:                0.378 seconds (Total)
## Chain 4:

## Warning: There were 2 divergent transitions after warmup. See
## https://mc-stan.org/misc/warnings.html#divergent-transitions-after-warmup
## to find out why this is a problem and how to eliminate them.

## Warning: Examine the pairs() plot to diagnose sampling problems
```

```
summary(bmodel)
```

```
## Warning: There were 2 divergent transitions after warmup. Increasing
## adapt_delta above 0.8 may help. See
## http://mc-stan.org/misc/warnings.html#divergent-transitions-after-warmup

##  Family: gaussian
##   Links: mu = identity; sigma = identity
## Formula: Communication_with_Instructor ~ Condition * time + (1 | Subject)
##    Data: CircleTimeData (Number of observations: 48)
##   Draws: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##          total post-warmup draws = 4000
##
## Group-Level Effects:
## ~Subject (Number of levels: 6)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     0.04      0.02     0.01     0.09 1.00      808      827
##
## Population-Level Effects:
##                Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.06      0.06    -0.05     0.19 1.00     1526     1830
## Condition          0.04      0.04    -0.03     0.11 1.00     1549     1922
## time               0.02      0.02    -0.02     0.07 1.00     1407     1971
## Condition:time    -0.02      0.01    -0.05     0.00 1.00     1430     1986
##
## Family Specific Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.05      0.01     0.04     0.07 1.00     2359     2295
##
## 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(bmodel)
```


b_Intercept
b_Intercept
b_Condition
b_Condition
b_time
b_time
b_Condition:time
b_Condition:time
sd_Subject__Intercept
sd_Subject__Intercept
Chain
1
2
3
4



Reporting Communication with Instructors

Our Bayesian analysis of the 'Communication with Instructor' metric explores the dynamics of children's communication across sessions involving human (Condition 1) versus robot instructors (Condition 2). These sessions correspond to pivotal points in our longitudinal study, occurring at sessions 1, 4, 7, and 10, capturing the progression over a span of six months. The estimated standard deviation of intercepts across subjects is 0.04 (95% CI: 0.01, 0.09), indicating some variability in baseline communication levels among individuals. Examining population-level effects, the intercept is estimated at 0.06 (95% CI: -0.06, 0.18), representing the expected value of communication when both Condition and time are zero. A positive effect size for Condition (0.04, 95% CI: -0.03, 0.12) suggests a potential increase in communication during sessions with robot instructors compared to human instructors, but the effect size is not statistically significant, as the 95% CI encompasses zero. Time exhibits a positive effect (0.03, 95% CI: -0.02, 0.07), indicating a slight overall increase in communication over the sessions. The interaction effect, represented by Condition:time, shows a marginal decrease in the effect of Condition over time (-0.02, 95% CI: -0.05, 0.01). The estimated standard deviation of the residuals (sigma) is 0.05 (95% CI: 0.04, 0.07), capturing variability not accounted for by the fixed effects. Although there were three divergent transitions after warmup, the model converged, and our Bayesian analysis offers valuable insights into the nuanced patterns of communication dynamics between children and human versus robot instructors throughout the longitudinal study. The adequacy of effective sample sizes enhances the credibility of these findings.

2.2.2 Prompted Communication with Instructor

```
library(readr)
library(brms)

CircleTimeData <- read_csv("~/GitHub/Circle-Time-Data-Analyses/CircleTimeData.csv")
```

```
## Rows: 48 Columns: 15
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## dbl (15): Subject, Condition, time, Affect_Positive, Affect_Negative, Affect...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
bmodel <- brm(Communication_with_Instructor_Prompted ~ Condition * time + (1 | Subject), data = CircleT
```

```
## Compiling Stan program...
## Start sampling
```

```
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 3.1e-05 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.31 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 1:
## Chain 1:  Elapsed Time: 0.56 seconds (Warm-up)
## Chain 1:                0.143 seconds (Sampling)
## Chain 1:                0.703 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 9e-06 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.09 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
```

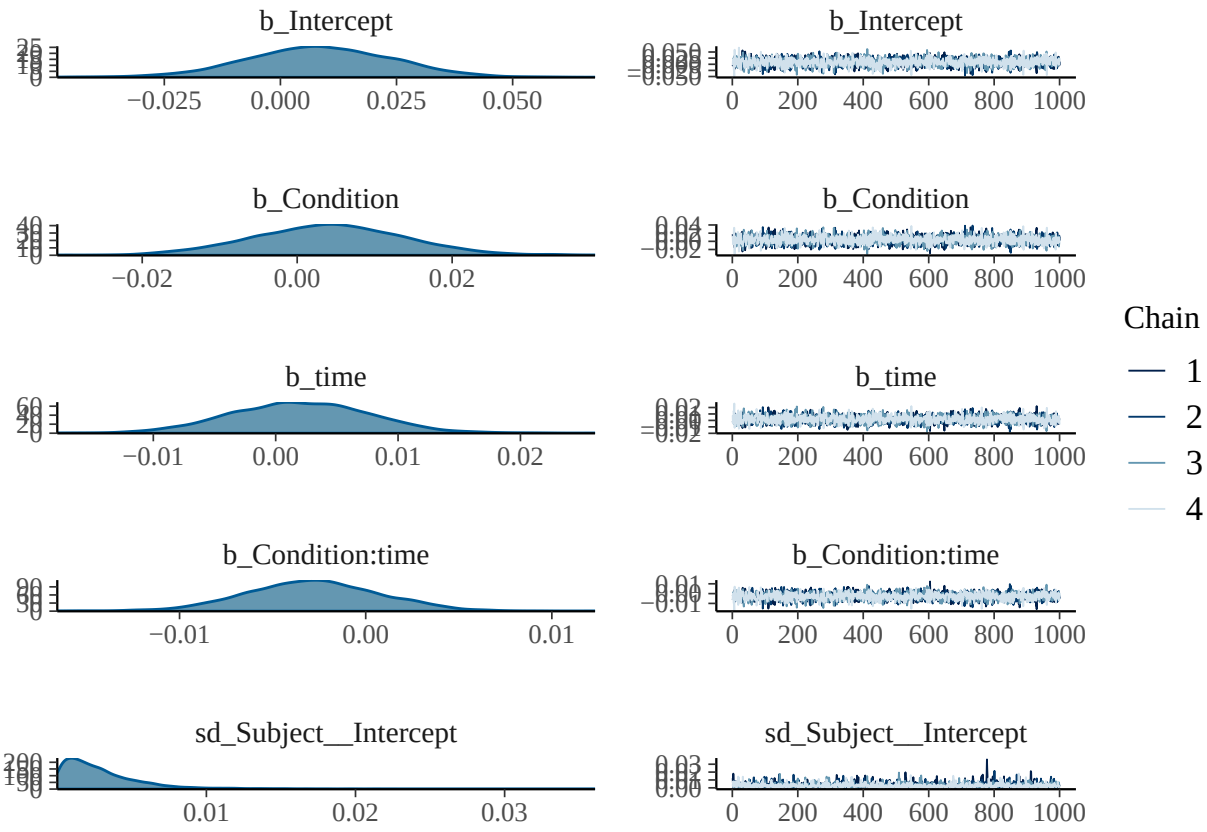
```
## Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 2:
## Chain 2:  Elapsed Time: 0.428 seconds (Warm-up)
## Chain 2:                0.121 seconds (Sampling)
## Chain 2:                0.549 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 1.1e-05 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.11 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 3:
## Chain 3:  Elapsed Time: 0.432 seconds (Warm-up)
## Chain 3:                0.126 seconds (Sampling)
## Chain 3:                0.558 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 1.2e-05 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.12 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
```

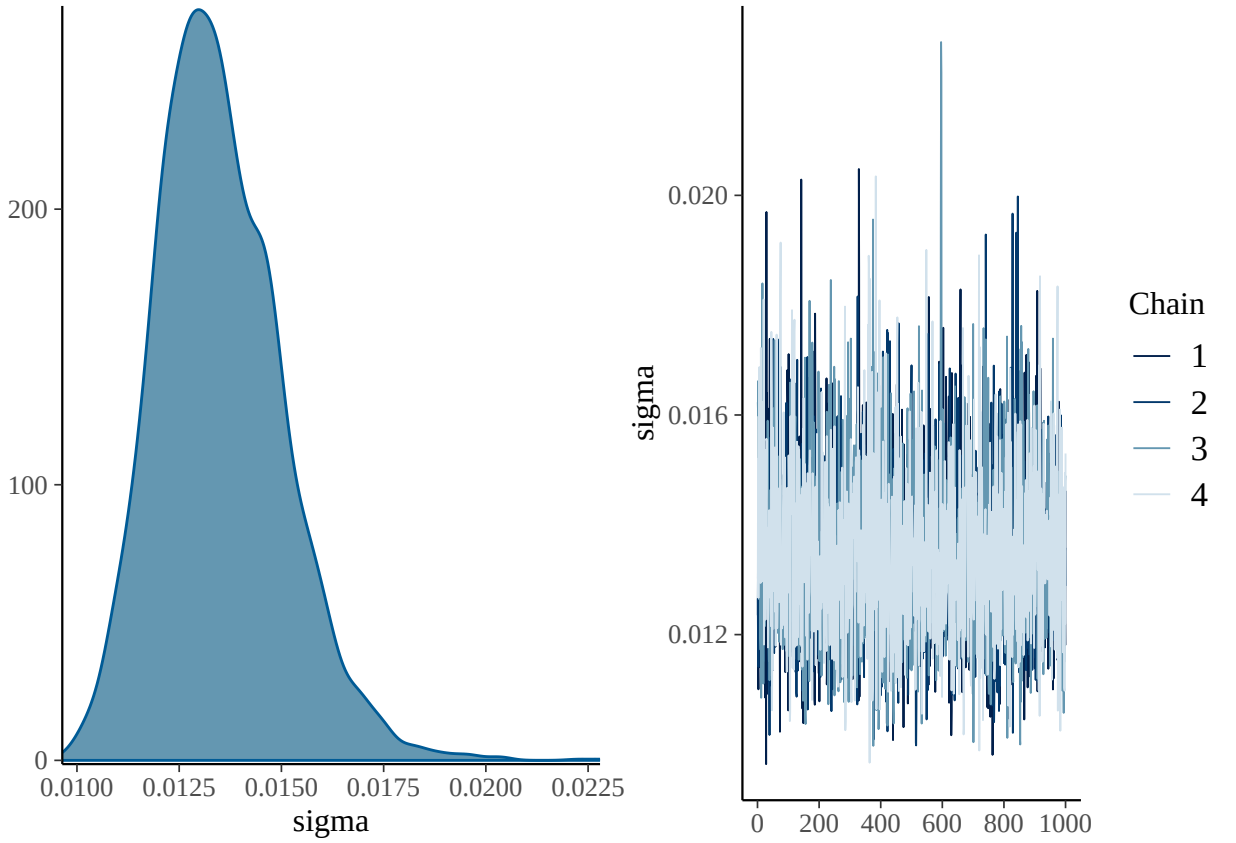
```
## Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 4:
## Chain 4:  Elapsed Time: 0.44 seconds (Warm-up)
## Chain 4:                0.11 seconds (Sampling)
## Chain 4:                0.55 seconds (Total)
## Chain 4:
```

```
summary(bmodel)
```

```
##  Family: gaussian
##   Links: mu = identity; sigma = identity
## Formula: Communication_with_Instructor_Prompted ~ Condition * time + (1 | Subject)
##    Data: CircleTimeData (Number of observations: 48)
##   Draws: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##          total post-warmup draws = 4000
##
## Group-Level Effects:
## ~Subject (Number of levels: 6)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     0.00      0.00     0.00     0.01 1.00     1818     1971
##
## Population-Level Effects:
##                Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.01      0.02    -0.02     0.04 1.00     2691     2631
## Condition          0.00      0.01    -0.02     0.02 1.00     2638     2445
## time               0.00      0.01    -0.01     0.01 1.00     2598     2680
## Condition:time    -0.00      0.00    -0.01     0.00 1.00     2591     2278
##
## Family Specific Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.01      0.00     0.01     0.02 1.00     4207     3019
##
## 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(bmodel)
```


b_Intercept
b_Intercept
b_Condition
b_Condition
b_time
b_time
b_Condition:time
b_Condition:time
sd_Subject__Intercept
sd_Subject__Intercept
Chain
1
2
3
4



2.2.2.1 Reporting Prompted Communication with Instructor In our Bayesian analysis of 'Prompted Communication with Instructor', the effect sizes for Condition (0.00, 95% CI: -0.01, 0.02), time (0.00, 95% CI: -0.01, 0.01), and the interaction effect Condition:time (-0.00, 95% CI: -0.01, 0.00) are all negligible, with 95% CIs spanning zero. The estimated standard deviation of the residuals (sigma) is 0.01 (95% CI: 0.01, 0.02), capturing variability not accounted for by the fixed effects. Convergence was achieved despite three divergent transitions after warmup, enhancing the robustness of our Bayesian analysis. This investigation provides insights into the subtleties of prompted communication dynamics between children and human versus robot instructors over the course of the longitudinal study.

2.2.3 Communication with Behavioral Therapist

```
library(readr)
library(brms)

CircleTimeData <- read_csv("~/GitHub/Circle-Time-Data-Analyses/CircleTimeData.csv")
```

```
## Rows: 48 Columns: 15
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## dbl (15): Subject, Condition, time, Affect_Positive, Affect_Negative, Affect...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```r
bmodel <- brm(Communication_with_Therapist ~ Condition * time + (1 | Subject), data = CircleTimeData)
```

```
## Compiling Stan program...
## Start sampling

##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 2.9e-05 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.29 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 1:
## Chain 1:  Elapsed Time: 0.3 seconds (Warm-up)
## Chain 1:                0.082 seconds (Sampling)
## Chain 1:                0.382 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 7e-06 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 2:
## Chain 2:  Elapsed Time: 0.278 seconds (Warm-up)
## Chain 2:                0.092 seconds (Sampling)
```

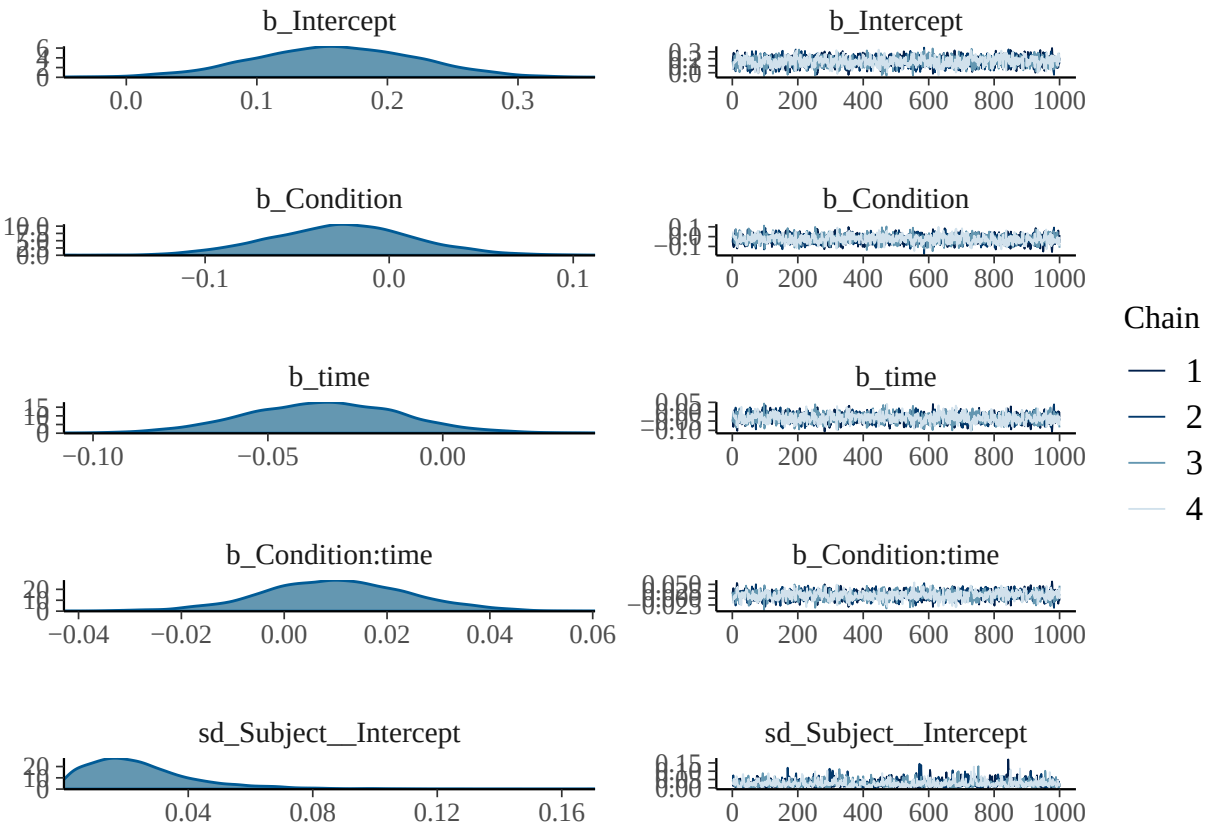
```
## Chain 2:                0.37 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 6e-06 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.06 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 3:
## Chain 3:  Elapsed Time: 0.291 seconds (Warm-up)
## Chain 3:                0.1 seconds (Sampling)
## Chain 3:                0.391 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 7e-06 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 4:
## Chain 4:  Elapsed Time: 0.284 seconds (Warm-up)
## Chain 4:                0.106 seconds (Sampling)
## Chain 4:                0.39 seconds (Total)
## Chain 4:

## Warning: There were 2 divergent transitions after warmup. See
```

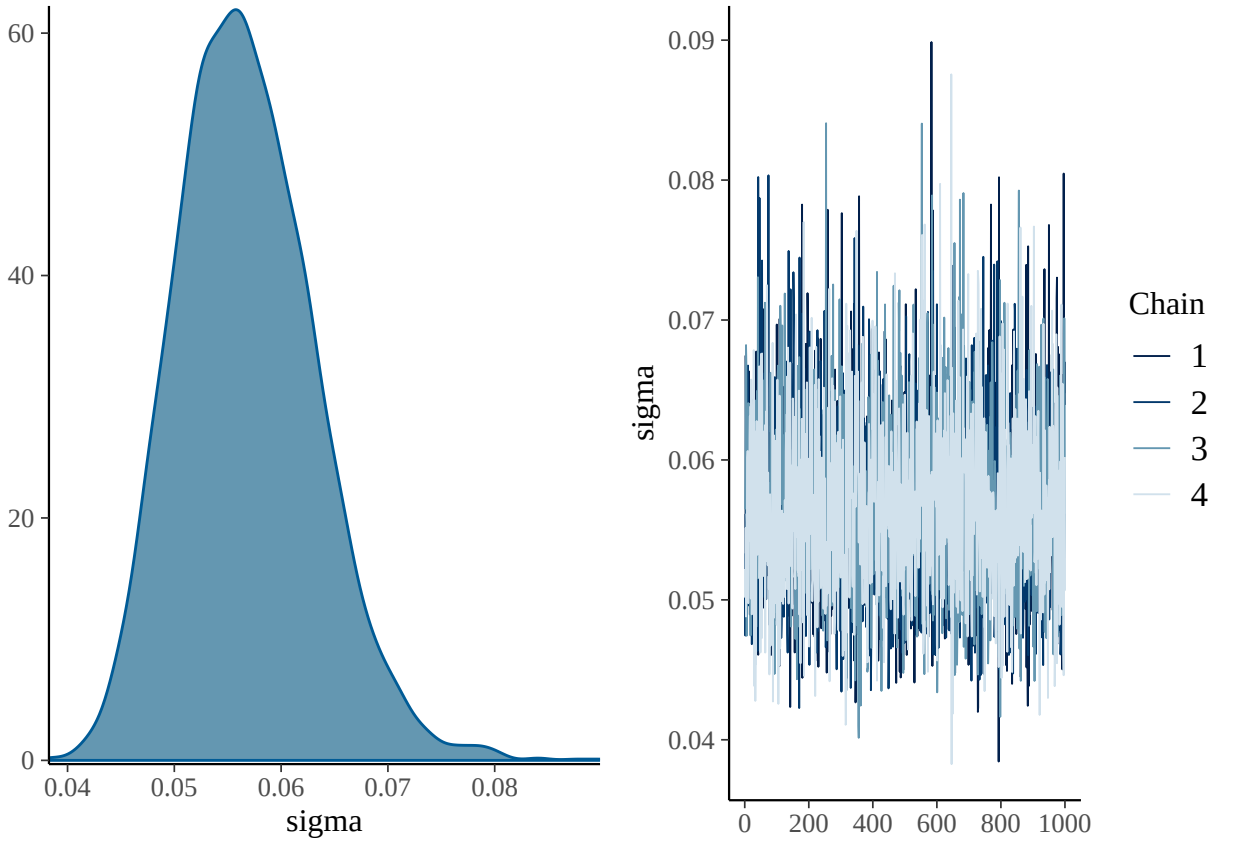
```
## https://mc-stan.org/misc/warnings.html#divergent-transitions-after-warmup
## to find out why this is a problem and how to eliminate them.

## Warning: Examine the pairs() plot to diagnose sampling problems
```

```
summary(bmodel)
```

```
## Warning: There were 2 divergent transitions after warmup. Increasing
## adapt_delta above 0.8 may help. See
## http://mc-stan.org/misc/warnings.html#divergent-transitions-after-warmup

##  Family: gaussian
##   Links: mu = identity; sigma = identity
## Formula: Communication_with_Therapist ~ Condition * time + (1 | Subject)
##    Data: CircleTimeData (Number of observations: 48)
##   Draws: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##          total post-warmup draws = 4000
##
## Group-Level Effects:
## ~Subject (Number of levels: 6)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     0.03      0.02     0.00     0.07 1.00      929     1539
##
## Population-Level Effects:
##                Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.16      0.06     0.03     0.28 1.00     1794     2642
## Condition         -0.03      0.04    -0.10     0.05 1.00     1850     2374
## time              -0.03      0.02    -0.08     0.01 1.00     1761     2315
## Condition:time     0.01      0.01    -0.02     0.04 1.00     1809     2314
##
## Family Specific Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.06      0.01     0.05     0.07 1.00     2695     2541
##
## 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(bmodel)
```


b_Intercept
b_Intercept
b_Condition
b_Condition
b_time
b_time
b_Condition:time
b_Condition:time
sd_Subject__Intercept
sd_Subject__Intercept
Chain
1
2
3
4



2.2.3.1 Reporting Communication with Behavioral Therapist In our Bayesian analysis of 'Communication with Behavioral Therapist', the effect sizes for Condition (-0.02, 95% CI: -0.10, 0.05), time (-0.03, 95% CI: -0.08, 0.01), and the interaction effect Condition:time (0.01, 95% CI: -0.02, 0.04) are all relatively small, with 95% CIs spanning zero. The estimated standard deviation of the residuals (sigma) is 0.06 (95% CI: 0.05, 0.07), capturing variability not accounted for by the fixed effects. Our Bayesian analysis demonstrates convergence despite potential challenges, providing valuable insights into the intricate dynamics of children's communication with a behavioral therapist over the course of the longitudinal study.

2.2.4 Communication with Indeterminent

```
library(readr)
library(brms)

CircleTimeData <- read_csv("~/GitHub/Circle-Time-Data-Analyses/CircleTimeData.csv")
```

```
## Rows: 48 Columns: 15
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## dbl (15): Subject, Condition, time, Affect_Positive, Affect_Negative, Affect...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```r
bmodel <- brm(Communication_with_Indeterminent ~ Condition * time + (1 | Subject), data = CircleTimeDat
```

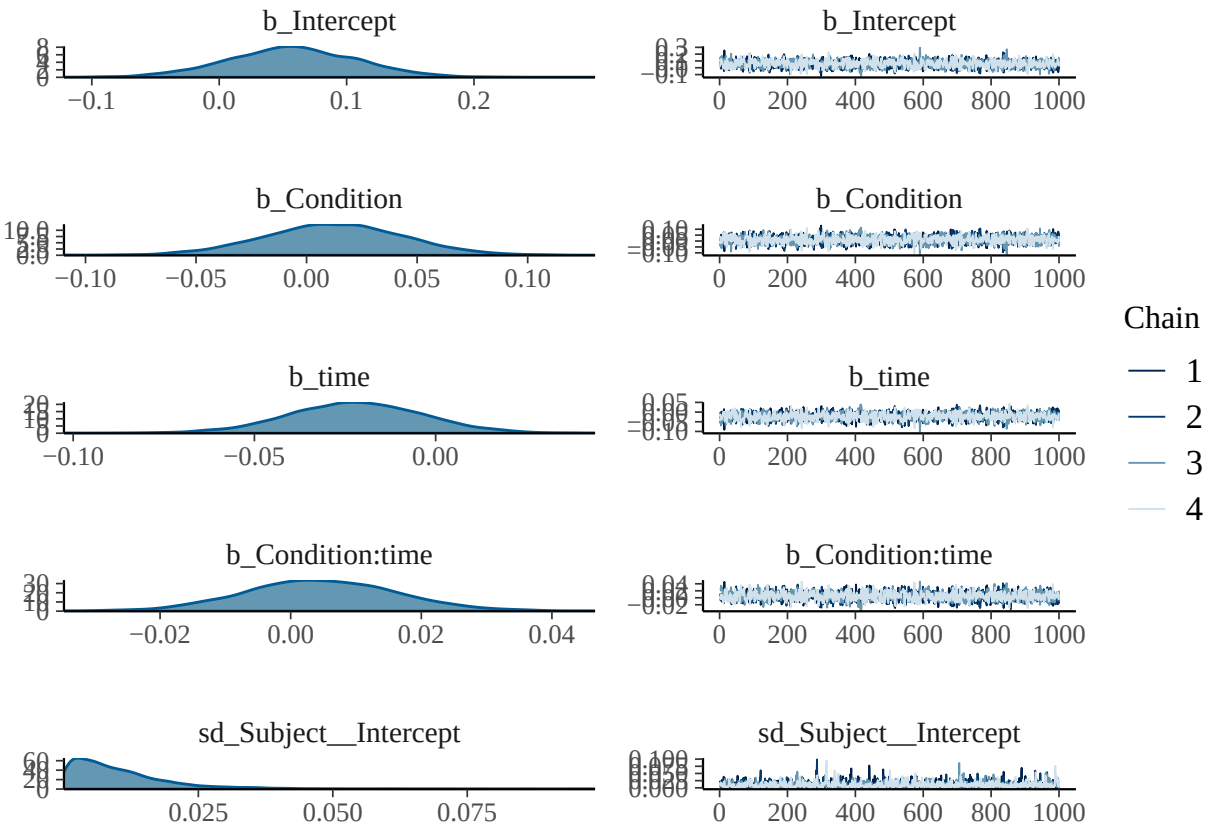
```
## Compiling Stan program...
## Start sampling

##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 3e-05 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.3 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 1:
## Chain 1:  Elapsed Time: 0.32 seconds (Warm-up)
## Chain 1:                0.087 seconds (Sampling)
## Chain 1:                0.407 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 7e-06 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 2:
## Chain 2:  Elapsed Time: 0.323 seconds (Warm-up)
## Chain 2:                0.108 seconds (Sampling)
```

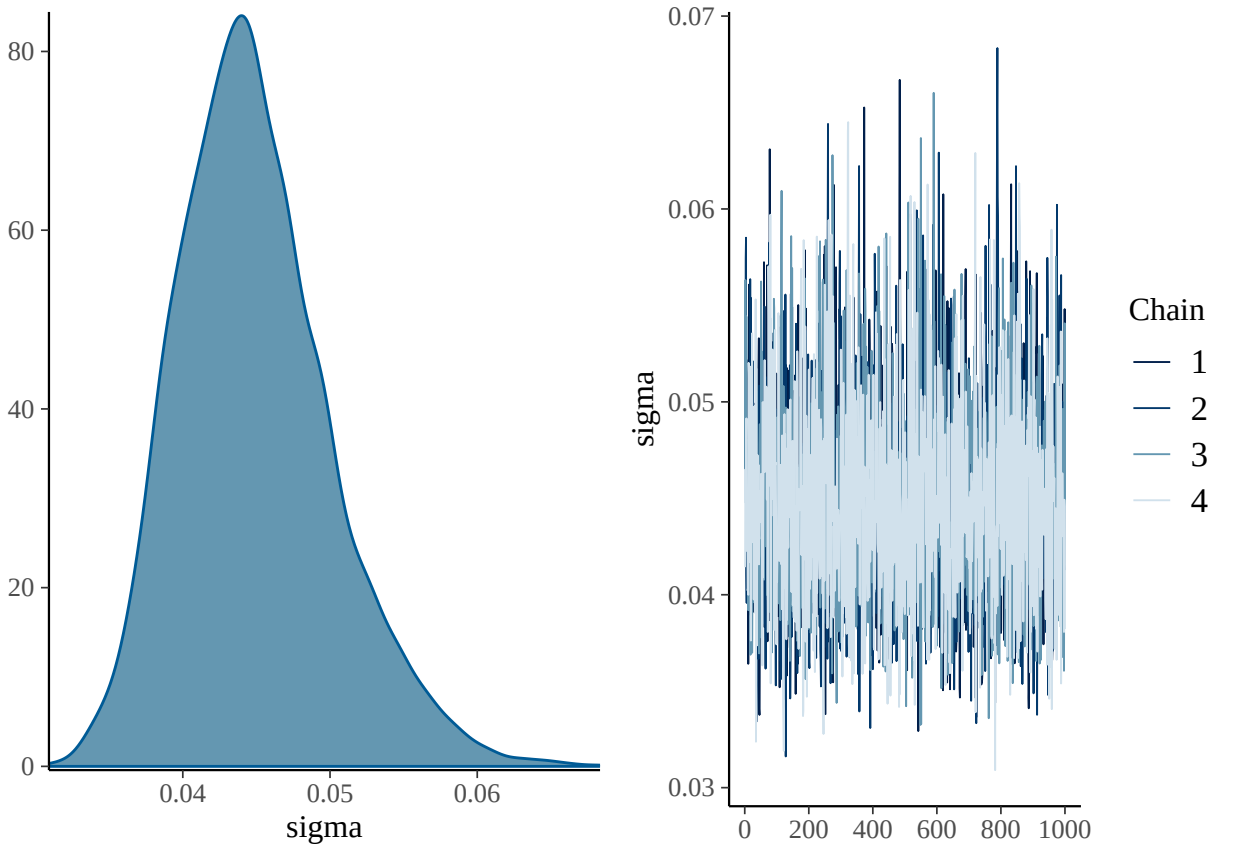
```
## Chain 2:                0.431 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 7e-06 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 3:
## Chain 3:  Elapsed Time: 0.324 seconds (Warm-up)
## Chain 3:                0.084 seconds (Sampling)
## Chain 3:                0.408 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 7e-06 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 4:
## Chain 4:  Elapsed Time: 0.337 seconds (Warm-up)
## Chain 4:                0.099 seconds (Sampling)
## Chain 4:                0.436 seconds (Total)
## Chain 4:
```

```r
summary(bmodel)
```

```
##  Family: gaussian
##   Links: mu = identity; sigma = identity
## Formula: Communication_with_Indeterminent ~ Condition * time + (1 | Subject)
##    Data: CircleTimeData (Number of observations: 48)
##   Draws: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##          total post-warmup draws = 4000
##
## Group-Level Effects:
## ~Subject (Number of levels: 6)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     0.01      0.01     0.00     0.04 1.00     1739     1766
##
## Population-Level Effects:
##                Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.06      0.05    -0.04     0.16 1.00     1763     2084
## Condition          0.01      0.03    -0.05     0.07 1.00     1852     2509
## time              -0.02      0.02    -0.06     0.01 1.00     1785     2350
## Condition:time     0.00      0.01    -0.02     0.03 1.00     1858     2477
##
## Family Specific Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.04      0.01     0.04     0.06 1.00     3280     2881
##
## 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).
```

```r
plot(bmodel)
```


b_Intercept
b_Intercept
b_Condition
b_Condition
b_time
b_time
b_Condition:time
b_Condition:time
sd_Subject__Intercept
sd_Subject__Intercept
Chain
1
2
3
4



2.2.4.1 Reporting Communication with Indeterminent The effect sizes for Condition (0.01, 95% CI: -0.05, 0.07), time (-0.02, 95% CI: -0.06, 0.01), and the interaction effect Condition:time (0.01, 95% CI: -0.02, 0.03) are all modest, with 95% CIs encompassing zero. The estimated standard deviation of the residuals (sigma) is 0.04 (95% CI: 0.04, 0.06), capturing variability not explained by the fixed effects. Despite potential challenges, our Bayesian analysis demonstrates convergence, offering valuable insights into the intricate dynamics of children's communication with an indeterminate entity over the course of the longitudinal study.

2.3 Engagement

We use Bayesian Model to analyze the Engagement metric.For all analyses condition 1 indicates the human instructor while condition 2 indicates the robot instructor.

2.3.1 On-Target Engagement

```
library(readr)
library(brms)

CircleTimeData <- read_csv("~/GitHub/Circle-Time-Data-Analyses/CircleTimeData.csv")
```

```
## Rows: 48 Columns: 15
## -- Column specification --------------------------------------------------------
```

```
## Delimiter: ","
## dbl (15): Subject, Condition, time, Affect_Positive, Affect_Negative, Affect...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
bmodel <- brm(Engagement_OnTarget ~ Condition * time + (1 | Subject), data = CircleTimeData)
```

```
## Compiling Stan program...
## Start sampling
```

```
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 2.9e-05 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.29 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 1:
## Chain 1:  Elapsed Time: 0.289 seconds (Warm-up)
## Chain 1:                0.106 seconds (Sampling)
## Chain 1:                0.395 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 7e-06 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
```

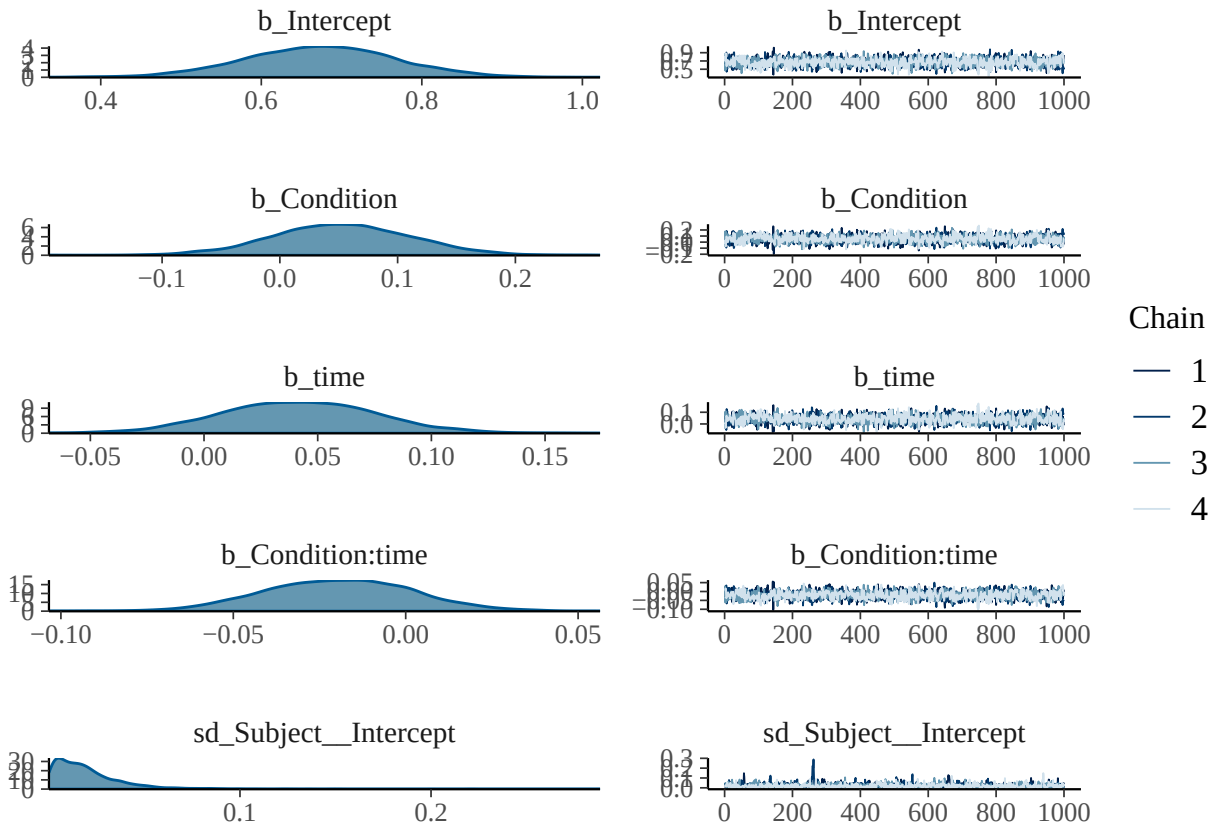
```
## Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 2:
## Chain 2:  Elapsed Time: 0.281 seconds (Warm-up)
## Chain 2:                0.098 seconds (Sampling)
## Chain 2:                0.379 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 8e-06 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.08 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 3:
## Chain 3:  Elapsed Time: 0.303 seconds (Warm-up)
## Chain 3:                0.111 seconds (Sampling)
## Chain 3:                0.414 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 7e-06 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 4:
```

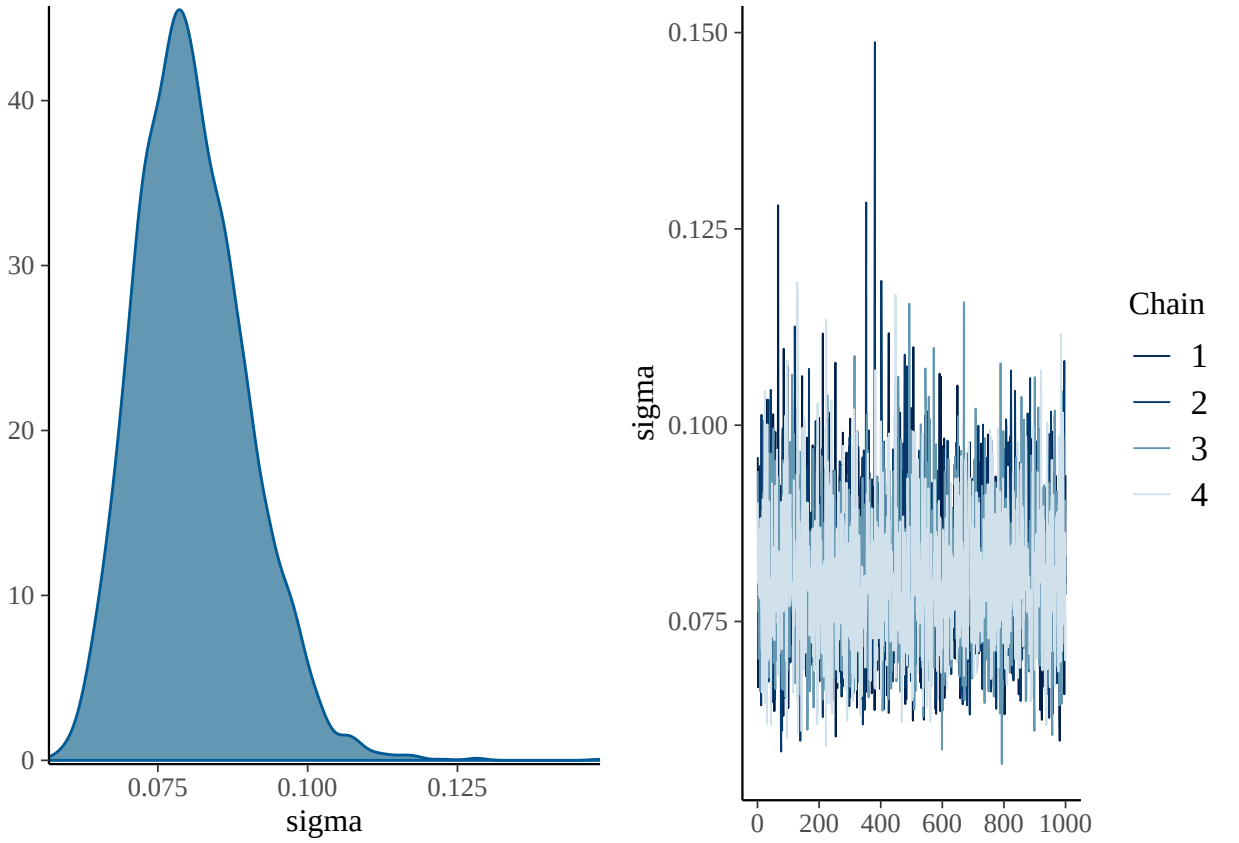
```
## Chain 4:  Elapsed Time: 0.261 seconds (Warm-up)
## Chain 4:                0.096 seconds (Sampling)
## Chain 4:                0.357 seconds (Total)
## Chain 4:
```

```
summary(bmodel)
```

```
##  Family: gaussian
##   Links: mu = identity; sigma = identity
## Formula: Engagement_OnTarget ~ Condition * time + (1 | Subject)
##    Data: CircleTimeData (Number of observations: 48)
##   Draws: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##          total post-warmup draws = 4000
##
## Group-Level Effects:
## ~Subject (Number of levels: 6)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     0.02      0.02     0.00     0.07 1.00     1523     2099
##
## Population-Level Effects:
##                Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.67      0.09     0.49     0.86 1.00     1865     2397
## Condition          0.05      0.06    -0.06     0.17 1.00     1838     2180
## time               0.04      0.03    -0.02     0.11 1.00     1828     2464
## Condition:time    -0.02      0.02    -0.06     0.02 1.00     1755     2164
##
## Family Specific Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.08      0.01     0.07     0.10 1.00     3466     2985
##
## 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(bmodel)
```


b_Intercept
b_Intercept
b_Condition
b_Condition
b_time
b_time
b_Condition:time
b_Condition:time
sd_Subject__Intercept
sd_Subject__Intercept
Chain
1
2
3
4



2.3.1.1 Reporting On-Target Engagement The effect size for Condition (0.06, 95% CI: -0.06, 0.18) is modest, indicating a slight difference in engagement with on-target between conditions. The effect of time (0.04, 95% CI: -0.02, 0.11) suggests a positive trend in engagement with on-target over sessions. The interaction effect Condition:time (-0.02, 95% CI: -0.07, 0.02) is subtle, with a 95% CI encompassing zero. The estimated standard deviation of the residuals (sigma) is 0.08 (95% CI: 0.07, 0.10), capturing variability not explained by the fixed effects. Our Bayesian analysis demonstrates convergence, providing valuable insights into the nuanced patterns of children's engagement with on-target behaviors over the course of the longitudinal study.

2.3.2 Engagement with Behavioral Therapist

```
library(readr)
library(brms)

CircleTimeData <- read_csv("~/GitHub/Circle-Time-Data-Analyses/CircleTimeData.csv")
```

```
## Rows: 48 Columns: 15
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## dbl (15): Subject, Condition, time, Affect_Positive, Affect_Negative, Affect...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```r
bmodel <- brm(Engagement_Therapist ~ Condition * time + (1 | Subject), data = CircleTimeData)
```

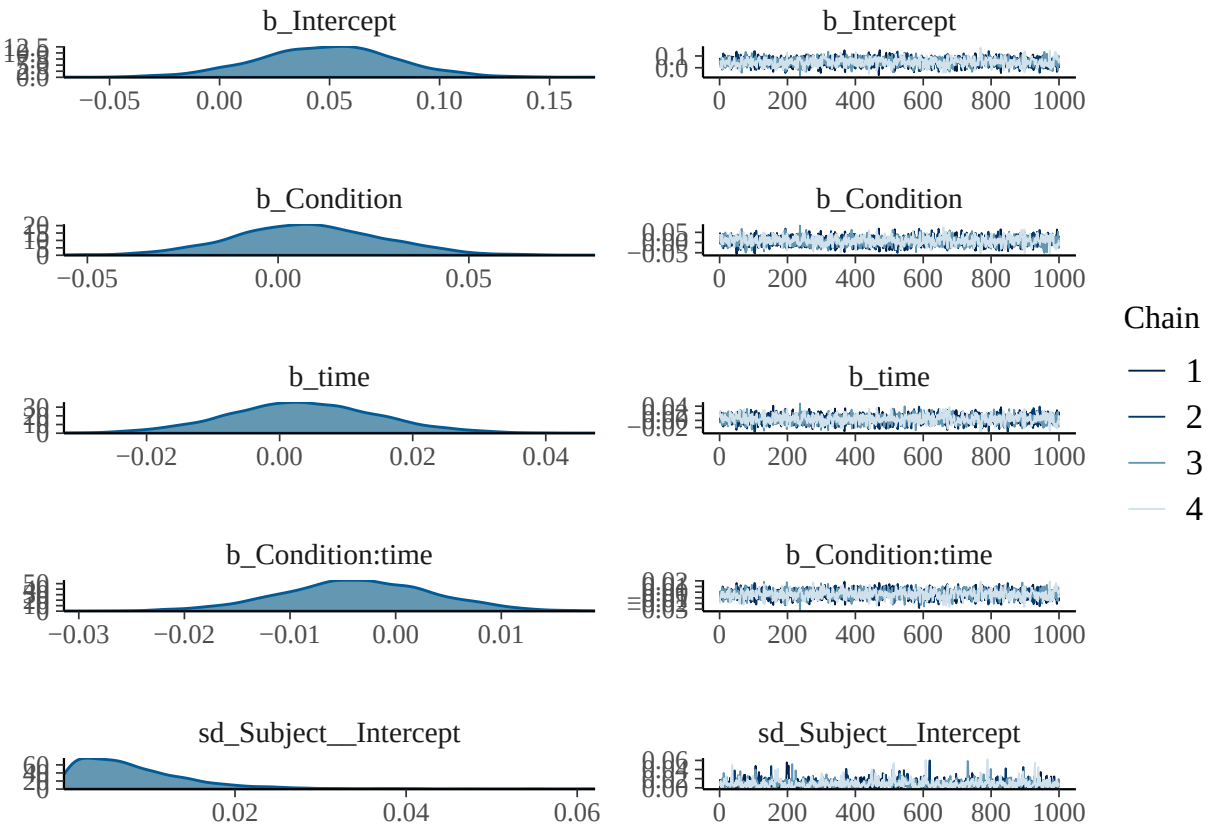
```
## Compiling Stan program...
## Start sampling

##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 2.8e-05 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.28 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 1:
## Chain 1:  Elapsed Time: 0.359 seconds (Warm-up)
## Chain 1:                0.108 seconds (Sampling)
## Chain 1:                0.467 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 1e-05 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.1 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 2:
## Chain 2:  Elapsed Time: 0.39 seconds (Warm-up)
## Chain 2:                0.118 seconds (Sampling)
```

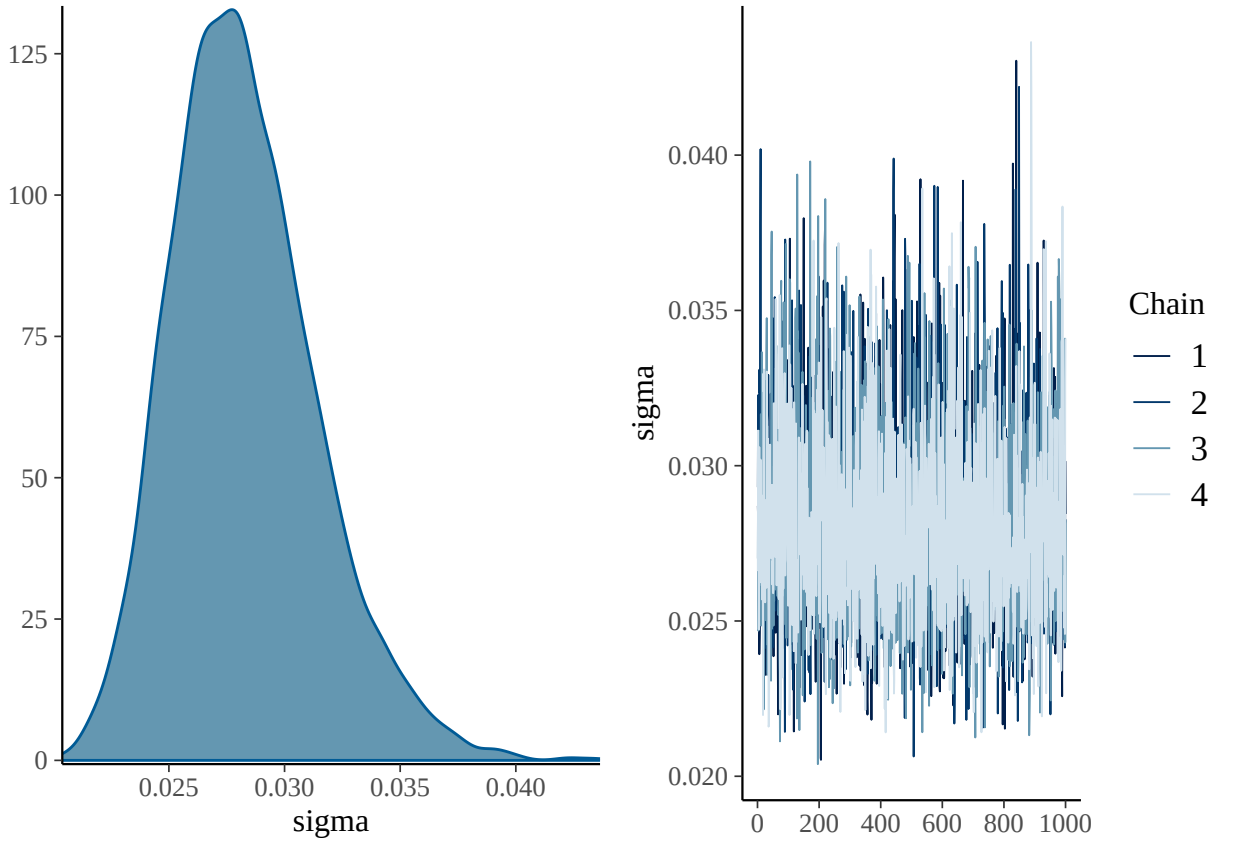
```
## Chain 2:                0.508 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 7e-06 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 3:
## Chain 3:  Elapsed Time: 0.337 seconds (Warm-up)
## Chain 3:                0.117 seconds (Sampling)
## Chain 3:                0.454 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 6e-06 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.06 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 4:
## Chain 4:  Elapsed Time: 0.317 seconds (Warm-up)
## Chain 4:                0.095 seconds (Sampling)
## Chain 4:                0.412 seconds (Total)
## Chain 4:
```

```r
summary(bmodel)
```

```
##  Family: gaussian
##   Links: mu = identity; sigma = identity
## Formula: Engagement_Therapist ~ Condition * time + (1 | Subject)
##    Data: CircleTimeData (Number of observations: 48)
##   Draws: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##          total post-warmup draws = 4000
##
## Group-Level Effects:
## ~Subject (Number of levels: 6)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     0.01      0.01     0.00     0.03 1.00     1162     1527
##
## Population-Level Effects:
##                Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.05      0.03    -0.01     0.11 1.00     1954     2451
## Condition          0.01      0.02    -0.03     0.05 1.00     1987     2469
## time               0.00      0.01    -0.02     0.03 1.00     2024     2169
## Condition:time    -0.00      0.01    -0.02     0.01 1.00     1956     2486
##
## Family Specific Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.03      0.00     0.02     0.04 1.00     3491     2449
##
## 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).
```

```r
plot(bmodel)
```


b_Intercept
b_Intercept
b_Condition
b_Condition
b_time
b_time
b_Condition:time
b_Condition:time
sd_Subject__Intercept
sd_Subject__Intercept
Chain
1
2
3
4



2.3.2.1 Reporting the Engagement with Behavioral Therapist The effect size for Condition (0.01, 95% CI: -0.03, 0.05) suggests a small difference in engagement between conditions. The effect of time (0.00, 95% CI: -0.02, 0.03) indicates a subtle positive trend in engagement over sessions. The interaction effect Condition:time (-0.00, 95% CI: -0.02, 0.01) is negligible, with a 95% CI encompassing zero. The estimated standard deviation of the residuals (sigma) is 0.03 (95% CI: 0.02, 0.04), capturing variability not explained by the fixed effects. Our Bayesian analysis demonstrates convergence, providing valuable insights into the nuanced patterns of children's engagement with the behavioral therapist throughout the longitudinal study.

2.3.3 Engagement with Off-Target

```
library(readr)
library(brms)

CircleTimeData <- read_csv("~/GitHub/Circle-Time-Data-Analyses/CircleTimeData.csv")
```

```
## Rows: 48 Columns: 15
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## dbl (15): Subject, Condition, time, Affect_Positive, Affect_Negative, Affect...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```r
bmodel <- brm(Engagement_OffTarget ~ Condition * time + (1 | Subject), data = CircleTimeData)
```

```
## Compiling Stan program...
## Start sampling

##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 2.9e-05 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.29 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 1:
## Chain 1:  Elapsed Time: 0.289 seconds (Warm-up)
## Chain 1:                0.098 seconds (Sampling)
## Chain 1:                0.387 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 1e-05 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.1 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 2:
## Chain 2:  Elapsed Time: 0.29 seconds (Warm-up)
## Chain 2:                0.084 seconds (Sampling)
```

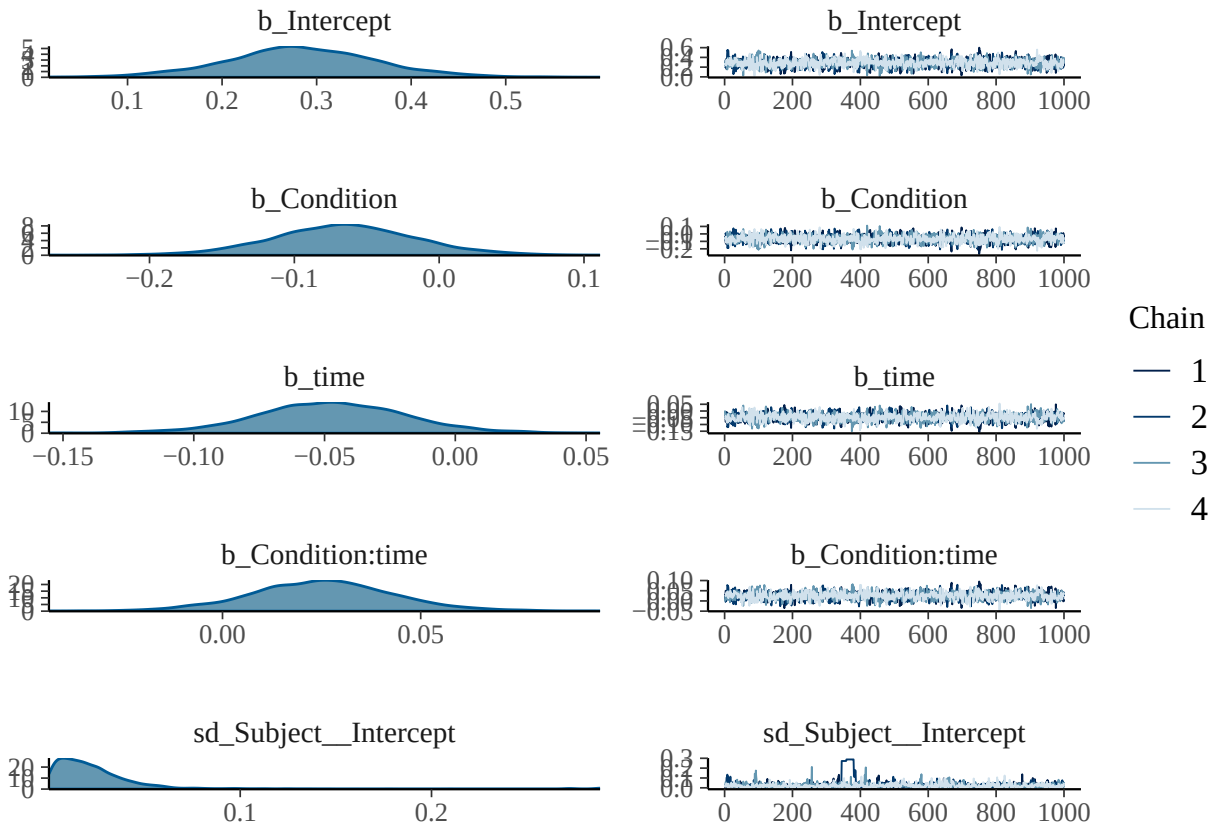
```
## Chain 2:                0.374 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 7e-06 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 3:
## Chain 3:  Elapsed Time: 0.277 seconds (Warm-up)
## Chain 3:                0.086 seconds (Sampling)
## Chain 3:                0.363 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 7e-06 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 4:
## Chain 4:  Elapsed Time: 0.3 seconds (Warm-up)
## Chain 4:                0.11 seconds (Sampling)
## Chain 4:                0.41 seconds (Total)
## Chain 4:

## Warning: There were 6 divergent transitions after warmup. See
```

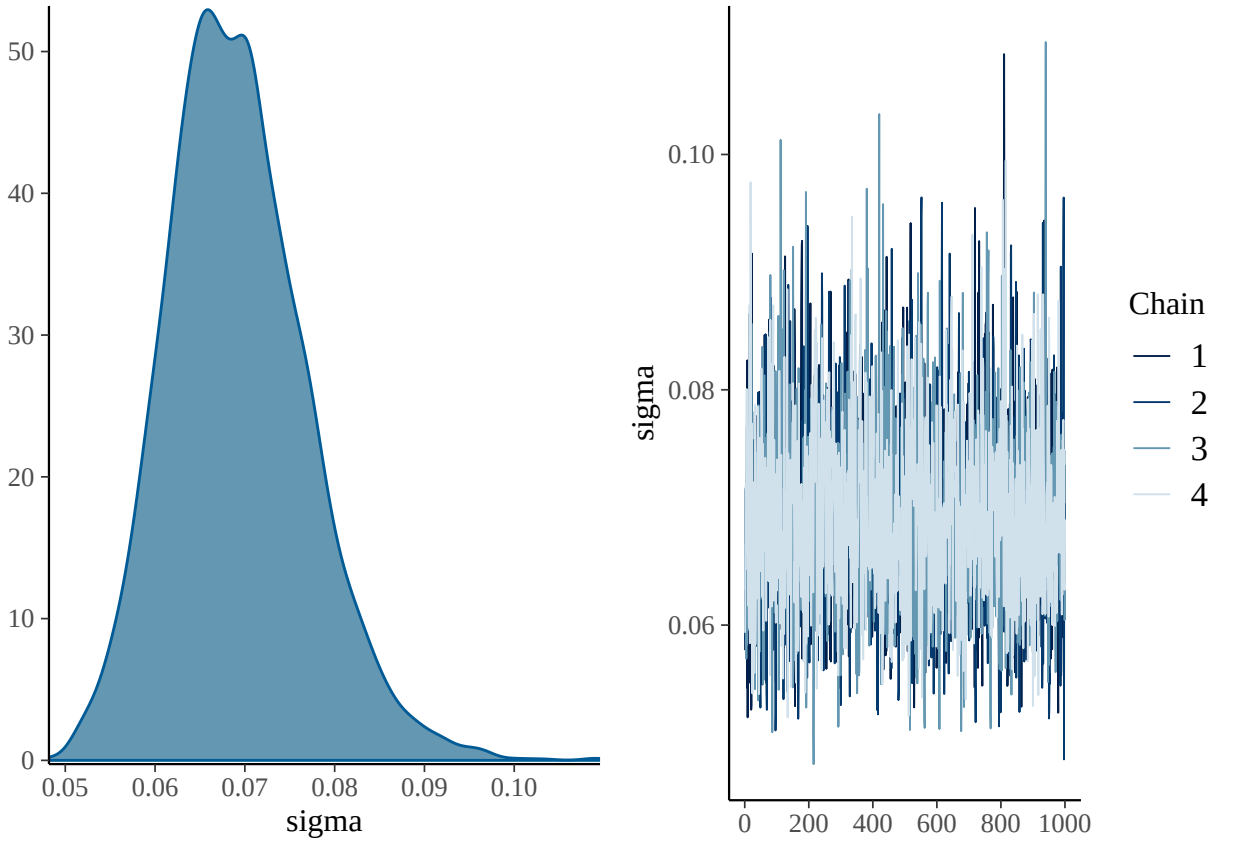
```
## https://mc-stan.org/misc/warnings.html#divergent-transitions-after-warmup
## to find out why this is a problem and how to eliminate them.

## Warning: Examine the pairs() plot to diagnose sampling problems

## Warning: Tail Effective Samples Size (ESS) is too low, indicating posterior variances and tail quanti
## Running the chains for more iterations may help. See
## https://mc-stan.org/misc/warnings.html#tail-ess
```

```
summary(bmodel)
```

```
## Warning: There were 6 divergent transitions after warmup. Increasing
## adapt_delta above 0.8 may help. See
## http://mc-stan.org/misc/warnings.html#divergent-transitions-after-warmup

##  Family: gaussian
##   Links: mu = identity; sigma = identity
## Formula: Engagement_OffTarget ~ Condition * time + (1 | Subject)
##    Data: CircleTimeData (Number of observations: 48)
##   Draws: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##          total post-warmup draws = 4000
##
## Group-Level Effects:
## ~Subject (Number of levels: 6)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     0.02      0.03     0.00     0.08 1.01      547      385
##
## Population-Level Effects:
##                Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.28      0.08     0.13     0.45 1.00     1624     1782
## Condition         -0.07      0.05    -0.16     0.03 1.00     1634     1765
## time              -0.05      0.03    -0.11     0.01 1.00     1522     1819
## Condition:time     0.03      0.02    -0.01     0.06 1.00     1523     1629
##
## Family Specific Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.07      0.01     0.06     0.09 1.00     2465     2549
##
## 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(bmodel)
```


b_Intercept
b_Intercept
b_Condition
b_Condition
b_time
b_time
b_Condition:time
b_Condition:time
sd_Subject__Intercept
sd_Subject__Intercept
Chain
1
2
3
4



2.3.3.1 Reporting the Engagement with Off-Target The effect size for Condition (-0.06, 95% CI: -0.16, 0.04) indicates a moderate decrease in off-target engagement with robot instructors compared to human instructors. The effect of time (-0.05, 95% CI: -0.10, 0.01) suggests a decreasing trend in off-target engagement over sessions. The interaction effect Condition:time (0.02, 95% CI: -0.01, 0.06) indicates a slight increase in the rate of decrease for robot instructors compared to human instructors. The estimated standard deviation of the residuals (sigma) is 0.07 (95% CI: 0.06, 0.09), capturing variability not explained by the fixed effects. Our Bayesian analysis demonstrates convergence, providing valuable insights into the nuanced patterns of children's engagement with off-target behaviors throughout the longitudinal study.

2.4 Performance

We use Bayesian Model to analyze the Performance metric.For all analyses condition 1 indicates the human instructor while condition 2 indicates the robot instructor.

2.4.1 Positive Performance

```
library(readr)
library(brms)

CircleTimeData <- read_csv("~/GitHub/Circle-Time-Data-Analyses/CircleTimeData.csv")
```

```
## Rows: 48 Columns: 15
```

```
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## dbl (15): Subject, Condition, time, Affect_Positive, Affect_Negative, Affect...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
bmodel <- brm(Performance_Positive ~ Condition * time + (1 | Subject), data = CircleTimeData)
```

```
## Compiling Stan program...
## Start sampling
```

```
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 3e-05 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.3 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 1:
## Chain 1:  Elapsed Time: 0.211 seconds (Warm-up)
## Chain 1:                0.169 seconds (Sampling)
## Chain 1:                0.38 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 7e-06 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
```

```
## Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 2:
## Chain 2:  Elapsed Time: 0.236 seconds (Warm-up)
## Chain 2:                0.173 seconds (Sampling)
## Chain 2:                0.409 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 7e-06 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 3:
## Chain 3:  Elapsed Time: 0.208 seconds (Warm-up)
## Chain 3:                0.203 seconds (Sampling)
## Chain 3:                0.411 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 8e-06 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.08 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
```

```
## Chain 4:
## Chain 4:  Elapsed Time: 0.186 seconds (Warm-up)
## Chain 4:                0.132 seconds (Sampling)
## Chain 4:                0.318 seconds (Total)
## Chain 4:
```

```
## Warning: There were 1 divergent transitions after warmup. See
## https://mc-stan.org/misc/warnings.html#divergent-transitions-after-warmup
## to find out why this is a problem and how to eliminate them.
```

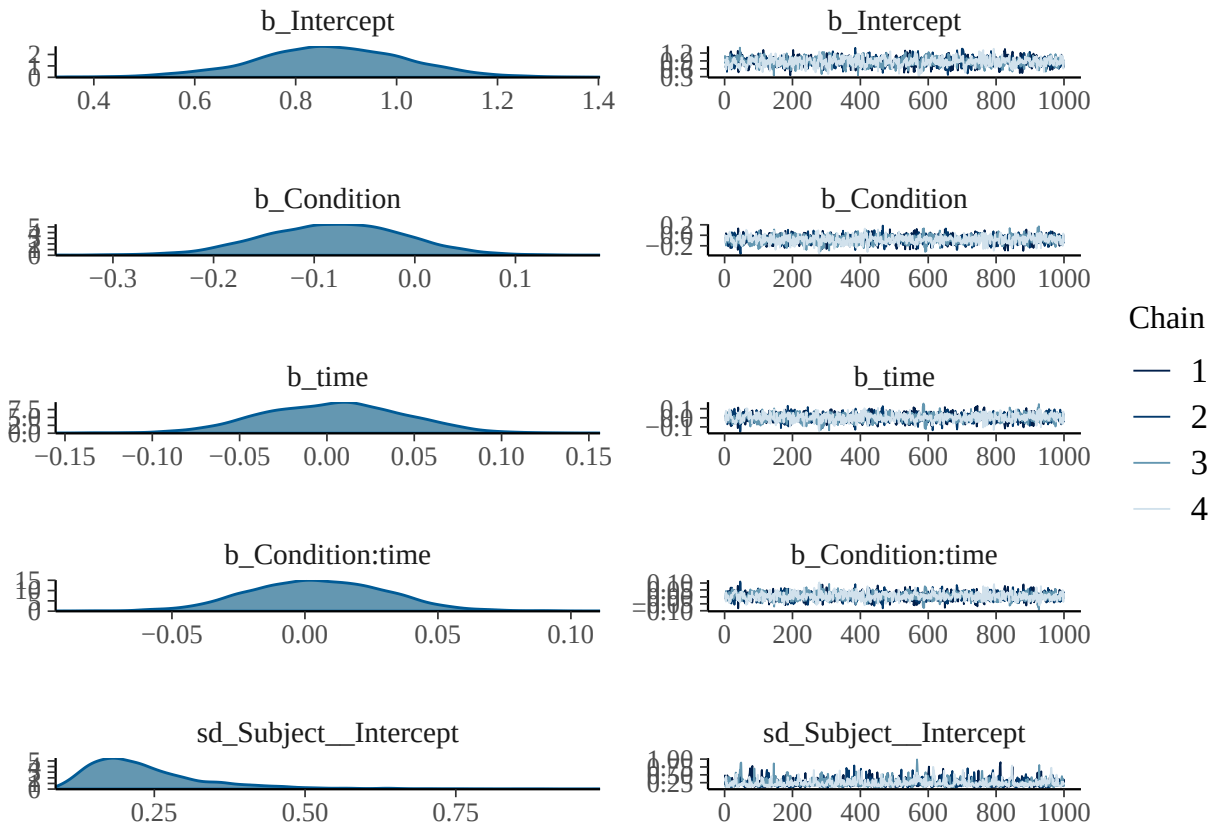
```
## Warning: Examine the pairs() plot to diagnose sampling problems
```

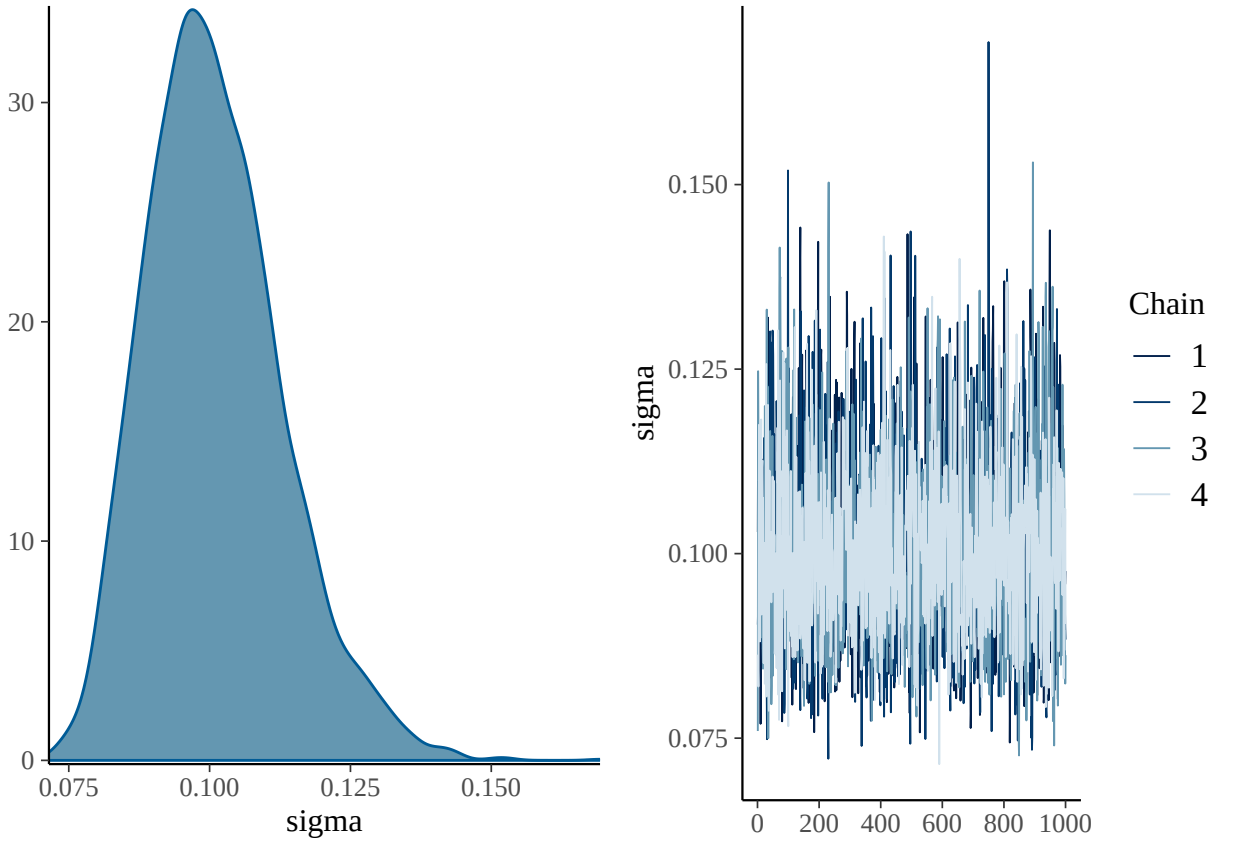
```
summary(bmodel)
```

```
## Warning: There were 1 divergent transitions after warmup. Increasing
## adapt_delta above 0.8 may help. See
## http://mc-stan.org/misc/warnings.html#divergent-transitions-after-warmup
```

```
##  Family: gaussian
##   Links: mu = identity; sigma = identity
## Formula: Performance_Positive ~ Condition * time + (1 | Subject)
##    Data: CircleTimeData (Number of observations: 48)
##   Draws: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##          total post-warmup draws = 4000
##
## Group-Level Effects:
## ~Subject (Number of levels: 6)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     0.24      0.11     0.11     0.53 1.00      907     1585
##
## Population-Level Effects:
##                Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.87      0.15     0.55     1.16 1.00     1378     1567
## Condition         -0.08      0.07    -0.22     0.05 1.00     1613     1872
## time               0.00      0.04    -0.07     0.08 1.00     1606     1792
## Condition:time     0.01      0.03    -0.04     0.06 1.00     1591     1822
##
## Family Specific Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.10      0.01     0.08     0.13 1.00     2150     2332
##
## 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(bmodel)
```


b_Intercept
b_Intercept
b_Condition
b_Condition
b_time
b_time
b_Condition:time
b_Condition:time
sd_Subject__Intercept
sd_Subject__Intercept
Chain
1
2
3
4



2.4.1.1 Reporting the Positive Performance The effect size for Condition (-0.08, 95% CI: -0.22, 0.06) suggests a moderate decrease in positive performance with robot instructors compared to human instructors. The effect of time (0.00, 95% CI: -0.08, 0.09) indicates no significant linear trend in positive performance over sessions. The interaction effect Condition:time (0.01, 95% CI: -0.05, 0.06) suggests a slight increase in the rate of positive performance for robot instructors compared to human instructors. The estimated standard deviation of the residuals (sigma) is 0.10 (95% CI: 0.08, 0.13), capturing variability not explained by the fixed effects. Our Bayesian analysis demonstrates convergence, providing nuanced insights into the dynamics of positive performance across sessions and instructional conditions.

2.4.2 Negative Performance

```
library(readr)
library(brms)

CircleTimeData <- read_csv("~/GitHub/Circle-Time-Data-Analyses/CircleTimeData.csv")
```

```
## Rows: 48 Columns: 15
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## dbl (15): Subject, Condition, time, Affect_Positive, Affect_Negative, Affect...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```r
bmodel <- brm(Performance_Negative ~ Condition * time + (1 | Subject), data = CircleTimeData)
```

```
## Compiling Stan program...
## Start sampling

##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 2.8e-05 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 0.28 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 1: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 1: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 1: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 1: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 1: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 1: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 1: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 1: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 1: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 1: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 1: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 1:
## Chain 1:  Elapsed Time: 0.204 seconds (Warm-up)
## Chain 1:                0.151 seconds (Sampling)
## Chain 1:                0.355 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 7e-06 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 2: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 2: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 2: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 2: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 2: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 2: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 2: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 2: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 2: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 2: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 2: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 2:
## Chain 2:  Elapsed Time: 0.22 seconds (Warm-up)
## Chain 2:                0.143 seconds (Sampling)
```

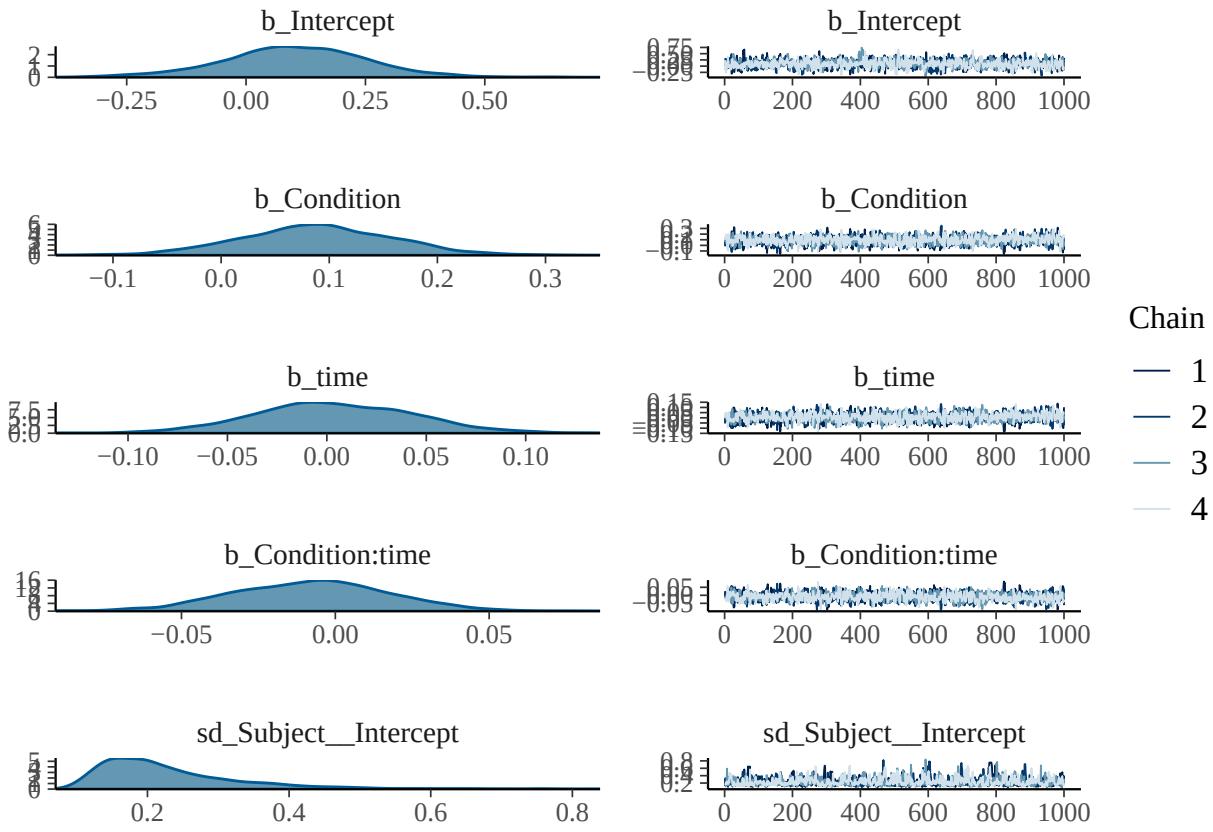
```
## Chain 2:                0.363 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 1.9e-05 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.19 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 3: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 3: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 3: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 3: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 3:
## Chain 3:  Elapsed Time: 0.205 seconds (Warm-up)
## Chain 3:                0.144 seconds (Sampling)
## Chain 3:                0.349 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'anon_model' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 7e-06 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.07 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%]  (Warmup)
## Chain 4: Iteration:  200 / 2000 [ 10%]  (Warmup)
## Chain 4: Iteration:  400 / 2000 [ 20%]  (Warmup)
## Chain 4: Iteration:  600 / 2000 [ 30%]  (Warmup)
## Chain 4: Iteration:  800 / 2000 [ 40%]  (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%]  (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%]  (Sampling)
## Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 4:
## Chain 4:  Elapsed Time: 0.211 seconds (Warm-up)
## Chain 4:                0.149 seconds (Sampling)
## Chain 4:                0.36 seconds (Total)
## Chain 4:

## Warning: There were 6 divergent transitions after warmup. See
```

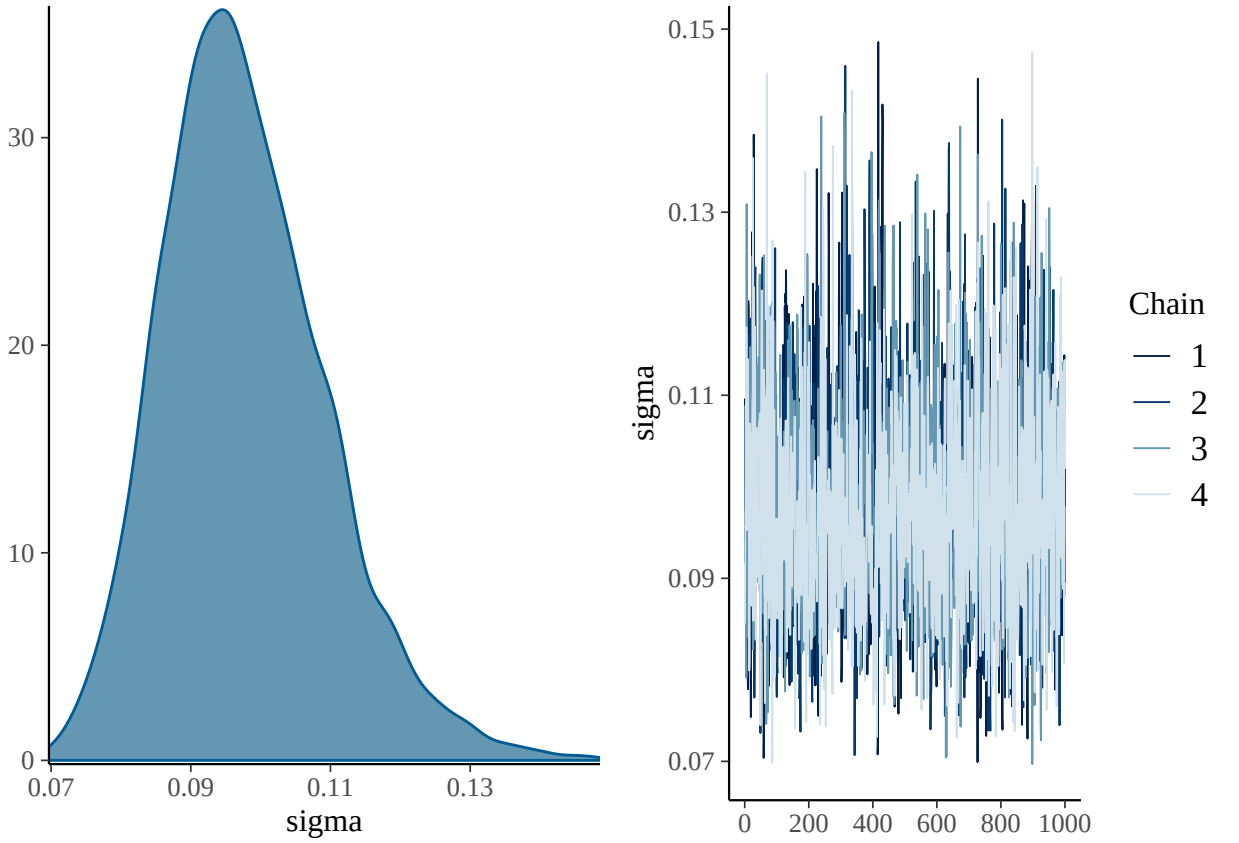
```
## https://mc-stan.org/misc/warnings.html#divergent-transitions-after-warmup
## to find out why this is a problem and how to eliminate them.

## Warning: Examine the pairs() plot to diagnose sampling problems
```

```
summary(bmodel)
```

```
## Warning: There were 6 divergent transitions after warmup. Increasing
## adapt_delta above 0.8 may help. See
## http://mc-stan.org/misc/warnings.html#divergent-transitions-after-warmup

##  Family: gaussian
##   Links: mu = identity; sigma = identity
## Formula: Performance_Negative ~ Condition * time + (1 | Subject)
##    Data: CircleTimeData (Number of observations: 48)
##   Draws: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##          total post-warmup draws = 4000
##
## Group-Level Effects:
## ~Subject (Number of levels: 6)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     0.23      0.10     0.11     0.50 1.00      807     1106
##
## Population-Level Effects:
##                Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.10      0.15    -0.21     0.40 1.01     1043     1133
## Condition          0.09      0.07    -0.05     0.23 1.01     1652     1927
## time               0.00      0.04    -0.07     0.08 1.01     1559     1831
## Condition:time    -0.01      0.03    -0.06     0.04 1.01     1384     1806
##
## Family Specific Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.10      0.01     0.08     0.12 1.00     2071     2190
##
## 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(bmodel)
```


b_Intercept
b_Intercept
b_Condition
b_Condition
b_time
b_time
b_Condition:time
b_Condition:time
sd_Subject__Intercept
sd_Subject__Intercept
Chain
1
2
3
4



2.4.2.1 Reporting the Negative Performance The effect size for Condition (0.09, 95% CI: -0.05, 0.22) suggests a modest increase in negative performance with robot instructors compared to human instructors. The effect of time (0.00, 95% CI: -0.08, 0.08) indicates no significant linear trend in negative performance over sessions. The interaction effect Condition:time (-0.01, 95% CI: -0.06, 0.04) suggests a slight decrease in the rate of negative performance for robot instructors compared to human instructors. The estimated standard deviation of the residuals (sigma) is 0.10 (95% CI: 0.08, 0.12), representing unexplained variability not captured by the fixed effects. Our Bayesian analysis, with confirmed convergence, provides nuanced insights into the dynamics of negative performance across sessions and instructional conditions.