Variational Inference analysis on raw data

corrado

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```r
library("here")
```

```
## here() starts at /Users/corrado/_repositories/surprise
```

```r
suppressPackageStartupMessages(
  {
    library("tidyverse")
    library("brms")
    library("cmdstanr")
    library("reshape")
    library("devtools")
    library("mice")
    library("tidybayes")
    library("emmeans")
    library("broom.mixed")
    library("rstanarm")
  }
)

theme_set(bayesplot::theme_default(base_family = "sans", base_size = 14))
set.seed(123)

source(here("libraries", "functions.R"))
```

```r
# Import complete data set
```

```r
# Import the data that have been created by the previous scripts.
# The data have been created with the 01_, 10_, 11_ scripts in
# the present directory.
data <- get_data()
```

```
## Rows: 64098 Columns: 23
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr  (10): subj_name, resp, movie_id, date, is_surprise_clip, is_clip_trial,...
## dbl  (12): subject_number, trial, target_or, flanker_or, correct, rt, block,...
## time  (1): time_of_day
##
## 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.
```

```
# Tidy data
```

```
# tidy the data frame
data_tidy <- tidy_flanker(data)
```

```
## ‘summarise()‘ has grouped output by ’subj_name’. You can override using the
## ‘.groups‘ argument.
## Joining with ‘by = join_by(subj_name, block)‘
```

```
# Perform some participants' flanker checks.
flanker_accuracy_overall <- get_flanker_accuracy(data_tidy, overall = TRUE)
```

```
## ‘summarise()‘ has grouped output by ’experiment’. You can override using the
## ‘.groups‘ argument.
```

```
# Get a list of participants who scored below 80% accuracy.
accuracy_removal <- flanker_accuracy_overall |>
  filter(accuracy < 0.80) |>
  pull(subj_id)

length(accuracy_removal)
```

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

```
# Remove the <80% accuracy participants from the flanker data.
flanker_data <- data_tidy |>
  filter(!subj_id %in% accuracy_removal)

# Check number of subjecta by condition.
flanker_data |>
  group_by(experiment, is_surprise_clip) |>
  summarize(
    n = n_distinct(subj_id)
  )
```

```
## ‘summarise()‘ has grouped output by ’experiment’. You can override using the
## ‘.groups‘ argument.
```

```
## # A tibble: 3 x 3
## # Groups:   experiment [2]
##   experiment is_surprise_clip     n
##   <fct>      <fct>            <int>
## 1 control    No                  81
## 2 surprise   No Surprise        120
## 3 surprise   Surprise           120
```

```
# Select correct trials only
```

```r
dt_cor <- flanker_data |>
  dplyr::filter(correct == 1)

nrow_total <- nrow(dt_cor)

# remove missing data on rt.
dt_cor <- dt_cor[!is.na(dt_cor$rt), ]

nrow_na_removed <- nrow(dt_cor)

# percent removed
(1 - nrow_na_removed / nrow_total) * 100
```

```
## [1] 0.07513148
```

```r
nrow_total - nrow_na_removed
```

```
## [1] 45
```

```r
nrow_total
```

```
## [1] 59895
```

```r
# Select correct trials by experiment
```

```r
# Select correct trials of the surprise experiment
surprise_cor_df <- dt_cor[dt_cor$experiment == "surprise", ]

# Select correct trials of the control experiment
control_cor_df <- dt_cor[dt_cor$experiment == "control", ]
```

```r
# Data wrangling
```

```r
surprise_cor_df$BL <- surprise_cor_df$block
surprise_cor_df$blk <- factor(surprise_cor_df$block)
surprise_cor_df$BF <- surprise_cor_df$blk

surprise_cor_df$zrt <- scale(surprise_cor_df$rt) |> as.numeric()

surprise_cor_df$CT <- surprise_cor_df$is_congruent_trial |>
  as.factor()

surprise_cor_df$SC <- surprise_cor_df$is_surprise_clip |>
  as.factor()

surprise_cor_df$movie_id <- factor(surprise_cor_df$movie_id)

d <- surprise_cor_df |>
  dplyr::select(rt, zrt, CT, SC, BL, BF, subj_id, movie_id)
```

```
## Adding missing grouping variables: ‘subj_name‘
```

```r
# brm() analysis
```

```r
m0 <- brm(
  bf(
    zrt ~ 1 + (1 | subj_id) + (1 | movie_id)
  ),
  algorithm = "meanfield",
  family = asym_laplace(),
  iter = 20000, # Increase the number of iterations
  data = d
)
```

```
## Compiling Stan program...
```

```
## Trying to compile a simple C file
```

```
## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## using C compiler: ‘Apple clang version 14.0.3 (clang-1403.0.22.14.1)’
## using SDK: ‘MacOSX13.3.sdk’
## clang -arch arm64 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG   -I"/Library/Framew
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeader
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## namespace Eigen {
## ^
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## namespace Eigen {
##                ^
##                ;
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeader
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/Core:96
## #include <complex>
##          ^~~~~~~~~
## 3 errors generated.
## make: *** [foo.o] Error 1
```

```
## Start sampling
```

```
## Chain 1: ------------------------------------------------------------
## Chain 1: EXPERIMENTAL ALGORITHM:
## Chain 1:   This procedure has not been thoroughly tested and may be unstable
## Chain 1:   or buggy. The interface is subject to change.
## Chain 1: ------------------------------------------------------------
## Chain 1:
## Chain 1:
## Chain 1:
## Chain 1: Gradient evaluation took 0.006438 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 64.38 seconds.
```

```
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Begin eta adaptation.
## Chain 1: Iteration:   1 / 250 [  0%]  (Adaptation)
## Chain 1: Iteration:  50 / 250 [ 20%]  (Adaptation)
## Chain 1: Iteration: 100 / 250 [ 40%]  (Adaptation)
## Chain 1: Iteration: 150 / 250 [ 60%]  (Adaptation)
## Chain 1: Iteration: 200 / 250 [ 80%]  (Adaptation)
## Chain 1: Iteration: 250 / 250 [100%]  (Adaptation)
## Chain 1: Success! Found best value [eta = 0.1].
## Chain 1:
## Chain 1: Begin stochastic gradient ascent.
## Chain 1:   iter             ELBO   delta_ELBO_mean   delta_ELBO_med   notes
## Chain 1:    100       -64838.990             1.000            1.000
## Chain 1:    200       -53064.649             0.611            1.000
## Chain 1:    300       -46714.580             0.453            0.222
## Chain 1:    400       -43890.726             0.356            0.222
## Chain 1:    500       -41308.425             0.297            0.136
## Chain 1:    600       -39501.326             0.255            0.136
## Chain 1:    700       -38413.951             0.223            0.064
## Chain 1:    800       -37507.849             0.198            0.064
## Chain 1:    900       -36918.863             0.178            0.063
## Chain 1:   1000       -36447.570             0.161            0.063
## Chain 1:   1100       -36372.503             0.147            0.046
## Chain 1:   1200       -36033.955             0.135            0.046
## Chain 1:   1300       -35944.438             0.125            0.028
## Chain 1:   1400       -35794.259             0.116            0.028
## Chain 1:   1500       -35743.137             0.109            0.024
## Chain 1:   1600       -35697.972             0.102            0.024
## Chain 1:   1700       -35642.698             0.096            0.016
## Chain 1:   1800       -35625.928             0.091            0.016
## Chain 1:   1900       -35592.546             0.086            0.013
## Chain 1:   2000       -35575.157             0.082            0.013
## Chain 1:   2100       -35567.682             0.032            0.009   MEDIAN ELBO CONVERGED
## Chain 1:
## Chain 1: Drawing a sample of size 1000 from the approximate posterior...
## Chain 1: COMPLETED.
```

```
## Warning: Pareto k diagnostic value is 3.88. Resampling is disabled. Decreasing
## tol_rel_obj may help if variational algorithm has terminated prematurely.
## Otherwise consider using sampling instead.
```

```r
loo_m0 <- loo(m0)
```

```r
m1 <- brm(
  bf(zrt ~ CT * SC * BL +
       (1 | subj_id) + (1 | movie_id)
  ),
  algorithm = "meanfield",
  family = asym_laplace(),
  iter = 20000, # Increase the number of iterations
  data = d
)
```

```
## Compiling Stan program...

## Trying to compile a simple C file

## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## using C compiler: ‘Apple clang version 14.0.3 (clang-1403.0.22.14.1)’
## using SDK: ‘MacOSX13.3.sdk’
## clang -arch arm64 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG   -I"/Library/Framew
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeade
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## namespace Eigen {
## ^
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## namespace Eigen {
##                ^
##                ;
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeade
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/Core:96
## #include <complex>
##          ^~~~~~~~
## 3 errors generated.
## make: *** [foo.o] Error 1

## Start sampling

## Chain 1: ------------------------------------------------------------
## Chain 1: EXPERIMENTAL ALGORITHM:
## Chain 1:   This procedure has not been thoroughly tested and may be unstable
## Chain 1:   or buggy. The interface is subject to change.
## Chain 1: ------------------------------------------------------------
## Chain 1:
## Chain 1:
## Chain 1:
## Chain 1: Gradient evaluation took 0.007534 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 75.34 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Begin eta adaptation.
## Chain 1: Iteration:   1 / 250 [  0%]  (Adaptation)
## Chain 1: Iteration:  50 / 250 [ 20%]  (Adaptation)
## Chain 1: Iteration: 100 / 250 [ 40%]  (Adaptation)
## Chain 1: Iteration: 150 / 250 [ 60%]  (Adaptation)
## Chain 1: Iteration: 200 / 250 [ 80%]  (Adaptation)
## Chain 1: Success! Found best value [eta = 1] earlier than expected.
## Chain 1:
## Chain 1: Begin stochastic gradient ascent.
## Chain 1:   iter             ELBO   delta_ELBO_mean   delta_ELBO_med   notes
```

```
## Chain 1:    100       -43344.856             1.000            1.000
## Chain 1:    200       -35981.350             0.602            1.000
## Chain 1:    300       -35342.905             0.408            0.205
## Chain 1:    400       -36782.953             0.315            0.205
## Chain 1:    500       -36734.259             0.253            0.039
## Chain 1:    600       -35009.725             0.219            0.049
## Chain 1:    700       -34941.284             0.188            0.039
## Chain 1:    800       -35363.621             0.166            0.039
## Chain 1:    900       -34970.158             0.149            0.018
## Chain 1:   1000       -35598.362             0.136            0.018
## Chain 1:   1100       -35064.395             0.125            0.018
## Chain 1:   1200       -34868.101             0.115            0.018
## Chain 1:   1300       -35238.346             0.107            0.015
## Chain 1:   1400       -34864.103             0.100            0.015
## Chain 1:   1500       -34720.122             0.093            0.012
## Chain 1:   1600       -34984.200             0.088            0.012
## Chain 1:   1700       -34640.099             0.083            0.011
## Chain 1:   1800       -34616.734             0.079            0.011
## Chain 1:   1900       -35187.764             0.076            0.011
## Chain 1:   2000       -34624.619             0.073            0.012
## Chain 1:   2100       -34577.506             0.023            0.011
## Chain 1:   2200       -34782.792             0.013            0.011
## Chain 1:   2300       -35000.670             0.012            0.011
## Chain 1:   2400       -34666.471             0.011            0.010   MEDIAN ELBO CONVERGED
## Chain 1:
## Chain 1: Drawing a sample of size 1000 from the approximate posterior...
## Chain 1: COMPLETED.
```

```
## Warning: Pareto k diagnostic value is 10.07. Resampling is disabled. Decreasing
## tol_rel_obj may help if variational algorithm has terminated prematurely.
## Otherwise consider using sampling instead.
```

```r
loo_m1 <- loo(m1)

comp <- loo_compare(loo_m0, loo_m1)
print(comp, digits = 2)
```

```
##    elpd_diff se_diff
## m1     0.00      0.00
## m0 -1009.17     55.04
```

```r
m2 <- brm(
  bf(zrt ~ CT * SC * BF +
       (1 + CT * SC * BF | subj_id) + (1 | movie_id)
  ),
  algorithm = "meanfield",
  family = asym_laplace(),
  iter = 20000, # Increase the number of iterations
  data = d
)
```

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

```
## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## using C compiler: ‘Apple clang version 14.0.3 (clang-1403.0.22.14.1)’
## using SDK: ‘MacOSX13.3.sdk’
## clang -arch arm64 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG   -I"/Library/Framew
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeader
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## namespace Eigen {
## ^
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## namespace Eigen {
##                 ^
##                 ;
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeader
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/Core:96
## #include <complex>
##          ^~~~~~~~
## 3 errors generated.
## make: *** [foo.o] Error 1
```

```
## Start sampling
```

```
## Chain 1: -----------------------------------------------------------
## Chain 1: EXPERIMENTAL ALGORITHM:
## Chain 1:   This procedure has not been thoroughly tested and may be unstable
## Chain 1:   or buggy. The interface is subject to change.
## Chain 1: -----------------------------------------------------------
## Chain 1: 
## Chain 1: 
## Chain 1: 
## Chain 1: Gradient evaluation took 0.02324 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 232.4 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1: 
## Chain 1: 
## Chain 1: Begin eta adaptation.
## Chain 1: Iteration:   1 / 250 [  0%]  (Adaptation)
## Chain 1: Iteration:  50 / 250 [ 20%]  (Adaptation)
## Chain 1: Iteration: 100 / 250 [ 40%]  (Adaptation)
## Chain 1: Iteration: 150 / 250 [ 60%]  (Adaptation)
## Chain 1: Iteration: 200 / 250 [ 80%]  (Adaptation)
## Chain 1: Iteration: 250 / 250 [100%]  (Adaptation)
## Chain 1: Success! Found best value [eta = 0.1].
## Chain 1: 
## Chain 1: Begin stochastic gradient ascent.
## Chain 1:   iter             ELBO   delta_ELBO_mean   delta_ELBO_med   notes
## Chain 1:    100       -94438.280             1.000            1.000
```

```
## Chain 1:    200       -74693.885             0.632            1.000
## Chain 1:    300       -63948.696             0.477            0.264
## Chain 1:    400       -56278.678             0.392            0.264
## Chain 1:    500       -51370.599             0.333            0.168
## Chain 1:    600       -47427.613             0.291            0.168
## Chain 1:    700       -44805.837             0.258            0.136
## Chain 1:    800       -42725.292             0.232            0.136
## Chain 1:    900       -40514.278             0.212            0.096
## Chain 1:   1000       -39736.673             0.193            0.096
## Chain 1:   1100       -38532.088             0.178            0.083
## Chain 1:   1200       -37957.374             0.165            0.083
## Chain 1:   1300       -37064.266             0.154            0.059
## Chain 1:   1400       -36407.065             0.144            0.059
## Chain 1:   1500       -36030.097             0.135            0.055
## Chain 1:   1600       -35517.196             0.128            0.055
## Chain 1:   1700       -35108.074             0.121            0.049
## Chain 1:   1800       -34928.275             0.114            0.049
## Chain 1:   1900       -34657.303             0.109            0.031
## Chain 1:   2000       -34334.634             0.104            0.031
## Chain 1:   2100       -34257.042             0.054            0.024
## Chain 1:   2200       -34024.182             0.041            0.020
## Chain 1:   2300       -33927.681             0.033            0.018
## Chain 1:   2400       -33814.622             0.026            0.015
## Chain 1:   2500       -33698.340             0.022            0.014
## Chain 1:   2600       -33628.717             0.017            0.012
## Chain 1:   2700       -33526.929             0.015            0.010
## Chain 1:   2800       -33467.605             0.012            0.009   MEDIAN ELBO CONVERGED
## Chain 1:
## Chain 1: Drawing a sample of size 1000 from the approximate posterior...
## Chain 1: COMPLETED.
```

```
## Warning: Pareto k diagnostic value is 17. Resampling is disabled. Decreasing
## tol_rel_obj may help if variational algorithm has terminated prematurely.
## Otherwise consider using sampling instead.
```

```
loo_m2 <- loo(m2)

comp <- loo_compare(loo_m1, loo_m2)
print(comp, digits = 2)
```

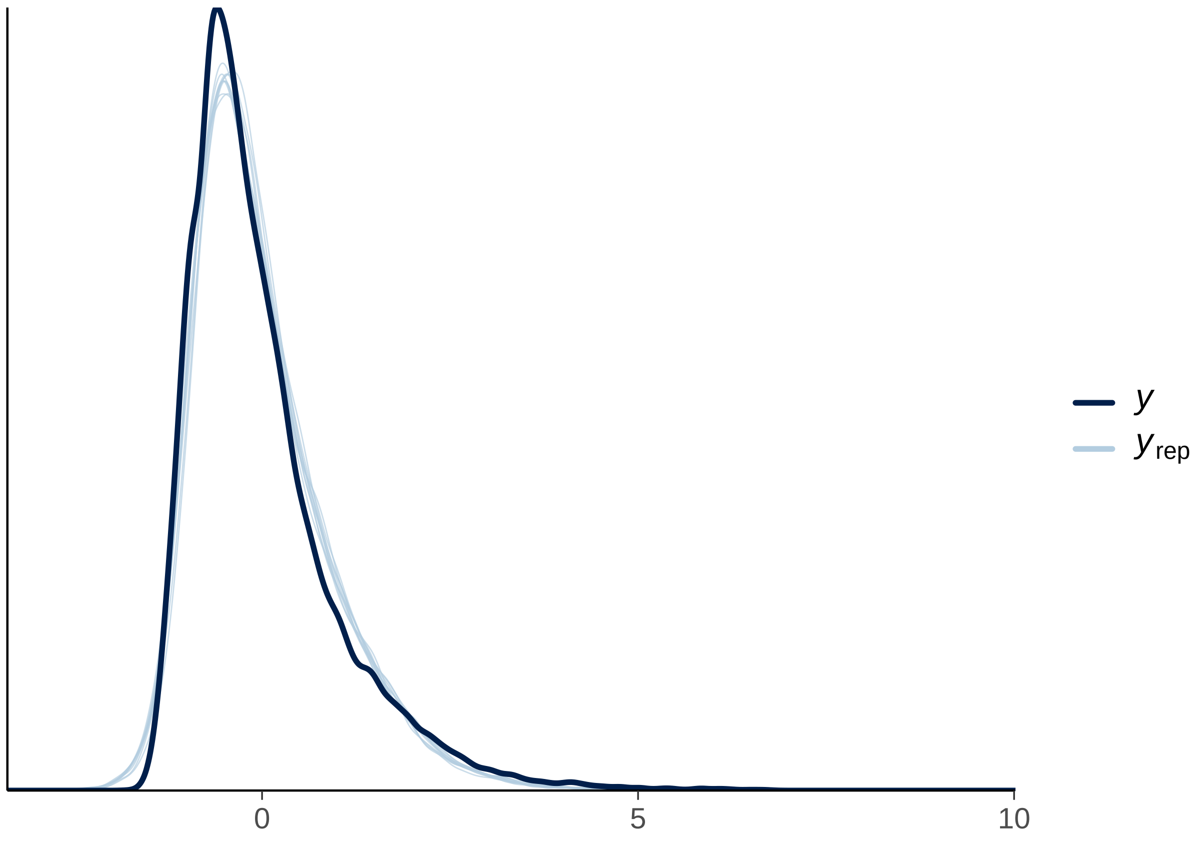
```
##    elpd_diff se_diff
## m2     0.00      0.00
## m1 -1258.82     68.60
```

```
print(loo_m2)
```

```
##
## Computed from 1000 by 36032 log-likelihood matrix
##
##          Estimate    SE
## elpd_loo -33108.7 190.9
## p_loo      1594.4  11.0
## looic     66217.4 381.8
## ------
## Monte Carlo SE of elpd_loo is 1.4.
##
## Pareto k diagnostic values:
##                          Count Pct.    Min. n_eff
## (-Inf, 0.5]   (good)     35986 99.9%   407
##  (0.5, 0.7]   (ok)          46  0.1%   705
##    (0.7, 1]   (bad)          0  0.0%   <NA>
##    (1, Inf)   (very bad)     0  0.0%   <NA>
##
## All Pareto k estimates are ok (k < 0.7).
## See help('pareto-k-diagnostic') for details.
```

```
pp_check(m2)
```

```
## Using 10 posterior draws for ppc type 'dens_overlay' by default.
```



```
m3 <- brm(
  bf(zrt ~ CT * SC * BL +
       (1 + CT * SC * BL | subj_id) + (1 | movie_id)
  ),
  algorithm = "meanfield",
  family = asym_laplace(),
  iter = 20000, # Increase the number of iterations
  init = 0.01,
  data = d
)
```

```
## Compiling Stan program...
```

```
## Trying to compile a simple C file
```

```
## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## using C compiler: ‘Apple clang version 14.0.3 (clang-1403.0.22.14.1)’
## using SDK: ‘MacOSX13.3.sdk’
## clang -arch arm64 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG   -I"/Library/Framew
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeader
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## namespace Eigen {
## ^
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## namespace Eigen {
##                ^
##                ;
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeader
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/Core:96
## #include <complex>
##          ^~~~~~~~~
## 3 errors generated.
## make: *** [foo.o] Error 1
```

```
## Start sampling
```

```
## Chain 1: ------------------------------------------------------------
## Chain 1: EXPERIMENTAL ALGORITHM:
## Chain 1:   This procedure has not been thoroughly tested and may be unstable
## Chain 1:   or buggy. The interface is subject to change.
## Chain 1: ------------------------------------------------------------
## Chain 1:
## Chain 1:
## Chain 1:
## Chain 1: Gradient evaluation took 0.01595 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 159.5 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Begin eta adaptation.
## Chain 1: Iteration:   1 / 250 [  0%]  (Adaptation)
## Chain 1: Iteration:  50 / 250 [ 20%]  (Adaptation)
## Chain 1: Iteration: 100 / 250 [ 40%]  (Adaptation)
## Chain 1: Iteration: 150 / 250 [ 60%]  (Adaptation)
```

```
## Chain 1: Iteration: 200 / 250 [ 80%]  (Adaptation)
## Chain 1: Iteration: 250 / 250 [100%]  (Adaptation)
## Chain 1: Success! Found best value [eta = 0.1].
## Chain 1:
## Chain 1: Begin stochastic gradient ascent.
## Chain 1:   iter             ELBO   delta_ELBO_mean   delta_ELBO_med   notes
## Chain 1:    100       -89242.372             1.000            1.000
## Chain 1:    200       -69762.930             0.640            1.000
## Chain 1:    300       -59435.485             0.484            0.279
## Chain 1:    400       -52369.742             0.397            0.279
## Chain 1:    500       -47080.961             0.340            0.174
## Chain 1:    600       -44839.808             0.292            0.174
## Chain 1:    700       -42276.676             0.259            0.135
## Chain 1:    800       -40885.306             0.231            0.135
## Chain 1:    900       -39443.867             0.209            0.112
## Chain 1:   1000       -38534.916             0.191            0.112
## Chain 1:   1100       -37962.628             0.175            0.061
## Chain 1:   1200       -36940.742             0.162            0.061
## Chain 1:   1300       -36521.419             0.151            0.050
## Chain 1:   1400       -36020.410             0.141            0.050
## Chain 1:   1500       -35625.508             0.132            0.037
## Chain 1:   1600       -35322.309             0.125            0.037
## Chain 1:   1700       -35285.399             0.117            0.034
## Chain 1:   1800       -34956.527             0.111            0.034
## Chain 1:   1900       -34710.912             0.106            0.028
## Chain 1:   2000       -34530.643             0.101            0.028
## Chain 1:   2100       -34466.292             0.051            0.024
## Chain 1:   2200       -34341.981             0.037            0.015
## Chain 1:   2300       -34272.140             0.029            0.014
## Chain 1:   2400       -34198.874             0.022            0.011
## Chain 1:   2500       -34117.966             0.016            0.011
## Chain 1:   2600       -34061.827             0.014            0.009   MEDIAN ELBO CONVERGED
## Chain 1:
## Chain 1: Drawing a sample of size 1000 from the approximate posterior...
## Chain 1: COMPLETED.
```

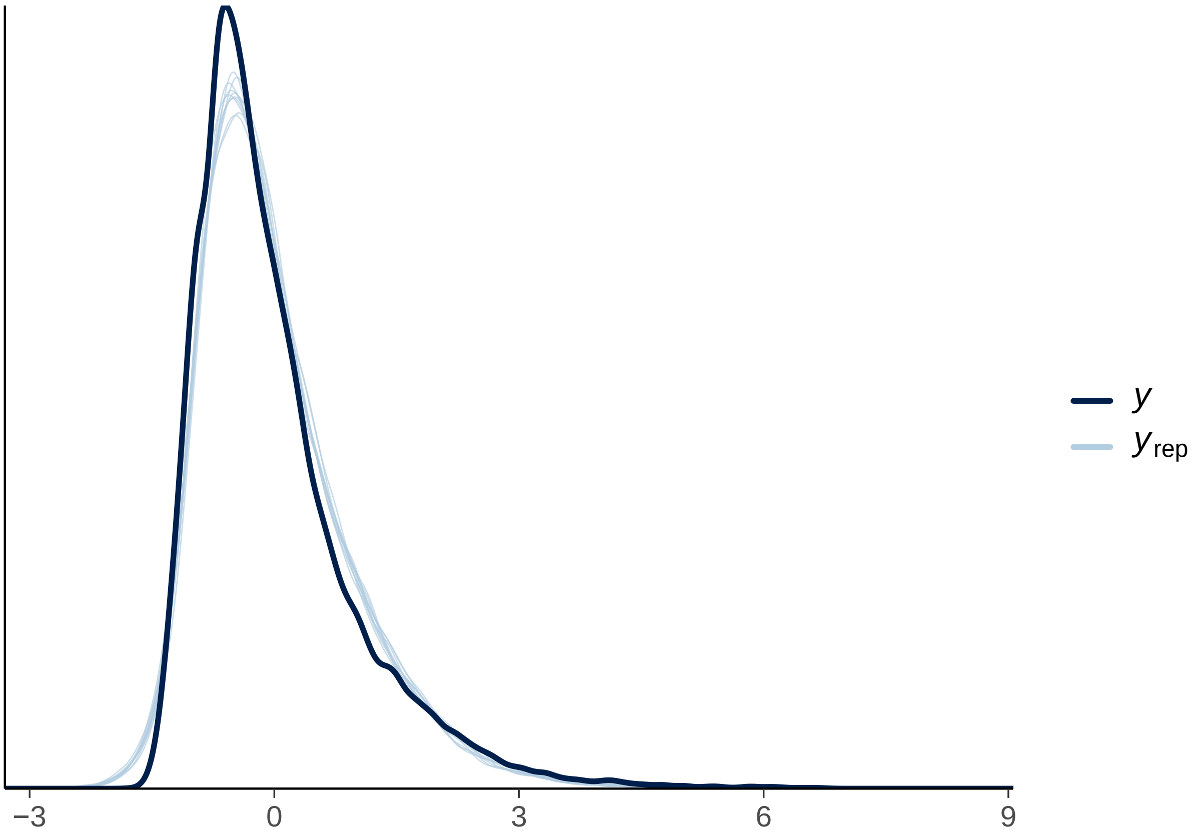
```
## Warning: Pareto k diagnostic value is 13.53. Resampling is disabled. Decreasing
## tol_rel_obj may help if variational algorithm has terminated prematurely.
## Otherwise consider using sampling instead.
```

```
loo_m3 <- loo(m3)

comp <- loo_compare(loo_m3, loo_m2)
print(comp, digits = 2)
```

```
##    elpd_diff se_diff
## m2    0.00      0.00
## m3 -738.09     48.10
```

```
pp_check(m3)
```

```
## Using 10 posterior draws for ppc type 'dens_overlay' by default.
```



```
print(loo_m3)
```

```
##
## Computed from 1000 by 36032 log-likelihood matrix
##
##          Estimate    SE
## elpd_loo -33846.8 190.3
## p_loo       932.3   6.2
## looic     67693.6 380.6
## ------
## Monte Carlo SE of elpd_loo is 1.0.
##
## Pareto k diagnostic values:
##                          Count Pct.    Min. n_eff
## (-Inf, 0.5]   (good)     36025 100.0%  524
##  (0.5, 0.7]   (ok)           7   0.0%  551
##    (0.7, 1]   (bad)          0   0.0%  <NA>
##    (1, Inf)   (very bad)     0   0.0%  <NA>
##
## All Pareto k estimates are ok (k < 0.7).
## See help('pareto-k-diagnostic') for details.
```

```
# Test whether the kind of video is important within the surprise experiment.

m4 <- brm(
```

```r
  bf(zrt ~ CT * BL +
       (1 + CT * BL | subj_id) + (1 | movie_id)
  ),
  algorithm = "meanfield",
  family = asym_laplace(),
  iter = 20000, # Increase the number of iterations
  init = 0.01,
  data = d
)
```

```
## Compiling Stan program...

## Trying to compile a simple C file

## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## using C compiler: ‘Apple clang version 14.0.3 (clang-1403.0.22.14.1)’
## using SDK: ‘MacOSX13.3.sdk’
## clang -arch arm64 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG   -I"/Library/Framew
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeader
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## namespace Eigen {
## ^
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## namespace Eigen {
##                ^
##                ;
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeader
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/Core:96
## #include <complex>
##          ^~~~~~~~~
## 3 errors generated.
## make: *** [foo.o] Error 1

## Start sampling

## Chain 1: ------------------------------------------------------------
## Chain 1: EXPERIMENTAL ALGORITHM:
## Chain 1:   This procedure has not been thoroughly tested and may be unstable
## Chain 1:   or buggy. The interface is subject to change.
## Chain 1: ------------------------------------------------------------
## Chain 1:
## Chain 1:
## Chain 1:
## Chain 1: Gradient evaluation took 0.012266 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 122.66 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
```

```
## Chain 1:
## Chain 1: Begin eta adaptation.
## Chain 1: Iteration:   1 / 250 [  0%]  (Adaptation)
## Chain 1: Iteration:  50 / 250 [ 20%]  (Adaptation)
## Chain 1: Iteration: 100 / 250 [ 40%]  (Adaptation)
## Chain 1: Iteration: 150 / 250 [ 60%]  (Adaptation)
## Chain 1: Iteration: 200 / 250 [ 80%]  (Adaptation)
## Chain 1: Success! Found best value [eta = 1] earlier than expected.
## Chain 1:
## Chain 1: Begin stochastic gradient ascent.
## Chain 1:   iter             ELBO   delta_ELBO_mean   delta_ELBO_med   notes
## Chain 1:    100       -40570.431             1.000            1.000
## Chain 1:    200       -34800.329             0.583            1.000
## Chain 1:    300       -34610.230             0.390            0.166
## Chain 1:    400       -33765.720             0.299            0.166
## Chain 1:    500       -34145.628             0.241            0.025
## Chain 1:    600       -33967.189             0.202            0.025
## Chain 1:    700       -33555.053             0.175            0.012
## Chain 1:    800       -33882.057             0.154            0.012
## Chain 1:    900       -33524.302             0.138            0.011
## Chain 1:   1000       -33239.053             0.125            0.011
## Chain 1:   1100       -33588.039             0.115            0.011
## Chain 1:   1200       -33403.783             0.106            0.011
## Chain 1:   1300       -33480.677             0.098            0.010
## Chain 1:   1400       -33341.290             0.091            0.010
## Chain 1:   1500       -33198.028             0.085            0.010   MEDIAN ELBO CONVERGED
## Chain 1:
## Chain 1: Drawing a sample of size 1000 from the approximate posterior...
## Chain 1: COMPLETED.

## Warning: Pareto k diagnostic value is 7.23. Resampling is disabled. Decreasing
## tol_rel_obj may help if variational algorithm has terminated prematurely.
## Otherwise consider using sampling instead.
```

```r
loo_m4 <- loo(m4)


comp <- loo_compare(loo_m3, loo_m4)
print(comp, digits = 2)
```

```
##    elpd_diff se_diff
## m4     0.00      0.00
## m3 -1212.31     52.57
```

```r
# Remove the three-way interaction

m5 <- brm(
  bf(zrt ~ CT * SC + CT * BL + SC * BL +
       (1 + CT * SC + CT * BL + SC * BL | subj_id) + (1 | movie_id)
  ),
  algorithm = "meanfield",
  family = brms::asym_laplace(),
  iter = 20000, # Increase the number of iterations
  init = 0.01,
  data = d
)
```

```
## Compiling Stan program...
```

```
## Trying to compile a simple C file
```

```
## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## using C compiler: ‘Apple clang version 14.0.3 (clang-1403.0.22.14.1)’
## using SDK: ‘MacOSX13.3.sdk’
## clang -arch arm64 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG   -I"/Library/Framew
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeader
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## namespace Eigen {
## ^
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## namespace Eigen {
##                ^
##                ;
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeader
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/Core:96
## #include <complex>
##          ^~~~~~~~~
## 3 errors generated.
## make: *** [foo.o] Error 1
```

```
## Start sampling
```

```
## Chain 1: ------------------------------------------------------------
## Chain 1: EXPERIMENTAL ALGORITHM:
## Chain 1:   This procedure has not been thoroughly tested and may be unstable
## Chain 1:   or buggy. The interface is subject to change.
## Chain 1: ------------------------------------------------------------
## Chain 1:
## Chain 1:
## Chain 1:
## Chain 1: Gradient evaluation took 0.014241 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 142.41 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Begin eta adaptation.
## Chain 1: Iteration:   1 / 250 [  0%]  (Adaptation)
## Chain 1: Iteration:  50 / 250 [ 20%]  (Adaptation)
## Chain 1: Iteration: 100 / 250 [ 40%]  (Adaptation)
## Chain 1: Iteration: 150 / 250 [ 60%]  (Adaptation)
```

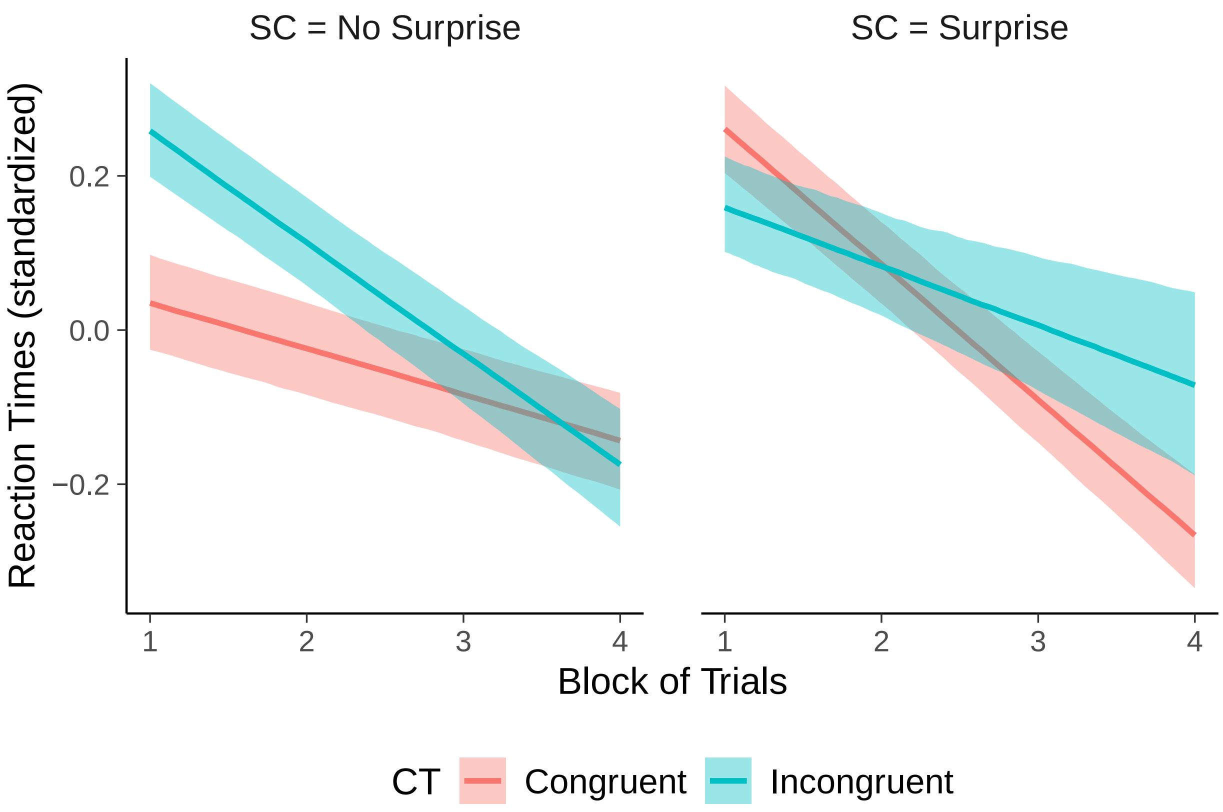
```
## Chain 1: Iteration: 200 / 250 [ 80%]  (Adaptation)
## Chain 1: Iteration: 250 / 250 [100%]  (Adaptation)
## Chain 1: Success! Found best value [eta = 0.1].
## Chain 1:
## Chain 1: Begin stochastic gradient ascent.
## Chain 1:   iter             ELBO   delta_ELBO_mean   delta_ELBO_med   notes
## Chain 1:    100      -207014.447             1.000            1.000
## Chain 1:    200      -122442.623             0.845            1.000
## Chain 1:    300       -98153.633             0.646            0.691
## Chain 1:    400       -83033.265             0.530            0.691
## Chain 1:    500       -71462.777             0.456            0.247
## Chain 1:    600       -63569.721             0.401            0.247
## Chain 1:    700       -57622.000             0.359            0.182
## Chain 1:    800       -53208.407             0.324            0.182
## Chain 1:    900       -50186.756             0.295            0.162
## Chain 1:   1000       -48587.525             0.269            0.162
## Chain 1:   1100       -45945.649             0.249            0.124
## Chain 1:   1200       -44571.188             0.231            0.124
## Chain 1:   1300       -43124.783             0.216            0.103
## Chain 1:   1400       -42257.253             0.202            0.103
## Chain 1:   1500       -41121.245             0.190            0.083
## Chain 1:   1600       -40378.575             0.180            0.083
## Chain 1:   1700       -39909.204             0.170            0.060
## Chain 1:   1800       -39233.737             0.161            0.060
## Chain 1:   1900       -38708.476             0.154            0.058
## Chain 1:   2000       -38414.435             0.146            0.058
## Chain 1:   2100       -38064.603             0.097            0.034
## Chain 1:   2200       -37716.130             0.063            0.033
## Chain 1:   2300       -37522.596             0.050            0.031
## Chain 1:   2400       -37267.549             0.042            0.028
## Chain 1:   2500       -36987.929             0.034            0.021
## Chain 1:   2600       -36934.083             0.028            0.018
## Chain 1:   2700       -36714.540             0.023            0.017
## Chain 1:   2800       -36588.581             0.019            0.014
## Chain 1:   2900       -36478.459             0.016            0.012
## Chain 1:   3000       -36375.133             0.015            0.009   MEDIAN ELBO CONVERGED
## Chain 1:
## Chain 1: Drawing a sample of size 1000 from the approximate posterior...
## Chain 1: COMPLETED.
```

```
## Warning: Pareto k diagnostic value is 25.03. Resampling is disabled. Decreasing
## tol_rel_obj may help if variational algorithm has terminated prematurely.
## Otherwise consider using sampling instead.
```

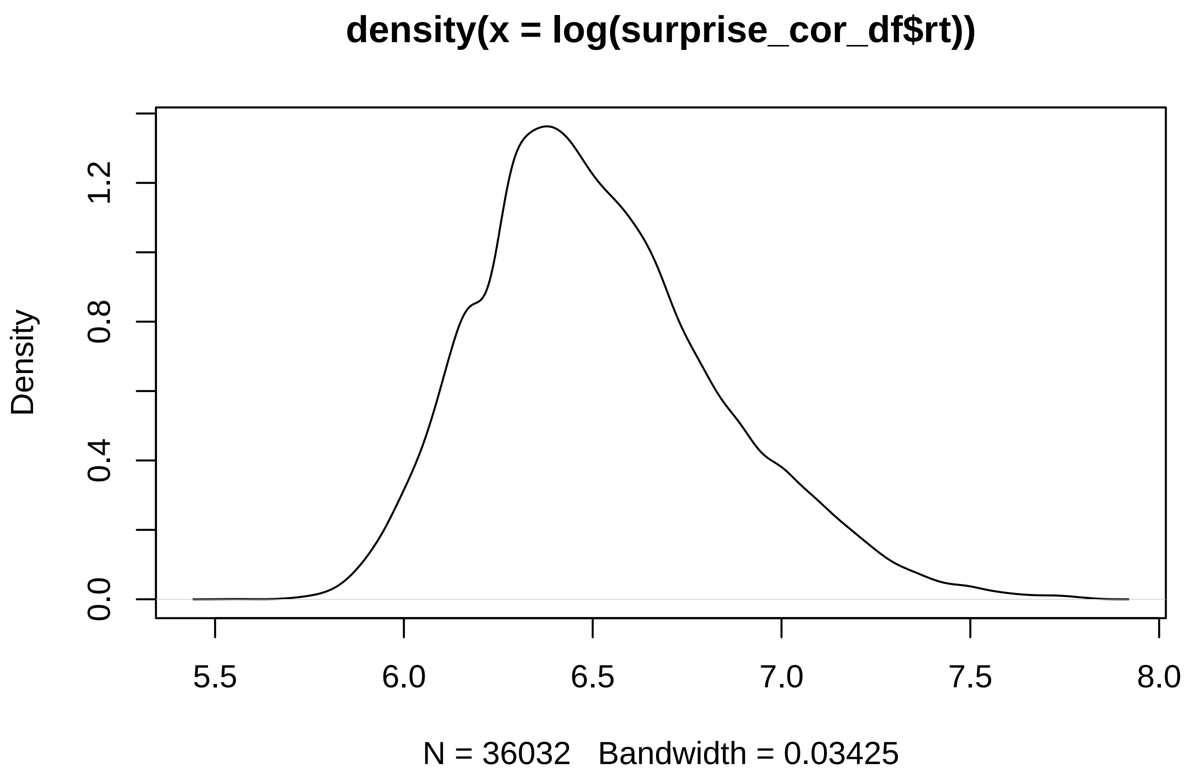
```
loo_m5 <- loo(m5)

# Test of the three-way interaction
comp <- loo_compare(loo_m3, loo_m5)
print(comp, digits = 2)
```

```
##    elpd_diff se_diff
## m3     0.00     0.00
## m5 -2405.31    80.41
```

```r
# Conditional plot.

mod <- m3

# Three-way interaction
conditions <- make_conditions(mod, "SC")
c_eff <- conditional_effects(mod, "BL:CT", conditions=conditions)
plot(c_eff, plot = FALSE)[[1]] +
  theme(legend.position = "bottom") +
  labs(
    y = "Reaction Times (standardized)",
    x = "Block of Trials"
  )
```

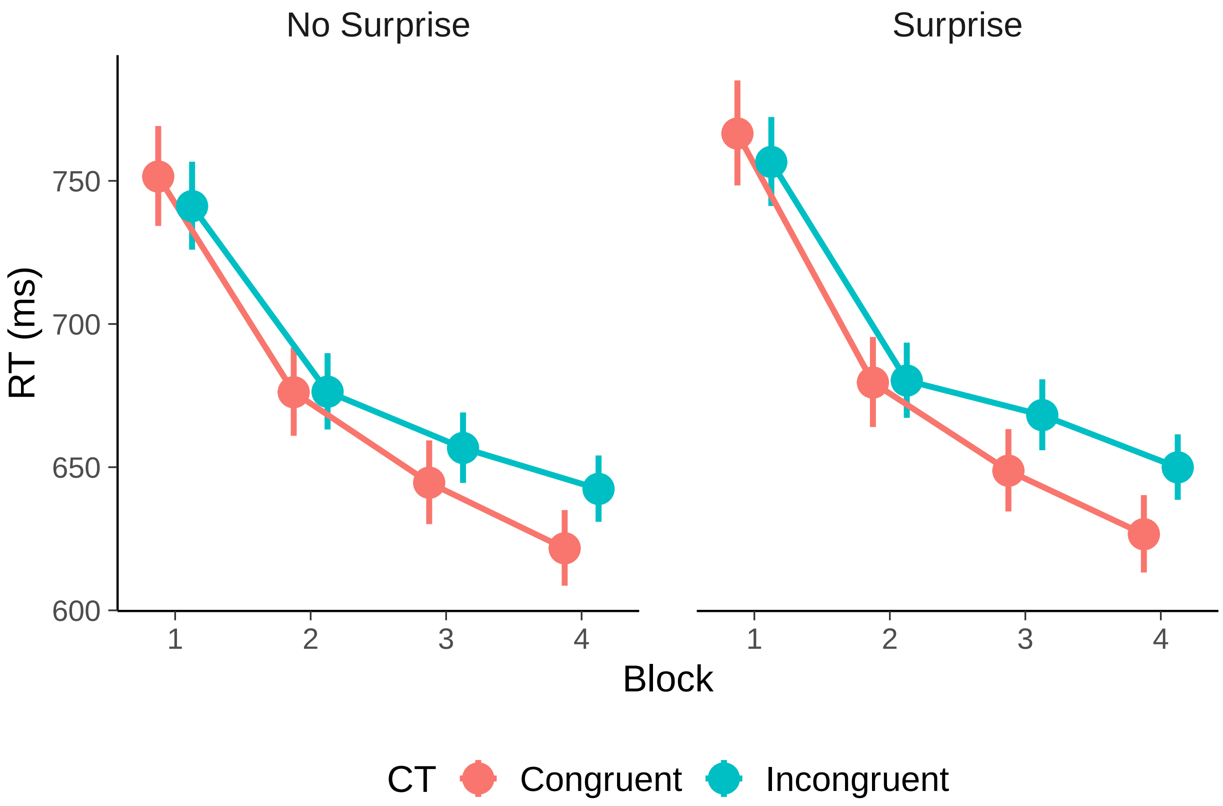


```r
# Plot of the raw data means

plot(density(log(surprise_cor_df$rt)))
```



```r
surprise_cor_df$lrt <- log(surprise_cor_df$rt)

# Calculate the within-subject mean and standard error for each condition
subject_summary <- surprise_cor_df %>%
  group_by(subj_id, SC, CT, BL) %>%
  summarize(
    subj_mean = mean(lrt, na.rm = TRUE),
    .groups = 'drop'
  )

# Calculate the overall mean and within-subject standard error for each condition
plot_df <- subject_summary %>%
  group_by(SC, CT, BL) %>%
  summarize(
    m = mean(subj_mean, na.rm = TRUE),
    stderr = sd(subj_mean, na.rm = TRUE) / sqrt(n()),
    .groups = 'drop'
  )

# Create the lower and upper bounds for the error bars
plot_df$lower <- plot_df$m - plot_df$stderr
plot_df$upper <- plot_df$m + plot_df$stderr

plot_df$m <- exp(plot_df$m)
plot_df$stderr <- exp(plot_df$stderr)
plot_df$lower <- exp(plot_df$lower)
```

```
plot_df$upper <- exp(plot_df$upper)

# Create the plot
pd <- position_dodge(0.5)

ggplot(plot_df, aes(x = BL, y = m, color = CT)) +
  geom_pointrange(aes(ymin = lower, ymax = upper), lwd = 1.05, position = pd) +
  geom_line(position = pd, lwd = 1.05) +
  geom_point(position = pd, size = 5) +
  facet_grid(~SC) +
  xlab("Block") +
  ylab("RT (ms)") +
  theme(legend.position = "bottom")
```



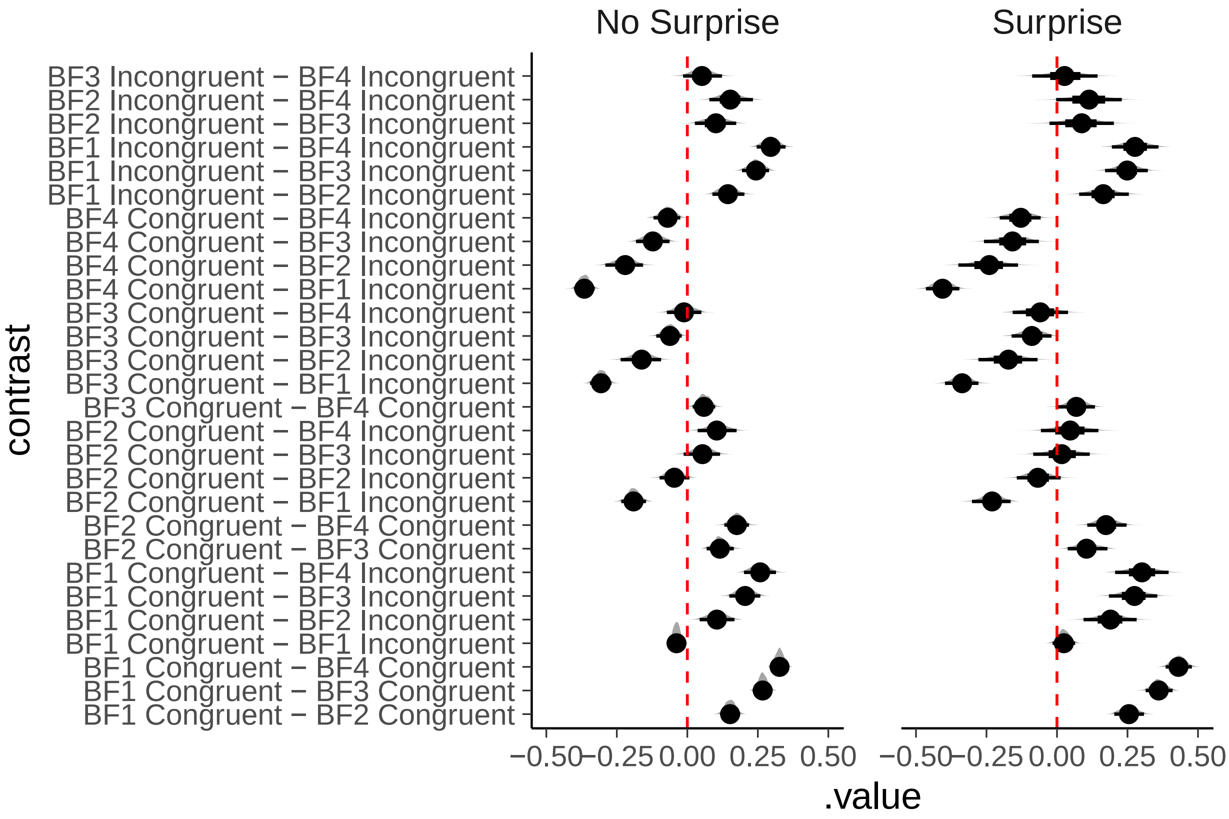
```
# Compute contrasts.

mod <- m2  # Use block as factor

#get the adjusted means
em <- emmeans (mod, ~ BF:CT | SC)
em
```

```
## SC = No Surprise:
##  BF CT              emmean lower.HPD upper.HPD
##  1  Congruent    -0.000897 -0.032312    0.0406
##   2  Congruent   -0.152757 -0.192000   -0.1037
##   3  Congruent   -0.267424 -0.308094   -0.2225
##   4  Congruent   -0.327470 -0.365367   -0.2880
##   1  Incongruent  0.039031  0.000861    0.0746
##   2  Incongruent -0.105621 -0.160468   -0.0412
##   3  Incongruent -0.204678 -0.261306   -0.1553
##   4  Incongruent -0.256855 -0.315761   -0.2029
##
## SC = Surprise:
##  BF CT             emmean lower.HPD upper.HPD
##   1  Congruent    0.410658  0.375315    0.4449
##   2  Congruent    0.154978  0.103596    0.2113
##   3  Congruent    0.049769  0.000821    0.0988
##   4  Congruent   -0.020332 -0.066870    0.0301
##   1  Incongruent  0.385291  0.348062    0.4273
##   2  Incongruent  0.221274  0.134159    0.3028
##   3  Incongruent  0.139107  0.059979    0.2150
##   4  Incongruent  0.109118  0.028787    0.1885
##
## Point estimate displayed: median
## HPD interval probability: 0.95
```

```r
#get all possible contrasts
cont <- contrast(em, "tukey")
cont
```

```
## SC = No Surprise:
##  contrast                          estimate lower.HPD upper.HPD
##  BF1 Congruent - BF2 Congruent       0.1517   0.11712    0.1873
##  BF1 Congruent - BF3 Congruent       0.2672   0.23908    0.3008
##  BF1 Congruent - BF4 Congruent       0.3271   0.29705    0.3527
##  BF1 Congruent - BF1 Incongruent    -0.0384  -0.06414   -0.0172
##  BF1 Congruent - BF2 Incongruent     0.1047   0.04086    0.1645
##  BF1 Congruent - BF3 Incongruent     0.2048   0.14835    0.2578
##  BF1 Congruent - BF4 Incongruent     0.2583   0.19999    0.3126
##  BF2 Congruent - BF3 Congruent       0.1152   0.06729    0.1615
##  BF2 Congruent - BF4 Congruent       0.1756   0.13128    0.2188
##  BF2 Congruent - BF1 Incongruent    -0.1908  -0.23335   -0.1458
##  BF2 Congruent - BF2 Incongruent    -0.0464  -0.09265    0.0107
##  BF2 Congruent - BF3 Incongruent     0.0537  -0.01071    0.1193
##  BF2 Congruent - BF4 Incongruent     0.1043   0.03420    0.1704
##  BF3 Congruent - BF4 Congruent       0.0588   0.01845    0.0980
##  BF3 Congruent - BF1 Incongruent    -0.3061  -0.34778   -0.2723
##  BF3 Congruent - BF2 Incongruent    -0.1621  -0.23261   -0.0920
##  BF3 Congruent - BF3 Incongruent    -0.0617  -0.10611   -0.0182
##  BF3 Congruent - BF4 Incongruent    -0.0119  -0.06913    0.0529
##  BF4 Congruent - BF1 Incongruent    -0.3653  -0.40390   -0.3315
##  BF4 Congruent - BF2 Incongruent    -0.2204  -0.29316   -0.1582
##  BF4 Congruent - BF3 Incongruent    -0.1224  -0.17890   -0.0609
##  BF4 Congruent - BF4 Incongruent    -0.0697  -0.11884   -0.0240
##  BF1 Incongruent - BF2 Incongruent   0.1438   0.08799    0.2000
##  BF1 Incongruent - BF3 Incongruent   0.2435   0.19492    0.2899
##  BF1 Incongruent - BF4 Incongruent   0.2957   0.24368    0.3449
##  BF2 Incongruent - BF3 Incongruent   0.1013   0.02934    0.1738
##  BF2 Incongruent - BF4 Incongruent   0.1524   0.07600    0.2293
##  BF3 Incongruent - BF4 Incongruent   0.0516  -0.01850    0.1191
##
## SC = Surprise:
##  contrast                          estimate lower.HPD upper.HPD
##  BF1 Congruent - BF2 Congruent       0.2552   0.20116    0.3061
##  BF1 Congruent - BF3 Congruent       0.3607   0.31800    0.4112
##  BF1 Congruent - BF4 Congruent       0.4308   0.38522    0.4784
##  BF1 Congruent - BF1 Incongruent     0.0244  -0.01648    0.0619
##  BF1 Congruent - BF2 Incongruent     0.1898   0.09369    0.2826
##  BF1 Congruent - BF3 Incongruent     0.2747   0.19121    0.3616
##  BF1 Congruent - BF4 Incongruent     0.3013   0.21352    0.3998
##  BF2 Congruent - BF3 Congruent       0.1047   0.03761    0.1781
##  BF2 Congruent - BF4 Congruent       0.1738   0.10725    0.2468
##  BF2 Congruent - BF1 Incongruent    -0.2302  -0.29010   -0.1587
##  BF2 Congruent - BF2 Incongruent    -0.0681  -0.14027    0.0140
##  BF2 Congruent - BF3 Incongruent     0.0168  -0.08702    0.1098
##  BF2 Congruent - BF4 Incongruent     0.0469  -0.05754    0.1469
##  BF3 Congruent - BF4 Congruent       0.0686   0.00805    0.1367
##  BF3 Congruent - BF1 Incongruent    -0.3365  -0.39746   -0.2790
##  BF3 Congruent - BF2 Incongruent    -0.1722  -0.28552   -0.0772
##  BF3 Congruent - BF3 Incongruent    -0.0893  -0.16195   -0.0213
##  BF3 Congruent - BF4 Incongruent    -0.0593  -0.15902    0.0363
##  BF4 Congruent - BF1 Incongruent    -0.4058  -0.46263   -0.3442
##  BF4 Congruent - BF2 Incongruent    -0.2400  -0.34569   -0.1359
##  BF4 Congruent - BF3 Incongruent    -0.1577  -0.26298   -0.0704
##  BF4 Congruent - BF4 Incongruent    -0.1283  -0.20336   -0.0587
##  BF1 Incongruent - BF2 Incongruent   0.1642   0.07679    0.2521
##  BF1 Incongruent - BF3 Incongruent   0.2489   0.17045    0.3220
##  BF1 Incongruent - BF4 Incongruent   0.2767   0.19663    0.3616
##  BF2 Incongruent - BF3 Incongruent   0.0877  -0.03519    0.1919
##  BF2 Incongruent - BF4 Incongruent   0.1139   0.00548    0.2377
##  BF3 Incongruent - BF4 Incongruent   0.0269  -0.10537    0.1244
##
## Point estimate displayed: median
## HPD interval probability: 0.95
```

```
#get the posterior draws from the contrasts
cont_posterior <- gather_emmeans_draws(cont)

#plot
ggplot(cont_posterior,
       aes(y = contrast, x = .value)) +
  stat_halfeye() +
  facet_wrap(~SC) +
  geom_vline(xintercept = 0, color = "red", lty = 2)
```



```
# Control experiment
```

```
control_cor_df$blk <- factor(control_cor_df$block)

control_cor_df$zrt <- scale(control_cor_df$rt) |>
  as.numeric()

control_cor_df$CT <- control_cor_df$is_congruent_trial |>
  as.factor()

control_cor_df$BF <- control_cor_df$blk
control_cor_df$BL <- control_cor_df$block

control_cor_df$movie_id <- factor(control_cor_df$movie_id)
control_cor_df$subj_id <- factor(control_cor_df$subj_id)


dc <- control_cor_df |>
  dplyr::select(zrt, CT, BL, BF, subj_id, movie_id)
```

```
## Adding missing grouping variables: `subj_name`
```

```
c3 <- brm(
  bf(zrt ~ CT * BL +
       (1 + CT * BL | subj_id) + (1 | movie_id)
```

```r
  ),
  algorithm = "meanfield",
  family = brms::asym_laplace(),
  iter = 20000, # Increase the number of iterations
  init = 0.01,
  data = dc
)
```

```
## Compiling Stan program...
```

```
## Trying to compile a simple C file
```

```
## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## using C compiler: ‘Apple clang version 14.0.3 (clang-1403.0.22.14.1)’
## using SDK: ‘MacOSX13.3.sdk’
## clang -arch arm64 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG   -I"/Library/Frame
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeade
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## namespace Eigen {
## ^
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
## namespace Eigen {
##                 ^
##                 ;
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeade
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/Core:96
## #include <complex>
##          ^~~~~~~~~
## 3 errors generated.
## make: *** [foo.o] Error 1
```

```
## Start sampling
```

```
## Chain 1: ------------------------------------------------------------
## Chain 1: EXPERIMENTAL ALGORITHM:
## Chain 1:   This procedure has not been thoroughly tested and may be unstable
## Chain 1:   or buggy. The interface is subject to change.
## Chain 1: ------------------------------------------------------------
## Chain 1:
## Chain 1:
## Chain 1:
## Chain 1: Gradient evaluation took 0.008785 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 87.85 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Begin eta adaptation.
```

```
## Chain 1: Iteration:   1 / 250 [  0%]  (Adaptation)
## Chain 1: Iteration:  50 / 250 [ 20%]  (Adaptation)
## Chain 1: Iteration: 100 / 250 [ 40%]  (Adaptation)
## Chain 1: Iteration: 150 / 250 [ 60%]  (Adaptation)
## Chain 1: Iteration: 200 / 250 [ 80%]  (Adaptation)
## Chain 1: Success! Found best value [eta = 1] earlier than expected.
## Chain 1:
## Chain 1: Begin stochastic gradient ascent.
## Chain 1:   iter             ELBO   delta_ELBO_mean   delta_ELBO_med   notes
## Chain 1:    100       -26834.126             1.000            1.000
## Chain 1:    200       -26134.424             0.513            1.000
## Chain 1:    300       -25621.156             0.349            0.027
## Chain 1:    400       -25513.701             0.263            0.027
## Chain 1:    500       -25239.639             0.212            0.020
## Chain 1:    600       -25221.502             0.177            0.020
## Chain 1:    700       -25255.717             0.152            0.011
## Chain 1:    800       -25050.032             0.134            0.011
## Chain 1:    900       -25031.850             0.119            0.008   MEDIAN ELBO CONVERGED
## Chain 1:
## Chain 1: Drawing a sample of size 1000 from the approximate posterior...
## Chain 1: COMPLETED.
```

```
## Warning: Pareto k diagnostic value is 7.11. Resampling is disabled. Decreasing
## tol_rel_obj may help if variational algorithm has terminated prematurely.
## Otherwise consider using sampling instead.
```

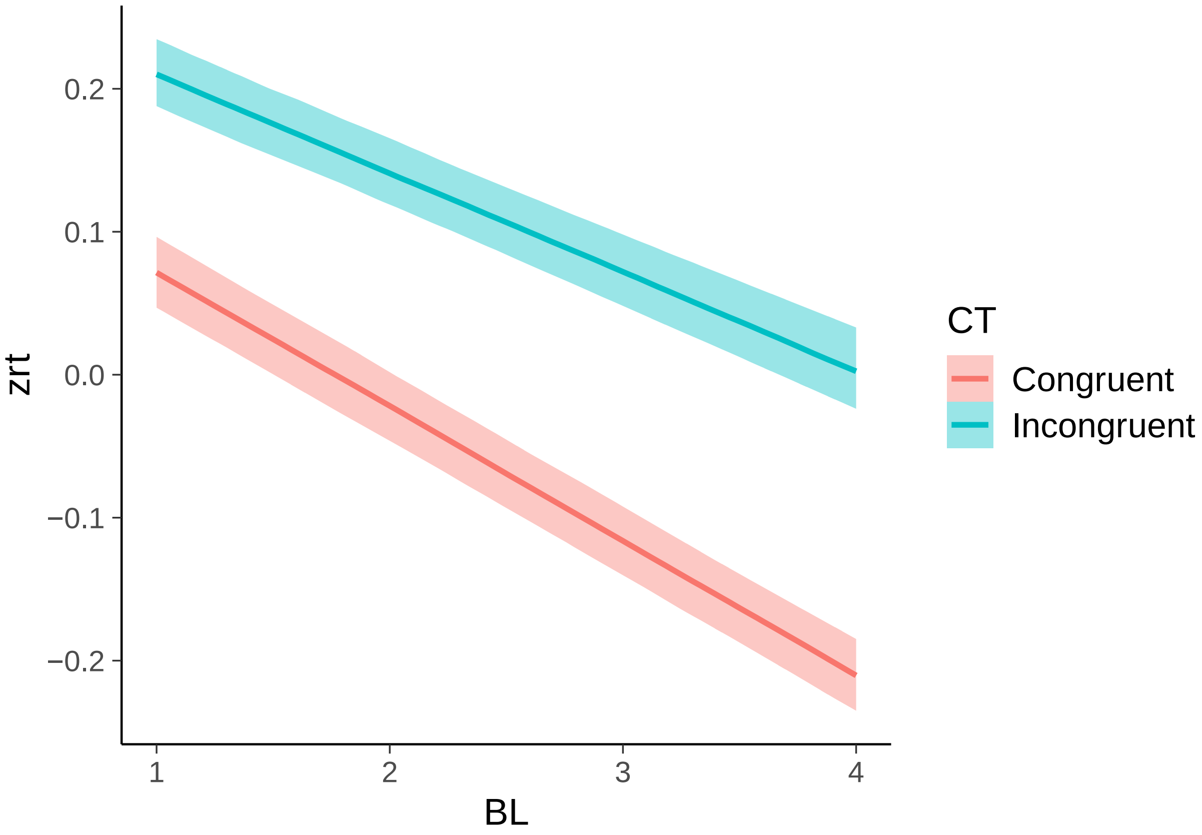
```
loo_c3 <- loo(c3)

print(loo_c3)
```

```
##
## Computed from 1000 by 23818 log-likelihood matrix
##
##          Estimate    SE
## elpd_loo -24703.5 150.0
## p_loo       360.2   2.9
## looic     49407.0 300.1
## ------
## Monte Carlo SE of elpd_loo is 0.6.
##
## Pareto k diagnostic values:
##                          Count Pct.    Min. n_eff
## (-Inf, 0.5]   (good)     23817 100.0%  550
##  (0.5, 0.7]   (ok)           1   0.0%  889
##    (0.7, 1]   (bad)          0   0.0%  <NA>
##    (1, Inf)   (very bad)     0   0.0%  <NA>
##
## All Pareto k estimates are ok (k < 0.7).
## See help('pareto-k-diagnostic') for details.
```

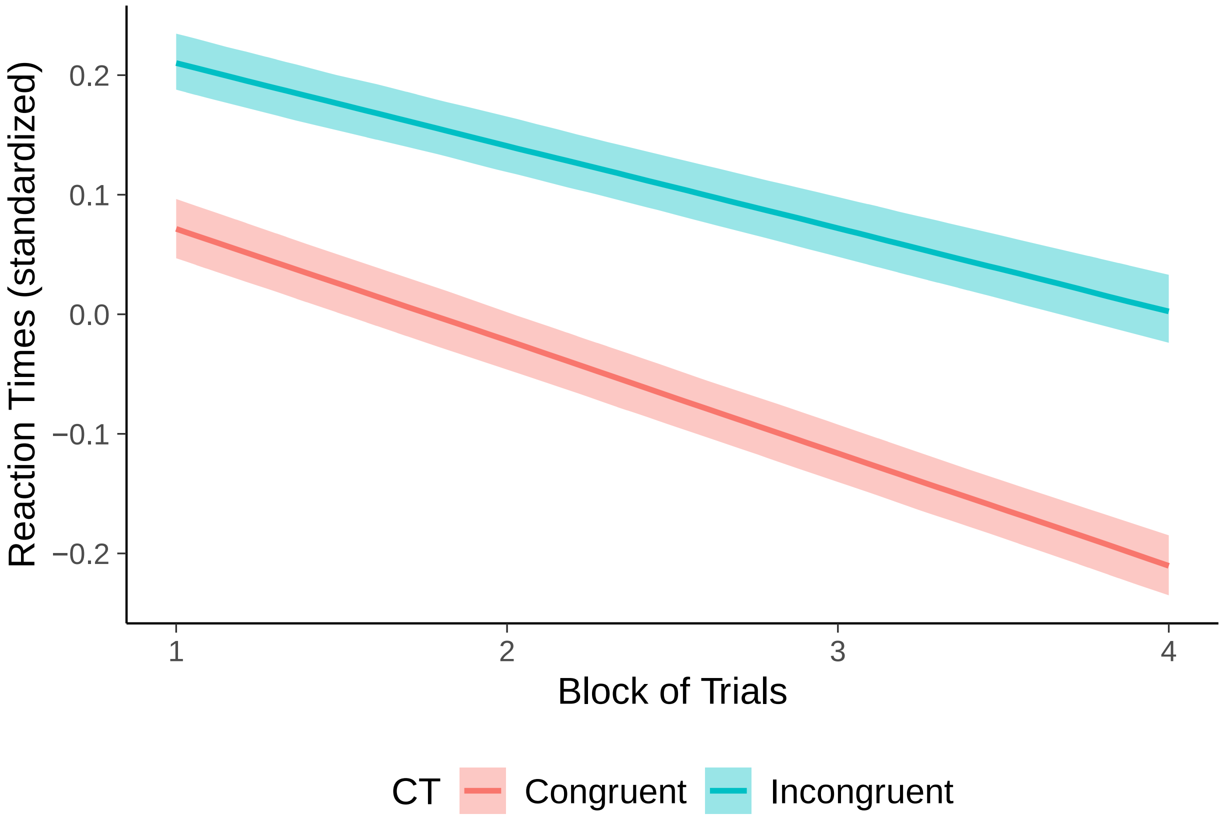
```
summary(c3)
```

```
##  Family: asym_laplace
##   Links: mu = identity; sigma = identity; quantile = identity
## Formula: zrt ~ CT * BL + (1 + CT * BL | subj_id) + (1 | movie_id)
##    Data: dc (Number of observations: 23818)
##   Draws: 1 chains, each with iter = 1000; warmup = 0; thin = 1;
##          total post-warmup draws = 1000
##
## Group-Level Effects:
## ~movie_id (Number of levels: 10)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     0.01      0.00     0.00     0.01 1.00     1006      982
##
## ~subj_id (Number of levels: 81)
##                                     Estimate Est.Error l-95% CI u-95% CI Rhat
## sd(Intercept)                           0.50      0.00     0.50     0.51 1.00
## sd(CTIncongruent)                       0.28      0.00     0.27     0.29 1.00
## sd(BL)                                  0.06      0.00     0.06     0.06 1.00
## sd(CTIncongruent:BL)                    0.00      0.00     0.00     0.00 1.00
## cor(Intercept,CTIncongruent)           -0.66      0.01    -0.68    -0.63 1.00
## cor(Intercept,BL)                      -0.63      0.02    -0.67    -0.58 1.00
## cor(CTIncongruent,BL)                   0.07      0.03     0.01     0.12 1.00
## cor(Intercept,CTIncongruent:BL)         0.11      0.38    -0.60     0.80 1.00
## cor(CTIncongruent,CTIncongruent:BL)    -0.13      0.44    -0.86     0.71 1.00
## cor(BL,CTIncongruent:BL)               -0.00      0.43    -0.78     0.79 1.00
##                                     Bulk_ESS Tail_ESS
## sd(Intercept)                            938      994
## sd(CTIncongruent)                        977      868
## sd(BL)                                  1126      992
## sd(CTIncongruent:BL)                     915      981
## cor(Intercept,CTIncongruent)            1003      972
## cor(Intercept,BL)                        921     1009
## cor(CTIncongruent,BL)                   1002      981
## cor(Intercept,CTIncongruent:BL)         1082      983
## cor(CTIncongruent,CTIncongruent:BL)      881     1017
## cor(BL,CTIncongruent:BL)                1015      871
##
## Population-Level Effects:
##                  Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept           -0.37      0.01    -0.39    -0.36 1.00      952      944
## CTIncongruent        0.11      0.01     0.09     0.14 1.00      982      944
## BL                  -0.09      0.00    -0.10    -0.09 1.00      992      923
## CTIncongruent:BL     0.02      0.00     0.02     0.03 1.00     1041      858
##
## Family Specific Parameters:
##          Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma        0.20      0.00     0.20     0.20 1.00      842      890
## quantile     0.25      0.00     0.24     0.25 1.00     1046      871
##
## Draws were sampled using variational(meanfield).
```

```
mod_c <- c3

conditional_effects(mod_c, "BL:CT")
```



```r
# Two-way interaction
c_eff <- conditional_effects(mod_c, "BL:CT")
plot(c_eff, plot = FALSE)[[1]] +
  theme(legend.position = "bottom") +
  labs(
    y = "Reaction Times (standardized)",
    x = "Block of Trials"
  )
```



```r
# No interaction
c4 <- brm(
  bf(zrt ~ CT + BL +
       (1 + CT + BL | subj_id) + (1 | movie_id)
  ),
  algorithm = "meanfield",
  family = brms::asym_laplace(),
  iter = 20000, # Increase the number of iterations
  init = 0.1,
  data = dc
)
```

```
## Compiling Stan program...
```

```
## Trying to compile a simple C file
```

```
## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## using C compiler: ‘Apple clang version 14.0.3 (clang-1403.0.22.14.1)’
## using SDK: ‘MacOSX13.3.sdk’
## clang -arch arm64 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG   -I"/Library/Frame
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeade
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Cor
## namespace Eigen {
## ^
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/src/Cor
## namespace Eigen {
##                ^
##                ;
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/StanHeade
## In file included from /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen
## /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/library/RcppEigen/include/Eigen/Core:96
## #include <complex>
##          ^~~~~~~~~
## 3 errors generated.
## make: *** [foo.o] Error 1
```

```
## Start sampling
```

```
## Chain 1: ------------------------------------------------------------
## Chain 1: EXPERIMENTAL ALGORITHM:
## Chain 1:   This procedure has not been thoroughly tested and may be unstable
## Chain 1:   or buggy. The interface is subject to change.
## Chain 1: ------------------------------------------------------------
## Chain 1:
## Chain 1:
## Chain 1:
## Chain 1: Gradient evaluation took 0.016007 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 160.07 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Begin eta adaptation.
## Chain 1: Iteration:   1 / 250 [  0%]  (Adaptation)
## Chain 1: Iteration:  50 / 250 [ 20%]  (Adaptation)
## Chain 1: Iteration: 100 / 250 [ 40%]  (Adaptation)
## Chain 1: Iteration: 150 / 250 [ 60%]  (Adaptation)
## Chain 1: Iteration: 200 / 250 [ 80%]  (Adaptation)
## Chain 1: Success! Found best value [eta = 1] earlier than expected.
## Chain 1:
## Chain 1: Begin stochastic gradient ascent.
## Chain 1:   iter             ELBO   delta_ELBO_mean   delta_ELBO_med   notes
## Chain 1:    100       -26378.298             1.000            1.000
## Chain 1:    200       -26012.581             0.507            1.000
## Chain 1:    300       -26083.200             0.339            0.014
## Chain 1:    400       -25528.815             0.260            0.022
## Chain 1:    500       -25169.292             0.211            0.014
## Chain 1:    600       -25122.351             0.176            0.014
## Chain 1:    700       -25148.635             0.151            0.014
## Chain 1:    800       -25078.506             0.132            0.014
## Chain 1:    900       -25048.131             0.118            0.003   MEDIAN ELBO CONVERGED
## Chain 1:
## Chain 1: Drawing a sample of size 1000 from the approximate posterior...
## Chain 1: COMPLETED.
```

```
## Warning: Pareto k diagnostic value is 4.96. Resampling is disabled. Decreasing
```

```
## tol_rel_obj may help if variational algorithm has terminated prematurely.
## Otherwise consider using sampling instead.
```

```
loo_c4 <- loo(c4)

# Test of the interaction
comp <- loo_compare(loo_c3, loo_c4)
print(comp, digits = 2)
```

```
##    elpd_diff se_diff
## c3   0.00      0.00
## c4 -92.39     22.90
```

```
message("\n20_variational_inference.R: done!")
```

```
##
## 20_variational_inference.R: done!
```

```
# Accuracy modeling
```

```
# TODO

# Get the accuracy split by congruency.
flanker_accuracy <- get_flanker_accuracy(flanker_data, overall = FALSE)
```

```
## `summarise()` has grouped output by 'experiment', 'subj_id'. You can override
## using the `.groups` argument.
```

```
flanker_accuracy |>
  group_by(experiment, is_congruent_trial) |>
  summarize(
    acc = mean(accuracy)
  )
```

```
## `summarise()` has grouped output by 'experiment'. You can override using the
## `.groups` argument.
```

```
## # A tibble: 4 x 3
## # Groups:   experiment [2]
##   experiment is_congruent_trial   acc
##   <fct>      <chr>              <dbl>
## 1 control    Congruent          0.967
## 2 control    Incongruent        0.954
## 3 surprise   Congruent          0.963
## 4 surprise   Incongruent        0.961
```

```
# eof ----
```