

# PESI analysis with brms

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## Introduction

The PESI project focuses on “Perception of nonverbal social interaction in people with and without autism”. Specifically, autistic and non-autistic adult participants watched 64 silent videos of dyadic conversations between two non-autistic or one autistic and one non-autistic adult. These videos were 10 seconds of longer conversations and either portrayed moments of high or low interpersonal synchrony of motion. The videos only showed outlines of the dyad to direct the focus on the movement. During the video presentation, participants’ gaze is tracked and after each video they are asked to rate how comfortable they imagine this interaction to be.

We preregistered the following hypotheses:

1. Ratings
  - (a) Dyad type: Social interactions of no-diagnosis non-autistic dyads are rated more positively than mixed-diagnosis dyads consisting of one autistic and one non-autistic interaction partner.
  - (b) Synchrony: Social interactions with high interpersonal synchrony of motion energy are rated more positively than social interactions with low interpersonal synchrony of motion energy.
  - (c) Diagnostic status: Ratings of social interactions differ between autistic and non-autistic participants.
  - (d) Synchrony x dyad type: The effect of interpersonal motion synchrony on ratings is decreased for mixed-diagnosis dyads compared to no-diagnosis dyads.
  - (e) Dyad type x diagnostic status: The effect of dyad type on ratings is decreased in autistic compared to non-autistic participants.
2. Fixation duration in areas of interest (AOI)
  - (a) Dyad type x AOI: Fixation durations for each area of interest differ between clips of no-diagnosis and mixed-diagnosis dyads.
  - (b) Synchrony x AOI: Fixation durations for each area of interest differ between high and low synchrony clips.
  - (c) Diagnostic status x AOI: Fixation durations for each area of interest differ between autistic and non-autistic participants.

## Some general settings

```
# number of simulations
nsim = 500

# set number of iterations and warmup for models
iter = 4500
warm = 1500
```

```
# set the seed
set.seed(2468)
```

## Package versions

```
## [1] "R version 4.4.2 (2024-10-31)"
## [1] "knitr version 1.46"
## [1] "ggplot2 version 3.5.1"
## [1] "brms version 2.21.0"
## [1] "designr version 0.1.13"
## [1] "bridgesampling version 1.1.2"
## [1] "tidyverse version 2.0.0"
## [1] "ggpubr version 0.6.0"
## [1] "ggrain version 0.0.4"
## [1] "bayesplot version 1.11.1"
## [1] "SBC version 0.3.0.9000"
## [1] "rstatix version 0.7.2"
## [1] "readODS version 2.3.0"
## [1] "BayesFactor version 0.9.12.4.7"
```

## General info

We planned to determine the group-level effect subjects following Barr (2013). For each model, experiment specific priors were set based on previous literature or the task (see comments in the code).

We perform prior predictive checks as proposed in Schad, Betancourt and Vasishth (2020) using the SBC package. To do so, we create simulated datasets where parameters are simulated from the priors. These parameters are used to create one fake dataset. Both the true underlying parameters and the simulated values are saved.

Then, we create graphs showing the prior predictive distribution of the simulated discrimination threshold to check whether our priors fit our general expectations about the data. Next, we perform checks of computational faithfulness and model sensitivity as proposed by Schad, Betancourt and Vasishth (2020) and implemented in the SBC package. We create models for each of the simulated datasets. Last, we calculate performance metrics for each of these models, focusing on the population-level parameters.

## Preparation and group comparisons

First, we load the data and combine it with demographic information including the diagnostic status of the subjects. Then, all predictors are set to sum contrasts. We have a look at the demographics describing our two diagnostic groups: autistic adults and adults without any neurological and psychiatric diagnoses.

Since this is sensitive data, we load the anonymised version of the processed data at this point but also leave the code we used to create it.

```
# check if the data file exists, if yes load it:
if (!file.exists("PESI_data.RData")) {

  # set file paths
  fl.path = '/media/emba/emba-2/PESI'
  dt.path = paste(fl.path, 'BVET', sep = "/")

  # read in list of participants
  df.inc = read_ods(file.path(fl.path, "PESI_inc.ods"), range = "A1:K100") %>%
    select(subID, include_BV, include_ET)
```

```

# create an anonymisation key
df.inc = df.inc %>%
  mutate(
    PID    = subID,
    subID = as.numeric(as.factor(subID))
  )
df.recode = df.inc %>% select(PID, subID) %>% distinct()
recode = as.character(df.recode$subID)
names(recode) = df.recode$PID

# filter out pilots and cancelled testings
df.inc = df.inc %>%
  filter(include_BV == 1)

# load the relevant data in long format
df.beh = list.files(path = dt.path, pattern = "PESI-BV", full.names = T) %>%
  map_df(~read_delim(., show_col_types = F, delim = ",",
                      col_types = "cddcccccddd")) %>%
  select(-dyad, -sync) %>%
  filter(subID %in% df.inc$PID) %>%
  group_by(subID) %>%
  mutate(
    no_trials = n()
  ) %>%
# filter out participants where not the full task was recorded > no participants
  filter(no_trials == 64)

# load demographic information to get diagnostic status
df.sub = read_csv(file.path(dt.path, "PESI_centraXX.csv"), show_col_types = F) %>%
  mutate(
    diagnosis = recode(diagnosis, "CTR" = "COMP")
  )

# load PST values
df.pst = read_csv(file.path(dt.path, "PST_simult-params.csv"), show_col_types = F) %>%
  rename("subID" = "ID") %>% select(-group)

# load the stimulus description file
df.stm = read_csv(paste(f1.path, "PESI_videosel-full_230404.csv",
                        sep = "/"), show_col_types = F) %>%
  mutate(
    video = sprintf("PESI_%s_%08d", substr(dyad, 1, 3), frame_sta),
    dyad.type = case_match(context,
                           "homogeneous" ~ "non-autistic",
                           "heterogeneous" ~ "mixed")
  ) %>%
  select(video, dyad, sync, dyad.type, mot, peak, s1peak, s2peak)

# merge together
df = merge(df.beh, df.stm, all.x = T, by = "video") %>%
  mutate(
    # only use trials with confirmed rating and correct video duration
    use = if_else(confirmed == 1 & abs(dur-10) < 0.1, 1, 0),

```

```

rating.confirmed = if_else(use == 1, rating, NA)
) %>%
arrange(subID, trl)

# merge with group information and PST values
df = merge(df.sub %>% select(subID, diagnosis), df, all.y = T) %>%
merge(., df.pst, all.x = T) %>%
mutate_if(is.character, as.factor)

# check how many participants per group need to be excluded
df.exc = df %>%
group_by(subID, diagnosis) %>%
summarise(
  total = sum(use)/64
) %>%
filter(total <= 2/3) %>%
group_by(diagnosis) %>%
summarise(
  n = n()
)

# exclude participants with more than 33% of trials missing
df = df %>%
group_by(subID) %>%
mutate(
  total = sum(use)/64
) %>%
filter(total > 2/3)

# get a list of the subIDs
subIDs = unique(df$subID)

# anonymise the data
df$subID = str_replace_all(df$subID, recode)

# load preprocessed eye tracking data and rename variables
df.fix = readRDS(file.path(dt.path, "PESI-ET_fix.rds")) %>%
rename(
  "trl" = "on_trialNo", "video" = "on_trialVid"
)
df.sac.agg = readRDS(file.path(dt.path, "PESI-ET_sac.rds")) %>%
rename(
  "trl" = "on_trialNo", "video" = "on_trialVid"
)

# add information on the videos to the eye tracking data
df.fix = merge(df.fix, df.stm, all.x = T) %>%
# add diagnostic group
merge(., df.sub %>% select(subID, diagnosis), all.x = T) %>%
mutate(across(where(is.character), as.factor))
df.sac.agg = merge(df.sac.agg, df.stm, all.x = T) %>%
# add diagnostic group
merge(., df.sub %>% select(subID, diagnosis), all.x = T) %>%

```

```

    mutate(across(where(is.character), as.factor))

# add subjects to the subIDs
subIDs = unique(c(subIDs, df.fix$subID))
subIDs = unique(c(subIDs, df.sac.agg$subID))

# get numbers of participants included in ET per group and gender identity
df.incET = merge(df.fix %>%
                  select(subID, diagnosis) %>%
                  distinct(),
                  df.sub %>% select(subID, gender)
                  ) %>%
group_by(diagnosis, gender) %>%
summarise(
  n = n()
)

# anonymise ET data in the same way as the behavioural data
df.fix$subID      = str_replace_all(df.fix$subID, recode)
df.sac.agg$subID = str_replace_all(df.sac.agg$subID, recode)

# remove participants not included in the behavioural or the eye tracking
# analysis from the subjects data frame
df.sub = df.sub %>%
  filter(subID %in% subIDs) %>%
  merge(., df.pst, all.x = T)

# print gender frequencies and compare them across groups
tb.gen = xtabs(~ gender + diagnosis, data = df.sub)
ct.full = contingencyTableBF(tb.gen, sampleType = "indepMulti", fixedMargin = "cols")

# check which outcomes of interest are normally distributed
df.sht = df.sub %>%
  group_by(diagnosis) %>%
  shapiro_test(age, CFT_iq, BDI_total, STAITT_total, RAADS_total, ISH_total,
               UI_total, sw_gz, sw_kl, thre, steep) %>%
  arrange(variable) %>%
  mutate(
    sig = if_else(p < 0.05, "*", "")
  )

# some of the measures are not normally distributed;
# therefore, we compute ranks for these outcomes
df.sub = df.sub %>%
  mutate(
    rBDI    = rank(BDI_total),
    rISH    = rank(Ish_total),
    rRAADS = rank(RAADS_total),
    rUI     = rank(UI_total),
    rage    = rank(age),
    rsw_kl = rank(sw_kl),
    rsteep = rank(stEEP),
    rthre   = rank(thre),
  )

```

```

    diagnosis = as.factor(diagnosis)
)

# now we can compute our ttests
ostt.age     = ttestBF(formula = rage           ~ diagnosis, data = df.sub)
ostt.iq      = ttestBF(formula = CFT_iq        ~ diagnosis, data = df.sub)
ostt.kl      = ttestBF(formula = sw_gz         ~ diagnosis, data = df.sub)
ostt.gz      = ttestBF(formula = rsw_kl        ~ diagnosis, data = df.sub)
ostt.STAITT   = ttestBF(formula = STAITT_total ~ diagnosis, data = df.sub)
ostt.BDI      = ttestBF(formula = rBDI          ~ diagnosis, data = df.sub)
ostt.ISH      = ttestBF(formula = rISH          ~ diagnosis, data = df.sub)
ostt.RAADS    = ttestBF(formula = rRAADS        ~ diagnosis, data = df.sub)
ostt.UI       = ttestBF(formula = rUI           ~ diagnosis, data = df.sub)
ostt.thre    = ttestBF(formula = rthre         ~ diagnosis, data = df.sub)
ostt.steep   = ttestBF(formula = rsteep        ~ diagnosis, data = df.sub)

# ...and put everything in a new dataframe for printing
measurement  = "Age"
ASD          = sprintf("%.2f (%.2f)",
                      mean(df.sub[df.sub$diagnosis == "ASD",]$age),
                      sd(df.sub[df.sub$diagnosis == "ASD",]$age) /
                      sqrt(nrow(df.sub[df.sub$diagnosis == "ASD",]))))
COMP         = sprintf("%.2f (%.2f)",
                      mean(df.sub[df.sub$diagnosis == "COMP",]$age),
                      sd(df.sub[df.sub$diagnosis == "COMP",]$age) /
                      sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))))
logBF10     = sprintf("%.3f", ostt.age@bayesFactor[["bf"]])
df.table    = data.frame(measurement, ASD, COMP, logBF10)
df.table    = rbind(df.table,
                   c(
                     "BDI",
                     sprintf("%.2f (%.2f)",
                             mean(df.sub[df.sub$diagnosis == "ASD",]$BDI_total),
                             sd(df.sub[df.sub$diagnosis == "ASD",]$BDI_total) /
                             sqrt(nrow(df.sub[df.sub$diagnosis == "ASD",]))),
                     sprintf("%.2f (%.2f)",
                             mean(df.sub[df.sub$diagnosis == "COMP",]$BDI_total),
                             sd(df.sub[df.sub$diagnosis == "COMP",]$BDI_total) /
                             sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))),
                     sprintf("%.3f", ostt.BDI@bayesFactor[["bf"]]))
                   ),
                   c(
                     "Gender (diverse/agender/non-binary - female - male)",
                     sprintf("%d - %d - %d",
                             nrow(df.sub[df.sub$diagnosis == "ASD" &
                                         df.sub$gender == "dan",]),
                             nrow(df.sub[df.sub$diagnosis == "ASD" &
                                         df.sub$gender == "fem",]),
                             nrow(df.sub[df.sub$diagnosis == "ASD" &
                                         df.sub$gender == "mal",])),
                     sprintf("%d - %d - %d",
                             nrow(df.sub[df.sub$diagnosis == "COMP" &
                                         df.sub$gender == "dan",]),

```

```

        nrow(df.sub[df.sub$diagnosis == "COMP" &
                     df.sub$gender == "fem",]),
        nrow(df.sub[df.sub$diagnosis == "COMP" &
                     df.sub$gender == "mal",])),
        sprintf("%.3f", ct.full@bayesFactor[["bf"]])
),
c(
  "IQ",
  sprintf("%.2f (%.2f)",
         mean(df.sub[df.sub$diagnosis == "ASD",]$CFT_iq),
         sd(df.sub[df.sub$diagnosis == "ASD",]$CFT_iq) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "ASD",]))),
  sprintf("%.2f (%.2f)",
         mean(df.sub[df.sub$diagnosis == "COMP",]$CFT_iq),
         sd(df.sub[df.sub$diagnosis == "COMP",]$CFT_iq) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))),
  sprintf("%.3f", ostt.iq@bayesFactor[["bf"]])
),
c(
  "RAADS",
  sprintf("%.2f (%.2f)",
         mean(df.sub[df.sub$diagnosis == "ASD",]$RAADS_total),
         sd(df.sub[df.sub$diagnosis == "ASD",]$RAADS_total) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "ASD",]))),
  sprintf("%.2f (%.2f)",
         mean(df.sub[df.sub$diagnosis == "COMP",]$RAADS_total),
         sd(df.sub[df.sub$diagnosis == "COMP",]$RAADS_total) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))),
  sprintf("%.3f", ostt.RAADS@bayesFactor[["bf"]])
),
c(
  "D2 - concentration performance",
  sprintf("%.2f (%.2f)",
         mean(df.sub[df.sub$diagnosis == "ASD",]$sw_kl),
         sd(df.sub[df.sub$diagnosis == "ASD",]$sw_kl) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "ASD",]))),
  sprintf("%.2f (%.2f)",
         mean(df.sub[df.sub$diagnosis == "COMP",]$sw_kl),
         sd(df.sub[df.sub$diagnosis == "COMP",]$sw_kl) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))),
  sprintf("%.3f", ostt.kl@bayesFactor[["bf"]])
),
c(
  "D2 - speed",
  sprintf("%.2f (%.2f)",
         mean(df.sub[df.sub$diagnosis == "ASD",]$sw_gz),
         sd(df.sub[df.sub$diagnosis == "ASD",]$sw_gz) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "ASD",]))),
  sprintf("%.2f (%.2f)",
         mean(df.sub[df.sub$diagnosis == "COMP",]$sw_gz),
         sd(df.sub[df.sub$diagnosis == "COMP",]$sw_gz) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))),
  sprintf("%.3f", ostt.gz@bayesFactor[["bf"]])
)

```

```

),
c(
  "STAI-trait",
  sprintf("%.2f (%.2f)",
    mean(df.sub[df.sub$diagnosis == "ASD",]$STAITT_total),
    sd(df.sub[df.sub$diagnosis == "ASD",]$STAITT_total) /
      sqrt(nrow(df.sub[df.sub$diagnosis == "ASD",]))),
  sprintf("%.2f (%.2f)",
    mean(df.sub[df.sub$diagnosis == "COMP",]$STAITT_total),
    sd(df.sub[df.sub$diagnosis == "COMP",]$STAITT_total) /
      sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))),
  sprintf("%.3f", ostt.STAITT@bayesFactor[["bf"]])
),
c(
  "Ishihara",
  sprintf("%.2f (%.2f)",
    mean(df.sub[df.sub$diagnosis == "ASD",]$ISH_total),
    sd(df.sub[df.sub$diagnosis == "ASD",]$ISH_total) /
      sqrt(nrow(df.sub[df.sub$diagnosis == "ASD",]))),
  sprintf("%.2f (%.2f)",
    mean(df.sub[df.sub$diagnosis == "COMP",]$ISH_total),
    sd(df.sub[df.sub$diagnosis == "COMP",]$ISH_total) /
      sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))),
  sprintf("%.3f", ostt.ISH@bayesFactor[["bf"]])
),
c(
  "UI",
  sprintf("%.2f (%.2f)",
    mean(df.sub[df.sub$diagnosis == "ASD",]$UI_total),
    sd(df.sub[df.sub$diagnosis == "ASD",]$UI_total) /
      sqrt(nrow(df.sub[df.sub$diagnosis == "ASD",]))),
  sprintf("%.2f (%.2f)",
    mean(df.sub[df.sub$diagnosis == "COMP",]$UI_total),
    sd(df.sub[df.sub$diagnosis == "COMP",]$UI_total) /
      sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))),
  sprintf("%.3f", ostt.UI@bayesFactor[["bf"]])
),
c(
  "PST - threshold",
  sprintf("%.2f (%.2f)",
    mean(df.sub[df.sub$diagnosis == "ASD",]$thre,
      na.rm = T),
    sd(df.sub[df.sub$diagnosis == "ASD",]$thre,
      na.rm = T) /
      sqrt(nrow(df.sub[df.sub$diagnosis == "ASD" &
        !is.na(df.sub$thre),]))),
  sprintf("%.2f (%.2f)",
    mean(df.sub[df.sub$diagnosis == "COMP",]$thre,
      na.rm = T),
    sd(df.sub[df.sub$diagnosis == "COMP",]$thre,
      na.rm = T) /
      sqrt(nrow(df.sub[df.sub$diagnosis == "COMP" &
        !is.na(df.sub$thre),]))),

```

```

    sprintf("%.3f", ostt.thre@bayesFactor[["bf"]])
),
c(
  "PST - steepness",
  sprintf("%.2f (%.2f)", mean(df.sub[df.sub$diagnosis == "ASD",]$steep,
                                na.rm = T),
         sd(df.sub[df.sub$diagnosis == "ASD",]$steep,
              na.rm = T) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "ASD" &
                           !is.na(df.sub$steep),]))),
  sprintf("%.2f (%.2f)", mean(df.sub[df.sub$diagnosis == "COMP",]$steep,
                                na.rm = T),
         sd(df.sub[df.sub$diagnosis == "COMP",]$steep,
              na.rm = T) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "COMP" &
                           !is.na(df.sub$steep),]))),
  sprintf("%.3f", ostt.steep@bayesFactor[["bf"]])
)
) %>% arrange(measurement)

# save it all
df = df %>% select(subID, diagnosis, dyad, video, run, trl, sync, rating,
                     dyad.type, mot, peak, rating.confirmed, thre, steep, s1peak, s2peak)
save(df, df.table, df.sht, ct.full, df.exc, df.incET, df.fix, df.sac.agg,
      file = "PESI_data.RData")

} else {

  load("PESI_data.RData")

}

# print the group of included participants
kable(df %>% select(subID, diagnosis) %>% distinct() %>% group_by(diagnosis) %>% count())

```

diagnosis	n
ASD	27
COMP	36

```
# print the group of excluded participants
kable(df.exc)
```

diagnosis	n
ASD	5
COMP	2

```
rm(df.exc)
```

```
# print number of included participants in eye tracking
kable(df.incET)
```

diagnosis	gender	n
ASD	fem	10
ASD	mal	9
COMP	fem	17
COMP	mal	9

```
rm(df.incET)
```

```
# print the outcome of the shapiro tests
kable(df.sht)
```

diagnosis	variable	statistic	p	sig
ASD	BDI_total	0.8702525	0.0020434	*
COMP	BDI_total	0.8485989	0.0001460	*
ASD	CFT_iq	0.9318967	0.0616085	
COMP	CFT_iq	0.9540986	0.1308021	
ASD	ISH_total	0.4497204	0.0000000	*
COMP	ISH_total	0.4886485	0.0000000	*
ASD	RAADS_total	0.8252280	0.0002451	*
COMP	RAADS_total	0.8207023	0.0000350	*
ASD	STAITT_total	0.9650488	0.4344732	
COMP	STAITT_total	0.9647118	0.2837083	
ASD	UI_total	0.9130345	0.0203844	*
COMP	UI_total	0.8950080	0.0021478	*
ASD	age	0.9369153	0.0832609	
COMP	age	0.9454093	0.0686750	
ASD	steep	0.3956361	0.0000000	*
COMP	steep	0.5832662	0.0000000	*
ASD	sw_gz	0.9469503	0.1524481	
COMP	sw_gz	0.9540400	0.1302352	
ASD	sw_kl	0.9493858	0.1764397	
COMP	sw_kl	0.9395341	0.0445818	*
ASD	thre	0.8266074	0.0003265	*
COMP	thre	0.9488862	0.1339931	

```
rm(df.sht)
```

```
# print the outcome of the contingency table
ct.full@bayesFactor
```

```
##                                bf error                  time      code
## Non-indep. (a=1) -0.69531      0 Thu Nov  7 08:53:30 2024 1a874ad27788
# aggregate the data due to large differences between videos
df.agg = df %>%
  group_by(subID, diagnosis, dyad, sync, dyad.type) %>%
  summarise(
    rating.confirmed = mean(rating.confirmed, na.rm = T)
```

```

) %>% ungroup() %>%
  mutate_if(is.character, as.factor)
df.fix.agg = df.fix %>%
  group_by(subID, diagnosis, dyad, sync, dyad.type, AOI) %>%
  summarise(
    fix.dur      = median(fix.dur, na.rm = T),
    fix.total   = median(fix.total),
    fix.prop    = fix.dur*100/fix.total
  ) %>% ungroup() %>%
  mutate_if(is.character, as.factor)

# set and print the contrasts
contrasts(df.agg$sync) = contr.sum(2)
contrasts(df.agg$sync)

##      [,1]
## high     1
## low    -1

contrasts(df.agg$dyad.type) = contr.sum(2)
contrasts(df.agg$dyad.type)

##      [,1]
## mixed      1
## non-autistic -1

contrasts(df.agg$diagnosis) = contr.sum(2)
contrasts(df.agg$diagnosis)

##      [,1]
## ASD      1
## COMP    -1

contrasts(df.fix$sync) = contr.sum(2)
contrasts(df.fix$sync)

##      [,1]
## high     1
## low    -1

contrasts(df.fix$dyad.type) = contr.sum(2)
contrasts(df.fix$dyad.type)

##      [,1]
## mixed      1
## non-autistic -1

contrasts(df.fix$diagnosis) = contr.sum(2)
contrasts(df.fix$diagnosis)

##      [,1]
## ASD      1
## COMP    -1

contrasts(df.fix.agg$sync) = contr.sum(2)
contrasts(df.fix.agg$sync)

##      [,1]

```

```

## high    1
## low   -1
contrasts(df.fix.agg$dyad.type) = contr.sum(2)
contrasts(df.fix.agg$dyad.type)

##          [,1]
## mixed      1
## non-autistic -1
contrasts(df.fix.agg$diagnosis) = contr.sum(2)
contrasts(df.fix.agg$diagnosis)

##          [,1]
## ASD      1
## COMP   -1
contrasts(df.fix.agg$AOI) = contr.sum(3)[c(3,2,1),]
contrasts(df.fix.agg$AOI)

##          [,1] [,2]
## body   -1   -1
## hand    0    1
## head    1    0
contrasts(df.sac.agg$sync) = contr.sum(2)
contrasts(df.sac.agg$sync)

##          [,1]
## high    1
## low   -1
contrasts(df.sac.agg$dyad.type) = contr.sum(2)
contrasts(df.sac.agg$dyad.type)

##          [,1]
## mixed      1
## non-autistic -1
contrasts(df.sac.agg$diagnosis) = contr.sum(2)
contrasts(df.sac.agg$diagnosis)

##          [,1]
## ASD      1
## COMP   -1
# print final group comparisons for the paper
kable(df.table)

```

measurement	ASD	COMP	logBF10
Age	28.66 ( $\pm 1.26$ )	27.70 ( $\pm 0.92$ )	-1.297
BDI	16.59 ( $\pm 2.39$ )	4.78 ( $\pm 0.80$ )	10.761
D2 - concentration performance	100.93 ( $\pm 2.53$ )	104.70 ( $\pm 1.68$ )	-0.434
D2 - speed	100.86 ( $\pm 2.43$ )	105.11 ( $\pm 1.65$ )	-0.455
Gender (diverse/agender/non-binary - female - male)	0 - 12 - 17	0 - 20 - 17	-0.695
IQ	112.31 ( $\pm 3.97$ )	114.19 ( $\pm 2.14$ )	-1.289
Ishihara	29.03 ( $\pm 0.43$ )	28.30 ( $\pm 0.56$ )	0.024
PST - steepness	-0.14 ( $\pm 0.04$ )	-0.12 ( $\pm 0.01$ )	-1.370

measurement	ASD	COMP	logBF10
PST - threshold	47.09 ( $\pm 3.47$ )	44.18 ( $\pm 2.15$ )	-1.239
RAADS	31.48 ( $\pm 1.52$ )	7.32 ( $\pm 0.91$ )	31.083
STAI-trait	51.59 ( $\pm 2.10$ )	30.54 ( $\pm 1.59$ )	19.636
UI	65.45 ( $\pm 2.38$ )	37.70 ( $\pm 1.73$ )	23.287

The two diagnostic groups are similar in age, concentration and speed (D2), colorblindness score (Ishihara), IQ and gender distribution as well as on a perceptual simultaneity task (PST). However, they seem to differ in their questionnaire scores measuring depressive symptoms (BDI), autism-like traits (RAADS), trait anxiety (STAI-trait) and intolerance of uncertainty (UI).

## Hypothesis-guided analysis

### Aggregated ratings

After each video, participants were asked to rate the interaction on a continuous scale for “How comfortable to you imagine this interaction to be?” (from 0 “not at all” to 100 “very”).

### SBC

To achieve good posterior fit, we aggregated the rating data. First, we attempted to run a model including all main effects as slopes as well as the interaction of sync and dyad type for subjects. However, all models including random slopes had major divergence issues. Even the model only including the intercepts on the group-level had some divergent transitions. Nonetheless, we opted to include both the intercept for the dyads and the subjects, and look out for problems with the actual model.

```
# set formula considering all combinations
code = "PESI_int"
f.pesi = brms::bf(rating.confirmed ~ diagnosis * sync * dyad.type
+ (1 | subID) + (1 | dyad))

# set weakly informed priors
priors = c(
  prior(normal(50, 10), class = Intercept),
  prior(normal(0, 10), class = sigma),
  prior(normal(0, 10), class = sd),
  # differences due to dyad.type
  prior(normal(-5, 5), class = b, coef = dyad.type1), # mixed
  # differences due to synchrony
  prior(normal(5, 5), class = b, coef = sync1), # high
  # effect of synchrony decreased when mixed dyad
  prior(normal(-5, 5), class = b, coef = sync1:dyad.type1),
  # effect of dyad type decreased in autistic subjects
  prior(normal(-5, 5), class = b, coef = diagnosis1:dyad.type1),
  # no specific expectations for diagnostic groups and other interactions
  prior(normal(0, 5), class = b)
)

if (file.exists(file.path(cache_dir, paste0("df_res_", code, ".rds")))) {
  # load in the results of the SBC
  df.results = readRDS(file.path(cache_dir, paste0("df_res_", code, ".rds")))
  df.backend = readRDS(file.path(cache_dir, paste0("df_div_", code, ".rds")))
  dat       = readRDS(file.path(cache_dir, paste0("dat_", code, ".rds")))
}
```

```

} else {
  # set the seed
  set.seed(2469)
  # create the data
  gen = SBC_generator_brms(f.pesi, data = df.agg, prior = priors,
                           thin = 50, warmup = 20000, refresh = 2000
  )
  dat = generate_datasets(gen, nsim)
  saveRDS(dat, file = sprintf("%s/dat_%s.rds", cache_dir, code))

  # perform the SBC
  bck = SBC_backend_brms_from_generator(gen, chains = 4, thin = 1,
                                         warmup = warm, iter = iter,
                                         inits = 0.1)
  res = compute_SBC(dat, bck,
                     cache_mode = "results",
                     cache_location = file.path(cache_dir, sprintf("res_%s", code)))
  # save the results dataframes
  df.results = res$stats
  df.backend = res$backend_diagnostics
  saveRDS(df.results, file = file.path(cache_dir, paste0("df_res_", code, ".rds")))
  saveRDS(df.backend, file = file.path(cache_dir, paste0("df_div_", code, ".rds")))

}

```

We start by investigating the rhats and the number of divergent samples. This shows that 14 of 500 simulations had at least one parameter that had an rhat of at least 1.05, and 186 models had divergent samples (mean number of samples of the simulations with divergent samples: 7.85). We will have to watch out for this.

Next, we can plot the simulated values to perform prior predictive checks.

```

# create a matrix out of generated data
dvname = gsub(" ", "", gsub("[\\|~].*", "", f.pesi)[1])
dvfakemat = matrix(NA, nrow=dat[["generated"]][[1]]), length(dat[["generated"]]))
for (i in 1:length(dat[["generated"]])) {
  dvfakemat[,i] = dat[["generated"]][[i]][[dvname]]
}
truePars = dat$variables

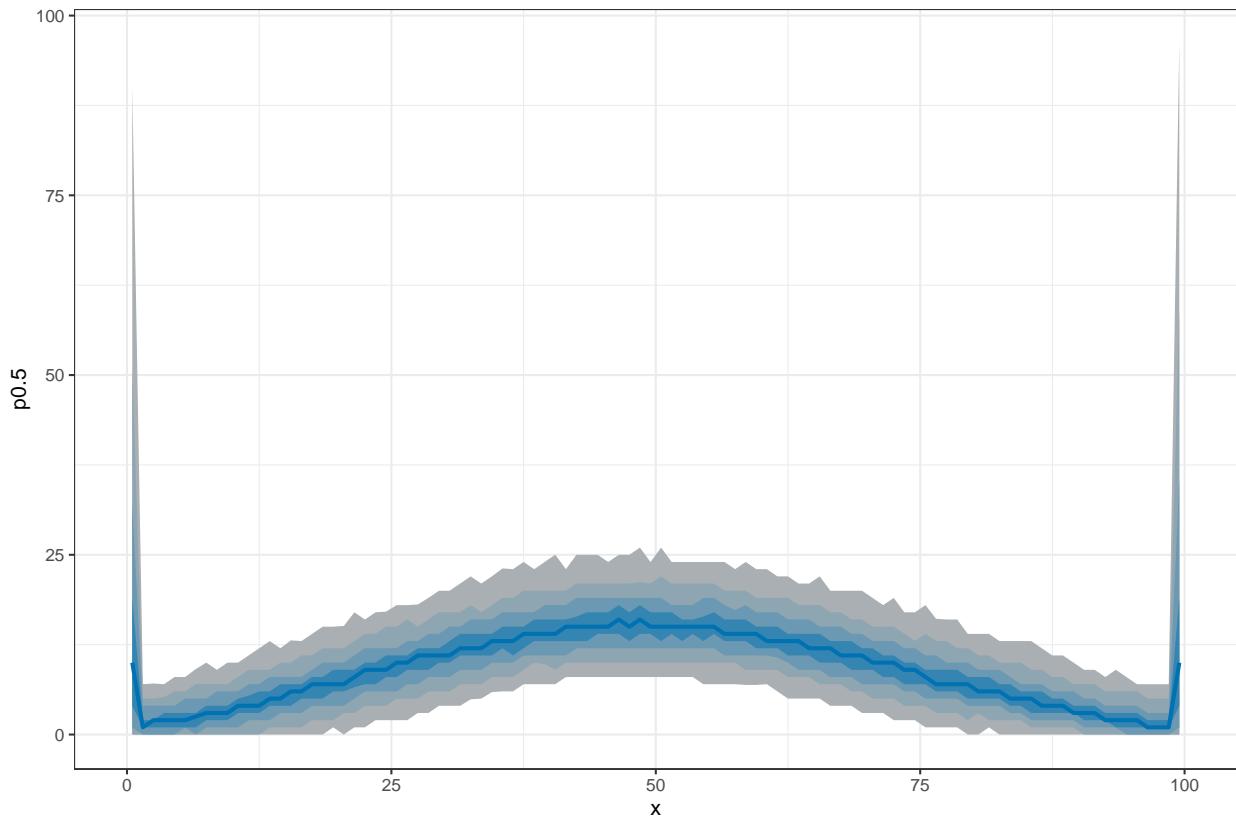
# plot simulated data for prior predictive checks
dvmax = 100
dvfakemath = dvfakemat;
dvfakemath[dvfakemath > dvmax] = dvmax
dvfakemath[dvfakemath < 0] = 0
breaks = seq(0, max(dvfakemath, na.rm=T), length.out = 100)
binwidth = round(breaks[2] - breaks[1])
breaks = seq(0, max(dvfakemath), by = binwidth)
histmat = matrix(NA, ncol = dim(dvfakemath)[2] + binwidth, nrow = length(breaks)-1)
for (i in 1:dim(dvfakemath)[2]) {
  histmat[,i] = hist(dvfakemath[,i], breaks = breaks, plot = F)$counts
}
probs = seq(0.1, 0.9, 0.1)
quantmat= as.data.frame(matrix(NA, nrow=dim(histmat)[1], ncol = length(probs)))
names(quantmat) = paste0("p", probs)
for (i in 1:dim(histmat)[1]) {

```

```

quantmat[i,] = quantile(histmat[i,], p = probs, na.rm = T)
}
quantmat$x = breaks[2:length(breaks)] - binwidth/2 # add bin mean
ggplot(data = quantmat, aes(x = x)) +
  geom_ribbon(aes(ymax = p0.9, ymin = p0.1), fill = c_light) +
  geom_ribbon(aes(ymax = p0.8, ymin = p0.2), fill = c_light_highlight) +
  geom_ribbon(aes(ymax = p0.7, ymin = p0.3), fill = c_mid) +
  geom_ribbon(aes(ymax = p0.6, ymin = p0.4), fill = c_mid_highlight) +
  geom_line(aes(y = p0.5), colour = c_dark, linewidth = 1) +
  xlim(0, max(dvfakemath)) +
  theme_bw()

```



The above figure shows the simulated data for the ratings. The data is centered around the middle of the rating scale. We had some outliers that were outside of the possible values (greater than 100 or smaller than 0), however, to keep our prior somewhat wide we chose to accept this in the simulated data.

```

# get simulation numbers with issues
rank = max(df.results$max_rank)
check = merge(df.results %>%
  group_by(sim_id) %>%
  summarise(
    rhat = max(rhat, na.rm = T),
    mean_rank = mean(max_rank)
  ) %>%
  filter(rhat >= 1.05 | mean_rank != rank),
  df.backend %>% filter(n_divergent > 0), all = T)

```

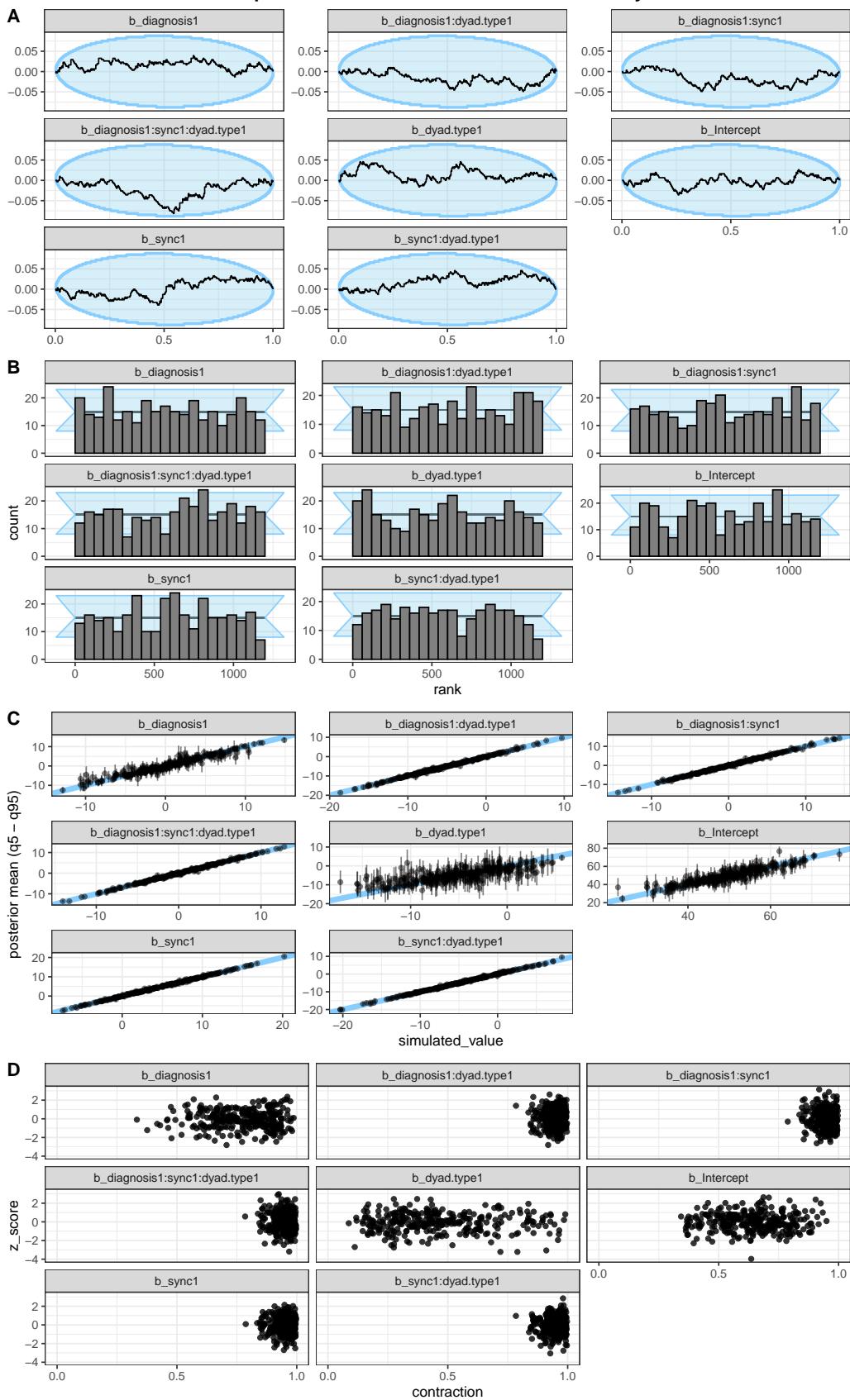
```

# plot SBC with functions from the SBC package focusing on population-level parameters
df.results.b = df.results %>%
  filter(substr(variable, 1, 2) == "b_") %>%
  filter(!(sim_id %in% check$sim_id))
p1 = plot_ecdf_diff(df.results.b) + theme_bw() + theme(legend.position = "none") +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))
p2 = plot_rank_hist(df.results.b, bins = 20) + theme_bw() +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))
p3 = plot_sim_estimated(df.results.b, alpha = 0.5) + theme_bw() +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))
p4 = plot_contraction(
  df.results.b,
  prior_sd = setNames(c(10, # Intercept
                        rep(5, length(unique(df.results.b$variable))-1)),
                        unique(df.results.b$variable))) +
  theme_bw() +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))

p = ggarrange(p1, p2, p3, p4, labels = "AUTO", ncol = 1, nrow = 4)
annotate_figure(p,
  top = text_grob("Computational faithfulness and model sensitivity",
  face = "bold", size = 14))

```

### Computational faithfulness and model sensitivity



Second, we check the ranks of the parameters. If the model is unbiased, these should be uniformly distributed (Schad, Betancourt and Vasishth, 2020). The sample empirical cumulative distribution function (ECDF) lies within the theoretical distribution (95%) and the rank histogram also shows ranks within the 95% expected range, although there are some small deviations. We judge this to be acceptable.

Third, we investigated the relationship between the simulated true parameters and the posterior estimates. Although there are individual values diverging from the expected pattern, most parameters were recovered successfully within an uncertainty interval of alpha = 0.05.

Last, we explore the z-score and the posterior contraction of our population-level predictors. The z-score “determines the distance of the posterior mean from the true simulating parameter”, while the posterior contraction “estimates how much prior uncertainty is reduced in the posterior estimation” (Schad, Betancourt and Vasishth, 2020). Both look acceptable.

### Posterior predictive checks

As the next step, we fit the model and check whether there were any obvious issues with it.

```
# fit the model
set.seed(2486)
m.pesi = brm(f.pesi,
              df.agg, prior = priors,
              iter = iter, warmup = warm,
              backend = "cmdstanr", threads = threading(8),
              file = "m_PESI",
              save_pars = save_pars(all = TRUE)
            )

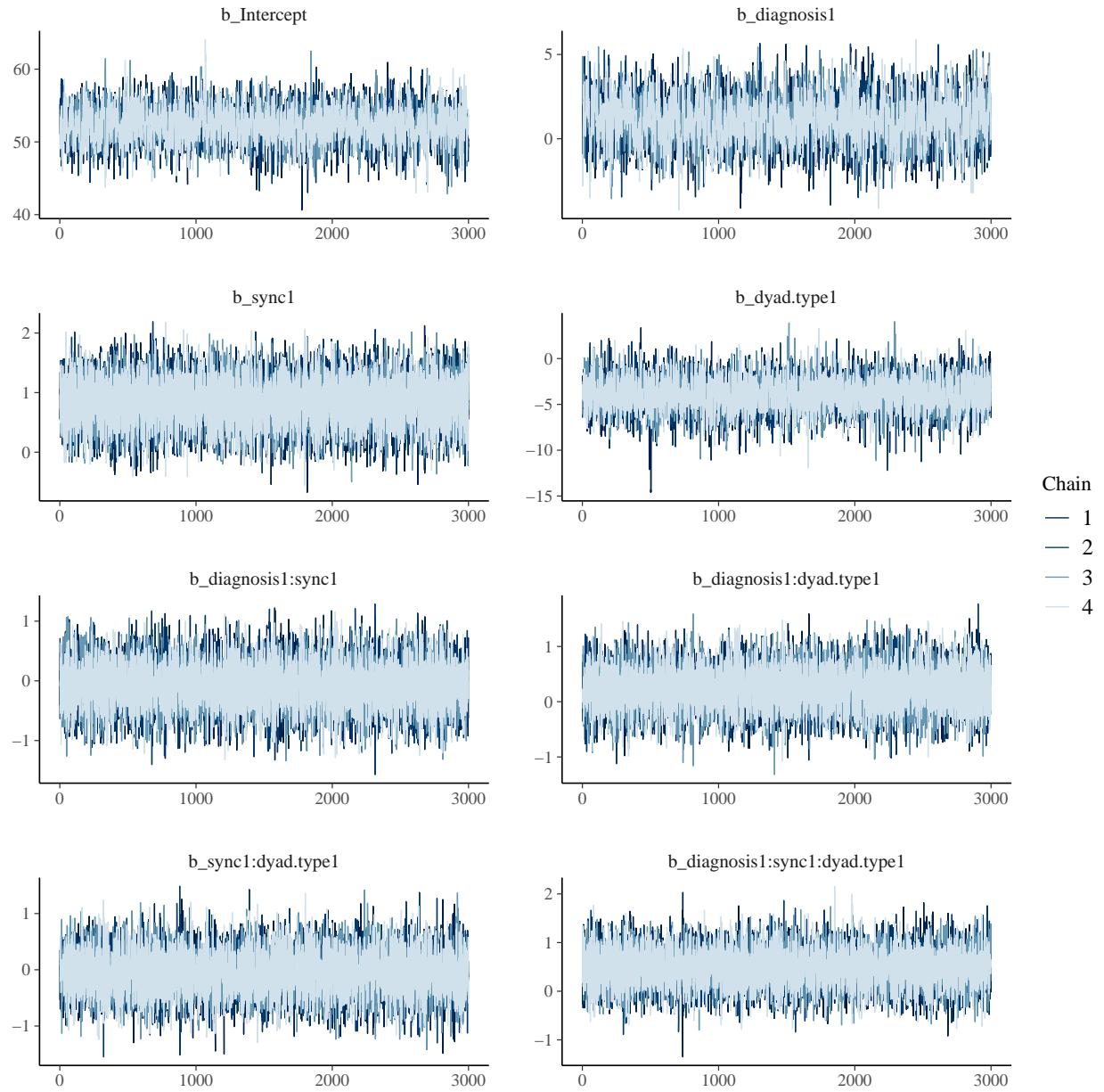
# in this model, there are no divergent samples
sum(subset(nuts_params(m.pesi), Parameter == "divergent_")$Value)

## [1] 0

# check that rhats are below 1.01
sum(brms::rhat(m.pesi) >= 1.01, na.rm = T)

## [1] 0

# and the chains have converged
post.draws = as_draws_df(m.pesi)
mcmc_trace(post.draws, regex_pars = "^b_",
            facet_args = list(ncol = 2)) +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))
```



This model has no divergent samples, and no rhat that is higher or equal to 1.01. Therefore, we go ahead and perform our posterior predictive checks.

```
# get the posterior predictions
post.pred = posterior_predict(m.pesi, ndraws = nsim)

# check the fit of the predicted data compared to the real data
p1 = pp_check(m.pesi, ndraws = nsim) +
  theme_bw() + theme(legend.position = "none") + xlim(0,100)

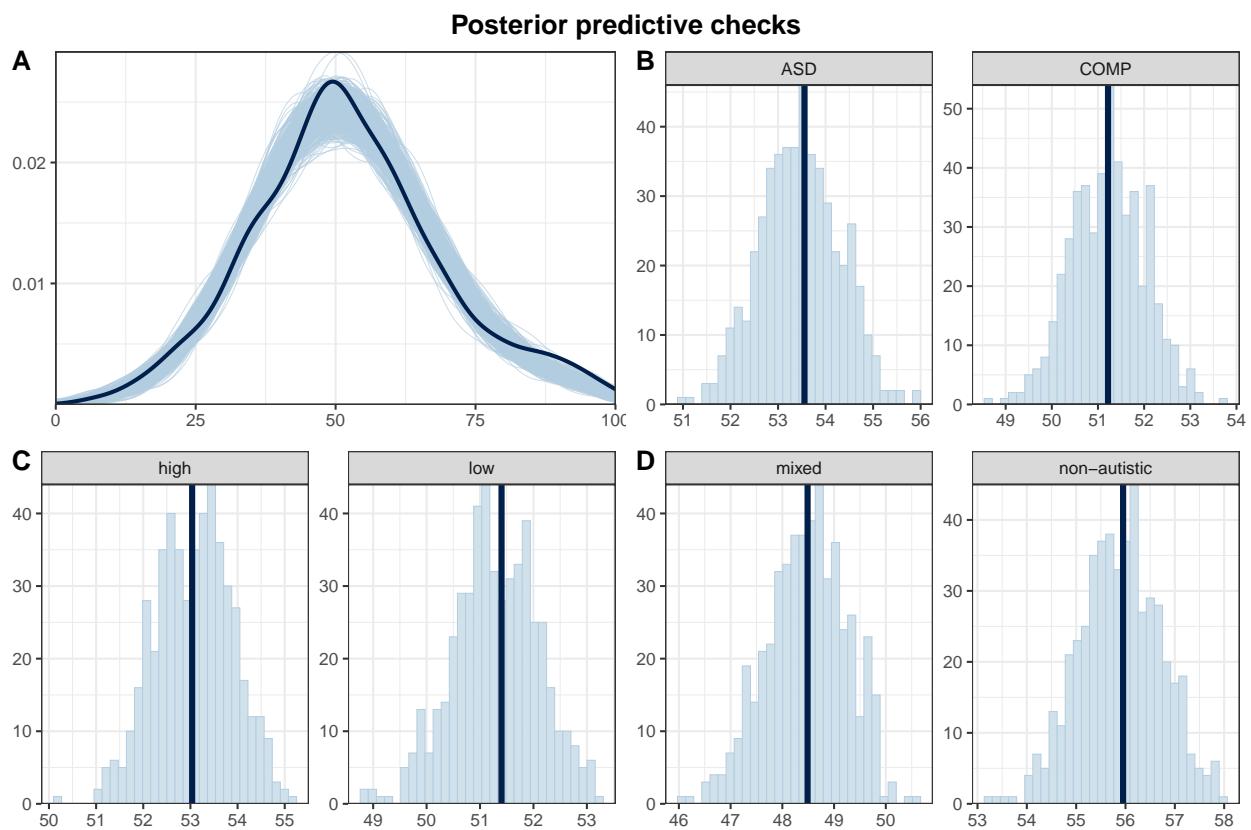
# distributions of means and sds compared to the real values per group
p2 = ppc_stat_grouped(df.agg$rating.confirmed, post.pred, df.agg$diagnosis) +
  theme_bw() + theme(legend.position = "none")
# ... sync level
p3 = ppc_stat_grouped(df.agg$rating.confirmed, post.pred, df.agg$sync) +
```

```

theme_bw() + theme(legend.position = "none")
# ... and dyad type
p4 = ppc_stat_grouped(df.agg$rating.confirmed, post.pred, df.agg$dyad.type) +
  theme_bw() + theme(legend.position = "none")

p = ggarrange(p1, p2, p3, p4,
              nrow = 2, ncol = 2, labels = "AUTO")
annotate_figure(p,
               top = text_grob("Posterior predictive checks",
                               face = "bold", size = 14))

```



The predictions based on the model (light blue) capture the data (dark blue) very well. The predicted means for each group are firmly distributed around the real values. This further increased our trust in the model and we move on to interpret it.

### Model summary

Now that we are convinced that we can trust our model, we have a look at the model and its estimates.

```

# print a summary
summary(m.pesi)

## Family: gaussian
## Links: mu = identity; sigma = identity
## Formula: rating.confirmed ~ diagnosis * sync * dyad.type + (1 | subID) + (1 | dyad)
## Data: df.agg (Number of observations: 1008)
## Draws: 4 chains, each with iter = 4500; warmup = 1500; thin = 1;

```

```

##          total post-warmup draws = 12000
##
## Multilevel Hyperparameters:
## ~dyad (Number of levels: 8)
##           Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     5.18      1.78     2.77    9.62 1.00      4251      6415
##
## ~subID (Number of levels: 63)
##           Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)    10.74      1.07     8.87   13.00 1.00      3107      5369
##
## Regression Coefficients:
##           Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS
## Intercept          52.24      2.32     47.65   56.84 1.00      2930
## diagnosis1         1.07      1.37     -1.61    3.78 1.00      2137
## sync1              0.83      0.40      0.02    1.60 1.00     22391
## dyad.type1        -3.87      1.78     -7.45   -0.40 1.00      5143
## diagnosis1:sync1  -0.08      0.40     -0.87    0.71 1.00     22927
## diagnosis1:dyad.type1  0.24      0.39     -0.54    1.02 1.00     21273
## sync1:dyad.type1  -0.06      0.40     -0.83    0.73 1.00     22302
## diagnosis1:sync1:dyad.type1  0.48      0.40     -0.30    1.24 1.00     21095
##           Tail_ESS
## Intercept          5158
## diagnosis1         4105
## sync1              7815
## dyad.type1         6811
## diagnosis1:sync1  8372
## diagnosis1:dyad.type1  8337
## sync1:dyad.type1  8364
## diagnosis1:sync1:dyad.type1  8549
##
## Further Distributional Parameters:
##           Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma       12.56      0.29     12.00    13.15 1.00     17960      9039
##
## Draws were sampled using sample(hmc). 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).

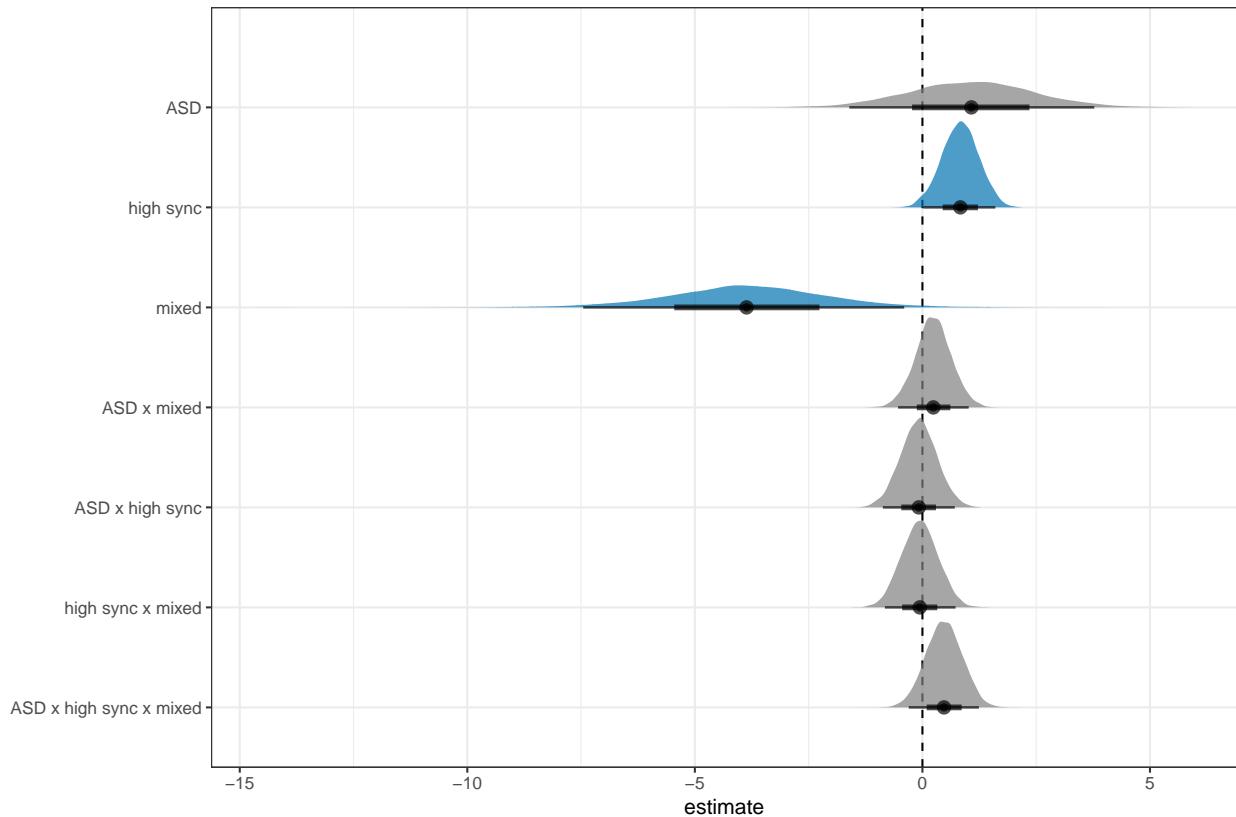
# plot the posterior distributions
post.draws %>%
  select(starts_with("b_")) %>%
  pivot_longer(cols = starts_with("b_"),
               names_to = "coef",
               values_to = "estimate") %>%
  subset(!startsWith(coef, "b_Int")) %>%
  mutate(
    coef = substr(coef, 3, nchar(coef)),
    coef = str_replace_all(coef, ":", " x "),
    coef = str_replace_all(coef, "diagnosis1", "ASD"),
    coef = str_replace_all(coef, "sync1", "high sync"),
    coef = str_replace_all(coef, "dyad.type1", "mixed"),
    coef_order = case_when(
      coef == "ASD" ~ 100,

```

```

    coef == "high sync" ~ 99,
    coef == "mixed" ~ 98,
    T ~ 100-nchar(coef)),
    coef = fct_reorder(coef, coef_order)
) %>%
group_by(coef) %>%
mutate(
  cred = case_when(
    (mean(estimate) < 0 & quantile(estimate, probs = 0.975) < 0) | 
      (mean(estimate) > 0 & quantile(estimate, probs = 0.025) > 0) ~ "credible",
    T ~ "not credible"
  )
) %>% ungroup() %>%
ggplot(aes(x = estimate, y = coef, fill = cred)) +
  geom_vline(xintercept = 0, linetype = 'dashed') +
  ggdist::stat_halfeye(alpha = 0.7) + ylab(NULL) + theme_bw() +
  scale_fill_manual(values = c(credible = c_dark, c_light)) +
  theme(legend.position = "none")

```



## Inferences

```

# H1.a Context: Social interactions of no-diagnosis non-autistic dyads are
# rated more positively than mixed-diagnosis dyads consisting of one autistic
# and one non-autistic interaction partner.
h1.a = hypothesis(m.pesi, "dyad.type1 < 0")

```

```

h1.a

## Hypothesis Tests for class b:
##          Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio Post.Prob
## 1 (dyad.type1) < 0      -3.87       1.78     -6.79     -1.01      59.91      0.98
##   Star
## 1   *
## ---
## 'CI': 90%-CI for one-sided and 95%-CI for two-sided hypotheses.
## '*': For one-sided hypotheses, the posterior probability exceeds 95%;
## for two-sided hypotheses, the value tested against lies outside the 95%-CI.
## Posterior probabilities of point hypotheses assume equal prior probabilities.

# H1.b Synchrony: Social interactions with high interpersonal synchrony of
# motion energy are rated more positively than social interactions with low
# interpersonal synchrony of motion energy.
h1.b = hypothesis(m.pesi, "sync1 > 0")
h1.b

## Hypothesis Tests for class b:
##          Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio Post.Prob Star
## 1 (sync1) > 0       0.83       0.4      0.16      1.49      43.78      0.98   *
## ---
## 'CI': 90%-CI for one-sided and 95%-CI for two-sided hypotheses.
## '*': For one-sided hypotheses, the posterior probability exceeds 95%;
## for two-sided hypotheses, the value tested against lies outside the 95%-CI.
## Posterior probabilities of point hypotheses assume equal prior probabilities.

# H1.c Diagnostic status: Ratings of social interactions differ between
# autistic and non-autistic participants.
h1.c = hypothesis(m.pesi, "diagnosis1 > 0")
h1.c

## Hypothesis Tests for class b:
##          Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio Post.Prob
## 1 (diagnosis1) > 0      1.07       1.37     -1.2      3.34      3.67      0.79
##   Star
## 1
## ---
## 'CI': 90%-CI for one-sided and 95%-CI for two-sided hypotheses.
## '*': For one-sided hypotheses, the posterior probability exceeds 95%;
## for two-sided hypotheses, the value tested against lies outside the 95%-CI.
## Posterior probabilities of point hypotheses assume equal prior probabilities.

# H1.d Synchrony x dyad type: The effect of interpersonal motion synchrony
# on ratings is decreased for mixed-diagnosis dyads compared to no-diagnosis dyads.
h1.d = hypothesis(m.pesi, "sync1:dyad.type1 < 0")
h1.d

## Hypothesis Tests for class b:
##          Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (sync1:dyad.type1) < 0     -0.06       0.4     -0.71      0.6      1.25
##   Post.Prob Star
## 1      0.56
## ---
## 'CI': 90%-CI for one-sided and 95%-CI for two-sided hypotheses.
## '*': For one-sided hypotheses, the posterior probability exceeds 95%;
```

```

## for two-sided hypotheses, the value tested against lies outside the 95%-CI.
## Posterior probabilities of point hypotheses assume equal prior probabilities.

# H1.e Dyad type x diagnostic status: The effect of dyad type on ratings is
# decreased in autistic compared to non-autistic participants.
h1.e = hypothesis(m.pesi, "diagnosis1:dyad.type1 < 0")
h1.e

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (diagnosis1:dyad.... < 0      0.24      0.39     -0.41      0.89      0.35
##   Post.Prob Star
## 1      0.26
## ---
## 'CI': 90%-CI for one-sided and 95%-CI for two-sided hypotheses.
## '*': For one-sided hypotheses, the posterior probability exceeds 95%;
## for two-sided hypotheses, the value tested against lies outside the 95%-CI.
## Posterior probabilities of point hypotheses assume equal prior probabilities.

# Explore interaction between sync and dyad type in the COMP group only
e1 = hypothesis(m.pesi,
                 "0 < diagnosis1:sync1:dyad.type1 - sync1:dyad.type1",
                 alpha = 0.025)
e1

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (0)-(diagnosis1:s... < 0     -0.53      0.52     -1.54      0.51      5.69
##   Post.Prob Star
## 1      0.85
## ---
## 'CI': 95%-CI for one-sided and 97.5%-CI for two-sided hypotheses.
## '*': For one-sided hypotheses, the posterior probability exceeds 97.5%;
## for two-sided hypotheses, the value tested against lies outside the 97.5%-CI.
## Posterior probabilities of point hypotheses assume equal prior probabilities.

```

Our Bayesian linear mixed model evaluating predictors for the ratings reveals support for our hypotheses postulating decreased ratings for mixed dyads (*Estimate* = -3.87 [-6.79, -1.01], *Posterior probability* = 0.984) and increased ratings for high synchrony videos (*Estimate* = 0.83 [0.16, 1.49], *Posterior probability* = 0.978). However, there is no support for our hypotheses regarding differences between the ratings of autistic and non-autistic participants (*Estimate* = 1.07 [-1.2, 3.34], *Posterior probability* = 0.786) or the interaction of synchrony and dyad type (*Estimate* = -0.06 [-0.71, 0.6], *Posterior probability* = 0.555) or dyad type and diagnostic status (*Estimate* = 0.24 [-0.41, 0.89], *Posterior probability* = 0.261).

## Plots

Finally, we can plot our data!

```

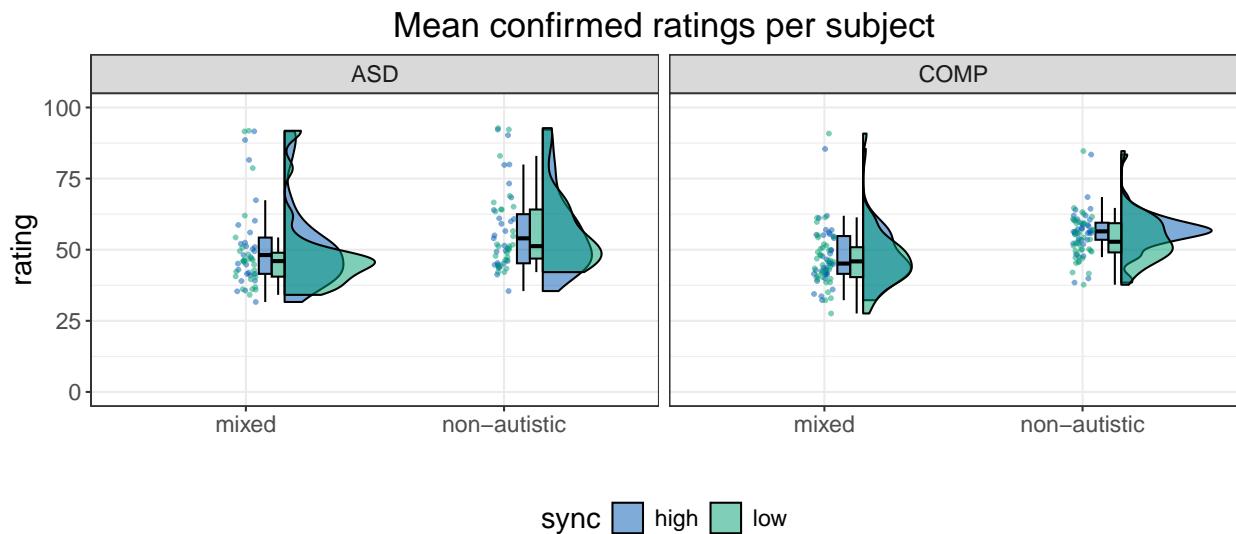
# rain cloud plot for ratings
df.agg %>%
  group_by(subID, diagnosis, dyad.type, sync) %>%
  summarise(
    rating.confirmed = mean(rating.confirmed, na.rm = T)
  ) %>%
  ggplot(aes(dyad.type, rating.confirmed, fill = sync, colour = sync)) +
  geom_rain(rain.side = 'r',
            boxplot.args = list(colour = "black",

```

```

        outlier.shape = NA,
        show.legend = FALSE,
        alpha = 0.5),
violin.args  = list(colour = "black",
                    outlier.shape = NA,
                    show.legend = T,
                    alpha = .5),
point.args   = list(show.legend = FALSE,
                    size   = .75,
                    alpha = .5),
boxplot.args.pos = list(
  position =
    ggpp::position_dodgeudge(x = .1, width = 0.1),
  width = 0.1
)) +
ylim(0, 100) +
facet_wrap(~ diagnosis) +
scale_fill_manual(values = custom.col) +
scale_color_manual(values = custom.col) +
labs(title = "Mean confirmed ratings per subject",
  x = "",
  y = "rating") +
theme_bw() +
theme(legend.position = "bottom",
  plot.title = element_text(hjust = 0.5),
  legend.direction = "horizontal",
  text = element_text(size = 15))

```



LOO?

```

# intercept model
m.pesi0 = brm(rating.confirmed ~ 1 + (1 | subID) + (1 | dyad),
               data = df.agg, prior = priors %>% filter(class != "b"),
               iter = iter, warmup = warm,

```

```

        backend = "cmdstanr", threads = threading(8),
        file = file.path(loo_dir, "m_PESI_0"),
        save_pars = save_pars(all = TRUE)
    )
# main effect models
m.pesi1 = brm(rating.confirmed ~ diagnosis + (1 | subID) + (1 | dyad),
               data = df.agg, prior = priors %>%
                 filter(class != "b"),
               iter = iter, warmup = warm,
               backend = "cmdstanr", threads = threading(8),
               file = file.path(loo_dir, "m_PESI_1"),
               save_pars = save_pars(all = TRUE)
)
m.pesi2 = brm(rating.confirmed ~ dyad.type + (1 | subID) + (1 | dyad),
               data = df.agg, prior = priors %>%
                 filter(class != "b" | coef == "dyad.type1"),
               iter = iter, warmup = warm,
               backend = "cmdstanr", threads = threading(8),
               file = file.path(loo_dir, "m_PESI_2"),
               save_pars = save_pars(all = TRUE)
)
m.pesi3 = brm(rating.confirmed ~ sync + (1 | subID) + (1 | dyad),
               data = df.agg, prior = priors %>%
                 filter(class != "b" | coef == "sync1"),
               iter = iter, warmup = warm,
               backend = "cmdstanr", threads = threading(8),
               file = file.path(loo_dir, "m_PESI_3"),
               save_pars = save_pars(all = TRUE)
)

# calculate the loos for these models
ls.loo = list(
  loo(m.pesi0),
  loo(m.pesi1),
  loo(m.pesi2),
  loo(m.pesi3)
)

loo_compare(ls.loo)

```

## Fixation durations

We also collected eye tracking data during the presentation of the videos. From the eye tracking data, we extracted fixations using the algorithm from Nyström und Holmqvist (2010) and then calculated the duration of fixations on areas of interest (heads, hands and body). For testing the hypotheses, we calculated proportions of fixation durations from the total fixation duration for each video.

## SBC

```

# set formula considering all combinations
code   = "PESI_fix"
f.fix = brms::bf(fix.prop ~ diagnosis * sync * dyad.type * AOI
                  + (sync * dyad.type * AOI | subID)

```

```

+ (diagnosis * sync * AOI | dyad))

# set weakly informed priors
priors = c(
  # three AOIs, therefore, intercept expected to be around 33%
  prior(normal(33, 11), class = Intercept),
  prior(normal(11, 11), class = sigma), # 1/3 of the Intercept
  prior(normal(5, 5), class = sd),
  prior(lkj(2) , class = cor),
  prior(normal(0, 10), class = b)
)

if (file.exists(file.path(cache_dir, paste0("df_res_", code, ".rds")))) {
  # load in the results of the SBC
  df.results = readRDS(file.path(cache_dir, paste0("df_res_", code, ".rds")))
  df.backend = readRDS(file.path(cache_dir, paste0("df_div_", code, ".rds")))
  dat       = readRDS(file.path(cache_dir, paste0("dat_", code, ".rds")))
} else {
  # set the seed
  set.seed(2469)
  # create the data
  gen   = SBC_generator_brms(f.fix, data = df.fix.agg, prior = priors,
                             thin = 50, warmup = 20000, refresh = 2000
  )
  dat   = generate_datasets(gen, nsim)
  saveRDS(dat, file = sprintf("%s/dat_%s.rds", cache_dir, code))

  # perform the SBC
  bck = SBC_backend_brms_from_generator(gen, chains = 4, thin = 1,
                                         warmup = warm, iter = iter,
                                         inits = 0.1)
  res = compute_SBC(dat, bck,
                    cache_mode = "results",
                    cache_location = file.path(cache_dir, sprintf("res_%s", code)))
  # save the results dataframes
  df.results = res$stats
  df.backend = res$backend_diagnostics
  saveRDS(df.results, file = file.path(cache_dir, paste0("df_res_", code, ".rds")))
  saveRDS(df.backend, file = file.path(cache_dir, paste0("df_div_", code, ".rds")))
}

}

```

Again, we start by investigating the rhats and the number of divergent samples. This shows that 8 of 500 simulations had at least one parameter that had an rhat of at least 1.05, and 17 models had divergent samples (mean number of samples of the simulations with divergent samples: 1.18). Although not perfect, we are satisfied with these numbers and continue.

Next, we can plot the simulated values to perform prior predictive checks.

```

# create a matrix out of generated data
dvname = gsub(" ", "", gsub("[\\|~].*", "", f.fix)[1])
dvfakemat = matrix(NA, nrow(dat[['generated']][[1]]), length(dat[['generated']]))

for (i in 1:length(dat[['generated']])){
  dvfakemat[,i] = dat[['generated']][[i]][[dvname]]
}

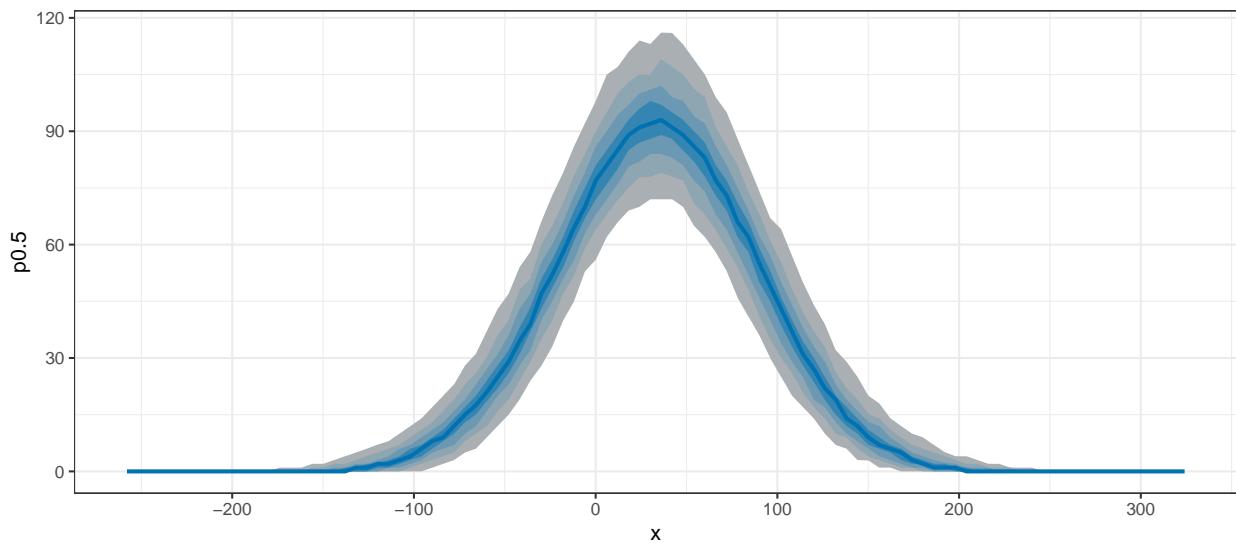
```

```

truePars = dat$variables

# plot simulated data for prior predictive checks
dvmax = 100
dvfakemath = dvfakemat;
#dvfakemath[dvfakemath > dvmax] = dvmax
#dvfakemath[dvfakemath < 0] = 0
breaks = seq(min(dvfakemath, na.rm = T)-1, max(dvfakemath, na.rm=T)+1, length.out = 100)
binwidth = ceiling(breaks[2] - breaks[1])
breaks = seq(min(dvfakemath, na.rm = T)-1, max(dvfakemath)+binwidth, by = binwidth)
histmat = matrix(NA, ncol = dim(dvfakemath)[2] + binwidth, nrow = length(breaks)-1)
for (i in 1:dim(dvfakemath)[2]) {
  histmat[,i] = hist(dvfakemath[,i], breaks = breaks, plot = F)$counts
}
probs = seq(0.1, 0.9, 0.1)
quantmat= as.data.frame(matrix(NA, nrow=dim(histmat)[1], ncol = length(probs)))
names(quantmat) = paste0("p", probs)
for (i in 1:dim(histmat)[1]) {
  quantmat[i,] = quantile(histmat[i,], p = probs, na.rm = T)
}
quantmat$x = breaks[2:length(breaks)] - binwidth/2 # add bin mean
ggplot(data = quantmat, aes(x = x)) +
  geom_ribbon(aes(ymax = p0.9, ymin = p0.1), fill = c_light) +
  geom_ribbon(aes(ymax = p0.8, ymin = p0.2), fill = c_light_highlight) +
  geom_ribbon(aes(ymax = p0.7, ymin = p0.3), fill = c_mid) +
  geom_ribbon(aes(ymax = p0.6, ymin = p0.4), fill = c_mid_highlight) +
  geom_line(aes(y = p0.5), colour = c_dark, linewidth = 1) +
  #xlim(0, max(dvfakemath)) +
  theme_bw()

```



Again, most of our data fits our expectations, however, we chose wider priors, therefore, there are also simulated values outside of the possible values (0 to 100).

```

# get simulation numbers with issues
rank = max(df.results$max_rank)

```

```

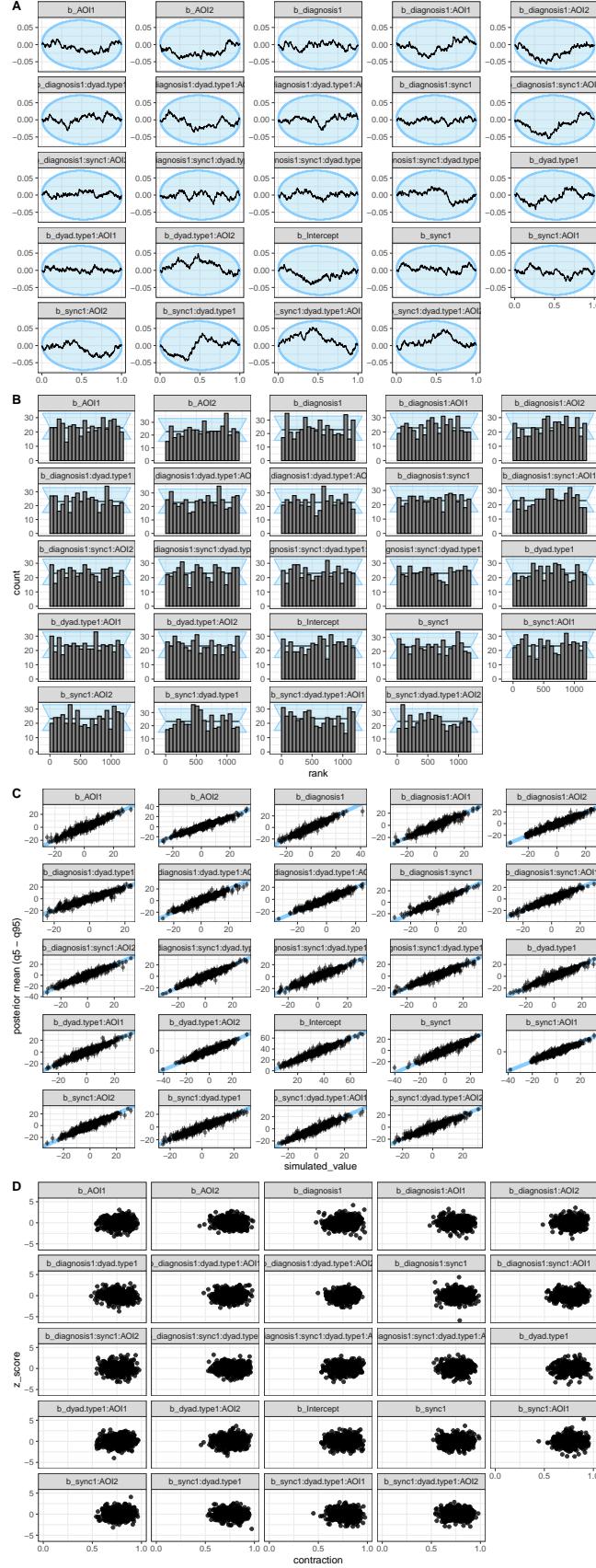
check = merge(df.results %>%
  group_by(sim_id) %>%
  summarise(
    rhat = max(rhat, na.rm = T),
    mean_rank = mean(max_rank)
  ) %>%
  filter(rhat >= 1.05 | mean_rank != rank),
  df.backend %>% filter(n_divergent > 0), all = T)

# plot SBC with functions from the SBC package focusing on population-level parameters
df.results.b = df.results %>%
  filter(substr(variable, 1, 2) == "b_") %>%
  filter(!(sim_id %in% check$sim_id))
p1 = plot_ecdf_diff(df.results.b) + theme_bw() + theme(legend.position = "none") +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))
p2 = plot_rank_hist(df.results.b, bins = 20) + theme_bw() +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))
p3 = plot_sim_estimated(df.results.b, alpha = 0.5) + theme_bw() +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))
p4 = plot_contraction(
  df.results.b,
  prior_sd = setNames(c(11,
                        rep(11, length(unique(df.results.b$variable))-1)),
                        unique(df.results.b$variable))) +
  theme_bw() +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))

p = ggarrange(p1, p2, p3, p4, labels = "AUTO", ncol = 1, nrow = 4)
annotate_figure(p,
               top = text_grob("Computational faithfulness and model sensitivity",
                               face = "bold", size = 14))

```

### Computational faithfulness and model sensitivity



Second, we check the ranks of the parameters. If the model is unbiased, these should be uniformly distributed (Schad, Betancourt and Vasishth, 2020). The sample empirical cumulative distribution function (ECDF) lies within the theoretical distribution (95%) and the rank histogram also shows ranks within the 95% expected range, although there are some small deviations. We judge this to be acceptable.

Third, we investigated the relationship between the simulated true parameters and the posterior estimates. Although there are individual values diverging from the expected pattern, most parameters were recovered successfully within an uncertainty interval of alpha = 0.05.

Last, we explore the z-score and the posterior contraction of our population-level predictors. The z-score “determines the distance of the posterior mean from the true simulating parameter”, while the posterior contraction “estimates how much prior uncertainty is reduced in the posterior estimation” (Schad, Betancourt and Vasishth, 2020). Both look acceptable.

### Posterior predictive checks

As the next step, we fit the model and check for issues.

```
# fit the model
set.seed(2486)
m.fix = brm(f.fix,
             df.fix.agg, prior = priors,
             iter = iter, warmup = warm,
             backend = "cmdstanr", threads = threading(8),
             file = "m_PESI_fix",
             save_pars = save_pars(all = TRUE)
             )

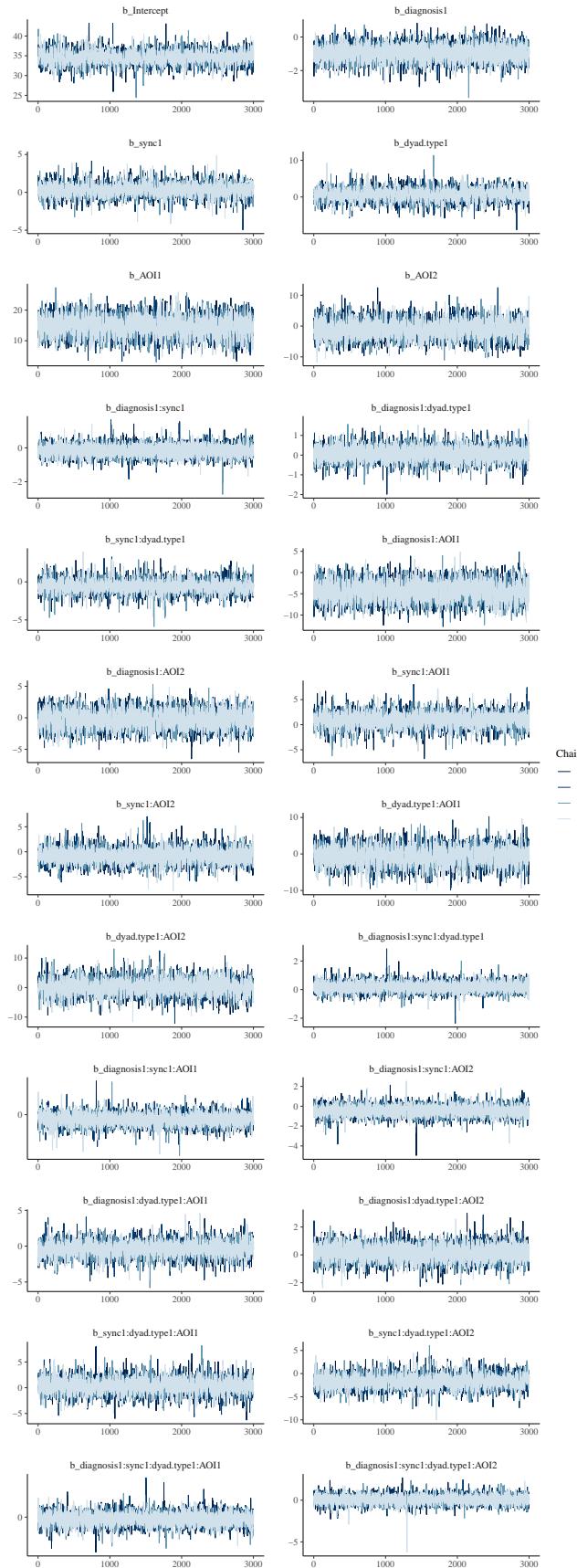
# in this model, there are no divergent samples
sum(subset(nuts_params(m.fix), Parameter == "divergent_")$Value)

## [1] 0

# check that rhats are below 1.01
sum(brms::rhat(m.fix) >= 1.01, na.rm = T)

## [1] 1

# and the chains have converged
post.draws = as_draws_df(m.fix)
mcmc_trace(post.draws, regex_pars = "^b_",
            facet_args = list(ncol = 2)) +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))
```



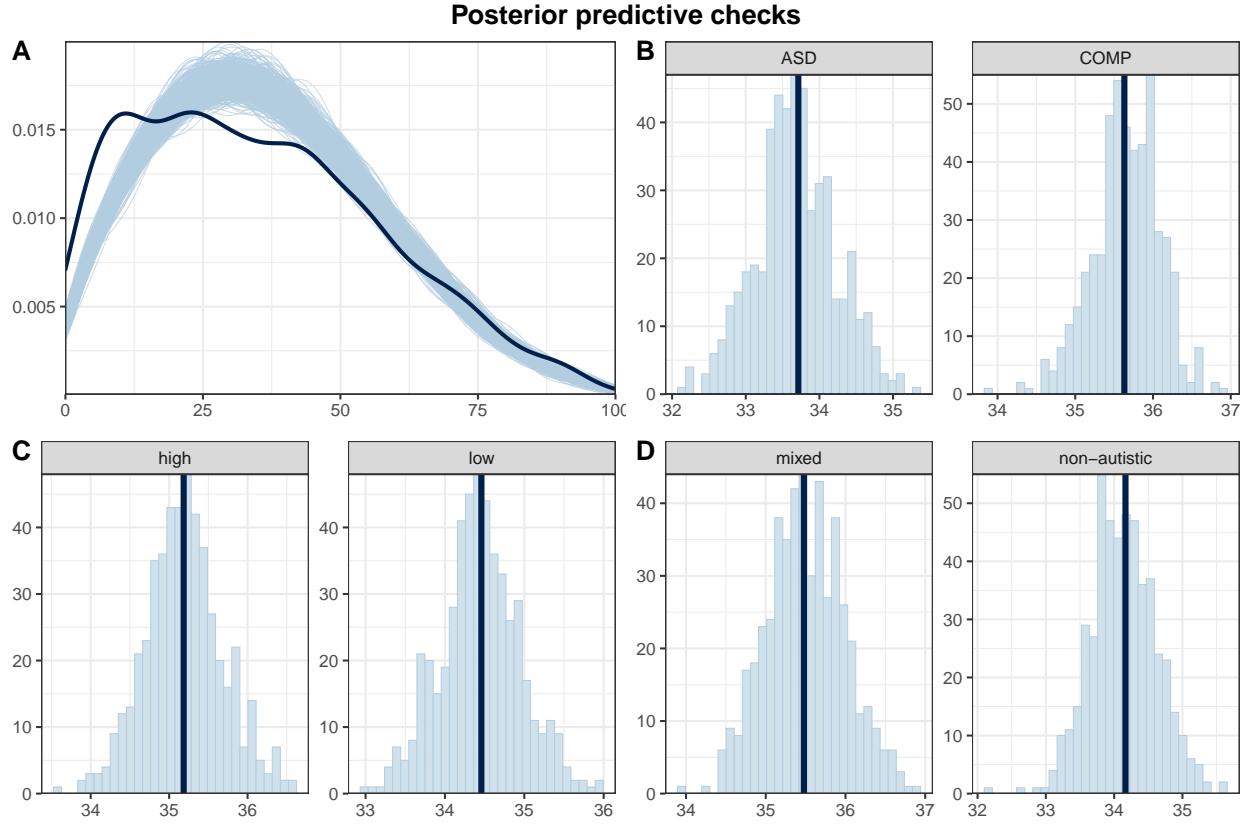
This model has no divergent samples, and only one rhat that is higher or equal to 1.01. Therefore, we go ahead and perform our posterior predictive checks.

```
# get the posterior predictions
post.pred = posterior_predict(m.fix, ndraws = nsim)

# check the fit of the predicted data compared to the real data
p1 = pp_check(m.fix, ndraws = nsim) +
  theme_bw() + theme(legend.position = "none") + xlim(0,100)

# distributions of means and sds compared to the real values per group
p2 = ppc_stat_grouped(df.fix.agg$fix.prop, post.pred, df.fix.agg$diagnosis) +
  theme_bw() + theme(legend.position = "none")
# ... sync level
p3 = ppc_stat_grouped(df.fix.agg$fix.prop, post.pred, df.fix.agg"sync") +
  theme_bw() + theme(legend.position = "none")
# ... and dyad type
p4 = ppc_stat_grouped(df.fix.agg$fix.prop, post.pred, df.fix.agg$dyad.type) +
  theme_bw() + theme(legend.position = "none")

p = ggarrange(p1, p2, p3, p4,
              nrow = 2, ncol = 2, labels = "AUTO")
annotate_figure(p,
                top = text_grob("Posterior predictive checks",
                                face = "bold", size = 14))
```



Although the overall shape is not perfect, the means are captured pretty well. Since we could not find a

likelihood shape that fit better than this, we accept this model and test our hypotheses.

## Model summary

Now that we are convinced that we can trust our model, we have a look at the model and its estimates.

```
# print a summary
```

```
summary(m.fix)
```

	Estimate	Est.Error	l-95% CI
## Family: gaussian			
## Links: mu = identity; sigma = identity			
## Formula: fix.prop ~ diagnosis * sync * dyad.type * AOI + (sync * dyad.type * AOI   subID) + (diagnos			
## Data: df.fix.agg (Number of observations: 2160)			
## Draws: 4 chains, each with iter = 4500; warmup = 1500; thin = 1;			
## total post-warmup draws = 12000			
##			
## Multilevel Hyperparameters:			
## ~dyad (Number of levels: 8)			
##			
## sd(Intercept)	4.05	1.44	2.18
## sd(diagnosis1)	0.50	0.42	0.02
## sd(sync1)	1.85	0.82	0.81
## sd(AOI1)	6.29	1.93	3.50
## sd(AOI2)	6.57	1.89	3.82
## sd(diagnosis1:sync1)	0.39	0.37	0.01
## sd(diagnosis1:AOI1)	2.03	1.07	0.55
## sd(diagnosis1:AOI2)	0.61	0.56	0.02
## sd(sync1:AOI1)	3.30	1.38	1.47
## sd(sync1:AOI2)	3.42	1.32	1.74
## sd(diagnosis1:sync1:AOI1)	0.95	0.77	0.05
## sd(diagnosis1:sync1:AOI2)	0.69	0.63	0.02
## cor(Intercept,diagnosis1)	-0.09	0.26	-0.56
## cor(Intercept, sync1)	0.23	0.24	-0.26
## cor(diagnosis1, sync1)	-0.07	0.26	-0.55
## cor(Intercept, AOI1)	0.06	0.23	-0.39
## cor(diagnosis1, AOI1)	-0.02	0.25	-0.51
## cor(sync1, AOI1)	0.11	0.23	-0.35
## cor(Intercept, AOI2)	0.20	0.23	-0.27
## cor(diagnosis1, AOI2)	-0.05	0.25	-0.54
## cor(sync1, AOI2)	0.16	0.23	-0.32
## cor(AOI1, AOI2)	-0.13	0.22	-0.54
## cor(Intercept, diagnosis1:sync1)	-0.04	0.26	-0.54
## cor(diagnosis1, diagnosis1:sync1)	0.01	0.26	-0.48
## cor(sync1, diagnosis1:sync1)	-0.03	0.26	-0.53
## cor(AOI1, diagnosis1:sync1)	-0.01	0.26	-0.50
## cor(AOI2, diagnosis1:sync1)	-0.03	0.26	-0.53
## cor(Intercept, diagnosis1:AOI1)	0.01	0.24	-0.45
## cor(diagnosis1, diagnosis1:AOI1)	-0.02	0.25	-0.51
## cor(sync1, diagnosis1:AOI1)	0.06	0.24	-0.42
## cor(AOI1, diagnosis1:AOI1)	-0.01	0.24	-0.47
## cor(AOI2, diagnosis1:AOI1)	-0.02	0.24	-0.48
## cor(diagnosis1:sync1, diagnosis1:AOI1)	0.01	0.26	-0.48
## cor(Intercept, diagnosis1:AOI2)	-0.03	0.25	-0.51
## cor(diagnosis1, diagnosis1:AOI2)	0.01	0.26	-0.49
## cor(sync1, diagnosis1:AOI2)	-0.02	0.25	-0.51

## cor(AOI1,diagnosis1:AOI2)	0.03	0.26	-0.48
## cor(AOI2,diagnosis1:AOI2)	-0.01	0.25	-0.49
## cor(diagnosis1:sync1,diagnosis1:AOI2)	-0.00	0.26	-0.50
## cor(diagnosis1:AOI1,diagnosis1:AOI2)	-0.04	0.26	-0.54
## cor(Intercept, sync1:AOI1)	0.03	0.23	-0.43
## cor(diagnosis1, sync1:AOI1)	0.01	0.26	-0.48
## cor(sync1, sync1:AOI1)	0.04	0.24	-0.42
## cor(AOI1, sync1:AOI1)	0.11	0.23	-0.36
## cor(AOI2, sync1:AOI1)	0.08	0.23	-0.36
## cor(diagnosis1:sync1, sync1:AOI1)	-0.02	0.26	-0.51
## cor(diagnosis1:AOI1, sync1:AOI1)	-0.12	0.24	-0.57
## cor(diagnosis1:AOI2, sync1:AOI1)	0.03	0.26	-0.47
## cor(Intercept, sync1:AOI2)	0.24	0.24	-0.26
## cor(diagnosis1, sync1:AOI2)	-0.07	0.26	-0.55
## cor(sync1, sync1:AOI2)	0.22	0.24	-0.27
## cor(AOI1, sync1:AOI2)	-0.02	0.23	-0.46
## cor(AOI2, sync1:AOI2)	0.22	0.23	-0.26
## cor(diagnosis1:sync1, sync1:AOI2)	-0.03	0.25	-0.51
## cor(diagnosis1:AOI1, sync1:AOI2)	0.09	0.24	-0.39
## cor(diagnosis1:AOI2, sync1:AOI2)	-0.04	0.26	-0.53
## cor(sync1:AOI1, sync1:AOI2)	-0.05	0.23	-0.50
## cor(Intercept, diagnosis1:sync1:AOI1)	-0.05	0.25	-0.53
## cor(diagnosis1, diagnosis1:sync1:AOI1)	-0.00	0.26	-0.50
## cor(sync1, diagnosis1:sync1:AOI1)	-0.04	0.26	-0.53
## cor(AOI1, diagnosis1:sync1:AOI1)	0.04	0.25	-0.45
## cor(AOI2, diagnosis1:sync1:AOI1)	-0.03	0.25	-0.51
## cor(diagnosis1:sync1, diagnosis1:sync1:AOI1)	0.01	0.26	-0.48
## cor(diagnosis1:AOI1, diagnosis1:sync1:AOI1)	-0.05	0.26	-0.54
## cor(diagnosis1:AOI2, diagnosis1:sync1:AOI1)	0.03	0.26	-0.48
## cor(sync1:AOI1, diagnosis1:sync1:AOI1)	0.01	0.25	-0.48
## cor(sync1:AOI2, diagnosis1:sync1:AOI1)	-0.06	0.25	-0.54
## cor(Intercept, diagnosis1:sync1:AOI2)	-0.03	0.25	-0.51
## cor(diagnosis1, diagnosis1:sync1:AOI2)	0.01	0.26	-0.49
## cor(sync1, diagnosis1:sync1:AOI2)	-0.00	0.26	-0.50
## cor(AOI1, diagnosis1:sync1:AOI2)	0.05	0.26	-0.45
## cor(AOI2, diagnosis1:sync1:AOI2)	-0.02	0.25	-0.51
## cor(diagnosis1:sync1, diagnosis1:sync1:AOI2)	0.00	0.26	-0.49
## cor(diagnosis1:AOI1, diagnosis1:sync1:AOI2)	-0.05	0.26	-0.54
## cor(diagnosis1:AOI2, diagnosis1:sync1:AOI2)	0.01	0.26	-0.50
## cor(sync1:AOI1, diagnosis1:sync1:AOI2)	0.02	0.26	-0.47
## cor(sync1:AOI2, diagnosis1:sync1:AOI2)	-0.03	0.25	-0.52
## cor(diagnosis1:sync1:AOI1, diagnosis1:sync1:AOI2)	0.01	0.26	-0.50
##	u-95% CI	Rhat	Bulk_ESS
## sd(Intercept)	7.68	1.00	3523
## sd(diagnosis1)	1.56	1.00	4678
## sd(sync1)	3.96	1.00	4023
## sd(AOI1)	10.94	1.00	5529
## sd(AOI2)	11.09	1.00	5686
## sd(diagnosis1:sync1)	1.30	1.00	5352
## sd(diagnosis1:AOI1)	4.69	1.00	4051
## sd(diagnosis1:AOI2)	2.00	1.00	6335
## sd(sync1:AOI1)	6.81	1.00	5175
## sd(sync1:AOI2)	6.77	1.00	5482
## sd(diagnosis1:sync1:AOI1)	2.88	1.00	4055

## sd(diagnosis1:sync1:AOI2)	2.22	1.00	4020
## cor(Intercept,diagnosis1)	0.42	1.00	12535
## cor(Intercept, sync1)	0.67	1.00	7312
## cor(diagnosis1, sync1)	0.44	1.00	7437
## cor(Intercept, AOI1)	0.50	1.00	6966
## cor(diagnosis1, AOI1)	0.46	1.00	5358
## cor(sync1, AOI1)	0.55	1.00	7013
## cor(Intercept, AOI2)	0.61	1.00	7676
## cor(diagnosis1, AOI2)	0.43	1.00	5918
## cor(sync1, AOI2)	0.59	1.00	7659
## cor(AOI1, AOI2)	0.31	1.00	8751
## cor(Intercept, diagnosis1:sync1)	0.45	1.00	15367
## cor(diagnosis1, diagnosis1:sync1)	0.51	1.00	14015
## cor(sync1, diagnosis1:sync1)	0.47	1.00	12953
## cor(AOI1, diagnosis1:sync1)	0.49	1.00	12893
## cor(AOI2, diagnosis1:sync1)	0.47	1.00	12228
## cor(Intercept, diagnosis1:AOI1)	0.45	1.00	10756
## cor(diagnosis1, diagnosis1:AOI1)	0.48	1.00	8256
## cor(sync1, diagnosis1:AOI1)	0.51	1.00	9893
## cor(AOI1, diagnosis1:AOI1)	0.45	1.00	10272
## cor(AOI2, diagnosis1:AOI1)	0.44	1.00	9803
## cor(diagnosis1:sync1, diagnosis1:AOI1)	0.51	1.00	7630
## cor(Intercept, diagnosis1:AOI2)	0.45	1.00	13807
## cor(diagnosis1, diagnosis1:AOI2)	0.50	1.00	12650
## cor(sync1, diagnosis1:AOI2)	0.48	1.00	13986
## cor(AOI1, diagnosis1:AOI2)	0.52	1.00	12137
## cor(AOI2, diagnosis1:AOI2)	0.48	1.00	12518
## cor(diagnosis1:sync1, diagnosis1:AOI2)	0.50	1.00	8959
## cor(diagnosis1:AOI1, diagnosis1:AOI2)	0.46	1.00	10264
## cor(Intercept, sync1:AOI1)	0.47	1.00	9732
## cor(diagnosis1, sync1:AOI1)	0.50	1.00	6468
## cor(sync1, sync1:AOI1)	0.50	1.00	9531
## cor(AOI1, sync1:AOI1)	0.54	1.00	9406
## cor(AOI2, sync1:AOI1)	0.52	1.00	8915
## cor(diagnosis1:sync1, sync1:AOI1)	0.49	1.00	7182
## cor(diagnosis1:AOI1, sync1:AOI1)	0.37	1.00	8171
## cor(diagnosis1:AOI2, sync1:AOI1)	0.53	1.00	6514
## cor(Intercept, sync1:AOI2)	0.66	1.00	8412
## cor(diagnosis1, sync1:AOI2)	0.43	1.00	7945
## cor(sync1, sync1:AOI2)	0.65	1.00	8996
## cor(AOI1, sync1:AOI2)	0.42	1.00	8838
## cor(AOI2, sync1:AOI2)	0.64	1.00	8964
## cor(diagnosis1:sync1, sync1:AOI2)	0.46	1.00	8034
## cor(diagnosis1:AOI1, sync1:AOI2)	0.53	1.00	9668
## cor(diagnosis1:AOI2, sync1:AOI2)	0.46	1.00	8063
## cor(sync1:AOI1, sync1:AOI2)	0.41	1.00	8243
## cor(Intercept, diagnosis1:sync1:AOI1)	0.45	1.00	13947
## cor(diagnosis1, diagnosis1:sync1:AOI1)	0.50	1.00	10357
## cor(sync1, diagnosis1:sync1:AOI1)	0.46	1.00	11457
## cor(AOI1, diagnosis1:sync1:AOI1)	0.52	1.00	11171
## cor(AOI2, diagnosis1:sync1:AOI1)	0.45	1.00	11282
## cor(diagnosis1:sync1, diagnosis1:sync1:AOI1)	0.52	1.00	7698
## cor(diagnosis1:AOI1, diagnosis1:sync1:AOI1)	0.46	1.00	9305
## cor(diagnosis1:AOI2, diagnosis1:sync1:AOI1)	0.52	1.00	7765

## cor(sync1:AOI1,diagnosis1:sync1:AOI1)	0.49	1.00	9954
## cor(sync1:AOI2,diagnosis1:sync1:AOI1)	0.43	1.00	8926
## cor(Intercept,diagnosis1:sync1:AOI2)	0.46	1.00	13415
## cor(diagnosis1,diagnosis1:sync1:AOI2)	0.51	1.00	10947
## cor(sync1,diagnosis1:sync1:AOI2)	0.49	1.00	13331
## cor(AOI1,diagnosis1:sync1:AOI2)	0.54	1.00	12003
## cor(AOI2,diagnosis1:sync1:AOI2)	0.47	1.00	12420
## cor(diagnosis1:sync1,diagnosis1:sync1:AOI2)	0.50	1.00	9145
## cor(diagnosis1:AOI1,diagnosis1:sync1:AOI2)	0.46	1.00	9354
## cor(diagnosis1:AOI2,diagnosis1:sync1:AOI2)	0.51	1.00	8132
## cor(sync1:AOI1,diagnosis1:sync1:AOI2)	0.51	1.00	9510
## cor(sync1:AOI2,diagnosis1:sync1:AOI2)	0.47	1.00	8314
## cor(diagnosis1:sync1:AOI1,diagnosis1:sync1:AOI2)	0.50	1.00	7658
##		Tail_ESS	
## sd(Intercept)	6008		
## sd(diagnosis1)	4711		
## sd(sync1)	5399		
## sd(AOI1)	7019		
## sd(AOI2)	6706		
## sd(diagnosis1:sync1)	5254		
## sd(diagnosis1:AOI1)	3969		
## sd(diagnosis1:AOI2)	5823		
## sd(sync1:AOI1)	6551		
## sd(sync1:AOI2)	6298		
## sd(diagnosis1:sync1:AOI1)	5611		
## sd(diagnosis1:sync1:AOI2)	4688		
## cor(Intercept,diagnosis1)	8595		
## cor(Intercept, sync1)	8325		
## cor(diagnosis1, sync1)	8326		
## cor(Intercept, AOI1)	7885		
## cor(diagnosis1, AOI1)	7602		
## cor(sync1, AOI1)	8200		
## cor(Intercept, AOI2)	7893		
## cor(diagnosis1, AOI2)	7834		
## cor(sync1, AOI2)	8289		
## cor(AOI1, AOI2)	9485		
## cor(Intercept, diagnosis1:sync1)	9241		
## cor(diagnosis1, diagnosis1:sync1)	9403		
## cor(sync1, diagnosis1:sync1)	8959		
## cor(AOI1, diagnosis1:sync1)	9491		
## cor(AOI2, diagnosis1:sync1)	8956		
## cor(Intercept, diagnosis1:AOI1)	9421		
## cor(diagnosis1, diagnosis1:AOI1)	8218		
## cor(sync1, diagnosis1:AOI1)	9056		
## cor(AOI1, diagnosis1:AOI1)	9439		
## cor(AOI2, diagnosis1:AOI1)	9365		
## cor(diagnosis1:sync1, diagnosis1:AOI1)	9371		
## cor(Intercept, diagnosis1:AOI2)	8726		
## cor(diagnosis1, diagnosis1:AOI2)	8262		
## cor(sync1, diagnosis1:AOI2)	9129		
## cor(AOI1, diagnosis1:AOI2)	8613		
## cor(AOI2, diagnosis1:AOI2)	9160		
## cor(diagnosis1:sync1, diagnosis1:AOI2)	8591		
## cor(diagnosis1:AOI1, diagnosis1:AOI2)	9092		

## cor(Intercept, sync1:AOI1)	8048		
## cor(diagnosis1, sync1:AOI1)	8172		
## cor(sync1, sync1:AOI1)	9439		
## cor(AOI1, sync1:AOI1)	9313		
## cor(AOI2, sync1:AOI1)	9964		
## cor(diagnosis1:sync1, sync1:AOI1)	9002		
## cor(diagnosis1:AOI1, sync1:AOI1)	9286		
## cor(diagnosis1:AOI2, sync1:AOI1)	8926		
## cor(Intercept, sync1:AOI2)	9188		
## cor(diagnosis1, sync1:AOI2)	8847		
## cor(sync1, sync1:AOI2)	9305		
## cor(AOI1, sync1:AOI2)	9311		
## cor(AOI2, sync1:AOI2)	9196		
## cor(diagnosis1:sync1, sync1:AOI2)	9518		
## cor(diagnosis1:AOI1, sync1:AOI2)	8939		
## cor(diagnosis1:AOI2, sync1:AOI2)	9305		
## cor(sync1:AOI1, sync1:AOI2)	10028		
## cor(Intercept, diagnosis1:sync1:AOI1)	8770		
## cor(diagnosis1, diagnosis1:sync1:AOI1)	8671		
## cor(sync1, diagnosis1:sync1:AOI1)	9031		
## cor(AOI1, diagnosis1:sync1:AOI1)	9082		
## cor(AOI2, diagnosis1:sync1:AOI1)	8938		
## cor(diagnosis1:sync1, diagnosis1:sync1:AOI1)	8794		
## cor(diagnosis1:AOI1, diagnosis1:sync1:AOI1)	9562		
## cor(diagnosis1:AOI2, diagnosis1:sync1:AOI1)	8483		
## cor(sync1:AOI1, diagnosis1:sync1:AOI1)	9717		
## cor(sync1:AOI2, diagnosis1:sync1:AOI1)	10228		
## cor(Intercept, diagnosis1:sync1:AOI2)	8482		
## cor(diagnosis1, diagnosis1:sync1:AOI2)	8687		
## cor(sync1, diagnosis1:sync1:AOI2)	8895		
## cor(AOI1, diagnosis1:sync1:AOI2)	9522		
## cor(AOI2, diagnosis1:sync1:AOI2)	9680		
## cor(diagnosis1:sync1, diagnosis1:sync1:AOI2)	8876		
## cor(diagnosis1:AOI1, diagnosis1:sync1:AOI2)	8779		
## cor(diagnosis1:AOI2, diagnosis1:sync1:AOI2)	8530		
## cor(sync1:AOI1, diagnosis1:sync1:AOI2)	9800		
## cor(sync1:AOI2, diagnosis1:sync1:AOI2)	9635		
## cor(diagnosis1:sync1:AOI1, diagnosis1:sync1:AOI2)	9647		
##			
## ~subID (Number of levels: 45)			
##			
## sd(Intercept)	1.69		
## sd(sync1)	0.24		
## sd(dyad.type1)	0.24		
## sd(AOI1)	13.43		
## sd(AOI2)	8.35		
## sd(sync1:dyad.type1)	0.25		
## sd(sync1:AOI1)	1.26		
## sd(sync1:AOI2)	0.61		
## sd(dyad.type1:AOI1)	1.98		
## sd(dyad.type1:AOI2)	1.73		
## sd(sync1:dyad.type1:AOI1)	1.82		
## sd(sync1:dyad.type1:AOI2)	0.58		
## cor(Intercept, sync1)	0.05		
	Estimate	Est.Error	l-95% CI

## cor(Intercept,dyad.type1)	0.02	0.25	-0.47
## cor(sync1,dyad.type1)	0.01	0.26	-0.51
## cor(Intercept,AOI1)	0.43	0.14	0.12
## cor(sync1,AOI1)	0.05	0.26	-0.47
## cor(dyad.type1,AOI1)	0.04	0.25	-0.46
## cor(Intercept,AOI2)	0.17	0.16	-0.15
## cor(sync1,AOI2)	-0.00	0.26	-0.50
## cor(dyad.type1,AOI2)	-0.00	0.26	-0.50
## cor(AOI1,AOI2)	-0.55	0.10	-0.72
## cor(Intercept, sync1:dyad.type1)	-0.06	0.26	-0.55
## cor(sync1, sync1:dyad.type1)	0.00	0.26	-0.50
## cor(dyad.type1, sync1:dyad.type1)	-0.00	0.26	-0.50
## cor(AOI1, sync1:dyad.type1)	-0.01	0.26	-0.50
## cor(AOI2, sync1:dyad.type1)	-0.05	0.26	-0.54
## cor(Intercept, sync1:AOI1)	-0.01	0.22	-0.44
## cor(sync1, sync1:AOI1)	0.01	0.26	-0.48
## cor(dyad.type1, sync1:AOI1)	-0.02	0.26	-0.52
## cor(AOI1, sync1:AOI1)	-0.16	0.20	-0.52
## cor(AOI2, sync1:AOI1)	0.01	0.21	-0.39
## cor(sync1:dyad.type1, sync1:AOI1)	0.02	0.26	-0.48
## cor(Intercept, sync1:AOI2)	0.02	0.24	-0.46
## cor(sync1, sync1:AOI2)	0.01	0.26	-0.48
## cor(dyad.type1, sync1:AOI2)	0.02	0.26	-0.49
## cor(AOI1, sync1:AOI2)	0.02	0.24	-0.45
## cor(AOI2, sync1:AOI2)	-0.05	0.24	-0.51
## cor(sync1:dyad.type1, sync1:AOI2)	0.00	0.26	-0.50
## cor(sync1:AOI1, sync1:AOI2)	0.01	0.25	-0.48
## cor(Intercept, dyad.type1:AOI1)	0.16	0.20	-0.23
## cor(sync1, dyad.type1:AOI1)	0.01	0.26	-0.50
## cor(dyad.type1, dyad.type1:AOI1)	0.05	0.26	-0.45
## cor(AOI1, dyad.type1:AOI1)	0.22	0.16	-0.11
## cor(AOI2, dyad.type1:AOI1)	-0.17	0.17	-0.49
## cor(sync1:dyad.type1, dyad.type1:AOI1)	-0.01	0.26	-0.51
## cor(sync1:AOI1, dyad.type1:AOI1)	-0.04	0.23	-0.46
## cor(sync1:AOI2, dyad.type1:AOI1)	0.13	0.25	-0.38
## cor(Intercept, dyad.type1:AOI2)	-0.12	0.21	-0.52
## cor(sync1, dyad.type1:AOI2)	-0.01	0.26	-0.50
## cor(dyad.type1, dyad.type1:AOI2)	-0.04	0.26	-0.54
## cor(AOI1, dyad.type1:AOI2)	-0.20	0.17	-0.52
## cor(AOI2, dyad.type1:AOI2)	-0.01	0.18	-0.37
## cor(sync1:dyad.type1, dyad.type1:AOI2)	0.01	0.26	-0.49
## cor(sync1:AOI1, dyad.type1:AOI2)	-0.00	0.23	-0.45
## cor(sync1:AOI2, dyad.type1:AOI2)	-0.09	0.25	-0.56
## cor(dyad.type1:AOI1, dyad.type1:AOI2)	-0.48	0.21	-0.80
## cor(Intercept, sync1:dyad.type1:AOI1)	0.10	0.20	-0.30
## cor(sync1, sync1:dyad.type1:AOI1)	0.01	0.26	-0.49
## cor(dyad.type1, sync1:dyad.type1:AOI1)	-0.00	0.26	-0.51
## cor(AOI1, sync1:dyad.type1:AOI1)	0.22	0.16	-0.10
## cor(AOI2, sync1:dyad.type1:AOI1)	0.04	0.18	-0.31
## cor(sync1:dyad.type1, sync1:dyad.type1:AOI1)	0.02	0.26	-0.48
## cor(sync1:AOI1, sync1:dyad.type1:AOI1)	0.02	0.23	-0.44
## cor(sync1:AOI2, sync1:dyad.type1:AOI1)	-0.03	0.25	-0.50
## cor(dyad.type1:AOI1, sync1:dyad.type1:AOI1)	-0.26	0.20	-0.62
## cor(dyad.type1:AOI2, sync1:dyad.type1:AOI1)	0.01	0.22	-0.43

## cor(Intercept, sync1:dyad.type1:AOI2)	-0.01	0.25	-0.50
## cor(sync1, sync1:dyad.type1:AOI2)	0.00	0.26	-0.49
## cor(dyad.type1, sync1:dyad.type1:AOI2)	-0.00	0.26	-0.49
## cor(AOI1, sync1:dyad.type1:AOI2)	-0.03	0.24	-0.50
## cor(AOI2, sync1:dyad.type1:AOI2)	0.05	0.24	-0.43
## cor(sync1:dyad.type1, sync1:dyad.type1:AOI2)	0.00	0.26	-0.51
## cor(sync1:AOI1, sync1:dyad.type1:AOI2)	0.00	0.25	-0.49
## cor(sync1:AOI2, sync1:dyad.type1:AOI2)	0.00	0.26	-0.49
## cor(dyad.type1:AOI1, sync1:dyad.type1:AOI2)	0.01	0.25	-0.48
## cor(dyad.type1:AOI2, sync1:dyad.type1:AOI2)	-0.08	0.25	-0.55
## cor(sync1:dyad.type1:AOI1, sync1:dyad.type1:AOI2)	-0.08	0.26	-0.55
##		u-95% CI	Rhat
## sd(Intercept)	2.41	1.00	6831
## sd(sync1)	0.70	1.00	6984
## sd(dyad.type1)	0.69	1.00	6310
## sd(AOI1)	16.12	1.00	4148
## sd(AOI2)	10.30	1.00	4337
## sd(sync1:dyad.type1)	0.69	1.00	7499
## sd(sync1:AOI1)	2.35	1.00	2695
## sd(sync1:AOI2)	1.55	1.00	3908
## sd(dyad.type1:AOI1)	2.99	1.00	2652
## sd(dyad.type1:AOI2)	2.80	1.00	2386
## sd(sync1:dyad.type1:AOI1)	2.80	1.00	4337
## sd(sync1:dyad.type1:AOI2)	1.54	1.00	4346
## cor(Intercept, sync1)	0.54	1.00	15770
## cor(Intercept, dyad.type1)	0.51	1.00	15762
## cor(sync1, dyad.type1)	0.51	1.00	13170
## cor(Intercept, AOI1)	0.68	1.00	2255
## cor(sync1, AOI1)	0.55	1.01	938
## cor(dyad.type1, AOI1)	0.53	1.01	937
## cor(Intercept, AOI2)	0.47	1.00	2429
## cor(sync1, AOI2)	0.50	1.01	821
## cor(dyad.type1, AOI2)	0.50	1.00	778
## cor(AOI1, AOI2)	-0.35	1.00	6048
## cor(Intercept, sync1:dyad.type1)	0.46	1.00	15762
## cor(sync1, sync1:dyad.type1)	0.50	1.00	14404
## cor(dyad.type1, sync1:dyad.type1)	0.49	1.00	12581
## cor(AOI1, sync1:dyad.type1)	0.49	1.00	15938
## cor(AOI2, sync1:dyad.type1)	0.46	1.00	15956
## cor(Intercept, sync1:AOI1)	0.42	1.00	7688
## cor(sync1, sync1:AOI1)	0.51	1.00	5117
## cor(dyad.type1, sync1:AOI1)	0.47	1.00	4882
## cor(AOI1, sync1:AOI1)	0.26	1.00	12164
## cor(AOI2, sync1:AOI1)	0.42	1.00	14549
## cor(sync1:dyad.type1, sync1:AOI1)	0.52	1.00	6465
## cor(Intercept, sync1:AOI2)	0.48	1.00	13418
## cor(sync1, sync1:AOI2)	0.50	1.00	9345
## cor(dyad.type1, sync1:AOI2)	0.52	1.00	10144
## cor(AOI1, sync1:AOI2)	0.48	1.00	14409
## cor(AOI2, sync1:AOI2)	0.43	1.00	14666
## cor(sync1:dyad.type1, sync1:AOI2)	0.49	1.00	9039
## cor(sync1:AOI1, sync1:AOI2)	0.49	1.00	10397
## cor(Intercept, dyad.type1:AOI1)	0.53	1.00	5719
## cor(sync1, dyad.type1:AOI1)	0.50	1.00	2753

## cor(dyad.type1,dyad.type1:AOI1)	0.54	1.00	2874
## cor(AOI1,dyad.type1:AOI1)	0.53	1.00	11151
## cor(AOI2,dyad.type1:AOI1)	0.17	1.00	12129
## cor(sync1:dyad.type1,dyad.type1:AOI1)	0.49	1.00	4129
## cor(sync1:AOI1,dyad.type1:AOI1)	0.41	1.00	6119
## cor(sync1:AOI2,dyad.type1:AOI1)	0.59	1.00	4193
## cor(Intercept,dyad.type1:AOI2)	0.30	1.00	5912
## cor(sync1,dyad.type1:AOI2)	0.48	1.00	3470
## cor(dyad.type1,dyad.type1:AOI2)	0.47	1.00	3790
## cor(AOI1,dyad.type1:AOI2)	0.16	1.00	11536
## cor(AOI2,dyad.type1:AOI2)	0.34	1.00	13329
## cor(sync1:dyad.type1,dyad.type1:AOI2)	0.50	1.00	5023
## cor(sync1:AOI1,dyad.type1:AOI2)	0.45	1.00	6602
## cor(sync1:AOI2,dyad.type1:AOI2)	0.41	1.00	5214
## cor(dyad.type1:AOI1,dyad.type1:AOI2)	0.03	1.00	3242
## cor(Intercept, sync1:dyad.type1:AOI1)	0.48	1.00	6057
## cor(sync1, sync1:dyad.type1:AOI1)	0.51	1.00	3095
## cor(dyad.type1, sync1:dyad.type1:AOI1)	0.49	1.00	2953
## cor(AOI1, sync1:dyad.type1:AOI1)	0.53	1.00	11901
## cor(AOI2, sync1:dyad.type1:AOI1)	0.38	1.00	13143
## cor(sync1:dyad.type1, sync1:dyad.type1:AOI1)	0.51	1.00	4742
## cor(sync1:AOI1, sync1:dyad.type1:AOI1)	0.47	1.00	6787
## cor(sync1:AOI2, sync1:dyad.type1:AOI1)	0.46	1.00	5325
## cor(dyad.type1:AOI1, sync1:dyad.type1:AOI1)	0.17	1.00	8274
## cor(dyad.type1:AOI2, sync1:dyad.type1:AOI1)	0.44	1.00	9205
## cor(Intercept, sync1:dyad.type1:AOI2)	0.48	1.00	12545
## cor(sync1, sync1:dyad.type1:AOI2)	0.49	1.00	12115
## cor(dyad.type1, sync1:dyad.type1:AOI2)	0.49	1.00	10504
## cor(AOI1, sync1:dyad.type1:AOI2)	0.45	1.00	14610
## cor(AOI2, sync1:dyad.type1:AOI2)	0.50	1.00	15064
## cor(sync1:dyad.type1, sync1:dyad.type1:AOI2)	0.50	1.00	9040
## cor(sync1:AOI1, sync1:dyad.type1:AOI2)	0.48	1.00	10710
## cor(sync1:AOI2, sync1:dyad.type1:AOI2)	0.50	1.00	8066
## cor(dyad.type1:AOI1, sync1:dyad.type1:AOI2)	0.49	1.00	11410
## cor(dyad.type1:AOI2, sync1:dyad.type1:AOI2)	0.43	1.00	9899
## cor(sync1:dyad.type1:AOI1, sync1:dyad.type1:AOI2)	0.44	1.00	9995
##		Tail_ESS	
## sd(Intercept)	7650		
## sd(sync1)	4136		
## sd(dyad.type1)	3983		
## sd(AOI1)	6699		
## sd(AOI2)	6916		
## sd(sync1:dyad.type1)	5035		
## sd(sync1:AOI1)	2621		
## sd(sync1:AOI2)	4211		
## sd(dyad.type1:AOI1)	2224		
## sd(dyad.type1:AOI2)	1604		
## sd(sync1:dyad.type1:AOI1)	3247		
## sd(sync1:dyad.type1:AOI2)	4335		
## cor(Intercept, sync1)	8738		
## cor(Intercept, dyad.type1)	8622		
## cor(sync1, dyad.type1)	8111		
## cor(Intercept, AOI1)	3873		
## cor(sync1, AOI1)	2366		

## cor(dyad.type1, AOI1)	2697
## cor(Intercept, AOI2)	4144
## cor(sync1, AOI2)	1901
## cor(dyad.type1, AOI2)	1846
## cor(AOI1, AOI2)	8575
## cor(Intercept, sync1:dyad.type1)	8131
## cor(sync1, sync1:dyad.type1)	9058
## cor(dyad.type1, sync1:dyad.type1)	9361
## cor(AOI1, sync1:dyad.type1)	9243
## cor(AOI2, sync1:dyad.type1)	9063
## cor(Intercept, sync1:AOI1)	8087
## cor(sync1, sync1:AOI1)	7453
## cor(dyad.type1, sync1:AOI1)	7829
## cor(AOI1, sync1:AOI1)	8147
## cor(AOI2, sync1:AOI1)	8775
## cor(sync1:dyad.type1, sync1:AOI1)	8693
## cor(Intercept, sync1:AOI2)	8610
## cor(sync1, sync1:AOI2)	9110
## cor(dyad.type1, sync1:AOI2)	9507
## cor(AOI1, sync1:AOI2)	9306
## cor(AOI2, sync1:AOI2)	8174
## cor(sync1:dyad.type1, sync1:AOI2)	9109
## cor(sync1:AOI1, sync1:AOI2)	9595
## cor(Intercept, dyad.type1:AOI1)	6976
## cor(sync1, dyad.type1:AOI1)	5409
## cor(dyad.type1, dyad.type1:AOI1)	5857
## cor(AOI1, dyad.type1:AOI1)	8569
## cor(AOI2, dyad.type1:AOI1)	9589
## cor(sync1:dyad.type1, dyad.type1:AOI1)	6903
## cor(sync1:AOI1, dyad.type1:AOI1)	8517
## cor(sync1:AOI2, dyad.type1:AOI1)	6722
## cor(Intercept, dyad.type1:AOI2)	8150
## cor(sync1, dyad.type1:AOI2)	6185
## cor(dyad.type1, dyad.type1:AOI2)	6027
## cor(AOI1, dyad.type1:AOI2)	8047
## cor(AOI2, dyad.type1:AOI2)	9866
## cor(sync1:dyad.type1, dyad.type1:AOI2)	7395
## cor(sync1:AOI1, dyad.type1:AOI2)	7944
## cor(sync1:AOI2, dyad.type1:AOI2)	7306
## cor(dyad.type1:AOI1, dyad.type1:AOI2)	3530
## cor(Intercept, sync1:dyad.type1:AOI1)	7598
## cor(sync1, sync1:dyad.type1:AOI1)	5792
## cor(dyad.type1, sync1:dyad.type1:AOI1)	5479
## cor(AOI1, sync1:dyad.type1:AOI1)	9903
## cor(AOI2, sync1:dyad.type1:AOI1)	9020
## cor(sync1:dyad.type1, sync1:dyad.type1:AOI1)	7316
## cor(sync1:AOI1, sync1:dyad.type1:AOI1)	7993
## cor(sync1:AOI2, sync1:dyad.type1:AOI1)	8266
## cor(dyad.type1:AOI1, sync1:dyad.type1:AOI1)	8605
## cor(dyad.type1:AOI2, sync1:dyad.type1:AOI1)	10558
## cor(Intercept, sync1:dyad.type1:AOI2)	8924
## cor(sync1, sync1:dyad.type1:AOI2)	8906
## cor(dyad.type1, sync1:dyad.type1:AOI2)	9313
## cor(AOI1, sync1:dyad.type1:AOI2)	9210

```

## cor(AOI2, sync1:dyad.type1:AOI2) 9300
## cor(sync1:dyad.type1, sync1:dyad.type1:AOI2) 8813
## cor(sync1:AOI1, sync1:dyad.type1:AOI2) 9751
## cor(sync1:AOI2, sync1:dyad.type1:AOI2) 8625
## cor(dyad.type1:AOI1, sync1:dyad.type1:AOI2) 9538
## cor(dyad.type1:AOI2, sync1:dyad.type1:AOI2) 9278
## cor(sync1:dyad.type1:AOI1, sync1:dyad.type1:AOI2) 10522
##
## Regression Coefficients:
##                                     Estimate Est.Error 1-95% CI u-95% CI Rhat
## Intercept                      34.58     1.52   31.48   37.63 1.00
## diagnosis1                     -0.95     0.42   -1.79   -0.13 1.00
## sync1                           0.32     0.75   -1.16   1.85  1.00
## dyad.type1                      0.66     1.50   -2.44   3.66  1.00
## AOI1                            14.86    2.99    8.79  20.54 1.00
## AOI2                            -1.05    2.59   -6.19   4.18  1.00
## diagnosis1:sync1                -0.16    0.31   -0.77   0.46  1.00
## diagnosis1:dyad.type1           0.08     0.33   -0.59   0.73  1.00
## sync1:dyad.type1                -0.58    0.76   -2.11   0.98  1.00
## diagnosis1:AOI1                 -4.38    2.13   -8.60  -0.15 1.00
## diagnosis1:AOI2                 -0.24    1.32   -2.83   2.43  1.00
## sync1:AOI1                      0.96     1.30   -1.69   3.57  1.00
## sync1:AOI2                      -0.80    1.31   -3.43   1.90  1.00
## dyad.type1:AOI1                 -0.58    2.26   -5.20   3.94  1.00
## dyad.type1:AOI2                 0.24     2.36   -4.56   4.93  1.00
## diagnosis1:sync1:dyad.type1     0.19     0.32   -0.41   0.80  1.00
## diagnosis1:sync1:AOI1            -0.52    0.60   -1.72   0.66  1.00
## diagnosis1:sync1:AOI2            -0.46    0.49   -1.37   0.52  1.00
## diagnosis1:dyad.type1:AOI1      -0.42    0.91   -2.27   1.38  1.00
## diagnosis1:dyad.type1:AOI2      0.16     0.52   -0.89   1.17  1.00
## sync1:dyad.type1:AOI1            0.37     1.33   -2.34   3.03  1.00
## sync1:dyad.type1:AOI2            -1.66    1.31   -4.26   1.01  1.00
## diagnosis1:sync1:dyad.type1:AOI1 -0.19    0.61   -1.39   1.00  1.00
## diagnosis1:sync1:dyad.type1:AOI2  0.06     0.50   -0.91   1.03  1.00
##                                     Bulk_ESS Tail_ESS
## Intercept                      2949     4129
## diagnosis1                     5069     6804
## sync1                           4209     4860
## dyad.type1                      2687     4055
## AOI1                            3193     5152
## AOI2                            4171     6520
## diagnosis1:sync1                7896     6777
## diagnosis1:dyad.type1           7978     6310
## sync1:dyad.type1                3636     4697
## diagnosis1:AOI1                 3241     5423
## diagnosis1:AOI2                 3625     5843
## sync1:AOI1                      4783     5573
## sync1:AOI2                      4814     5205
## dyad.type1:AOI1                 3669     5052
## dyad.type1:AOI2                 4184     5761
## diagnosis1:sync1:dyad.type1     8470     6303
## diagnosis1:sync1:AOI1            6093     6237
## diagnosis1:sync1:AOI2            6920     6645
## diagnosis1:dyad.type1:AOI1      5180     5930

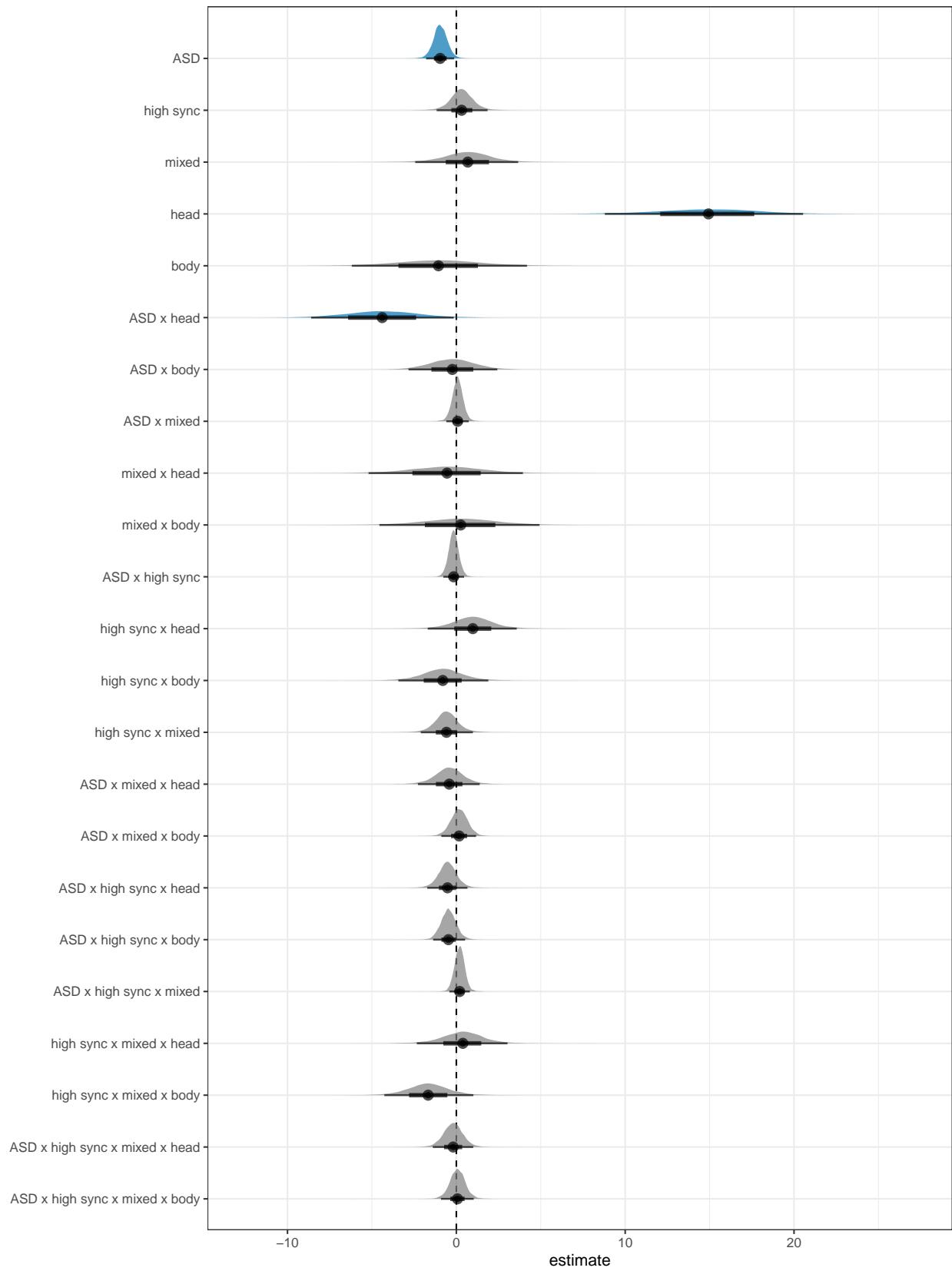
```

```

## diagnosis1:dyad.type1:AOI2           7605    7977
## sync1:dyad.type1:AOI1              4487    5273
## sync1:dyad.type1:AOI2           4570    5433
## diagnosis1:sync1:dyad.type1:AOI1      6260    6506
## diagnosis1:sync1:dyad.type1:AOI2      7034    6010
##
## Further Distributional Parameters:
##          Estimate   Est.Error  l-95% CI  u-95% CI   Rhat Bulk_ESS Tail_ESS
## sigma     11.33       0.19     10.98    11.72  1.00      7192     7919
##
## Draws were sampled using sample(hmc). 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 the posterior distributions
post.draws %>%
  select(starts_with("b_")) %>%
  pivot_longer(cols = starts_with("b_"),
               names_to = "coef",
               values_to = "estimate") %>%
  subset(!startsWith(coef, "b_Int")) %>%
  mutate(
    coef = substr(coef, 3, nchar(coef)),
    coef = str_replace_all(coef, ":", " x "),
    coef = str_replace_all(coef, "diagnosis1", "ASD"),
    coef = str_replace_all(coef, "sync1", "high sync"),
    coef = str_replace_all(coef, "dyad.type1", "mixed"),
    coef = str_replace_all(coef, "AOI1", "head"),
    coef = str_replace_all(coef, "AOI2", "body"),
    coef_order = case_when(
      coef == "ASD" ~ 100,
      coef == "high sync" ~ 99,
      coef == "mixed" ~ 98,
      coef == "head" ~ 97,
      coef == "body" ~ 96,
      T ~ 100-nchar(coef)),
    coef = fct_reorder(coef, coef_order)
  ) %>%
  group_by(coef) %>%
  mutate(
    cred = case_when(
      (mean(estimate) < 0 & quantile(estimate, probs = 0.975) < 0) |
        (mean(estimate) > 0 & quantile(estimate, probs = 0.025) > 0) ~ "credible",
      T ~ "not credible"
    )
  ) %>% ungroup() %>%
  ggplot(aes(x = estimate, y = coef, fill = cred)) +
  geom_vline(xintercept = 0, linetype = 'dashed') +
  ggdist::stat_halfeye(alpha = 0.7) + ylab(NULL) + theme_bw() +
  scale_fill_manual(values = c(credible = c_dark, c_light)) +
  theme(legend.position = "none")

```



## Inferences

```

# H2.a Dyad type x AOI: Fixation durations for each area of interest differ
# between clips of no-diagnosis and mixed-diagnosis dyads.
h2.a = hypothesis(m.fix, "(dyad.type1:AOI1 + dyad.type1:AOI2)/2 < 0", alpha = 0.025)
h2.a

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 ((dyad.type1:AOI1... < 0     -0.17      1.52    -3.25     2.81      1.21
##   Post.Prob Star
## 1      0.55
## ---
## 'CI': 95%-CI for one-sided and 97.5%-CI for two-sided hypotheses.
## '*': For one-sided hypotheses, the posterior probability exceeds 97.5%;
## for two-sided hypotheses, the value tested against lies outside the 97.5%-CI.
## Posterior probabilities of point hypotheses assume equal prior probabilities.

# H2.b Synchrony x AOI: Fixation durations for each AOI differ between
# high- and low-synchrony clips.
h2.b = hypothesis(m.fix, "(sync1:AOI1 + sync1:AOI2)/2 > 0", alpha = 0.025)
h2.b

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 ((sync1:AOI1+sync... > 0     0.08      0.89    -1.72     1.88      1.15
##   Post.Prob Star
## 1      0.54
## ---
## 'CI': 95%-CI for one-sided and 97.5%-CI for two-sided hypotheses.
## '*': For one-sided hypotheses, the posterior probability exceeds 97.5%;
## for two-sided hypotheses, the value tested against lies outside the 97.5%-CI.
## Posterior probabilities of point hypotheses assume equal prior probabilities.

# H2.c Diagnostic status x AOI: Fixation durations for each AOI differ between
# autistic and non-autistic participants
h2.c = hypothesis(m.fix, "(diagnosis1:AOI1 + diagnosis1:AOI2)/2 < 0", alpha = 0.025)
h2.c

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 ((diagnosis1:AOI1... < 0     -2.31      0.94    -4.13    -0.47    108.09
##   Post.Prob Star
## 1      0.99      *
## ---
## 'CI': 95%-CI for one-sided and 97.5%-CI for two-sided hypotheses.
## '*': For one-sided hypotheses, the posterior probability exceeds 97.5%;
## for two-sided hypotheses, the value tested against lies outside the 97.5%-CI.
## Posterior probabilities of point hypotheses assume equal prior probabilities.

# exploring which AOI is driving this...
e1 = hypothesis(m.fix, "diagnosis1:AOI1 < 0", alpha = 0.025)
e1

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (diagnosis1:AOI1) < 0     -4.38      2.13    -8.6     -0.15     45.69

```

```

## Post.Prob Star
## 1      0.98   *
## ---
## 'CI': 95%-CI for one-sided and 97.5%-CI for two-sided hypotheses.
## '*': For one-sided hypotheses, the posterior probability exceeds 97.5%;
## for two-sided hypotheses, the value tested against lies outside the 97.5%-CI.
## Posterior probabilities of point hypotheses assume equal prior probabilities.
e2 = hypothesis(m.fix, "diagnosis1:AOI2 < 0", alpha = 0.025)
e2

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (diagnosis1:AOI2) < 0     -0.24      1.32    -2.83     2.43      1.34
## Post.Prob Star
## 1      0.57
## ---
## 'CI': 95%-CI for one-sided and 97.5%-CI for two-sided hypotheses.
## '*': For one-sided hypotheses, the posterior probability exceeds 97.5%;
## for two-sided hypotheses, the value tested against lies outside the 97.5%-CI.
## Posterior probabilities of point hypotheses assume equal prior probabilities.
e3 = hypothesis(m.fix, "-diagnosis1:AOI1 -diagnosis1:AOI2 > 0", alpha = 0.025)
e3

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (-diagnosis1:AOI1... > 0     4.62      1.87     0.93     8.26    108.09
## Post.Prob Star
## 1      0.99   *
## ---
## 'CI': 95%-CI for one-sided and 97.5%-CI for two-sided hypotheses.
## '*': For one-sided hypotheses, the posterior probability exceeds 97.5%;
## for two-sided hypotheses, the value tested against lies outside the 97.5%-CI.
## Posterior probabilities of point hypotheses assume equal prior probabilities.

```

Our second Bayesian linear mixed model evaluating predictors for the proportional dwell times reveals support for our expectation of differences between autistic and non-autistic participants dependent on the specific AOI (*Estimate* = -2.31 [-4.13, -0.47], *Posterior probability* = 0.991). Further exploration shows that this is driven by reduced dwell times on the head region (*Estimate* = -4.38 [-8.6, -0.15], *Posterior probability* = 0.979) and increased dwell times on the body region (*Estimate* = 4.62 [0.93, 8.26], *Posterior probability* = 0.991) for autistic participants.

There is no support for our hypotheses regarding interactions between synchrony and AOI (*Estimate* = 0.08 [-1.72, 1.88], *Posterior probability* = 0.536) or dyad type and AOI (*Estimate* = -0.17 [-3.25, 2.81], *Posterior probability* = 0.547).

## Plots

At the end, we again plot our data.

```

# rain cloud plot for fixation durations
df.fix.agg %>%
  group_by(subID, diagnosis, sync, dyad.type, AOI) %>%
  summarise(
    fix.prop = mean(fix.prop, na.rm = T)
  ) %>%
  ggplot(aes(AOI, fix.prop, fill = sync, colour = sync)) +

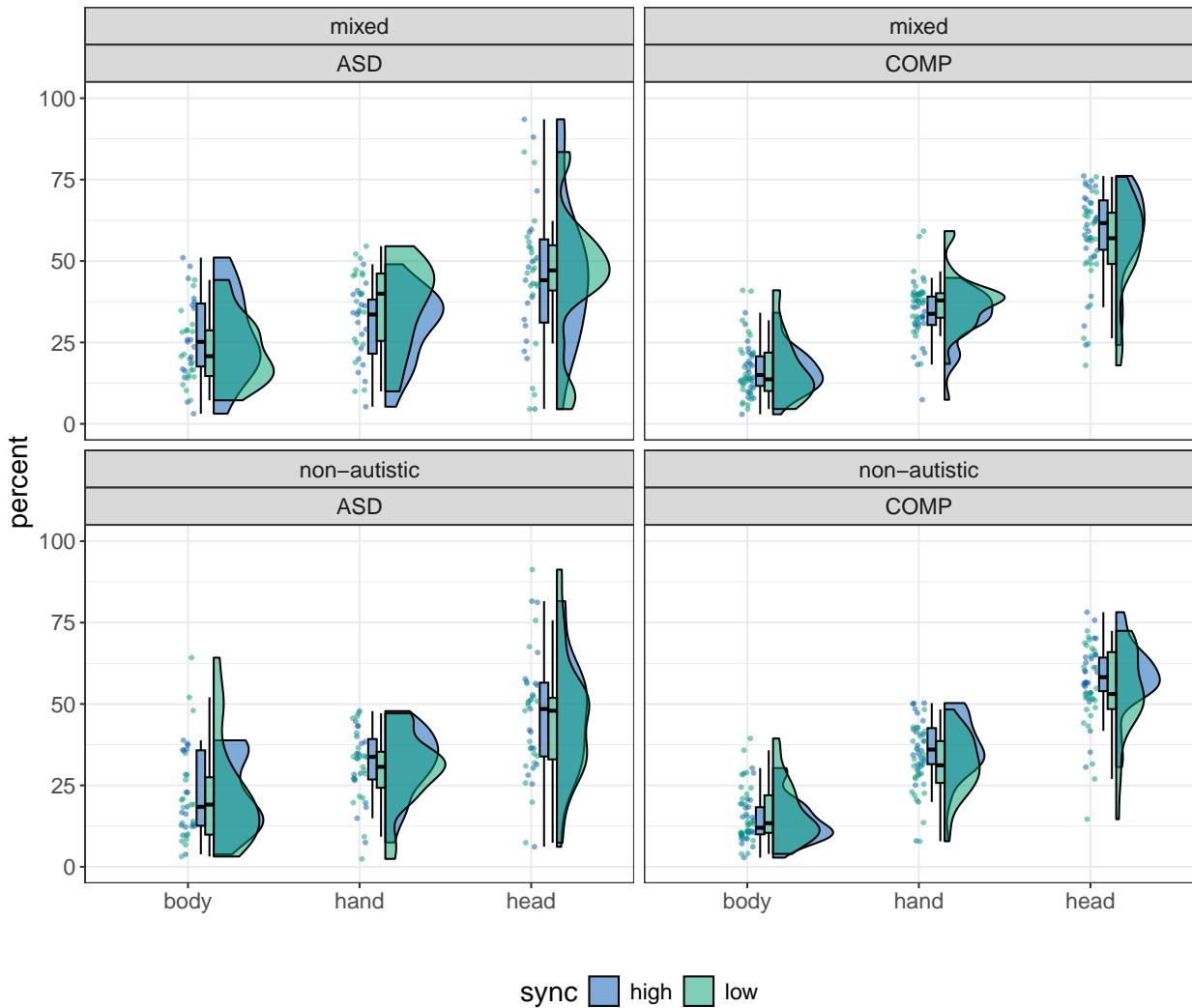
```

```

geom_rain(rain.side = 'r',
          boxplot.args = list(colour = "black",
                               outlier.shape = NA,
                               show.legend = FALSE,
                               alpha = 0.5),
          violin.args = list(colour = "black",
                             outlier.shape = NA,
                             show.legend = T,
                             alpha = .5),
          point.args = list(show.legend = FALSE,
                            size = 0.75,
                            alpha = .5),
          boxplot.args.pos = list(
            position =
              ggpp::position_dodgeudge(x = .1, width = 0.1),
            width = 0.1
          )) +
  ylim(0, 100) +
  facet_wrap(dyad.type ~ diagnosis) +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  labs(title = "Mean fixation duration proportions per subject",
       x = "",
       y = "percent") +
  theme_bw() +
  theme(legend.position = "bottom",
        plot.title = element_text(hjust = 0.5),
        legend.direction = "horizontal",
        text = element_text(size = 15))

```

### Mean fixation duration proportions per subject



sync █ high █ low

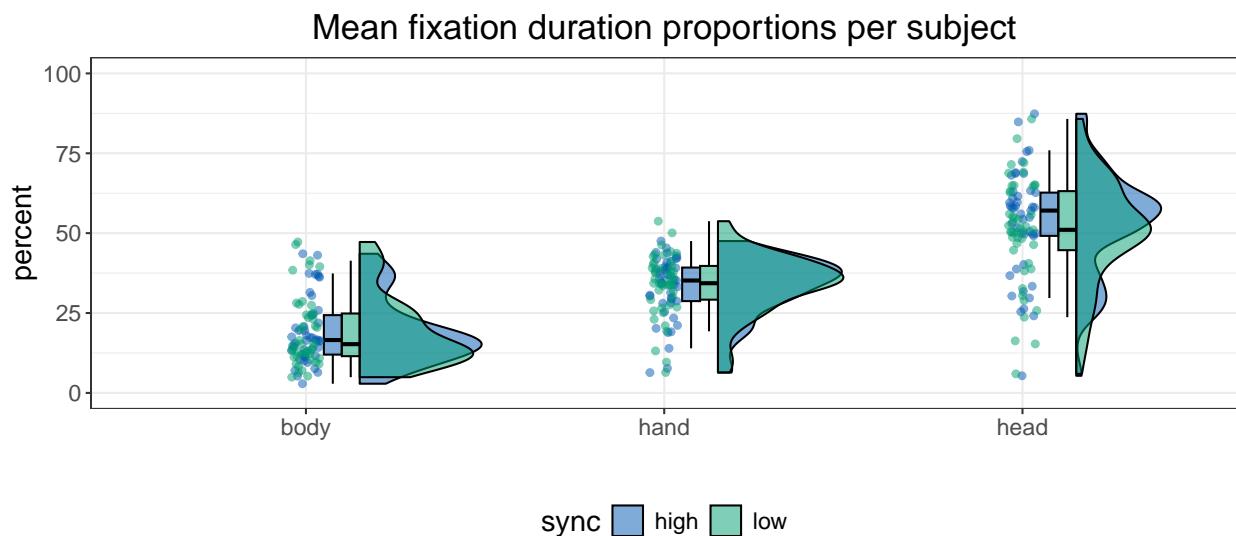
Additionally, we focus on specific interactions.

```
# rain cloud plot for fixation durations, focusing on synchrony x AOI
df.fix.agg %>%
  group_by(subID, diagnosis, sync, AOI) %>%
  summarise(
    fix.prop = mean(fix.prop, na.rm = T)
  ) %>%
  ggplot(aes(AOI, fix.prop, fill = sync, colour = sync)) +
  geom_rain(rain.side = 'r',
            boxplot.args = list(colour = "black",
                                 outlier.shape = NA,
                                 show.legend = FALSE,
                                 alpha = 0.5),
            violin.args   = list(colour = "black",
                                 outlier.shape = NA,
                                 show.legend = T,
                                 alpha = .5),
            point.args    = list(show.legend = FALSE,
```

```

            alpha = .5),
boxplot.args.pos = list(
  position =
    ggpp::position_dodgeudge(x = .1, width = 0.1),
  width = 0.1
)) +
ylim(0, 100) +
scale_fill_manual(values = custom.col) +
scale_color_manual(values = custom.col) +
labs(title = "Mean fixation duration proportions per subject",
  x = "",
  y = "percent") +
theme_bw() +
theme(legend.position = "bottom",
  plot.title = element_text(hjust = 0.5),
  legend.direction = "horizontal",
  text = element_text(size = 15))

```



```

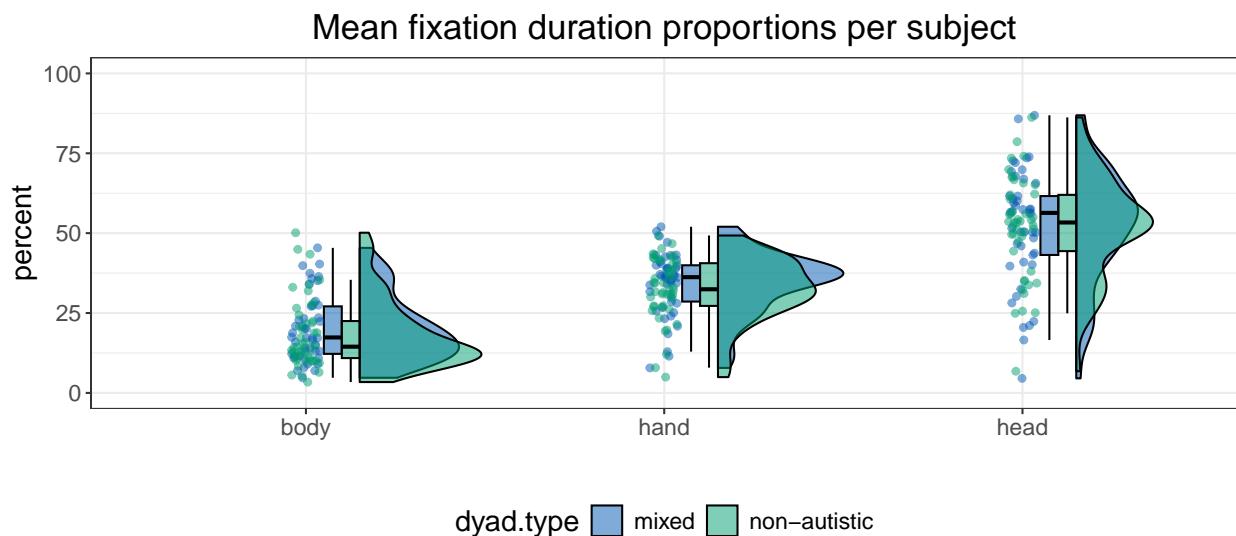
# rain cloud plot for fixation durations, focusing on dyad type x AOI
df.fix.agg %>%
  group_by(subID, diagnosis, dyad.type, AOI) %>%
  summarise(
    fix.prop = mean(fix.prop, na.rm = T)
  ) %>%
  ggplot(aes(AOI, fix.prop, fill = dyad.type, colour = dyad.type)) +
  geom_rain(rain.side = 'r',
            boxplot.args = list(colour = "black",
                                 outlier.shape = NA,
                                 show.legend = FALSE,
                                 alpha = 0.5),
            violin.args = list(colour = "black",
                               outlier.shape = NA,
                               show.legend = T,
                               alpha = .5),
            point.args = list(show.legend = FALSE,

```

```

            alpha = .5),
boxplot.args.pos = list(
  position =
    ggpp::position_dodgeudge(x = .1, width = 0.1),
  width = 0.1
)) +
ylim(0, 100) +
scale_fill_manual(values = custom.col) +
scale_color_manual(values = custom.col) +
labs(title = "Mean fixation duration proportions per subject",
  x = "",
  y = "percent") +
theme_bw() +
theme(legend.position = "bottom",
  plot.title = element_text(hjust = 0.5),
  legend.direction = "horizontal",
  text = element_text(size = 15))

```



```

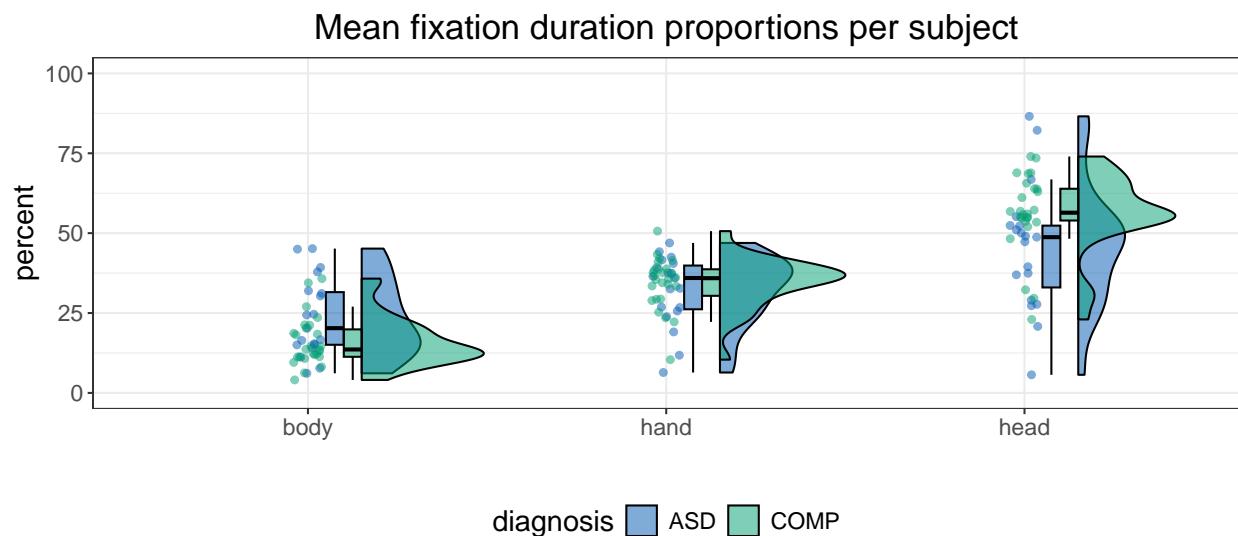
# rain cloud plot for fixation durations, focusing on diagnostic status x AOI
df.fix.agg %>%
  group_by(subID, diagnosis, AOI) %>%
  summarise(
    fix.prop = mean(fix.prop, na.rm = T)
  ) %>%
  ggplot(aes(AOI, fix.prop, fill = diagnosis, colour = diagnosis)) +
  geom_rain(rain.side = 'r',
            boxplot.args = list(colour = "black",
                                outlier.shape = NA,
                                show.legend = FALSE,
                                alpha = 0.5),
            violin.args = list(colour = "black",
                               outlier.shape = NA,
                               show.legend = T,
                               alpha = .5),
            point.args = list(show.legend = FALSE,

```

```

            alpha = .5),
boxplot.args.pos = list(
  position =
    ggpp::position_dodgeudge(x = .1, width = 0.1),
  width = 0.1
)) +
ylim(0, 100) +
scale_fill_manual(values = custom.col) +
scale_color_manual(values = custom.col) +
labs(title = "Mean fixation duration proportions per subject",
  x = "",
  y = "percent") +
theme_bw() +
theme(legend.position = "bottom",
  plot.title = element_text(hjust = 0.5),
  legend.direction = "horizontal",
  text = element_text(size = 15))

```



## Explorative analyses

We complement our hypotheses-guided analyses with some exploration of the data.

### Number of saccades

First, we use the saccades extracted by the Nyström and Holmqvist (2010) algorithm to explore whether there are differences in saccadic behaviour between our groups or the conditions.

#### SBC

```

# set formula considering all combinations
code   = "PESI_sac_int"
f.sac = brms::bf(n.sac ~ diagnosis * sync * dyad.type
                  + (1 | subID)
                  + (1 | dyad))

```

```

# set weakly informed priors
priors = c(
  # one saccade per second
  prior(normal(2.3, 1.00), class = Intercept),
  prior(normal(0, 0.20), class = sd),
  prior(normal(0, 0.10), class = b)
)

if (file.exists(file.path(cache_dir, paste0("df_res_", code, ".rds")))) {
  # load in the results of the SBC
  df.results = readRDS(file.path(cache_dir, paste0("df_res_", code, ".rds")))
  df.backend = readRDS(file.path(cache_dir, paste0("df_div_", code, ".rds")))
  dat       = readRDS(file.path(cache_dir, paste0("dat_", code, ".rds")))
} else {
  # set the seed
  set.seed(2489)
  # create the data
  gen   = SBC_generator_brms(f.sac, data = df.sac.agg, prior = priors,
                             thin = 50, warmup = 20000, refresh = 2000,
                             family = poisson
  )
  if (!file.exists(sprintf("%s/dat_%s.rds", cache_dir, code))) {
    dat = generate_datasets(gen, nsim)
    saveRDS(dat, file = sprintf("%s/dat_%s.rds", cache_dir, code))
  } else {
    dat = readRDS(sprintf("%s/dat_%s.rds", cache_dir, code))
  }

  # perform the SBC
  bck = SBC_backend_brms_from_generator(gen, chains = 4, thin = 1,
                                         warmup = warm, iter = iter,
                                         inits = 0.1)
  res = compute_SBC(dat, bck,
                    cache_mode = "results",
                    cache_location = file.path(cache_dir, sprintf("res_%s", code)))
  # save the results dataframes
  df.results = res$stats
  df.backend = res$backend_diagnostics
  saveRDS(df.results, file = file.path(cache_dir, paste0("df_res_", code, ".rds")))
  saveRDS(df.backend, file = file.path(cache_dir, paste0("df_div_", code, ".rds")))
}

}

```

Again, we start by investigating the rhats and the number of divergent samples. This shows that 0 of 500 simulations had at least one parameter that had an rhat of at least 1.05, and 162 models had divergent samples (mean number of samples of the simulations with divergent samples: 7.54). We will have to look out for divergence issues in the final model.

Next, we can plot the simulated values to perform prior predictive checks.

```

# create a matrix out of generated data
dvname = gsub(" ", "", gsub("[\\|~].*", "", f.sac)[1])
dvfakemat = matrix(NA, nrow(dat[['generated']][[1]]), length(dat[['generated']]))

for (i in 1:length(dat[['generated']])){

```

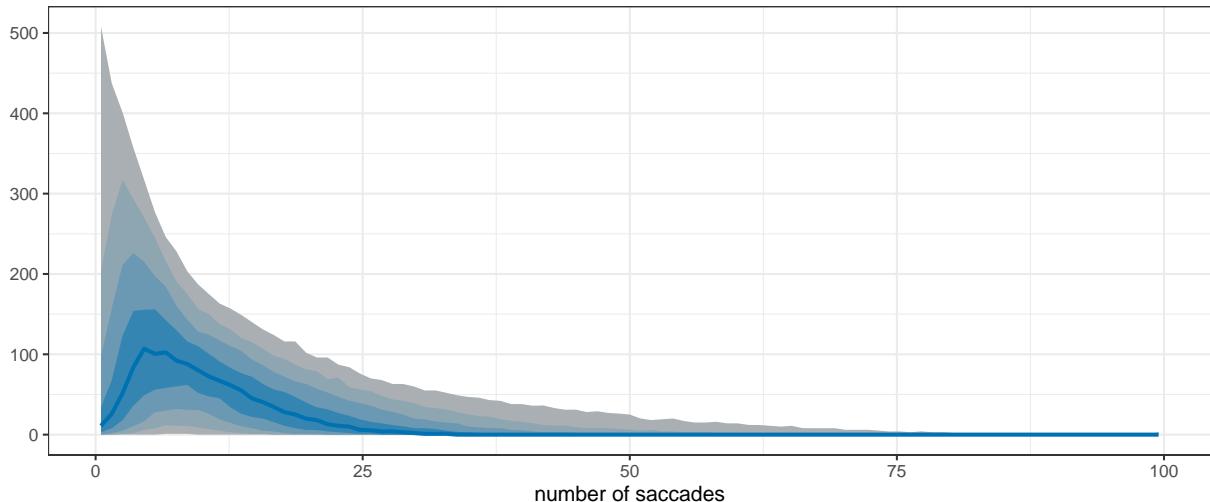
```

dvfakemat[,i] = dat[["generated"]][[i]][[dvname]]
}
truePars = dat$variables

# set very large data points to a value of 200
dvfakematH = dvfakemat;
dvfakematH[dvfakematH > 100] = 100
# compute one histogram per simulated data-set
breaks = seq(0, max(dvfakematH, na.rm=T), length.out = 100)
binwidth = breaks[2] - breaks[1]
histmat = matrix(NA, ncol = nrow(truePars) + binwidth, nrow = length(breaks)-1)
for (i in 1:nrow(truePars)) {
  histmat[,i] = hist(dvfakematH[,i], breaks = breaks, plot = F)$counts
}
# for each bin, compute quantiles across histograms
probs = seq(0.1, 0.9, 0.1)
quantmat= as.data.frame(matrix(NA, nrow=dim(histmat)[1], ncol = length(probs)))
names(quantmat) = paste0("p", probs)
for (i in 1:dim(histmat)[1]) {
  quantmat[i,] = quantile(histmat[i,], p = probs, na.rm = T)
}
quantmat$x = breaks[2:length(breaks)] - binwidth/2 # add bin mean
p1 = ggplot(data = quantmat, aes(x = x)) +
  geom_ribbon(aes(ymax = p0.9, ymin = p0.1), fill = c_light) +
  geom_ribbon(aes(ymax = p0.8, ymin = p0.2), fill = c_light_highlight) +
  geom_ribbon(aes(ymax = p0.7, ymin = p0.3), fill = c_mid) +
  geom_ribbon(aes(ymax = p0.6, ymin = p0.4), fill = c_mid_highlight) +
  geom_line(aes(y = p0.5), colour = c_dark, linewidth = 1) +
  labs(title = "Prior predictive distribution", y = "", x = "number of saccades") +
  theme_bw()
p1

```

Prior predictive distribution



Our simulated data centres around participants only producing a couple of saccades per video, which is reasonable since the videos are only 10 seconds long. However, there is some data simulated that shows up to 50 saccades, so it is reasonably wide and we are happy with the prior predictive distribution.

```

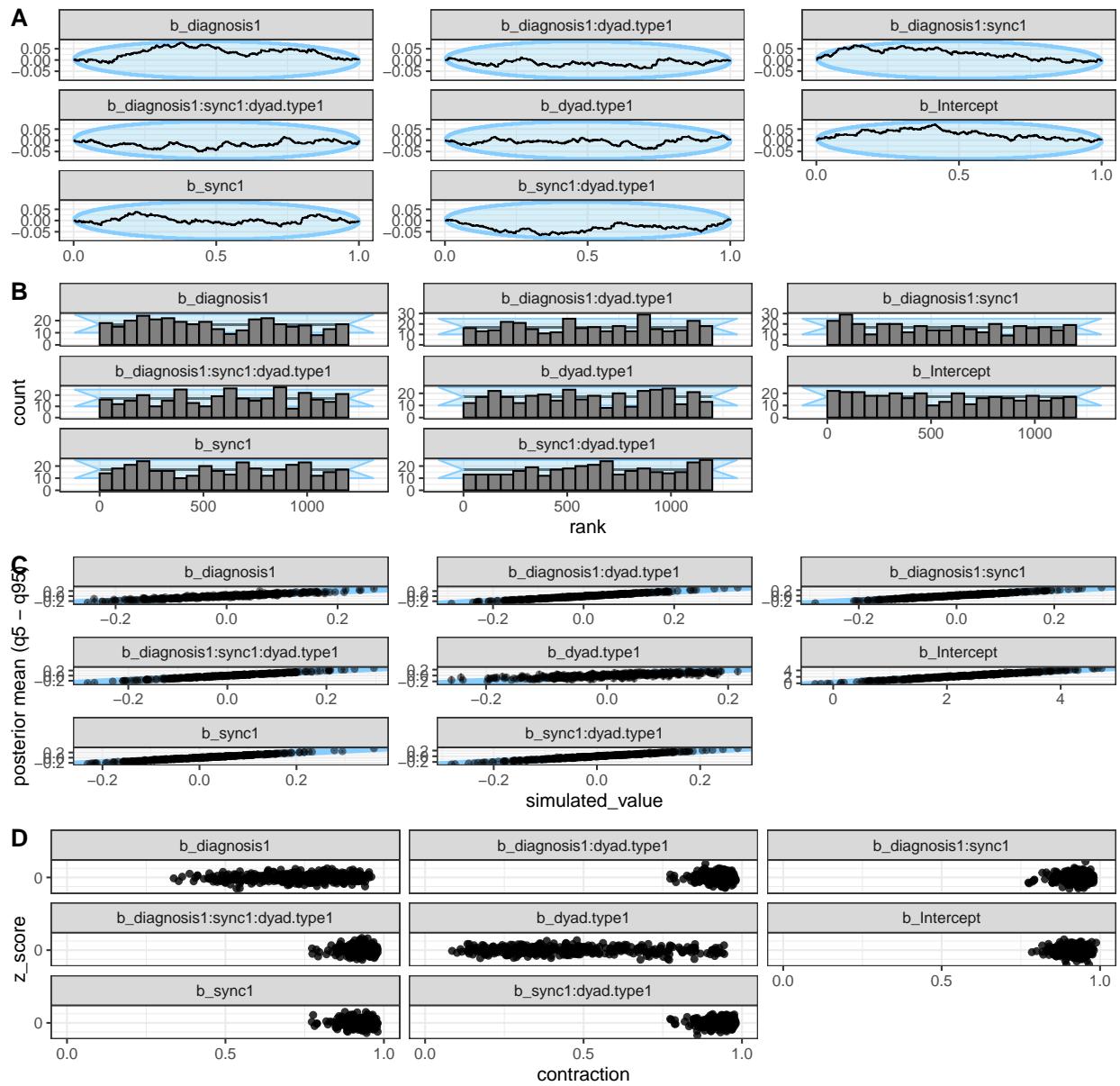
# get simulation numbers with issues
rank = max(df.results$max_rank)
check = merge(df.results %>%
  group_by(sim_id) %>%
  summarise(
    rhat = max(rhat, na.rm = T),
    mean_rank = mean(max_rank)
  ) %>%
  filter(rhat >= 1.05 | mean_rank != rank),
  df.backend %>% filter(n_divergent > 0), all = T)

# plot SBC with functions from the SBC package focusing on population-level parameters
df.results.b = df.results %>%
  filter(substr(variable, 1, 2) == "b_") %>%
  filter(!(sim_id %in% check$sim_id))
p1 = plot_ecdf_diff(df.results.b) + theme_bw() + theme(legend.position = "none") +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))
p2 = plot_rank_hist(df.results.b, bins = 20) + theme_bw() +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))
p3 = plot_sim_estimated(df.results.b, alpha = 0.5) + theme_bw() +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))
p4 = plot_contraction(
  df.results.b,
  prior_sd = setNames(c(1,
                        rep(0.1, length(unique(df.results.b$variable))-1)),
                        unique(df.results.b$variable))) +
  theme_bw() +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))

p = ggarrange(p1, p2, p3, p4, labels = "AUTO", ncol = 1, nrow = 4)
annotate_figure(p,
  top = text_grob("Computational faithfulness and model sensitivity",
  face = "bold", size = 14))

```

### Computational faithfulness and model sensitivity



Second, we check the outcome of the SBC. All looks acceptable.

### Posterior predictive checks

As the next step, we fit the model and check for issues.

```
# fit the model
set.seed(2496)
m.sac = brm(f.sac,
             df.sac.agg, prior = priors,
             family = poisson,
             iter = iter, warmup = warm,
             backend = "cmdstanr", threads = threading(8),
             file = "m_PESI_sac",
             save_pars = save_pars(all = TRUE))
```

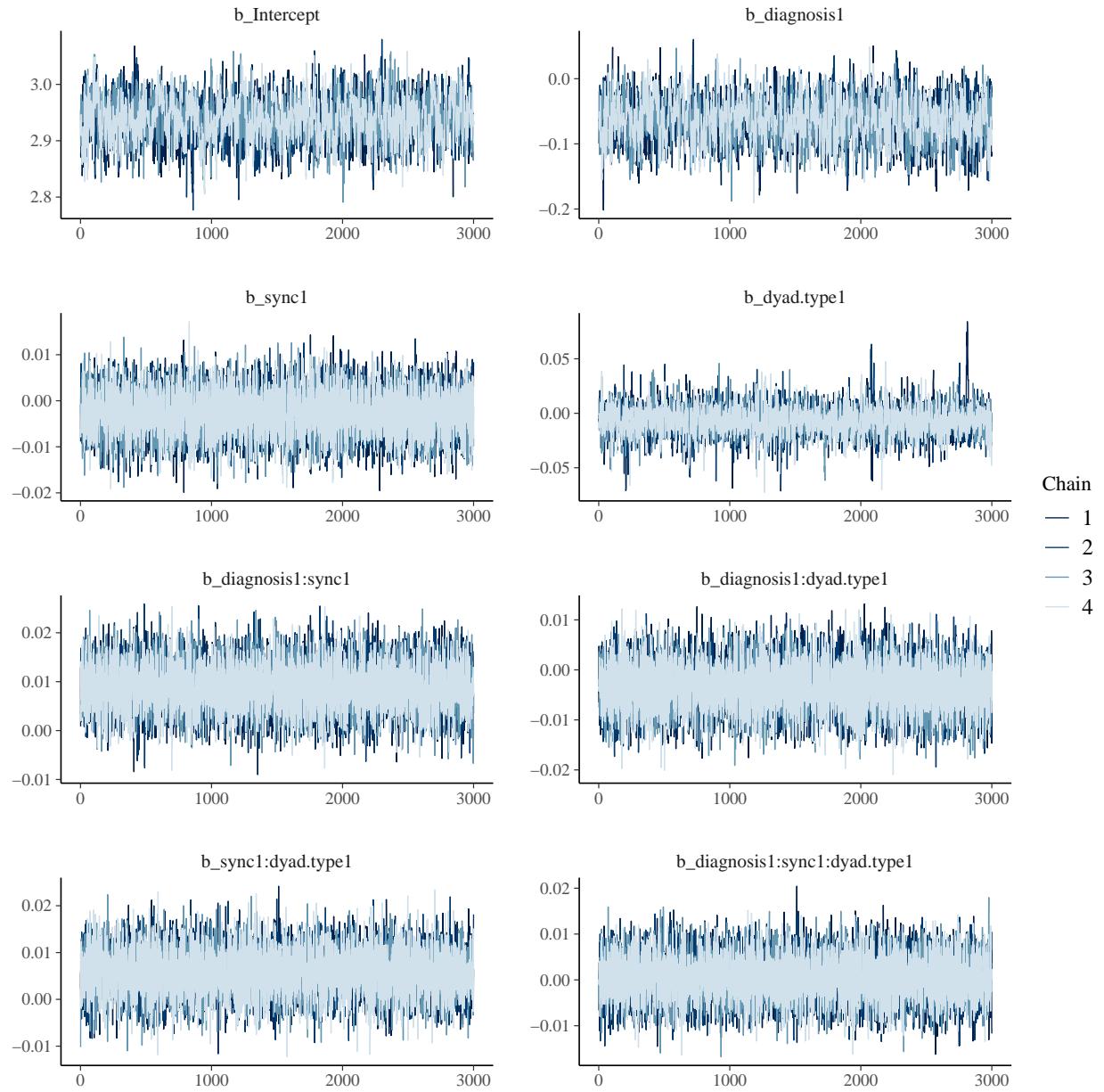
```

)
# in this model, there are no divergent samples
sum(subset(nuts_params(m.sac), Parameter == "divergent_")$Value)

## [1] 0
# check that rhats are below 1.01
sum(brms::rhat(m.sac) >= 1.01, na.rm = T)

## [1] 0
# and the chains have converged
post.draws = as_draws_df(m.sac)
mcmc_trace(post.draws, regex_pars = "^b_",
            facet_args = list(ncol = 2)) +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))

```



This model has no divergent samples, and no rhat that is higher or equal to 1.01. Therefore, we go ahead and perform our posterior predictive checks.

```
# get the posterior predictions
post.pred = posterior_predict(m.sac, ndraws = nsim)

# check the fit of the predicted data compared to the real data
p1 = pp_check(m.sac, ndraws = nsim) +
  theme_bw() + theme(legend.position = "none")

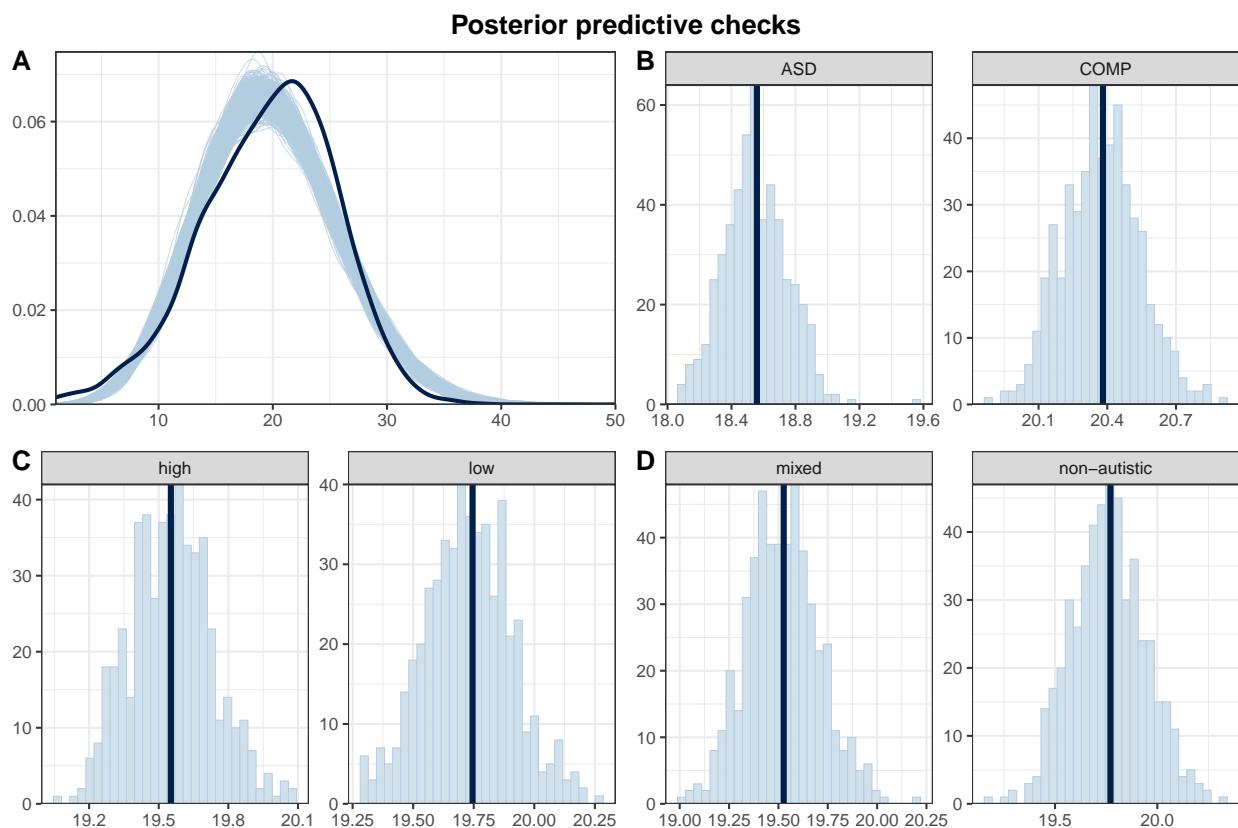
# distributions of means and sds compared to the real values per group
p2 = ppc_stat_grouped(df.sac.agg$n.sac, post.pred, df.sac.agg$diagnosis) +
  theme_bw() + theme(legend.position = "none")
# ... sync level
p3 = ppc_stat_grouped(df.sac.agg$n.sac, post.pred, df.sac.agg$sync) +
```

```

theme_bw() + theme(legend.position = "none")
# ... and dyad type
p4 = ppc_stat_grouped(df.sac.agg$n.sac, post.pred, df.sac.agg$dyad.type) +
  theme_bw() + theme(legend.position = "none")

p = ggarrange(p1, p2, p3, p4,
               nrow = 2, ncol = 2, labels = "AUTO")
annotate_figure(p,
               top = text_grob("Posterior predictive checks",
                               face = "bold", size = 14))

```



Although the overall shape is not perfect, the means are captured pretty well. Since we could not find a likelihood shape that fit better than this, we accept this model and test our hypotheses.

### Model summary

Now, we have a look at the model and its estimates.

```

# print a summary
summary(m.sac)

## Family: poisson
## Links: mu = log
## Formula: n.sac ~ diagnosis * sync * dyad.type + (1 | subID) + (1 | dyad)
## Data: df.sac.agg (Number of observations: 2392)
## Draws: 4 chains, each with iter = 4500; warmup = 1500; thin = 1;
##        total post-warmup draws = 12000

```

```

## Multilevel Hyperparameters:
## ~dyad (Number of levels: 8)
## Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept) 0.03 0.01 0.01 0.06 1.00 3109 5043
##
## ~subID (Number of levels: 46)
## Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept) 0.23 0.03 0.18 0.28 1.00 1581 3212
##
## Regression Coefficients:
## Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS
## Intercept 2.94 0.04 2.86 3.01 1.00 1233
## diagnosis1 -0.06 0.03 -0.13 -0.00 1.00 1538
## sync1 -0.00 0.00 -0.01 0.01 1.00 12282
## dyad.type1 -0.01 0.01 -0.03 0.02 1.00 3743
## diagnosis1:sync1 0.01 0.00 -0.00 0.02 1.00 12833
## diagnosis1:dyad.type1 -0.00 0.00 -0.01 0.01 1.00 13114
## sync1:dyad.type1 0.01 0.00 -0.00 0.02 1.00 13274
## diagnosis1:sync1:dyad.type1 0.00 0.00 -0.01 0.01 1.00 12940
## Tail_ESS
## Intercept 2633
## diagnosis1 2585
## sync1 8724
## dyad.type1 4266
## diagnosis1:sync1 8803
## diagnosis1:dyad.type1 8218
## sync1:dyad.type1 9142
## diagnosis1:sync1:dyad.type1 9342
##
## Draws were sampled using sample(hmc). 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).

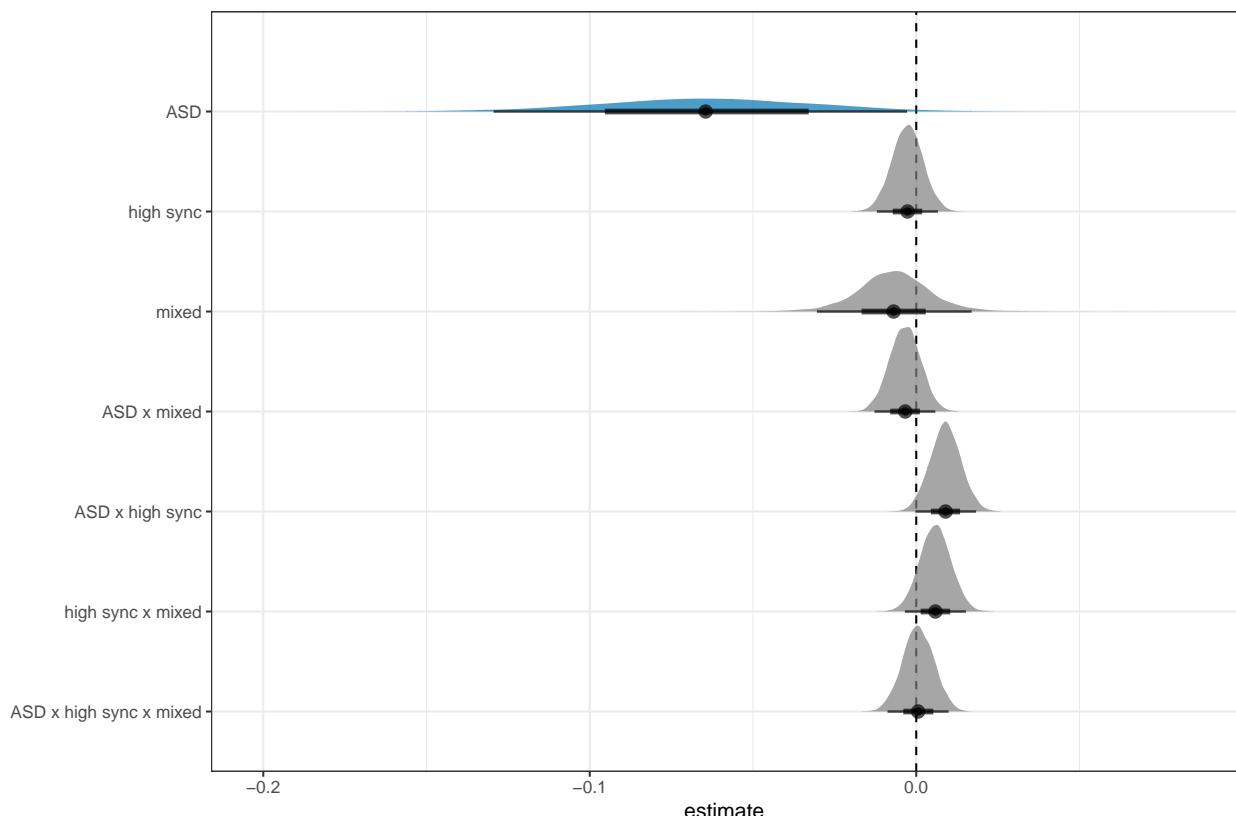
# plot the posterior distributions
post.draws %>%
  select(starts_with("b_")) %>%
  pivot_longer(cols = starts_with("b_"),
               names_to = "coef",
               values_to = "estimate") %>%
  subset(!startsWith(coef, "b_Int")) %>%
  mutate(
    coef = substr(coef, 3, nchar(coef)),
    coef = str_replace_all(coef, ":", " x "),
    coef = str_replace_all(coef, "diagnosis1", "ASD"),
    coef = str_replace_all(coef, "sync1", "high sync"),
    coef = str_replace_all(coef, "dyad.type1", "mixed"),
    coef_order = case_when(
      coef == "ASD" ~ 100,
      coef == "high sync" ~ 99,
      coef == "mixed" ~ 98,
      T ~ 100-nchar(coef)),
    coef = fct_reorder(coef, coef_order)
  ) %>%

```

```

group_by(coef) %>%
mutate(
  cred = case_when(
    (mean(estimate) < 0 & quantile(estimate, probs = 0.975) < 0) | 
      (mean(estimate) > 0 & quantile(estimate, probs = 0.025) > 0) ~ "credible",
    T ~ "not credible"
  )
) %>% ungroup() %>%
ggplot(aes(x = estimate, y = coef, fill = cred)) +
  geom_vline(xintercept = 0, linetype = 'dashed') +
  ggdist::stat_halfeye(alpha = 0.7) + ylab(NULL) + theme_bw() +
  scale_fill_manual(values = c(credible = c_dark, c_light)) +
  theme(legend.position = "none")

```



While autistic participants seem to have produced fewer saccades on average, this was independent of the conditions. Additionally, there seem to be no differences associated with the task conditions itself.

## Predicting ratings by gaze behaviour

We also want to see whether across groups gaze behaviour predicted ratings, i.e., focus on specific AOIs led to increased ratings.

### SBC

```

# combine data frames
df.com = df.fix %>%

```

```

select(subID, diagnosis, video, sync, dyad, dyad.type, AOI, fix.dur) %>%
pivot_wider(names_from = AOI, values_from = fix.dur) %>%
merge(., df.sac.agg) %>%
merge(., df) %>%
group_by(subID, diagnosis, sync, dyad, dyad.type) %>%
summarise(
  head = mean(head),
  hand = mean(hand),
  body = mean(body),
  n.sac = mean(n.sac),
  rating.confirmed = mean(rating.confirmed, na.rm = T)
) %>% ungroup() %>%
# scale the predictors
mutate(
  sn.sac = scale(n.sac),
  s.head = scale(head),
  s.hand = scale(hand),
  s.body = scale(body)
) %>% drop_na()

# set formula
code = "PESI_com"
f.com = brms::bf(rating.confirmed ~ sn.sac + s.head + s.hand + s.body +
  (1 | subID) + (1 | dyad))

# set weakly informed priors
priors = c(
  prior(normal(50, 10), class = Intercept),
  prior(normal(10, 10), class = sigma),
  prior(normal(0, 10), class = sd),
  prior(normal(0, 5), class = b)
)

if (file.exists(file.path(cache_dir, paste0("df_res_", code, ".rds")))) {
  # load in the results of the SBC
  df.results = readRDS(file.path(cache_dir, paste0("df_res_", code, ".rds")))
  df.backend = readRDS(file.path(cache_dir, paste0("df_div_", code, ".rds")))
  dat       = readRDS(file.path(cache_dir, paste0("dat_", code, ".rds")))
} else {
  # set the seed
  set.seed(2474)
  # create the data
  gen   = SBC_generator_brms(f.com, data = df.com, prior = priors,
                             thin = 50, warmup = 20000, refresh = 2000
  )
  dat   = generate_datasets(gen, nsim)
  saveRDS(dat, file = sprintf("%s/dat_%s.rds", cache_dir, code))

  # perform the SBC
  bck = SBC_backend_brms_from_generator(gen, chains = 4, thin = 1,
                                         warmup = warm, iter = iter,
                                         inits = 0.1)
  res = compute_SBC(dat, bck,
}

```

```

        cache_mode = "results",
        cache_location = file.path(cache_dir, sprintf("res_%s", code)))
    # save the results dataframes
    df.results = res$stats
    df.backend = res$backend_diagnostics
    saveRDS(df.results, file = file.path(cache_dir, paste0("df_res_", code, ".rds")))
    saveRDS(df.backend, file = file.path(cache_dir, paste0("df_div_", code, ".rds")))

}

```

Again, we start by investigating the rhats and the number of divergent samples. This shows that 4 of 500 simulations had at least one parameter that had an rhat of at least 1.05, and 83 models had divergent samples (mean number of samples of the simulations with divergent samples: 3.37). Again, we will look out for divergence issues in the final model.

Next, we can plot the simulated values to perform prior predictive checks.

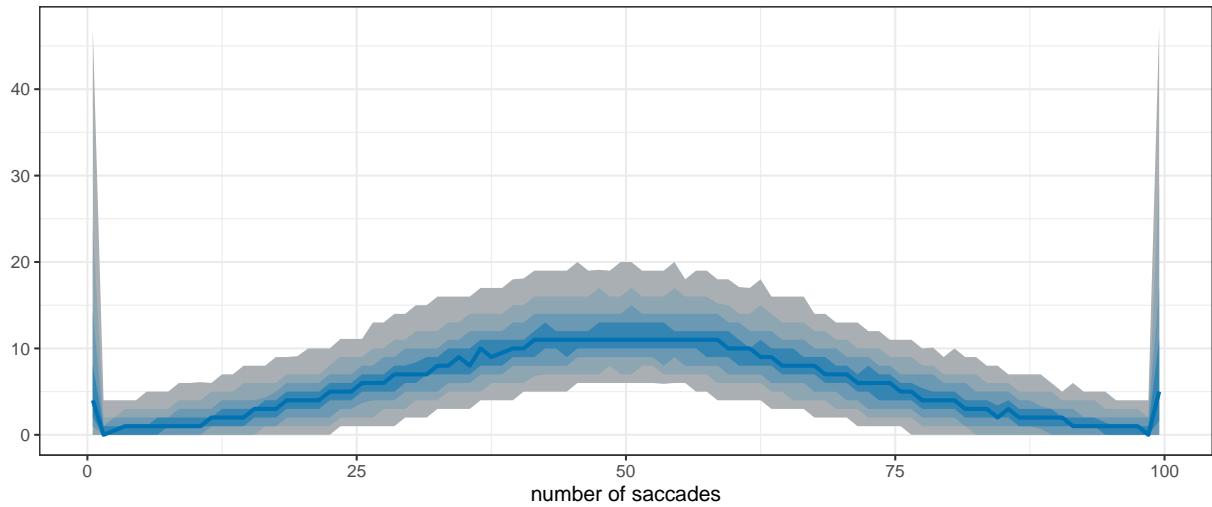
```

# create a matrix out of generated data
dvname = gsub(" ", "", gsub("[\\|~].*", "", f.com)[1])
dvfakemat = matrix(NA, nrow(dat[["generated"]][[1]]), length(dat[["generated"]]))
for (i in 1:length(dat[["generated"]])) {
  dvfakemat[,i] = dat[["generated"]][[i]][[dvname]]
}
truePars = dat$variables

# set very large data points to a value of 100 and small to 0
dvfakematH = dvfakemat;
dvfakematH[dvfakematH > 100] = 100
dvfakematH[dvfakematH < 0] = 0
# compute one histogram per simulated data-set
breaks = seq(0, 100, length.out = 101)
binwidth = breaks[2] - breaks[1]
histmat = matrix(NA, ncol = nrow(truePars) + binwidth, nrow = length(breaks)-1)
for (i in 1:nrow(truePars)) {
  histmat[,i] = hist(dvfakematH[,i], breaks = breaks, plot = F)$counts
}
# for each bin, compute quantiles across histograms
probs = seq(0.1, 0.9, 0.1)
quantmat = as.data.frame(matrix(NA, nrow=dim(histmat)[1], ncol = length(probs)))
names(quantmat) = paste0("p", probs)
for (i in 1:dim(histmat)[1]) {
  quantmat[i,] = quantile(histmat[i,], p = probs, na.rm = T)
}
quantmat$x = breaks[2:length(breaks)] - binwidth/2 # add bin mean
p1 = ggplot(data = quantmat, aes(x = x)) +
  geom_ribbon(aes(ymax = p0.9, ymin = p0.1), fill = c_light) +
  geom_ribbon(aes(ymax = p0.8, ymin = p0.2), fill = c_light_highlight) +
  geom_ribbon(aes(ymax = p0.7, ymin = p0.3), fill = c_mid) +
  geom_ribbon(aes(ymax = p0.6, ymin = p0.4), fill = c_mid_highlight) +
  geom_line(aes(y = p0.5), colour = c_dark, linewidth = 1) +
  labs(title = "Prior predictive distribution", y = "", x = "number of saccades") +
  theme_bw()
p1

```

Prior predictive distribution



The overall shape again looks acceptable, even though there are some impossible simulated values.

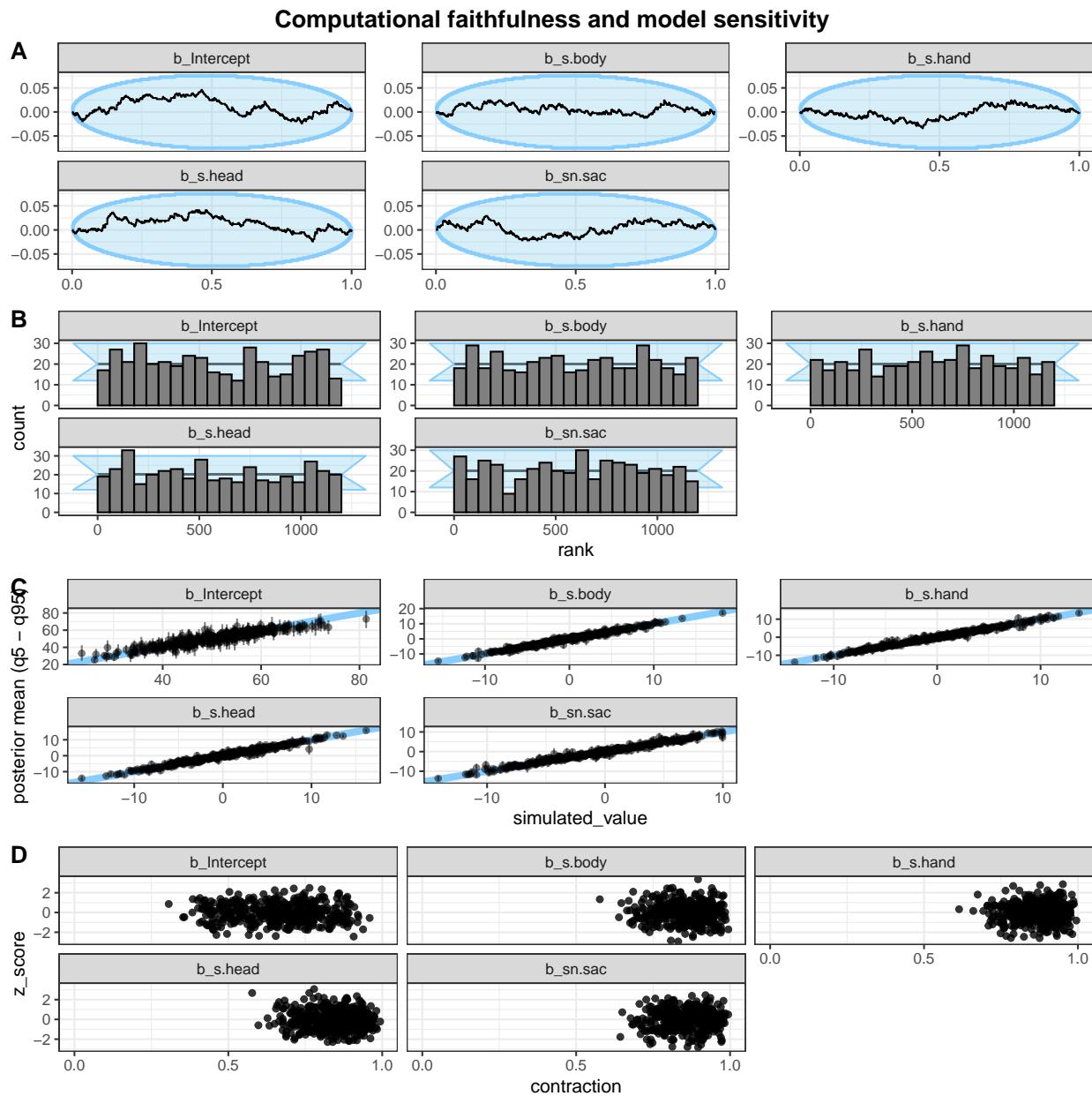
```
# get simulation numbers with issues
rank = max(df.results$max_rank)
check = merge(df.results %>%
  group_by(sim_id) %>%
  summarise(
    rhat = max(rhat, na.rm = T),
    mean_rank = mean(max_rank)
  ) %>%
  filter(rhat >= 1.05 | mean_rank != rank),
  df.backend %>% filter(n_divergent > 0), all = T)

# plot SBC with functions from the SBC package focusing on population-level parameters
df.results.b = df.results %>%
  filter(substr(variable, 1, 2) == "b_") %>%
  filter(!(sim_id %in% check$sim_id))

p1 = plot_ecdf_diff(df.results.b) + theme_bw() + theme(legend.position = "none") +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))
p2 = plot_rank_hist(df.results.b, bins = 20) + theme_bw() +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))
p3 = plot_sim_estimated(df.results.b, alpha = 0.5) + theme_bw() +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))
p4 = plot_contraction(
  df.results.b,
  prior_sd = setNames(c(10,
                        rep(5, length(unique(df.results.b$variable))-1)),
                      unique(df.results.b$variable))) +
  theme_bw() +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))

p = ggarrange(p1, p2, p3, p4, labels = "AUTO", ncol = 1, nrow = 4)
```

```
annotate_figure(p,
    top = text_grob("Computational faithfulness and model sensitivity",
    face = "bold", size = 14))
```



Second, we check the outcome of the SBC. All looks acceptable.

### Posterior predictive checks

As the next step, we fit the model and check for issues.

```
# fit the model
set.seed(2496)
m.com = brm(f.com,
            df.com, prior = priors,
```

```

    iter = iter, warmup = warm,
    backend = "cmdstanr", threads = threading(8),
    file = "m_PESI_com",
    save_pars = save_pars(all = TRUE)
  )

# in this model, there are no divergent samples
sum(subset(nuts_params(m.com), Parameter == "divergent_")$Value)

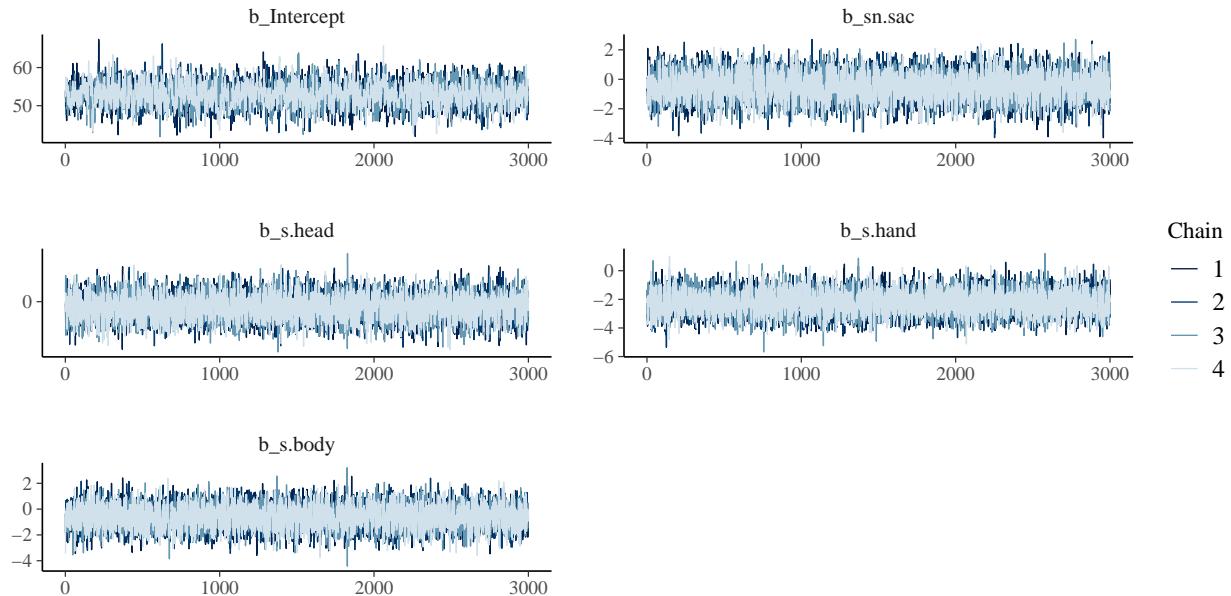
## [1] 0

# check that rhats are below 1.01
sum(brms::rhat(m.com) >= 1.01, na.rm = T)

## [1] 0

# and the chains have converged
post.draws = as_draws_df(m.com)
mcmc_trace(post.draws, regex_pars = "^b_",
            facet_args = list(ncol = 2)) +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))

```



This model has no divergent samples, and no rhat that is higher or equal to 1.01. Therefore, we go ahead and perform our posterior predictive checks.

```

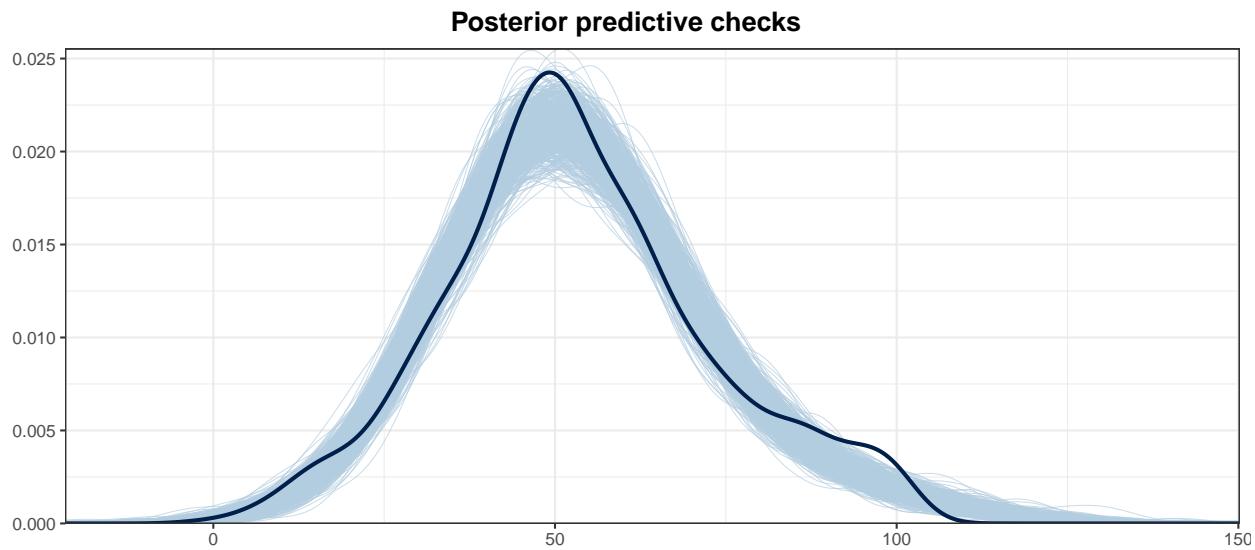
# get the posterior predictions
post.pred = posterior_predict(m.com, ndraws = nsim)

# check the fit of the predicted data compared to the real data
p1 = pp_check(m.com, ndraws = nsim) +
  theme_bw() + theme(legend.position = "none")

annotate_figure(p1,

```

```
top = text_grob("Posterior predictive checks",
face = "bold", size = 14)
```



The predicted values in light blue fit the actual values in dark blue quite well.

## Model summary

Now, we have a look at the model and its estimates.

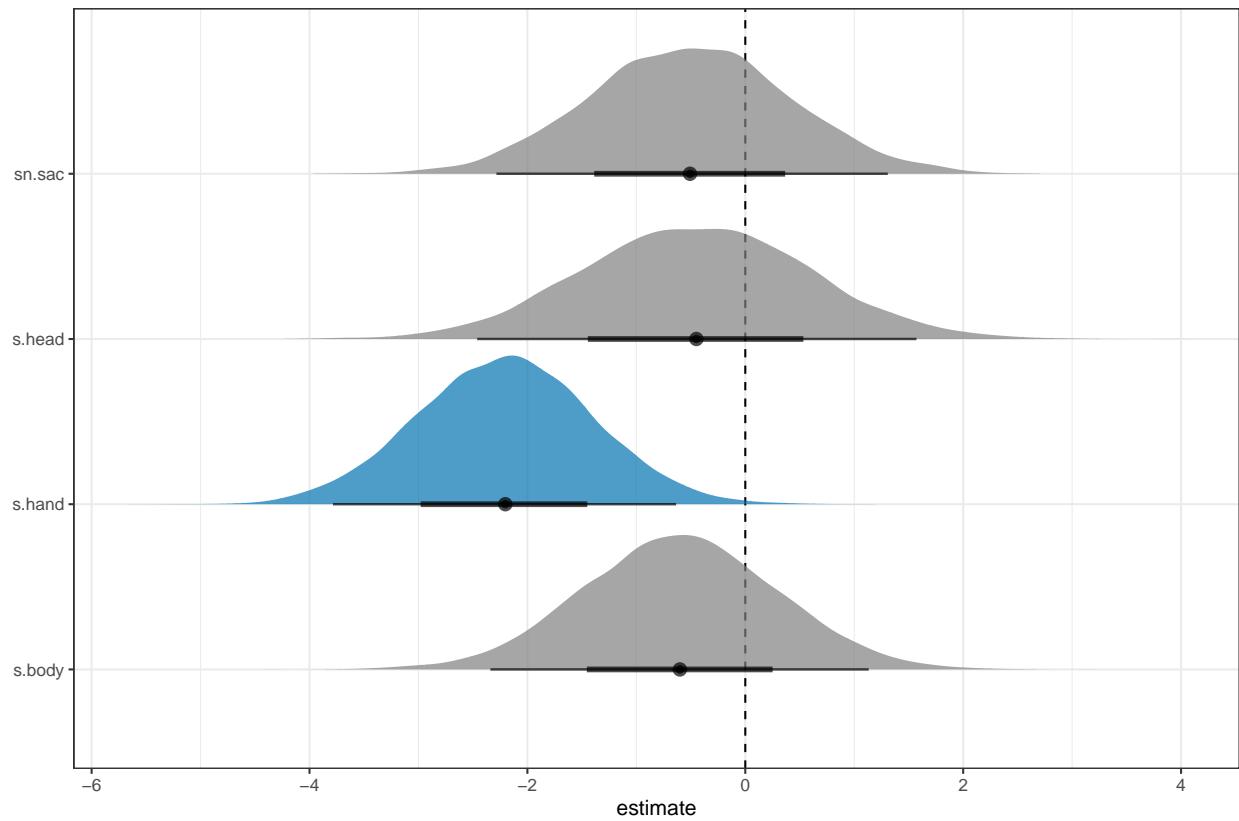
```
# print a summary
summary(m.com)

## Family: gaussian
## Links: mu = identity; sigma = identity
## Formula: rating.confirmed ~ sn.sac + s.head + s.hand + s.body + (1 | subID) + (1 | dyad)
## Data: df.com (Number of observations: 667)
## Draws: 4 chains, each with iter = 4500; warmup = 1500; thin = 1;
##         total post-warmup draws = 12000
##
## Multilevel Hyperparameters:
## ~dyad (Number of levels: 8)
##             Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)    6.28     2.04     3.46    11.36 1.00      4013     6643
##
## ~subID (Number of levels: 42)
##             Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)   12.44     1.49     9.87    15.73 1.00      2695     3984
##
## Regression Coefficients:
##             Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept     52.92     2.90    47.15    58.62 1.00      2708     4719
## sn.sac       -0.51     0.92    -2.28     1.31 1.00      7332     8588
## s.head       -0.45     1.03    -2.46     1.57 1.00      8901     8946
## s.hand       -2.21     0.80    -3.78    -0.63 1.00      9667     8978
## s.body       -0.60     0.89    -2.34     1.13 1.00     10219     8569
##
```

```

## Further Distributional Parameters:
##           Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma      14.00     0.40   13.23    14.82 1.00    12024     8416
##
## Draws were sampled using sample(hmc). 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 the posterior distributions
post.draws %>%
  select(starts_with("b_")) %>%
  pivot_longer(cols = starts_with("b_"),
               names_to = "coef",
               values_to = "estimate") %>%
  subset(!startsWith(coef, "b_Int")) %>%
  mutate(
    coef = substr(coef, 3, nchar(coef))
  ) %>%
  group_by(coef) %>%
  mutate(
    cred = case_when(
      (mean(estimate) < 0 & quantile(estimate, probs = 0.975) < 0) | 
      (mean(estimate) > 0 & quantile(estimate, probs = 0.025) > 0) ~ "credible",
      T ~ "not credible"
    )
  ) %>% ungroup() %>%
  ggplot(aes(x = estimate, y = coef, fill = cred)) +
  geom_vline(xintercept = 0, linetype = 'dashed') +
  ggdist::stat_halfeye(alpha = 0.7) + ylab(NULL) + theme_bw() +
  scale_fill_manual(values = c(credible = c_dark, not_credible)) +
  theme(legend.position = "none")

```



It seems as if decreased dwell times on the hands was associated with increased ratings.