

```

library(tidyverse)

## -- Attaching core tidyverse packages ----- tidyverse 2.0.0 --
## v dplyr     1.2.0     v readr     2.1.6
## v forcats   1.0.1     v stringr   1.6.0
## v ggplot2   4.0.2     v tibble    3.3.1
## v lubridate 1.9.5     v tidyverse 1.3.2
## v purrr    1.2.1
## -- Conflicts ----- tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()   masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors

library(brms)

## Loading required package: Rcpp
## Loading 'brms' package (version 2.23.0). 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

library(bayesplot)

## This is bayesplot version 1.15.0
## - Online documentation and vignettes at mc-stan.org/bayesplot
## - bayesplot theme set to bayesplot::theme_default()
##   * Does _not_ affect other ggplot2 plots
##   * See ?bayesplot_theme_set for details on theme setting
##
## Attaching package: 'bayesplot'
##
## The following object is masked from 'package:brms':
##
##     rhat

library(loo)

## This is loo version 2.9.0
## - Online documentation and vignettes at mc-stan.org/loo
## - As of v2.0.0 loo defaults to 1 core but we recommend using as many as possible. Use the 'cores' argument to change this.

options(mc.cores = parallel::detectCores())
rstan::rstan_options(auto_write = TRUE)

```

```

df_p1 <- read.csv("/Users/debarpita/Desktop/arjun/trial_wise_dataset_post.csv")
df_p2 <- read.csv("/Users/debarpita/Desktop/arjun/trial_wise_dataset_pre.csv")

df <- bind_rows(df_p1, df_p2)

df <- df %>%
  filter(!is.na(Reward), Reward != 0)
df <- df %>%
  group_by(Participant_ID, stim_cat, env) %>%
  arrange(patch_id, .by_group = TRUE) %>%
  mutate(patch_number = patch_id) %>%
  ungroup()

# Remove patches with zero cumulative reward
df <- df %>%
  group_by(Participant_ID, stim_cat, env, patch_number) %>%
  filter(min(TotalCumulativeReward, na.rm = TRUE) > 0) %>%
  ungroup()

# Z-score predictors
df <- df %>%
  mutate(
    patch_number_z = scale(patch_number)[,1],
    trait_anxiety_score_z = scale(trait_anxiety_score)[,1]
  )

summary(df$TotalCumulativeReward)

##      Min. 1st Qu. Median      Mean 3rd Qu.      Max.
##        91     1769    3231     3840     5449    11883

df %>%
  group_by(stim_cat, env) %>%
  summarise(
    n = n(),
    min_cum = min(TotalCumulativeReward, na.rm = TRUE),
    max_cum = max(TotalCumulativeReward, na.rm = TRUE),
    mean_cum = mean(TotalCumulativeReward, na.rm = TRUE),
    .groups = "drop"
  )

## # A tibble: 4 x 6
##   stim_cat   env     n min_cum max_cum mean_cum
##   <chr>     <int> <int>    <int>    <int>    <dbl>
## 1 post       1    1417     182    11883    4970.
## 2 post       2    1335     184    11840    5360.
## 3 pre        1    1309      91     6217    2488.
## 4 pre        2    1097      91     4514    2144.

```

Model 1: Learning Across Patches Do participants increase cumulative reward across patches within each environment, and does stimulation alter the rate of reward growth? Because cumulative reward is strictly positive and right-skewed, we use a Gamma regression with log link.

```

model1 <- brm(
  TotalCumulativeReward ~ patch_number_z * stim_cat + env +
  (1 | Participant_ID),
  data = df,
  family = Gamma(link = "log"),
  chains = 4,
  iter = 4000,
  warmup = 1500,
  cores = 4,
  seed = 123
)

## 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 17.0.0 (clang-1700.6.3.2)'
## using SDK: 'MacOSX26.2.sdk'
## clang -arch arm64 -std=gnu2x -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG -I"/Li
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.5-arm64/Resources/library/StanHeade
## In file included from /Library/Frameworks/R.framework/Versions/4.5-arm64/Resources/library/RcppEigen
## In file included from /Library/Frameworks/R.framework/Versions/4.5-arm64/Resources/library/RcppEigen
## /Library/Frameworks/R.framework/Versions/4.5-arm64/Resources/library/RcppEigen/include/Eigen/src/Core
##   679 | #include <cmath>
##       |           ^
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling

summary(model1)

## Family: gamma
## Links: mu = log
## Formula: TotalCumulativeReward ~ patch_number_z * stim_cat + env + (1 | Participant_ID)
## Data: df (Number of observations: 5158)
## Draws: 4 chains, each with iter = 4000; warmup = 1500; thin = 1;
##        total post-warmup draws = 10000
##
## Multilevel Hyperparameters:
## ~Participant_ID (Number of levels: 21)
##             Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)    0.47      0.08     0.34     0.66 1.00     1224     2214
##
## Regression Coefficients:
##                               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS
## Intercept                  10.53      0.11     10.31    10.75 1.00      976
## patch_number_z                1.14      0.02      1.10     1.17 1.00     3027
## stim_catpre                 -1.05      0.01     -1.08    -1.02 1.00     4556
## env                          -1.36      0.02     -1.40    -1.31 1.00     3412

```

```

## patch_number_z:stim_catpre -0.34      0.02     -0.38     -0.31 1.00      3792
##                                     Tail_ESS
## Intercept                         1455
## patch_number_z                      4262
## stim_catpre                        5216
## env                                4497
## patch_number_z:stim_catpre        4963
##
## Further Distributional Parameters:
##           Estimate   Est.Error  l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## shape       4.57      0.09      4.40      4.74 1.00      4500      4782
## 
## 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).

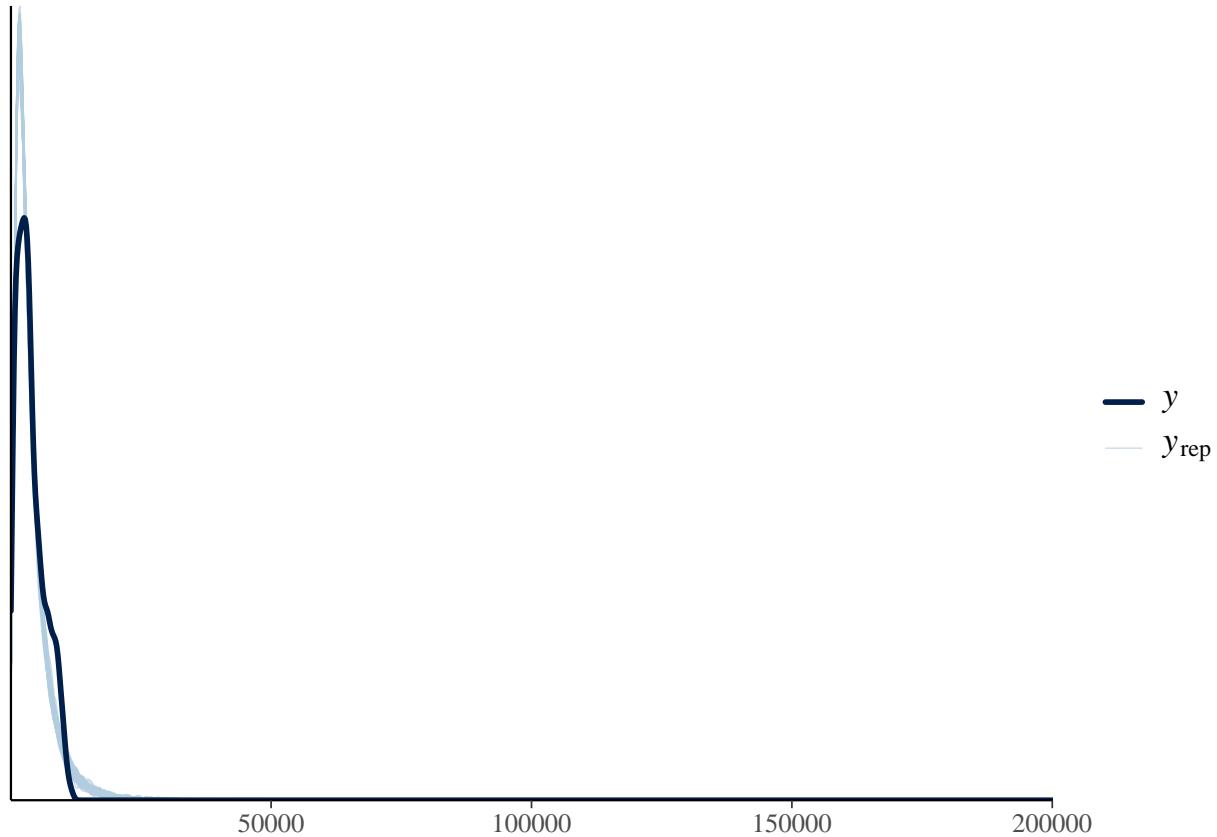
```

beta\_patch\_number\_z > 0: Cumulative reward increases across patches 4% increase

```
exp(fixef(model1))
```

	Estimate	Est.Error	Q2.5	Q97.5
## Intercept	3.746086e+04	1.116933	3.011070e+04	4.664710e+04
## patch_number_z	3.122599e+00	1.018267	3.016704e+00	3.235720e+00
## stim_catpre	3.503953e-01	1.013836	3.412160e-01	3.599415e-01
## env	2.572681e-01	1.024756	2.453699e-01	2.698190e-01
## patch_number_z:stim_catpre	7.085548e-01	1.015845	6.869153e-01	7.310267e-01

```
pp_check(model1, type = "dens_overlay", ndraws = 100)
```

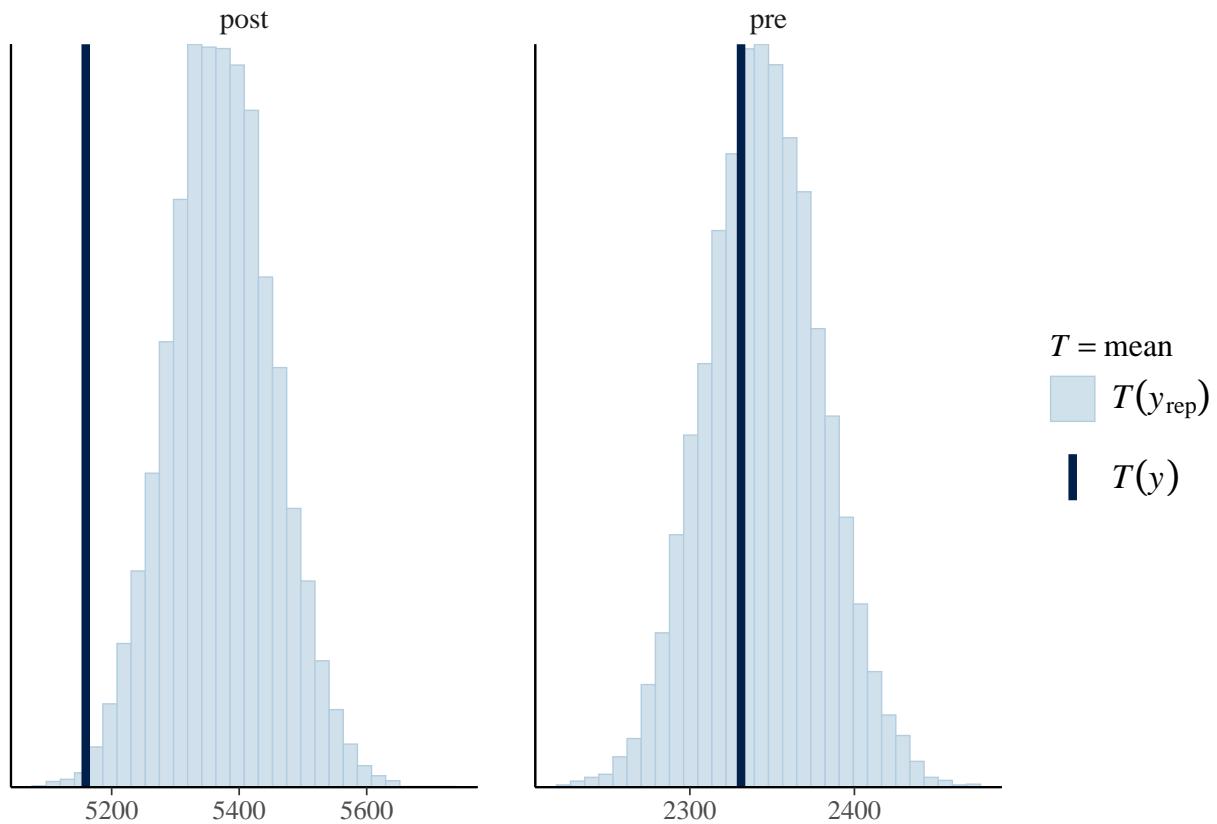


```
pp_check(model1, type = "stat_grouped", group = "stim_cat")
```

```
## Using all posterior draws for ppc type 'stat_grouped' by default.
```

```
## Note: in most cases the default test statistic 'mean' is too weak to detect anything of interest.
```

```
## 'stat_bin()' using 'bins = 30'. Pick better value 'binwidth'.
```



```

model2 <- brm(
  TotalCumulativeReward ~ patch_number_z * stim_cat *
    trait_anxiety_score_z + env +
  (1 | Participant_ID),
  data = df,
  family = Gamma(link = "log"),
  chains = 4,
  iter = 4000,
  warmup = 1500,
  cores = 4,
  seed = 123
)

## Compiling Stan program...

## recompiling to avoid crashing R session

## 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 17.0.0 (clang-1700.6.3.2)'
## using SDK: 'MacOSX26.2.sdk'
## clang -arch arm64 -std=gnu2x -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG -I"/Library/Frameworks/R.framework/Resources/include"
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.5-arm64/Resources/library/StanHeaders/include StanHeaders.h

```

```

## In file included from /Library/Frameworks/R.framework/Versions/4.5-arm64/Resources/library/RcppEigen
## In file included from /Library/Frameworks/R.framework/Versions/4.5-arm64/Resources/library/RcppEigen
## /Library/Frameworks/R.framework/Versions/4.5-arm64/Resources/library/RcppEigen/include/Eigen/src/Cor
##   679 | #include <cmath>
##       | ^~~~~~~
## 1 error generated.
## make: *** [foo.o] Error 1

## Start sampling

summary(model2)

## Family: gamma
## Links: mu = log
## Formula: TotalCumulativeReward ~ patch_number_z * stim_cat * trait_anxiety_score_z + env + (1 | Part
## Data: df (Number of observations: 5158)
## Draws: 4 chains, each with iter = 4000; warmup = 1500; thin = 1;
##         total post-warmup draws = 10000
##
## Multilevel Hyperparameters:
## ~Participant_ID (Number of levels: 21)
##             Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)    0.49     0.09     0.35     0.70 1.00      2592     4007
##
## Regression Coefficients:
##                                     Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept                      10.54     0.11    10.31
## patch_number_z                  1.14     0.02     1.11
## stim_catpre                     -1.05     0.01    -1.08
## trait_anxiety_score_z           0.01     0.11    -0.20
## env                            -1.37     0.02    -1.41
## patch_number_z:stim_catpre     -0.34     0.02    -0.37
## patch_number_z:trait_anxiety_score_z -0.02     0.01    -0.04
## stim_catpre:trait_anxiety_score_z -0.04     0.01    -0.06
## patch_number_z:stim_catpre:trait_anxiety_score_z -0.03     0.02    -0.06
## Intercept                      10.77     1.00    2489
## patch_number_z                  1.18     1.00    7767
## stim_catpre                     -1.02     1.00   10761
## trait_anxiety_score_z           0.22     1.00    3540
## env                            -1.32     1.00    8770
## patch_number_z:stim_catpre     -0.31     1.00    9509
## patch_number_z:trait_anxiety_score_z -0.01     1.00    8435
## stim_catpre:trait_anxiety_score_z -0.01     1.00   11198
## patch_number_z:stim_catpre:trait_anxiety_score_z -0.00     1.00    8400
## Intercept                      4155
## patch_number_z                  5753
## stim_catpre                     7263
## trait_anxiety_score_z           4376
## env                            6752
## patch_number_z:stim_catpre     6995
## patch_number_z:trait_anxiety_score_z 6949

```

```

## stim_catpre:trait_anxiety_score_z           6479
## patch_number_z:stim_catpre:trait_anxiety_score_z   6868
##
## Further Distributional Parameters:
##          Estimate   Est.Error  l-95% CI  u-95% CI Rhat Bulk_ESS Tail_ESS
## shape      4.59       0.09     4.42     4.77 1.00    10817    6896
##
## 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).

```

patch\_number\_z = 1.46- Participants clearly accumulate more reward over successive patches. Environment 2 has ~83% lower cumulative reward than Environment 1. patch\_number\_z:stim\_catpre = -0.30- The learning slope in pre-stim is 26% flatter than in post-stim Main anxiety effect: -0.01 -No overall anxiety effect on reward level stim × anxiety: -0.06 -Higher anxiety people have slightly lower cumulative reward in pre condition.

patch\_number\_z:stim\_catpre:trait\_anxiety\_score\_z = -0.05, CI excludes zero. In pre-stim condition, higher anxiety reduces learning slope. In post-stim condition, this anxiety-related reduction is attenuated. So stimulation may buffer anxiety-related learning deficits.

Random slope correlation = 0.95 -Participants who start with higher reward also show steeper learning slopes

```
pp_check(model2)
```

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

