```r
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 tidyr     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
```

```r
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
```

```r
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
```

```r
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' arg
```

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

```r
df_post <- read.csv("/Users/debarpita/Desktop/arjun/trial_wise_dataset_post.csv")
df_pre  <- read.csv("/Users/debarpita/Desktop/arjun/trial_wise_dataset_pre.csv")
df      <- bind_rows(df_post, df_pre)

df <- df %>%
  mutate(env = as.integer(env == 2))

df <- df %>% filter(Reward != 0)

df <- df %>%
  mutate(
    rew_base = ifelse(stim_cat == "post",  91, 181),
    rew_hi   = ifelse(stim_cat == "post",   9,  19)
  )

df <- df %>%
  group_by(Participant_ID, stim_cat, env) %>%
  mutate(
    R_min_empirical = min(Reward, na.rm = TRUE),
    R_max_empirical = max(Reward, na.rm = TRUE)
  ) %>%
  ungroup()


df <- df %>%
  group_by(Participant_ID, stim_cat, env) %>%
  arrange(patch_id, .by_group = TRUE) %>%
  mutate(patch_number = patch_id) %>%
  ungroup()

df <- df %>%
  group_by(Participant_ID, stim_cat, env) %>%
  mutate(
    Reward_rel_baseline = (Reward - rew_base) / (rew_hi + 1e-6),
    Reward_minmax_emp   = (Reward - R_min_empirical) /
                          (R_max_empirical - R_min_empirical + 1e-6)
  ) %>%
  ungroup()


df_nonzero <- df %>%
  group_by(Participant_ID, stim_cat, env) %>%
  arrange(patch_id, patch_number, .by_group = TRUE) %>%
  mutate(
    CumReward_raw          = cumsum(Reward),
    CumReward_rel_baseline = cumsum(Reward_rel_baseline),
    CumReward_minmax_emp   = cumsum(Reward_minmax_emp)
  ) %>%
  ungroup()

df_nonzero <- df_nonzero %>%
  group_by(Participant_ID, stim_cat, env) %>%
  mutate(
    patch_number_z = as.numeric(scale(patch_number))
  ) %>%
```

```r
  ungroup()
```

```r
df_nonzero <- df_nonzero %>%
  mutate(
    CumReward_raw_z          = scale(CumReward_raw)[, 1],
    CumReward_rel_baseline_z = scale(CumReward_rel_baseline)[, 1],
    CumReward_minmax_emp_z   = scale(CumReward_minmax_emp)[, 1],
    trait_anxiety_score_z    = scale(trait_anxiety_score)[, 1]
  )

cat(sprintf("Observations after dropping zero-reward trials: %d\n", nrow(df_nonzero)))
```

```
## Observations after dropping zero-reward trials: 5158
```

```r
df_nonzero %>%
  group_by(stim_cat, env) %>%
  summarise(
    n                = n(),
    mean_raw         = mean(CumReward_raw,          na.rm = TRUE),
    mean_rel_baseline = mean(CumReward_rel_baseline, na.rm = TRUE),
    mean_minmax_emp  = mean(CumReward_minmax_emp,   na.rm = TRUE),
    .groups = "drop"
  )
```

```
## # A tibble: 4 x 6
##   stim_cat   env     n mean_raw mean_rel_baseline mean_minmax_emp
##   <chr>    <int> <int>    <dbl>             <dbl>           <dbl>
## 1 post         0  1417    4772.              169.            20.7
## 2 post         1  1335    4574.              158.            19.7
## 3 pre          0  1309    2405.             -196.            19.5
## 4 pre          1  1097    1837.             -171.            15.9
```

```r
modelC1 <- brm(
  CumReward_rel_baseline_z ~ patch_number_z * stim_cat + env +
    (1 | Participant_ID),
  data    = df_nonzero,
  family  = gaussian(),
  chains  = 4,
  iter    = 4000,
  warmup  = 1500,
  cores   = 4,
  seed    = 123,
  file    = "modelC1_cum_rel_baseline_patches"
)

summary(modelC1)
```
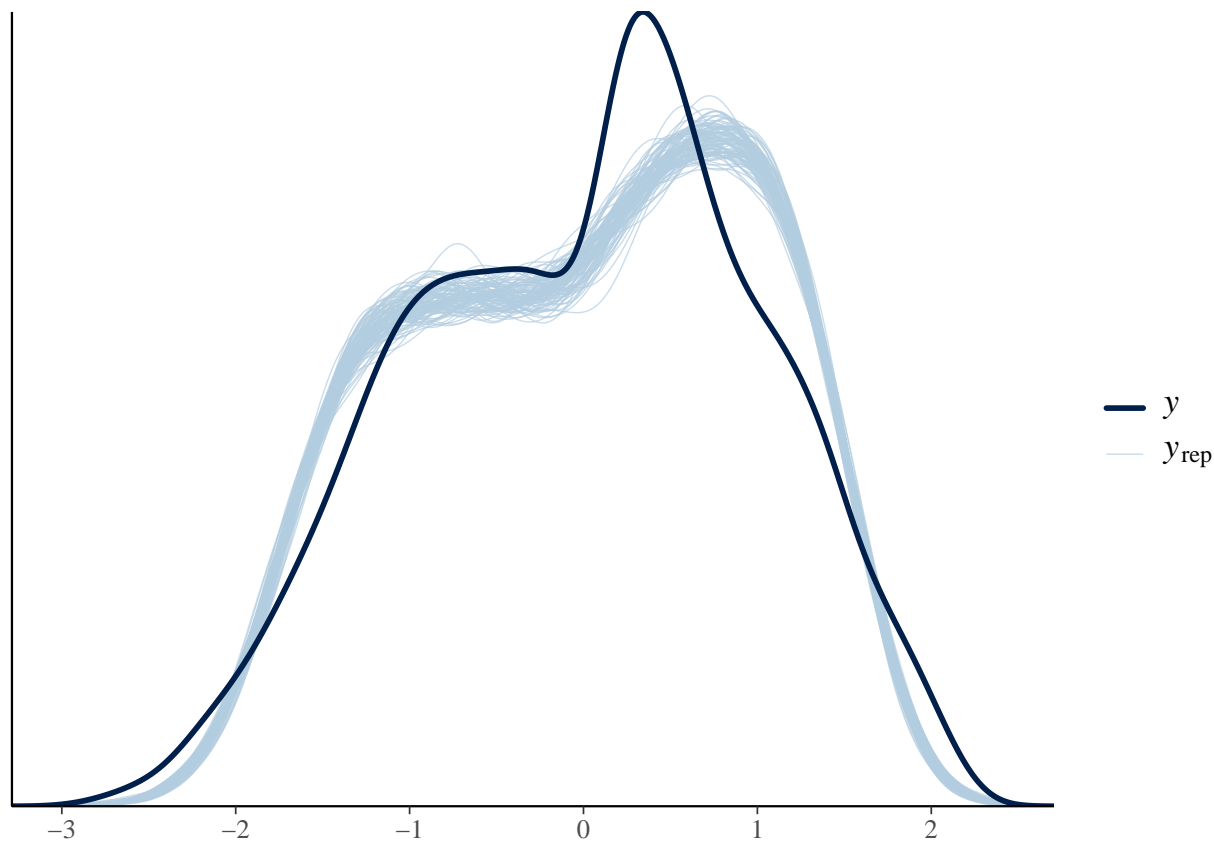
```
##  Family: gaussian
##   Links: mu = identity
## Formula: CumReward_rel_baseline_z ~ patch_number_z * stim_cat + env + (1 | Participant_ID)
##    Data: df_nonzero (Number of observations: 5158)
```

```
##  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)    0.19     0.03     0.14     0.27 1.00    1316     2252
##
## Regression Coefficients:
##                         Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS
## Intercept                   0.78      0.04     0.70     0.87 1.00      801
## patch_number_z              0.42      0.00     0.41     0.43 1.00     5339
## stim_catpre                -1.66      0.01    -1.68    -1.65 1.00     6318
## env                         0.03      0.01     0.02     0.04 1.00     6082
## patch_number_z:stim_catpre -0.92      0.01    -0.94    -0.91 1.00     5345
##                         Tail_ESS
## Intercept                   1386
## patch_number_z              6212
## stim_catpre                 5812
## env                         5182
## patch_number_z:stim_catpre  5778
##
## Further Distributional Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.24      0.00     0.24     0.25 1.00     6750     5263
##
## 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
pp_check(modelC1, type = "dens_overlay", ndraws = 100)
```

```r
modelC2 <- brm(
  CumReward_rel_baseline_z ~ patch_number_z * stim_cat * trait_anxiety_score_z + env +
    (1 | Participant_ID),
  data    = df_nonzero,
  family  = gaussian(),
  chains  = 4,
  iter    = 4000,
  warmup  = 1500,
  cores   = 4,
  seed    = 123,
  file    = "modelC2_cum_rel_baseline_anxiety"
)

summary(modelC2)
```

```
## Family: gaussian
##   Links: mu = identity
## Formula: CumReward_rel_baseline_z ~ patch_number_z * stim_cat * trait_anxiety_score_z + env + (1 | Pa
##    Data: df_nonzero (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
```
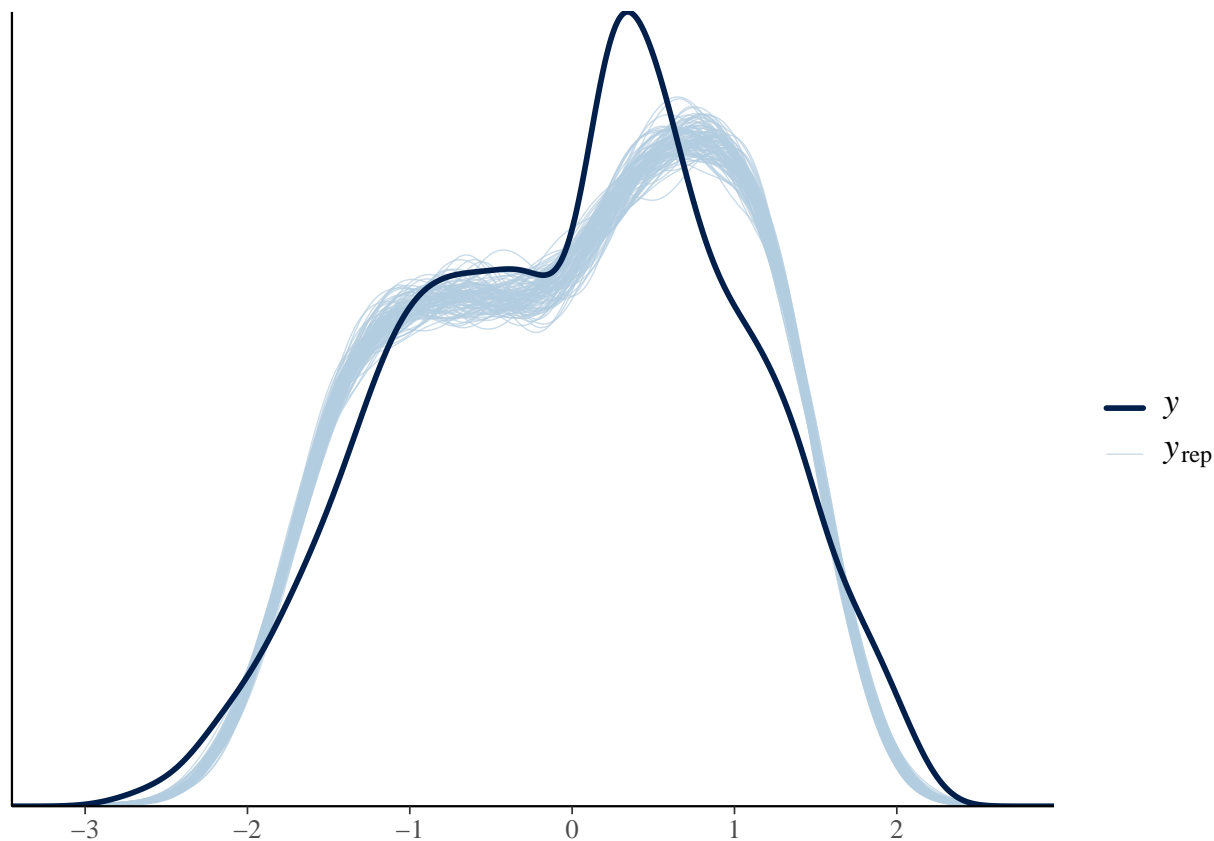
```
## sd(Intercept)      0.20      0.03      0.14      0.28 1.00      2382      3816
##
## Regression Coefficients:
##                                              Estimate Est.Error l-95% CI
## Intercept                                        0.78      0.04     0.69
## patch_number_z                                   0.42      0.00     0.41
## stim_catpre                                     -1.66      0.01    -1.68
## trait_anxiety_score_z                            0.00      0.04    -0.09
## env                                              0.03      0.01     0.02
## patch_number_z:stim_catpre                      -0.92      0.01    -0.94
## patch_number_z:trait_anxiety_score_z             0.00      0.00    -0.01
## stim_catpre:trait_anxiety_score_z               -0.02      0.01    -0.03
## patch_number_z:stim_catpre:trait_anxiety_score_z -0.00     0.01    -0.02
##                                              u-95% CI Rhat Bulk_ESS
## Intercept                                        0.87 1.00     2106
## patch_number_z                                   0.43 1.00     9537
## stim_catpre                                     -1.65 1.00    12682
## trait_anxiety_score_z                            0.09 1.00     2903
## env                                              0.04 1.00    12070
## patch_number_z:stim_catpre                      -0.91 1.00     9396
## patch_number_z:trait_anxiety_score_z             0.01 1.00     9548
## stim_catpre:trait_anxiety_score_z               -0.01 1.00    11897
## patch_number_z:stim_catpre:trait_anxiety_score_z 0.01 1.00     9529
##                                              Tail_ESS
## Intercept                                        2927
## patch_number_z                                   7696
## stim_catpre                                      7073
## trait_anxiety_score_z                            3748
## env                                              6431
## patch_number_z:stim_catpre                       7689
## patch_number_z:trait_anxiety_score_z             7520
## stim_catpre:trait_anxiety_score_z                7072
## patch_number_z:stim_catpre:trait_anxiety_score_z 7670
##
## Further Distributional Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.24      0.00     0.24     0.25 1.00    12081     6648
##
## 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
pp_check(modelC2, ndraws = 100)
```
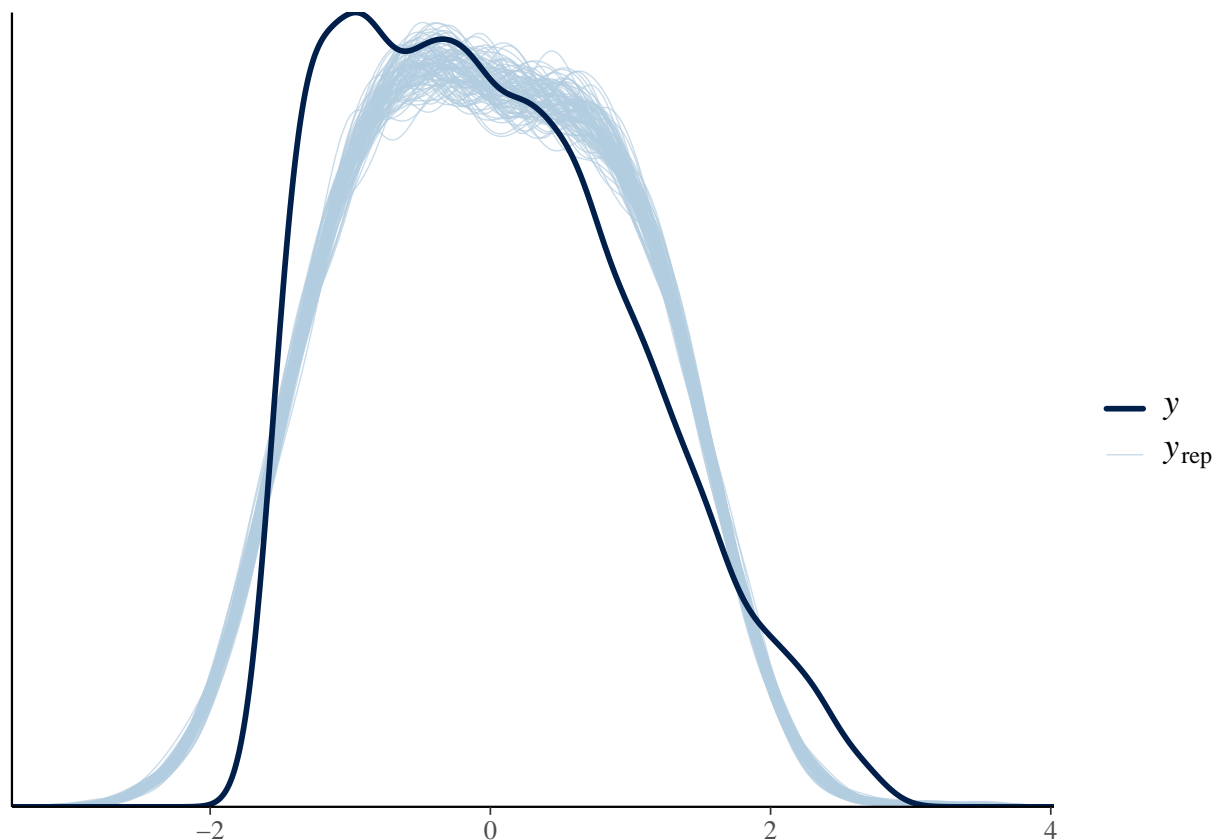
```r
modelD1 <- brm(
  CumReward_minmax_emp_z ~ patch_number_z * stim_cat + env +
    (1 | Participant_ID),
  data    = df_nonzero,
  family  = gaussian(),
  chains  = 4,
  iter    = 4000,
  warmup  = 1500,
  cores   = 4,
  seed    = 123,
  file    = "modelD1_cum_minmax_emp_patches"
)

summary(modelD1)
```

```
##  Family: gaussian
##   Links: mu = identity
## Formula: CumReward_minmax_emp_z ~ patch_number_z * stim_cat + env + (1 | Participant_ID)
##    Data: df_nonzero (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)       0.35        0.06        0.26        0.48 1.00        1231        2184
##
## Regression Coefficients:
##                           Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS
## Intercept                     0.12      0.08    -0.03     0.27 1.01      902
## patch_number_z                0.94      0.01     0.92     0.95 1.00     4785
## stim_catpre                  -0.21      0.01    -0.23    -0.19 1.00     5421
## env                          -0.19      0.01    -0.21    -0.18 1.00     6047
## patch_number_z:stim_catpre   -0.09      0.01    -0.10    -0.07 1.00     4685
##                           Tail_ESS
## Intercept                     1521
## patch_number_z                5440
## stim_catpre                   5297
## env                           5444
## patch_number_z:stim_catpre    5321
##
## Further Distributional Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.32      0.00     0.32     0.33 1.00     5620     5443
##
## 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).
```

```
pp_check(modelD1, type = "dens_overlay", ndraws = 100)
```

```r
modelD2 <- brm(
  CumReward_minmax_emp_z ~ patch_number_z * stim_cat * trait_anxiety_score_z + env +
    (1 | Participant_ID),
  data    = df_nonzero,
  family  = gaussian(),
  chains  = 4,
  iter    = 4000,
  warmup  = 1500,
  cores   = 4,
  seed    = 123,
  file    = "modelD2_cum_minmax_emp_anxiety"
)

summary(modelD2)
```

```
##  Family: gaussian
##   Links: mu = identity
## Formula: CumReward_minmax_emp_z ~ patch_number_z * stim_cat * trait_anxiety_score_z + env + (1 | Par
##    Data: df_nonzero (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)     0.36      0.06     0.26     0.50 1.00     2412     3880
##
## Regression Coefficients:
##                                               Estimate Est.Error l-95% CI
## Intercept                                         0.12      0.08    -0.04
## patch_number_z                                    0.93      0.01     0.92
## stim_catpre                                      -0.21      0.01    -0.23
## trait_anxiety_score_z                             0.06      0.08    -0.10
## env                                              -0.19      0.01    -0.21
## patch_number_z:stim_catpre                       -0.08      0.01    -0.10
## patch_number_z:trait_anxiety_score_z              0.03      0.01     0.02
## stim_catpre:trait_anxiety_score_z                -0.06      0.01    -0.08
## patch_number_z:stim_catpre:trait_anxiety_score_z -0.03      0.01    -0.05
##                                               u-95% CI Rhat Bulk_ESS
## Intercept                                         0.28 1.00     1963
## patch_number_z                                    0.95 1.00    10067
## stim_catpre                                      -0.19 1.00    11731
## trait_anxiety_score_z                             0.22 1.00     2863
## env                                              -0.18 1.00    11721
## patch_number_z:stim_catpre                       -0.07 1.00     9828
## patch_number_z:trait_anxiety_score_z              0.04 1.00    10504
## stim_catpre:trait_anxiety_score_z                -0.04 1.00    11130
## patch_number_z:stim_catpre:trait_anxiety_score_z -0.02 1.00     9879
##                                               Tail_ESS
## Intercept                                         3267
## patch_number_z                                    7638
## stim_catpre                                       6705
## trait_anxiety_score_z                             3820
```

```
## env                                          6973
## patch_number_z:stim_catpre                   7068
## patch_number_z:trait_anxiety_score_z         7500
## stim_catpre:trait_anxiety_score_z            7047
## patch_number_z:stim_catpre:trait_anxiety_score_z  7959
##
## Further Distributional Parameters:
##       Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma     0.32      0.00     0.32     0.33 1.00    12961     7763
##
## 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).
```

```
pp_check(modelD2, ndraws = 100)
```