

# S1: behavioural, conventional analysis with brms

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## S1.1 Task info and setup

This R Markdown script analyses data from the PAL (probabilistic associative learning) task of the EMBA project. The data was preprocessed before being read into this script.

In this task, participants view faces for which they have to judge whether the portrayed emotion is positive or negative. The faces are preceded by a tone which is predictive of the valence of the following face. The visual angle of the faces was 3.46 degrees wide and 4.72 degrees high.

### Plot the development of associations across task

```
# load the trial order
df.trl = read_csv('data/PAL_scheme.csv', show_col_types = F) %>%
  mutate(
    association = ut*100,
    prob_HP = prob_HP*100
  )

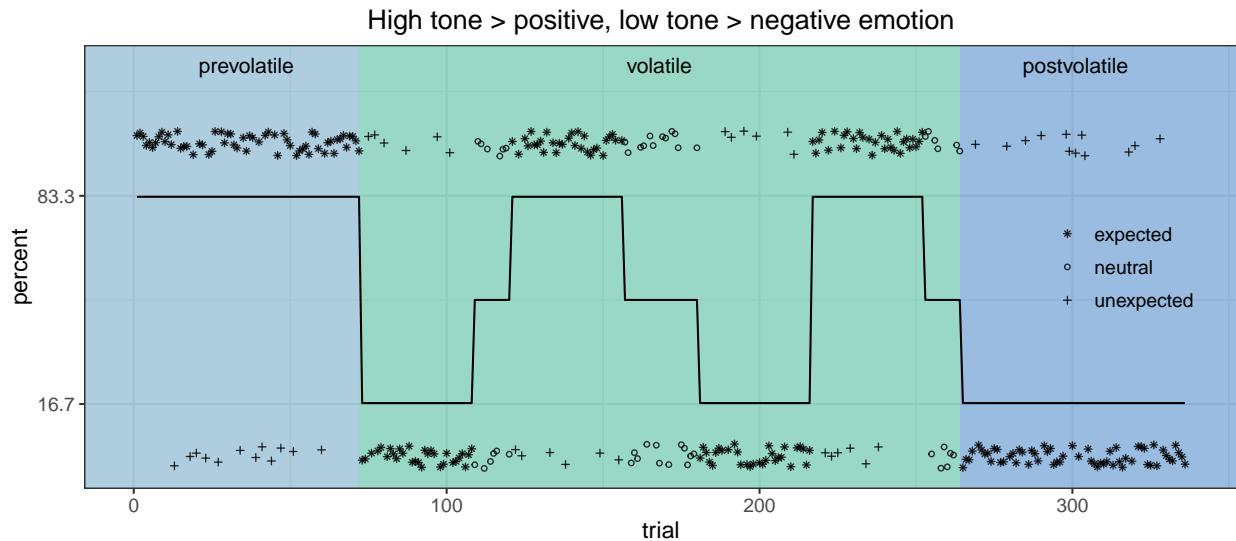
# create rectangles to colour the phases: prevolatile, volatile and postvolatile
rects = data.frame(xstart = c(-Inf, 72, 264),
                    xend = c(72, 264, Inf),
                    col = c("a", "b", "c"))

ggplot() +
  geom_rect(data = rects, aes(xmin = xstart, xmax = xend,
                               ymin = -Inf, ymax = Inf,
                               fill = col), alpha = 0.4) +
  scale_fill_manual(values=c(c_mid_highlight, c_green, c_dark_highlight),
                     guide = "none") +
  geom_jitter(data = df.trl,
              aes(x = trl, y = association, shape = expected),
              colour = "black", alpha = 0.8, size = 1, width = 0, height = 4) +
  geom_line(data = df.trl,
            aes(x = trl, y = prob_HP),
            colour = "black") +
  scale_shape_manual(values = c(8, 1, 3)) +
  theme_bw() +
  scale_y_continuous(breaks=c(16.7, 83.3)) +
  labs(x = "trial", y = "percent",
       title = "High tone > positive, low tone > negative emotion") +
  annotate("text", x = 36, y = 125, label= "prevolatile", size = 4) +
  annotate("text", x = 168, y = 125, label= "volatile", size = 4) +
```

```

annotate("text", x = 301, y = 125, label= "postvolatile", size = 4) +
theme(legend.position = c(0.9, 0.5), legend.title = element_blank(),
      legend.background = element_rect(fill = alpha("white", 0)),
      legend.key = element_rect(fill = alpha("white", 0)),
      plot.title = element_text(hjust = 0.5), text = element_text(size = 12))

```



```

ggsave("plots/PAL_scheme.png",
       units = "cm",
       width = 27,
       height = 9)

```

## Some general settings

```

# number of simulations
nsim = 500

# set number of iterations and warmup for models
iter = 6000
warm = 1500

# set the seed
set.seed(2468)

```

## Package versions

The following packages are used in this RMarkdown file:

```

## [1] "R version 4.5.0 (2025-04-11)"

## [1] "knitr version 1.50"
## [1] "ggplot2 version 3.5.2"
## [1] "brms version 2.22.0"
## [1] "desigrn 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 1.12.0"
## [1] "SBC version 0.3.0.9000"
## [1] "rstatix version 0.7.2"
## [1] "effectsize version 1.0.0"
## [1] "BayesFactor version 0.9.12.4.7"
## [1] "bayestestR version 0.15.2"

```

## Analysis guidelines

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 500 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 discrimination 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

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.

```

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

  # get demo info for subjects
  df.sub = read_csv(file.path("/home/emba/Documents/EMBA/CentraXX", "EMBA_centraXX.csv"),
                    show_col_types = F) %>%
    mutate(
      diagnosis = as.factor(recode(diagnosis, "CTR" = "COMP"))
    )

  # set the data path
  dt.path   = "/home/emba/Documents/EMBA/BVET"
  dt.explo = "/home/emba/Documents/EMBA/BVET-explo"

  # load the preprocessed data: df.tsk
  df.tsk = rbind(readRDS(file.path(dt.path, "PAL_tsk.rds")),
                 readRDS(file.path(dt.explo, "PAL_tsk.rds")))

  # load excluded participants (accuracy < 2/3)
  exc = c(scan(file.path(dt.path, 'PAL_exc.txt'), what="character", sep=NULL),
          scan(file.path(dt.explo, 'PAL_exc.txt'), what="character", sep=NULL))
  df.exc = df.sub %>% filter(subID %in% exc) %>%
    select(diagnosis) %>%
    group_by(diagnosis) %>% count()

  # merge with group
}
```

```

df.tsk = merge(df.sub %>% select(subID, diagnosis),
               df.tsk, all.y = T) %>%
  mutate_if(is.character, as.factor)

# load data and aggregate emotion discrimination threshold
df.fer = rbind(readRDS(file = paste0(dt.path, '/df_FER.RDS')),
               readRDS(file = paste0(dt.explo, '/df_FER.RDS'))))%>%
  group_by(subID, emo) %>%
  summarise(
    EDT = mean(disc, na.rm = T)
  ) %>%
  group_by(subID) %>%
  summarise(
    EDT = mean(EDT)
  )

# only keep participants included in the study in the subject data frame
df.sub = merge(df.tsk %>% select(subID) %>% distinct(), df.sub, all.x = T) %>%
  # merge with EDT dataframe
  merge(., df.fer, all.x = T)

# anonymise the data
df.tsk = df.tsk %>%
  mutate(
    PID = subID,
    subID = as.factor(as.numeric(subID))
  )

# get a correspondence of original PIDs and anonymised subIDs
df.recode = df.tsk %>% select(PID, subID, diagnosis) %>% distinct()
recode = as.character(df.recode$subID)
names(recode) = df.recode$PID

# save this information to use it with pupil sizes
write_csv(df.recode, file.path(dt.path, "PID_anonymisation.csv"))

# remove the PID from the dataframe
df.tsk = df.tsk %>% select(-PID)

# save the data in the EMBA_HGF toolbox
df.tsk %>% select(subID, trl, diagnosis, ut, difficulty, acc, rt) %>%
  ungroup() %>%
  arrange(subID, trl) %>%
  write_csv(., file = "data/PAL_data.csv")

# 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")
# since only DAN in the ADHD group, we try again after excluding them
ct.mf = contingencyTableBF(tb.gen[2:3,],
                           sampleType = "indepMulti",

```

```

fixedMargin = "cols")
tb.gen = xtabs(~ gender + diagnosis + cis, data = df.sub)

# get the gender descriptions of the not-male and not-female participants
gen.desc = unique(tolower(df.sub[df.sub$gender == "dan",]$gender_desc))

# check which outcomes of interest are normally distributed
df.sht = df.sub %>%
  group_by(diagnosis) %>%
  shapiro_test(age, iq, BDI_total, ASRS_total, RAADS_total, TAS_total) %>%
  mutate(
    sig = if_else(p < 0.05, "*", ""))
  ) %>% arrange(variable)

# most of the measures are not normally distributed;
# therefore, we compute ranks for these outcomes
df.sub = df.sub %>%
  ungroup() %>%
  mutate(
    rASRS = rank(ASRS_total),
    rage = rank(age),
    rBDI = rank(BDI_total),
    rRAADS = rank(RAADS_total),
    rTAS = rank(TAS_total),
    diagnosis = as.factor(diagnosis)
  )

# now we can compute our ANOVAs
aov.age = anovaBF(rage ~ diagnosis, data = df.sub)
aov.iq = anovaBF(iq ~ diagnosis, data = df.sub)
aov.BDI = anovaBF(rBDI ~ diagnosis, data = df.sub)
aov.ASRS = anovaBF(rASRS ~ diagnosis, data = df.sub)
aov.RAADS = anovaBF(rRAADS ~ diagnosis, data = df.sub)
aov.TAS = anovaBF(rTAS ~ diagnosis, data = df.sub)

# ...and put everything in a new dataframe for printing
measurement = "Age"
ADHD = sprintf("%.2f (%.2f)", 
               mean(df.sub[df.sub$diagnosis == "ADHD",]$age),
               sd(df.sub[df.sub$diagnosis == "ADHD",]$age) /
               sqrt(nrow(df.sub[df.sub$diagnosis == "ADHD",]))))
ASD = sprintf("%.2f (%.2f)", 
               mean(df.sub[df.sub$diagnosis == "ASD",]$age),
               sd(df.sub[df.sub$diagnosis == "ASD",]$age) /
               sqrt(nrow(df.sub[df.sub$diagnosis == "ASD",]))))
`ADHD+ASD` = sprintf("%.2f (%.2f)", 
               mean(df.sub[df.sub$diagnosis == "BOTH",]$age),
               sd(df.sub[df.sub$diagnosis == "BOTH",]$age) /
               sqrt(nrow(df.sub[df.sub$diagnosis == "BOTH",]))))
COMP = sprintf("%.2f (%.2f)", 
               mean(df.sub[df.sub$diagnosis == "COMP",]$age),
               sd(df.sub[df.sub$diagnosis == "COMP",]$age) /
               sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))))

```

```

logBF10 = sprintf("%.3f", aov.age@bayesFactor[["bf"]])
df.table = data.frame(measurement, ADHD, ASD, `ADHD+ASD`, COMP, logBF10)
df.table = rbind(df.table,
  c(
    "ASRS",
    sprintf("%.2f (%.2f)", mean(df.sub[df.sub$diagnosis == "ADHD",]$ASRS_total),
            sd(df.sub[df.sub$diagnosis == "ADHD",]$ASRS_total) /
            sqrt(nrow(df.sub[df.sub$diagnosis == "ADHD",]))),
    sprintf("%.2f (%.2f)", mean(df.sub[df.sub$diagnosis == "ASD",]$ASRS_total),
            sd(df.sub[df.sub$diagnosis == "ASD",]$ASRS_total) /
            sqrt(nrow(df.sub[df.sub$diagnosis == "ASD",]))),
    sprintf("%.2f (%.2f)", mean(df.sub[df.sub$diagnosis == "BOTH",]$ASRS_total),
            sd(df.sub[df.sub$diagnosis == "BOTH",]$ASRS_total) /
            sqrt(nrow(df.sub[df.sub$diagnosis == "BOTH",]))),
    sprintf("%.2f (%.2f)", mean(df.sub[df.sub$diagnosis == "COMP",]$ASRS_total),
            sd(df.sub[df.sub$diagnosis == "COMP",]$ASRS_total) /
            sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))),
    sprintf("%.3f", aov.ASRS@bayesFactor[["bf"]])
  ),
  c(
    "BDI",
    sprintf("%.2f (%.2f)", mean(df.sub[df.sub$diagnosis == "ADHD",]$BDI_total),
            sd(df.sub[df.sub$diagnosis == "ADHD",]$BDI_total) /
            sqrt(nrow(df.sub[df.sub$diagnosis == "ADHD",]))),
    sprintf("%.2f (%.2f)", mean(df.sub[df.sub$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$diagnosis == "BOTH",]$BDI_total),
            sd(df.sub[df.sub$diagnosis == "BOTH",]$BDI_total) /
            sqrt(nrow(df.sub[df.sub$diagnosis == "BOTH",]))),
    sprintf("%.2f (%.2f)", mean(df.sub[df.sub$diagnosis == "COMP",]$BDI_total),
            sd(df.sub[df.sub$diagnosis == "COMP",]$BDI_total) /
            sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))),
    sprintf("%.3f", aov.BDI@bayesFactor[["bf"]])
  ),
  c(
    "Gender (diverse/agender - female - male)",
    sprintf("%d - %d - %d",
           nrow(df.sub[df.sub$diagnosis == "ADHD" & df.sub$gender == "dan",]),
           nrow(df.sub[df.sub$diagnosis == "ADHD" & df.sub$gender == "fem",]),
           nrow(df.sub[df.sub$diagnosis == "ADHD" & df.sub$gender == "mal",])),
    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$diagnosis == "BOTH" & df.sub$gender == "dan",]),
       nrow(df.sub[df.sub$diagnosis == "BOTH" & df.sub$gender == "fem",]),
       nrow(df.sub[df.sub$diagnosis == "BOTH" & df.sub$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$diagnosis == "ADHD",]$iq),
         sd(df.sub[df.sub$diagnosis == "ADHD",]$iq) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "ADHD",]))),
  sprintf("%.2f (%.2f)",
         mean(df.sub[df.sub$diagnosis == "ASD",]$iq),
         sd(df.sub[df.sub$diagnosis == "ASD",]$iq) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "ASD",]))),
  sprintf("%.2f (%.2f)",
         mean(df.sub[df.sub$diagnosis == "BOTH",]$iq),
         sd(df.sub[df.sub$diagnosis == "BOTH",]$iq) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "BOTH",]))),
  sprintf("%.2f (%.2f)",
         mean(df.sub[df.sub$diagnosis == "COMP",]$iq),
         sd(df.sub[df.sub$diagnosis == "COMP",]$iq) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))),
  sprintf("%.3f", aov.iq@bayesFactor[["bf"]])
),
c(
  "RADS-R",
  sprintf("%.2f (%.2f)",
         mean(df.sub[df.sub$diagnosis == "ADHD",]$RAADS_total),
         sd(df.sub[df.sub$diagnosis == "ADHD",]$RAADS_total) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "ADHD",]))),
  sprintf("%.2f (%.2f)",
         mean(df.sub[df.sub$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$diagnosis == "BOTH",]$RAADS_total),
         sd(df.sub[df.sub$diagnosis == "BOTH",]$RAADS_total) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "BOTH",]))),
  sprintf("%.2f (%.2f)",
         mean(df.sub[df.sub$diagnosis == "COMP",]$RAADS_total),
         sd(df.sub[df.sub$diagnosis == "COMP",]$RAADS_total) /
         sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))),
  sprintf("%.3f", aov.RAADS@bayesFactor[["bf"]])
),
c(
  "TAS",
  sprintf("%.2f (%.2f)",

```

```

        mean(df.sub[df.sub$diagnosis == "ADHD",]$TAS_total),
        sd(df.sub[df.sub$diagnosis == "ADHD",]$TAS_total) /
        sqrt(nrow(df.sub[df.sub$diagnosis == "ADHD",]))),
sprintf("%.2f (%.2f)",
        mean(df.sub[df.sub$diagnosis == "ASD",]$TAS_total),
        sd(df.sub[df.sub$diagnosis == "ASD",]$TAS_total) /
        sqrt(nrow(df.sub[df.sub$diagnosis == "ASD",]))),
sprintf("%.2f (%.2f)",
        mean(df.sub[df.sub$diagnosis == "BOTH",]$TAS_total),
        sd(df.sub[df.sub$diagnosis == "BOTH",]$TAS_total) /
        sqrt(nrow(df.sub[df.sub$diagnosis == "BOTH",]))),
sprintf("%.2f (%.2f)",
        mean(df.sub[df.sub$diagnosis == "COMP",]$TAS_total),
        sd(df.sub[df.sub$diagnosis == "COMP",]$TAS_total) /
        sqrt(nrow(df.sub[df.sub$diagnosis == "COMP",]))),
sprintf("%.3f", aov.TAS@bayesFactor[["bf"]])
)
) %>% arrange(measurement)

# we aggregate the correct and the usable reaction times due to suboptimal
# posterior predictive fit of the full model
df.pal = df.tsk %>%
  group_by(subID, diagnosis, phase, expected, difficulty) %>%
  summarise(
    rt.cor = median(rt.cor, na.rm = T),
    rt.use = median(rt.use, na.rm = T),
    acc     = 100 * mean(acc) # accuracy in percent
  )

# calculate variance of reaction times:
# no difficulty due to suboptimal posterior fit
df.var = df.tsk %>%
  group_by(subID, diagnosis, phase, expected) %>%
  summarise(
    totaln = n(),
    valuen = sum(!is.na(rt.cor)),
    rt.var = sd(rt.cor, na.rm = T)
  ) %>%
  mutate(
    perc = valuen/totaln
  ) %>% filter(perc >= 2/3) %>%
  mutate_if(is.character, as.factor)

# we also aggregate it to check whether there were any differences between
# tone_pic combinations:
df.tp = df.tsk %>%
  filter(expected != "neutral") %>% droplevels() %>%
  mutate(
    tone_pic = if_else(ut == 1, "highpos_lowneg", "highneg_lowpos")
  ) %>%
  group_by(subID, diagnosis, tone_pic, expected) %>%
  summarise(
    rt.cor = median(rt.cor, na.rm = T)

```

```

    )

# save it all
save(df.pal, df.var, df.tp,
      df.table, df.sht, ct.full, ct.mf, df.exc, gen.desc, tb.gen,
      file = "data/PAL_data.RData")

} else {

  load("data/PAL_data.RData")

}

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

```

	diagnosis	n
ADHD	2	
ASD	2	
COMP	2	

```

rm(df.exc)

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

```

diagnosis	variable	statistic	p	sig
ADHD	ASRS_total	0.9364986	0.1675120	
ASD	ASRS_total	0.9307625	0.1135925	
BOTH	ASRS_total	0.9547574	0.3660251	
COMP	ASRS_total	0.9068414	0.0408291	*
ADHD	BDI_total	0.8019340	0.0005365	*
ASD	BDI_total	0.8511614	0.0028558	*
BOTH	BDI_total	0.8324214	0.0013277	*
COMP	BDI_total	0.7469562	0.0000825	*
ADHD	RAADS_total	0.9270567	0.1065426	
ASD	RAADS_total	0.9556216	0.3808761	
BOTH	RAADS_total	0.9524787	0.3291283	
COMP	RAADS_total	0.8644129	0.0061719	*
ADHD	TAS_total	0.9626930	0.5455600	
ASD	TAS_total	0.9240264	0.0812916	
BOTH	TAS_total	0.9445280	0.2245560	
COMP	TAS_total	0.8719909	0.0085270	*
ADHD	age	0.9439542	0.2386038	
ASD	age	0.9396864	0.1769487	
BOTH	age	0.9503886	0.2981103	
COMP	age	0.8212328	0.0010965	*
ADHD	iq	0.9736733	0.7942630	
ASD	iq	0.9591210	0.4458484	
BOTH	iq	0.9583546	0.4309600	
COMP	iq	0.9589488	0.4683259	

```

rm(df.sht)

# print the outcome of the two contingency tables for comparison: all participants
ct.full@bayesFactor

##                                bf error                  time      code
## Non-indep. (a=1) -4.442386      0 Fri Jan 31 11:35:26 2025 21d1d4b30029e

# only male and female participants
ct.mf@bayesFactor

##                                bf error                  time      code
## Non-indep. (a=1) -2.758595      0 Fri Jan 31 11:35:26 2025 21d1d66bae6d3

# print descriptions in not-female and not-male group > remove umlaute
print(gsub("[[:punct:]]", "", gen.desc))

## [1] "nicht binr" "divers"      "agender"

# print gender and trans/cis distribution
kable(tb.gen)

```

gender	diagnosis	cis	Freq
dan	ADHD	cis	0
fem	ADHD	cis	9
mal	ADHD	cis	10
dan	ASD	cis	0
fem	ASD	cis	11
mal	ASD	cis	11
dan	BOTH	cis	0
fem	BOTH	cis	12
mal	BOTH	cis	6
dan	COMP	cis	0
fem	COMP	cis	10
mal	COMP	cis	12
dan	ADHD	trans	2
fem	ADHD	trans	0
mal	ADHD	trans	1
dan	ASD	trans	0
fem	ASD	trans	0
mal	ASD	trans	1
dan	BOTH	trans	3
fem	BOTH	trans	0
mal	BOTH	trans	2
dan	COMP	trans	0
fem	COMP	trans	0
mal	COMP	trans	0

```

# drop the neutral condition for the analysis
df.pal = df.pal %>%
  filter(expected != "neutral") %>% droplevels() %>%
  mutate_if(is.character, as.factor) %>%
  ungroup()
df.var = df.var %>%

```

```

filter(expected != "neutral") %>% droplevels() %>%
  mutate_if(is.character, as.factor) %>%
  ungroup()

# set and print the contrasts
contrasts(df.pal$diagnosis) = contr.sum(4)
contrasts(df.pal$diagnosis)

##      [,1] [,2] [,3]
## ADHD    1    0    0
## ASD     0    1    0
## BOTH    0    0    1
## COMP   -1   -1   -1

contrasts(df.pal$expected) = contr.sum(2)
contrasts(df.pal$expected)

##      [,1]
## expected    1
## unexpected -1

contrasts(df.pal$phase) = contr.sum(3)
contrasts(df.pal$phase)

##      [,1] [,2]
## prevolatile 1    0
## volatile    0    1
## postvolatile -1   -1

contrasts(df.pal$difficulty) = contr.sum(3)
contrasts(df.pal$difficulty)

##      [,1] [,2]
## easy      1    0
## medium    0    1
## difficult -1   -1

contrasts(df.var$diagnosis) = contr.sum(4)
contrasts(df.var$diagnosis)

##      [,1] [,2] [,3]
## ADHD    1    0    0
## ASD     0    1    0
## BOTH    0    0    1
## COMP   -1   -1   -1

contrasts(df.var$expected) = contr.sum(2)
contrasts(df.var$expected)

##      [,1]
## expected    1
## unexpected -1

contrasts(df.var$phase) = contr.sum(3)
contrasts(df.var$phase)

##      [,1] [,2]
## prevolatile 1    0

```

```

## volatile      0    1
## postvolatile -1   -1
# print final group comparisons for the paper
kable(df.table)

```

measurement	ADHD	ASD	ADHD.ASD	COMP	logBF10
ASRS	43.95 (±2.59)	32.39 (±1.71)	46.43 (±1.94)	25.95 (±1.70)	19.617
Age	26.23 (±1.41)	29.35 (±1.64)	30.22 (±1.72)	27.59 (±1.25)	-1.489
BDI	7.82 (±1.71) (±1.69)	10.09	8.52 (±1.68)	2.32 (±0.68)	6.514
Gender (diverse/agender - female - male)	2 - 9 - 11	0 - 11 - 12	3 - 12 - 8	0 - 10 - 12	-4.442
IQ	108.57 (±2.39)	113.33 (±3.18)	112.93 (±2.34)	109.14 (±1.84)	-1.745
RADS-R	93.95 (±8.56)	150.26 (±8.37)	146.52 (±6.97)	46.50 (±7.68)	27.807
TAS	50.82 (±2.49)	62.61 (±1.31)	56.48 (±2.15)	39.36 (±2.07)	18.389

The three diagnostic groups are similar in age, IQ and gender distribution. However, they seem to differ in their questionnaire scores measuring ADHD (ASRS), depression (BDI), autism (RAADS) and alexithymia (TAS).

## S1.2 Reaction time variance

In the preregistration, we noted the following population-level effects for the model of the reaction time variances: group, expectancy, phase and difficulty. However, the posterior fit for this model was suboptimal, therefore, we dropped the predictor difficulty.

### Model setup

```

# figure out slopes for subjects
kable(head(df.var %>% count(subID, expected)))

```

subID	expected	n
1	expected	3
1	unexpected	3
2	expected	3
2	unexpected	3
3	expected	3
3	unexpected	3

```

kable(head(df.var %>% count(subID, phase)))

```

subID	phase	n
1	prevolatile	2
1	volatile	2

subID	phase	n
1	postvolatile	2
2	prevolatile	2
2	volatile	2
2	postvolatile	2

```
kable(head(df.var %>% count(subID, expected, phase)))
```

subID	expected	phase	n
1	expected	prevolatile	1
1	expected	volatile	1
1	expected	postvolatile	1
1	unexpected	prevolatile	1
1	unexpected	volatile	1
1	unexpected	postvolatile	1

```
# code for filenames
code = "PAL-var"

# model formula
f.var = brms::bf(rt.var ~ diagnosis * expected * phase +
                  (expected + phase | subID)
                  )

# set weakly informative priors
priors = c(
  prior(normal(4.50, 0.50), class = Intercept),
  prior(normal(0, 0.50), class = sigma),
  prior(normal(0.15, 0.15), class = sd),
  prior(normal(0, 0.25), class = b)
)
```

## Simulation-based calibration

```
# check if the SBC already exists
if (file.exists(file.path(cache_dir, sprintf("df_res_%s.rds", code)))) {
  # load in the results of the SBC
  df.results = readRDS(file.path(cache_dir, sprintf("df_res_%s.rds", code)))
  df.backend = readRDS(file.path(cache_dir, sprintf("df_div_%s.rds", code)))
} else {
  # stimulate some data
  set.seed(2486)
  gen = SBC_generator_brms(f.var, data = df.var, prior = priors,
    thin = 50, warmup = 10000, refresh = 2000,
    generate_lp = TRUE, family = lognormal, init = 0.1)
  bck = SBC_backend_brms_from_generator(gen, chains = 4, thin = 1,
    warmup = warm, iter = iter)
  dat = generate_datasets(gen, nsim)
  saveRDS(dat, file.path(cache_dir, sprintf("dat_%s.rds", code)))
  # perform the SBC on the first 250 simulated datasets
  res = compute_SBC(SBC_datasets(dat$variables[1:250],
```

```

            dat$generated[1:250]),
bck,
cache_mode      = "results",
cache_location = file.path(cache_dir, sprintf("res_%s", code)))
df.results = res$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 only 0 of 500 simulations had at least one parameter that had an rhat of at least 1.05 and 5 models had divergent samples. This suggests that this model performs well.

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

```

if (!file.exists(file.path(cache_dir, sprintf("dvfakemat_%s", code)))) {
  # create a matrix out of generated data
  dvname = gsub(" ", "", gsub("[\\|~].*", "", f.var)[1])
  dvfakemat = matrix(NA, nrow=dat[['generated']][[1]]), length(dat[['generated']])))
  for (i in 1:length(dat[['generated']])){
    dvfakemat[,i] = dat[['generated']][[i]][[dvname]]
  }
  saveRDS(dvfakemat, file.path(cache_dir, sprintf("dvfakemat_%s", code)))
} else {
  dvfakemat = readRDS(file.path(cache_dir, sprintf("dvfakemat_%s", code)))
}

# compute one histogram per simulated data-set
dvfakemath = dvfakemat
dvfakemath[dvfakemath > 1000] = 1000
breaks = seq(0, max(dvfakemath, na.rm=T), length.out = 101)
binwidth = breaks[2] - breaks[1]
histmat = matrix(NA, ncol = dim(dvfakemat)[2], nrow = length(breaks)-1)
for (i in 1:dim(dvfakemat)[2]) {
  histmat[,i] = hist(dvfakemath[,i], breaks = breaks, plot = F)$counts
}
# for each bin, compute quantiles across histograms
probs = seq(0.1, 0.9, 0.1)
quantmat = as.data.frame(matrix(NA, nrow=dim(histmat)[1], ncol = length(probs)))
names(quantmat) = paste0("p", probs)
for (i in 1:dim(histmat)[1]) {
  quantmat[i,] = quantile(histmat[i,], p = probs)
}
quantmat$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 = "Distribution of simulated reaction time variances", y = "", x = "") +
  theme_bw()

```

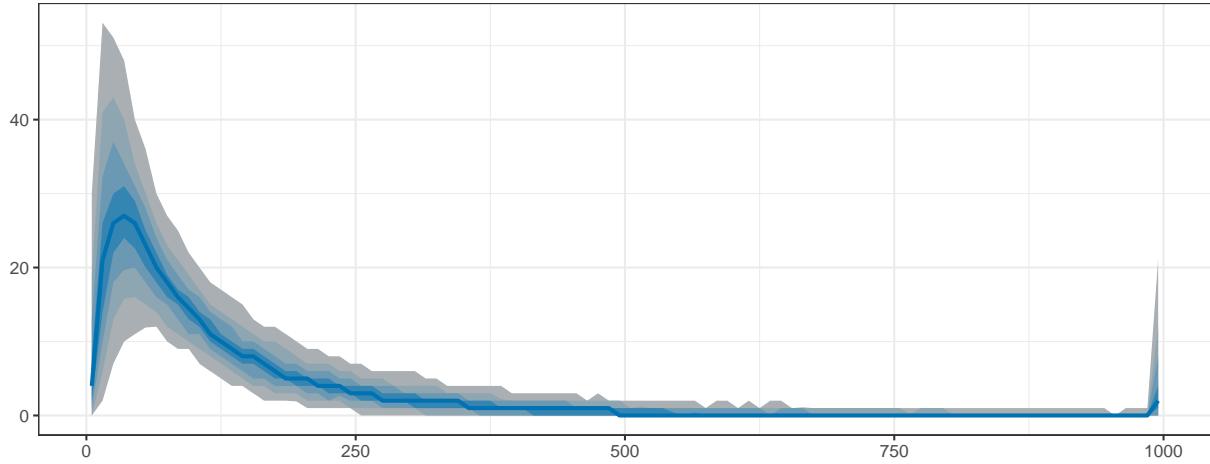
```

tmpM = apply(dvfakemat, 2, mean) # mean
tmpSD = apply(dvfakemat, 2, sd)
p2 = ggplot() +
  stat_bin(aes(x = tmpM), fill = c_dark) +
  labs(x = "Mean discrimination", title = "Means of simulated reaction time variances") +
  theme_bw()
p3 = ggplot() +
  stat_bin(aes(x = tmpSD), fill = c_dark) +
  labs(x = "SD discrimination", title = "SDs of simulated reaction time variances") +
  theme_bw()
p = ggarrange(p1,
  ggarrange(p2, p3, ncol = 2, labels = c("B", "C")),
  nrow = 2, labels = "A")
annotate_figure(p, top = text_grob("Prior predictive checks", face = "bold", size = 14))

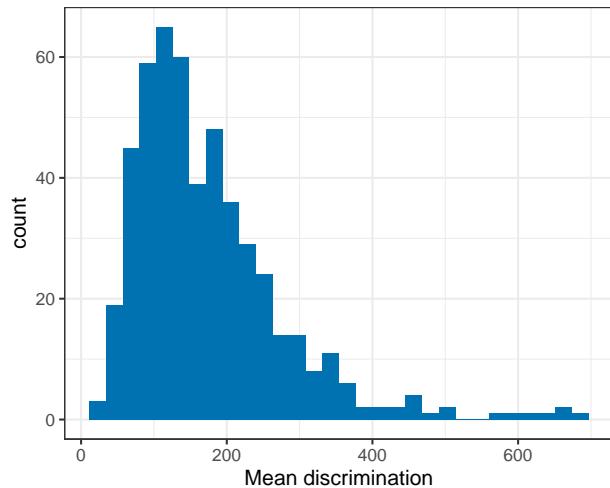
```

### Prior predictive checks

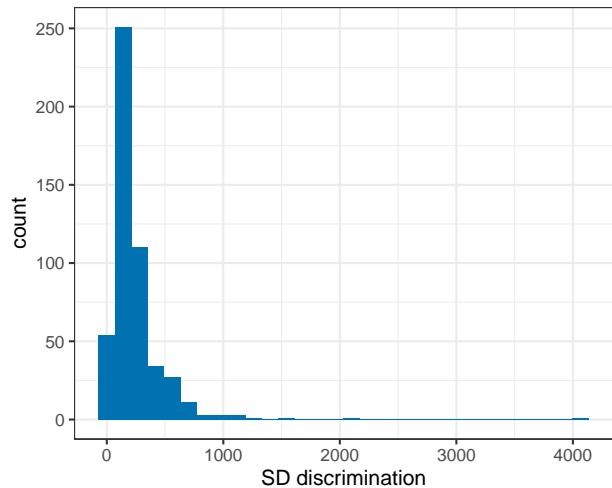
**A** Distribution of simulated reaction time variances



**B** Means of simulated reaction time variances



**C** SDs of simulated reaction time variances



Subfigure B shows the distribution of the simulated data with bluer bands being more likely than greyer bands. It shows a general distribution that fits our expectations, even though there are quite a few values that

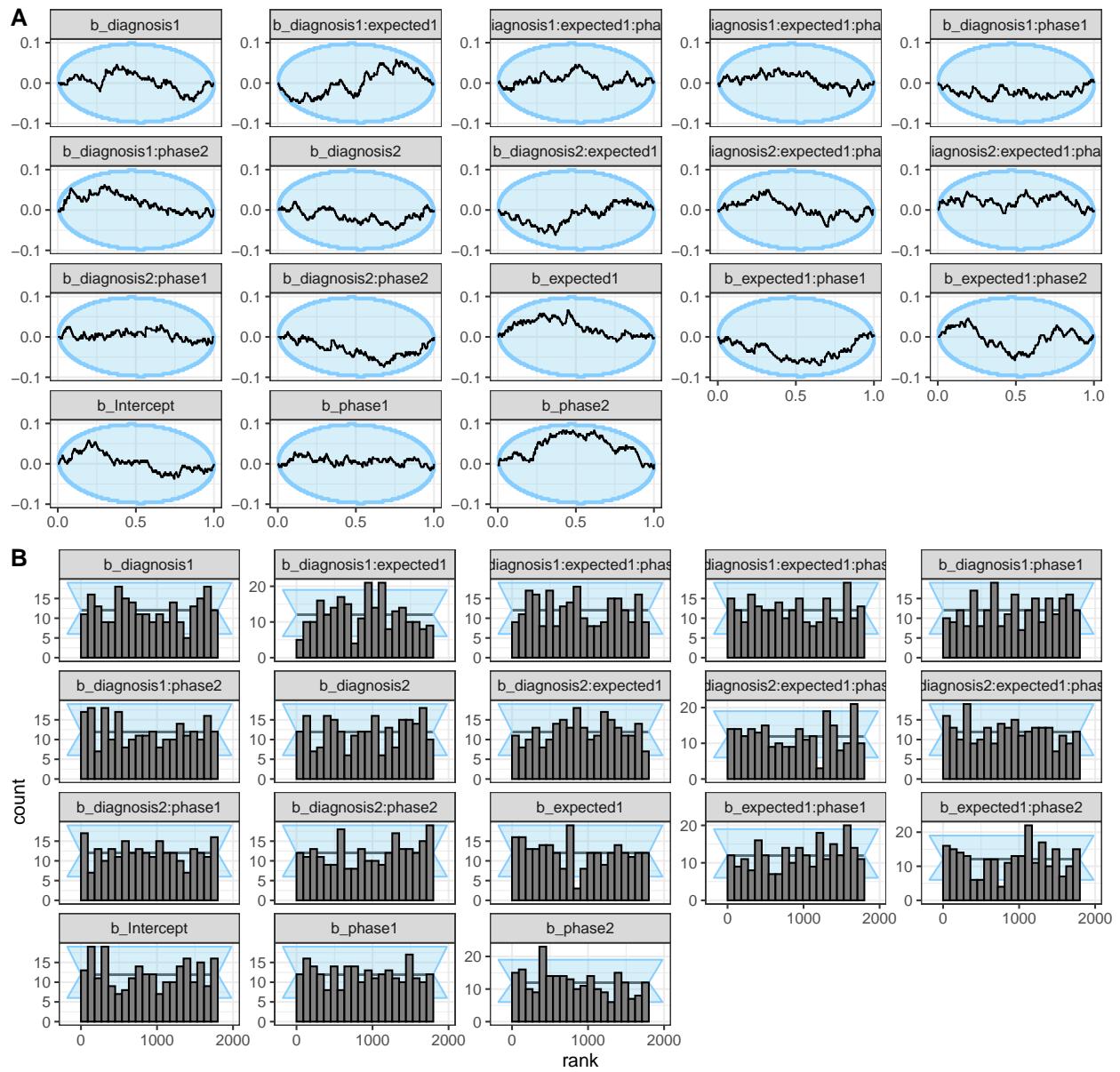
are unrealistically large. This is because we had to increase the standard deviations in the priors to achieve appropriate contraction values. The same applies to the distribution of the means and standard deviations in the simulated datasets. We go ahead with these priors and check the results of the SBC. We only plot the results from the models that had no divergence issues.

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

# plot SBC with functions from the SBC package focusing on population-level parameters
a = 0.5
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))

p = ggarrange(p1, p2, labels = "AUTO", ncol = 1, nrow = 2)
annotate_figure(p, top = text_grob("Computational faithfulness and model sensitivity",
                                   face = "bold", size = 14))
```

### Computational faithfulness and model sensitivity



Next, 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) shows deviations from the theoretical distribution (95%) and the rank histogram also shows ranks outside the 95% expected range. However, we judge this to be acceptable as we cannot identify clear bias patterns as described in the information accompanying the SBC package: [https://hyunjimoon.github.io/SBC/articles/rank\\_visualizations.html](https://hyunjimoon.github.io/SBC/articles/rank_visualizations.html)

```
p3 = plot_sim_estimated(df.results.b, alpha = .8) + 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(0.50,
      rep(0.25,

```

```

length(unique(df.results.b$variable))-1)),
unique(df.results.b$variable)) +  

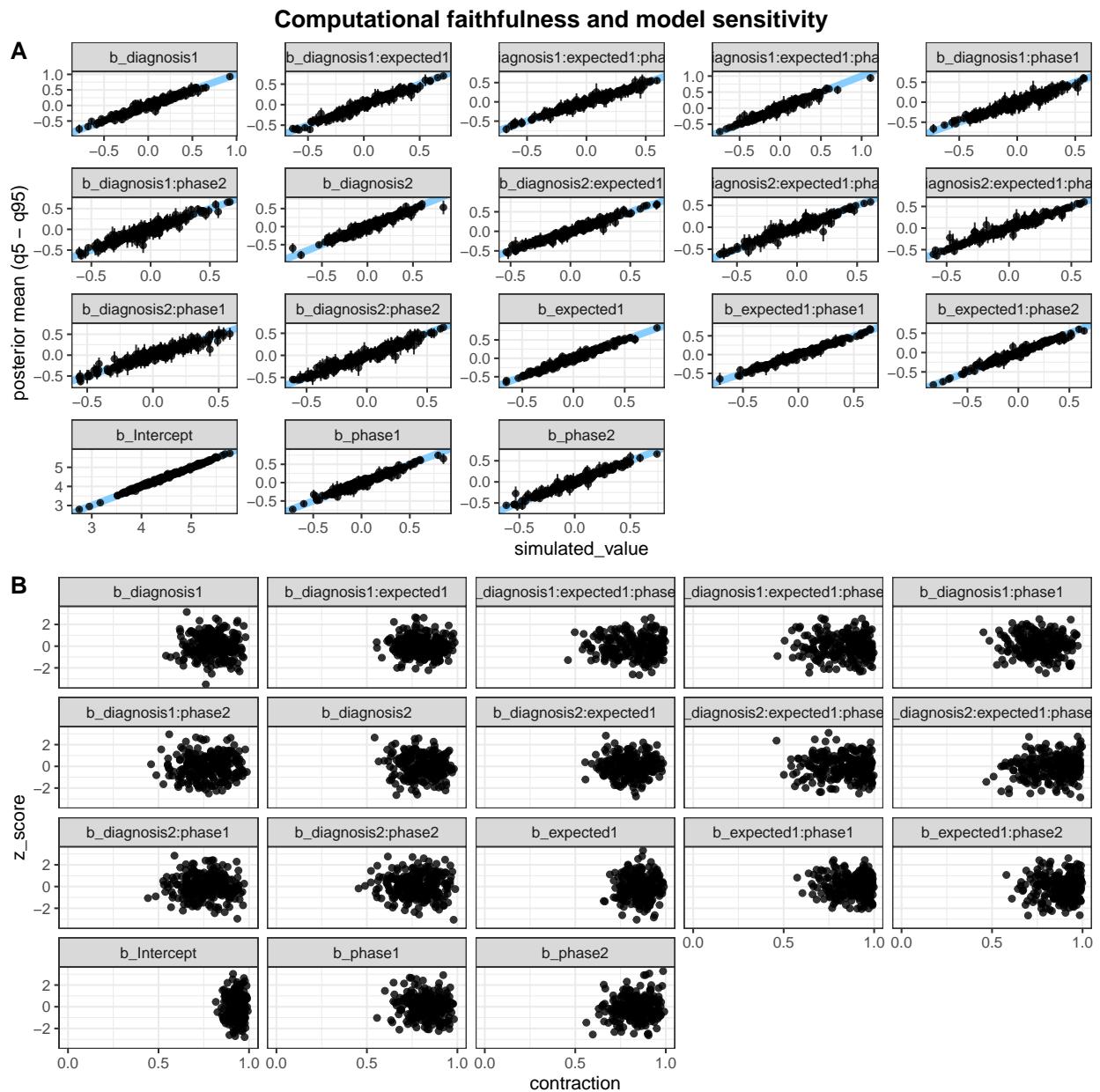
theme_bw() +  

scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +  

scale_y_continuous(breaks=scales::pretty_breaks(n = 3))

p = ggarrange(p3, p4, labels = "AUTO", ncol = 1, nrow = 2)
annotate_figure(p, top = text_grob("Computational faithfulness and model sensitivity",
face = "bold", size = 14))

```



Then, 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 Vasisth, 2020). The contraction reveals very narrow posterior standard deviations with slightly lower contraction scores than we would want in the optimal case, however, we judge this as acceptable.

## Posterior predictive checks

As the next step, we fit the model, check whether there are divergence or rhat issues, and then check whether the chains have converged.

```
# fit the final model
set.seed(2684)
m.var = brm(f.var,
             df.var, prior = priors,
             family = lognormal,
             iter = iter, warmup = warm,
             backend = "cmdstanr", threads = threading(8),
             file = file.path(brms_dir, "m_var"),
             save_pars = save_pars(all = TRUE)
            )
rstan::check_hmc_diagnostics(m.var$fit)

##
## Divergences:
## 0 of 18000 iterations ended with a divergence.

##
## Tree depth:
## 0 of 18000 iterations saturated the maximum tree depth of 10.

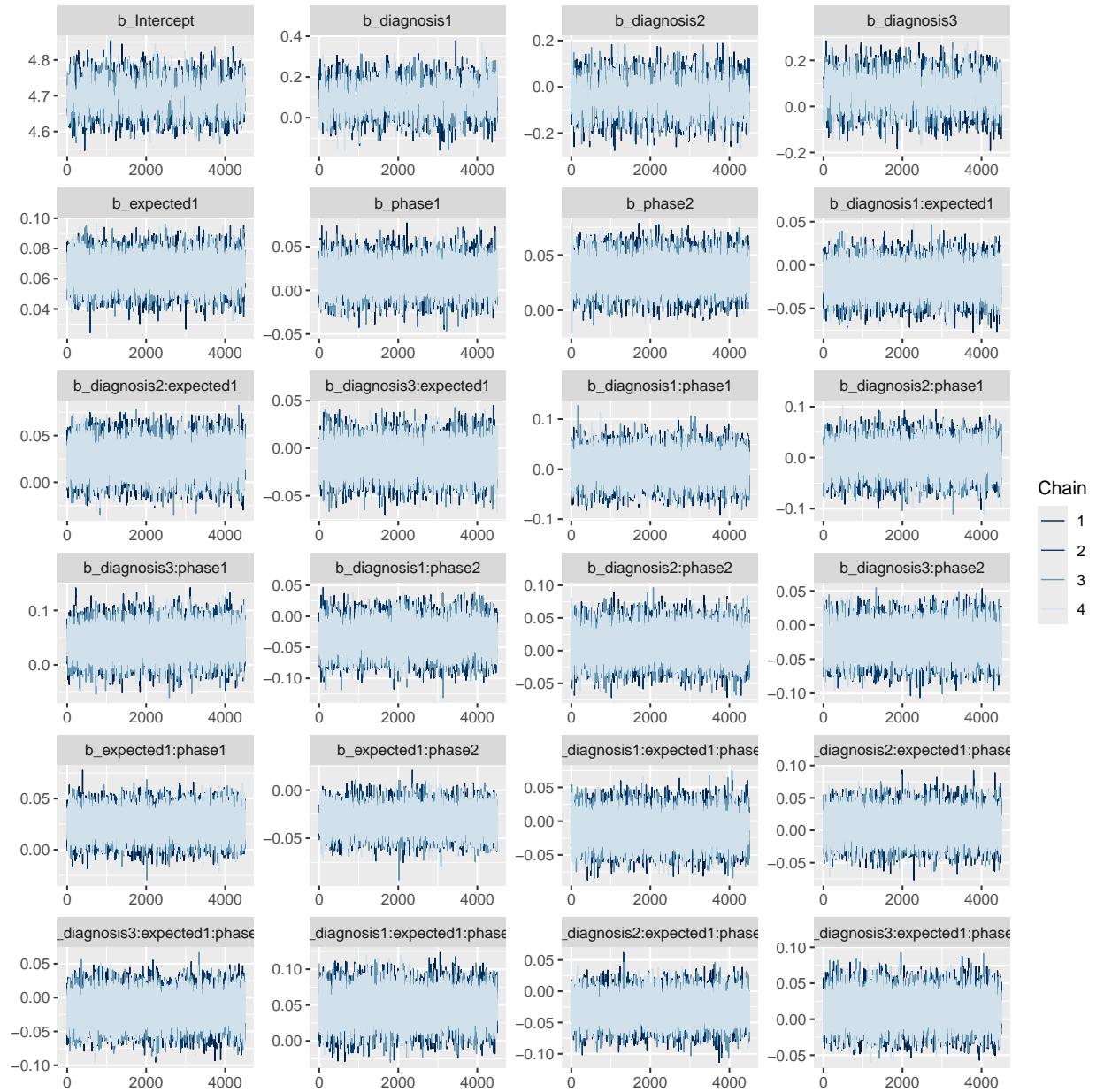
##
## Energy:
## E-BFMI indicated no pathological behavior.

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

## [1] 0

# check the trace plots
post.draws = as_draws_df(m.var)
mcmc_trace(post.draws, regex_pars = "^b_",
            facet_args = list(ncol = 4)) +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))

## Scale for x is already present.
## Adding another scale for x, which will replace the existing scale.
```



This model has no pathological behaviour with E-BFMI, no divergent sample and no rhats that are higher or equal to 1.01. Therefore, we go ahead and perform our posterior predictive checks.

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

# check the fit of the predicted data compared to the real data
p1 = pp_check(m.var, ndraws = nsim) +
  theme_bw() + theme(legend.position = "none") + xlim(0, 1000)

# distributions of means compared to the real values per group
p2 = ppc_stat_grouped(df.var$rt.var, post.pred, df.var$diagnosis) +
  theme_bw() + theme(legend.position = "none")

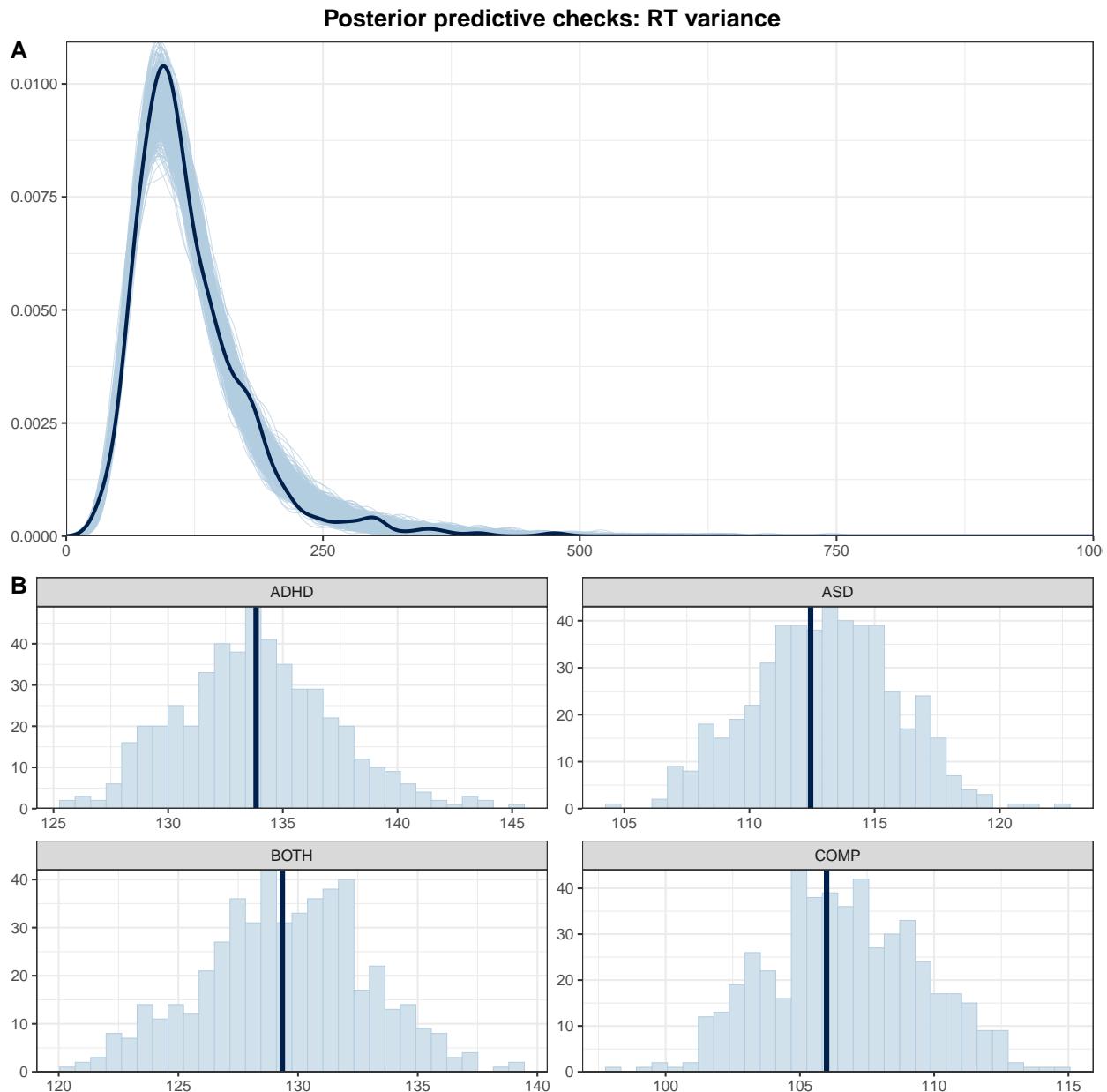
# distributions of means compared to the real values per group
```

```

p2 = ppc_stat_grouped(df.var$rt.var, post.pred, df.var$diagnosis) +
  theme_bw() + theme(legend.position = "none")

p = ggarrange(p1, p2,
              nrow = 2, ncol = 1, labels = "AUTO")
annotate_figure(p, top = text_grob("Posterior predictive checks: RT variance",
                                  face = "bold", size = 14))

```



The simulated data based on the model (light blue) fits well with the real data (dark blue), both for the overall distribution (A) and the aggregated scores for the diagnostic groups (B).

## Inferences

Now that we are convinced that we can trust our model, we have a look at its estimate and use the hypothesis function to assess our hypotheses and perform explorative tests.

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

## Family: lognormal
## Links: mu = identity; sigma = identity
## Formula: rt.var ~ diagnosis * expected * phase + (expected + phase | subID)
## Data: df.var (Number of observations: 523)
## Draws: 4 chains, each with iter = 6000; warmup = 1500; thin = 1;
##         total post-warmup draws = 18000
##
## Multilevel Hyperparameters:
## ~subID (Number of levels: 90)
##                                     Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS
## sd(Intercept)                  0.35     0.03    0.31    0.41 1.00   3239
## sd(expected1)                 0.03     0.01    0.00    0.05 1.00   3452
## sd(phase1)                     0.08     0.02    0.05    0.12 1.00   5911
## sd(phase2)                     0.03     0.02    0.00    0.07 1.00   3663
## cor(Intercept,expected1)      -0.41     0.30   -0.87    0.30 1.00  14682
## cor(Intercept,phase1)          -0.21     0.17   -0.54    0.14 1.00  12773
## cor(expected1,phase1)          0.38     0.34   -0.40    0.90 1.00   1445
## cor(Intercept,phase2)          -0.04     0.33   -0.69    0.64 1.00  17825
## cor(expected1,phase2)          0.33     0.41   -0.60    0.91 1.00   4350
## cor(phase1,phase2)             0.28     0.37   -0.53    0.88 1.00  12250
##                                     Tail_ESS
## sd(Intercept)                   6450
## sd(expected1)                  3281
## sd(phase1)                      5713
## sd(phase2)                      5471
## cor(Intercept,expected1)       8528
## cor(Intercept,phase1)          10789
## cor(expected1,phase1)          2579
## cor(Intercept,phase2)          10007
## cor(expected1,phase2)          7736
## cor(phase1,phase2)             12154
##
## Regression Coefficients:
##                                     Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS
## Intercept                         4.70     0.04    4.62    4.77 1.00   1765
## diagnosis1                        0.10     0.06   -0.03    0.22 1.00   2067
## diagnosis2                       -0.04     0.06   -0.17    0.08 1.00   2090
## diagnosis3                        0.06     0.06   -0.06    0.18 1.00   2256
## expected1                          0.06     0.01    0.05    0.08 1.00  22169
## phase1                            0.02     0.02   -0.01    0.05 1.00  15062
## phase2                            0.03     0.01    0.01    0.06 1.00  22768
## diagnosis1:expected1            -0.02     0.02   -0.05    0.01 1.00  20006
## diagnosis2:expected1            0.02     0.02   -0.01    0.06 1.00  18764
## diagnosis3:expected1            -0.01     0.02   -0.04    0.02 1.00  18730
## diagnosis1:phase1               0.01     0.03   -0.04    0.06 1.00  12597
## diagnosis2:phase1              -0.00     0.03   -0.05    0.05 1.00  13486
## diagnosis3:phase1               0.04     0.03   -0.01    0.09 1.00  11683
```

```

## diagnosis1:phase2          -0.03    0.02   -0.08    0.01 1.00    17888
## diagnosis2:phase2          0.01    0.02   -0.03    0.05 1.00    18854
## diagnosis3:phase2          -0.02    0.02   -0.06    0.02 1.00    18348
## expected1:phase1           0.02    0.01   0.00     0.05 1.00    22900
## expected1:phase2           -0.03    0.01   -0.05   -0.01 1.00    22647
## diagnosis1:expected1:phase1 -0.01    0.02   -0.05    0.03 1.00    16499
## diagnosis2:expected1:phase1 0.01    0.02   -0.03    0.05 1.00    16989
## diagnosis3:expected1:phase1 -0.02    0.02   -0.06    0.02 1.00    17984
## diagnosis1:expected1:phase2 0.05    0.02   0.01     0.09 1.00    16549
## diagnosis2:expected1:phase2 -0.03    0.02   -0.07    0.01 1.00    18130
## diagnosis3:expected1:phase2 0.01    0.02   -0.03    0.05 1.00    17244
##
## Tail_ESS
## Intercept                  3952
## diagnosis1                  3789
## diagnosis2                  3737
## diagnosis3                  4254
## expected1                   13632
## phase1                      14428
## phase2                      12519
## diagnosis1:expected1        13959
## diagnosis2:expected1        14598
## diagnosis3:expected1        14547
## diagnosis1:phase1           13028
## diagnosis2:phase1           13990
## diagnosis3:phase1           13236
## diagnosis1:phase2           14261
## diagnosis2:phase2           14368
## diagnosis3:phase2           15061
## expected1:phase1            14419
## expected1:phase2            14607
## diagnosis1:expected1:phase1 14031
## diagnosis2:expected1:phase1 14225
## diagnosis3:expected1:phase1 14514
## diagnosis1:expected1:phase2 13412
## diagnosis2:expected1:phase2 14890
## diagnosis3:expected1:phase2 15300
##
## Further Distributional Parameters:
##      Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma      0.19      0.01      0.18      0.21 1.00      6449     10684
##
## 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).
# get the estimates and compute group comparisons
df.m.var = post.draws %>%
  select(starts_with("b_")) %>%
  mutate(
    b_COMP      = - b_diagnosis1 - b_diagnosis2 - b_diagnosis3,
    b_postvolatile = - b_phase1 - b_phase2,
    ASD         = b_Intercept + b_diagnosis2,
    BOTH        = b_Intercept + b_diagnosis3,
    ADHD        = b_Intercept + b_diagnosis1,

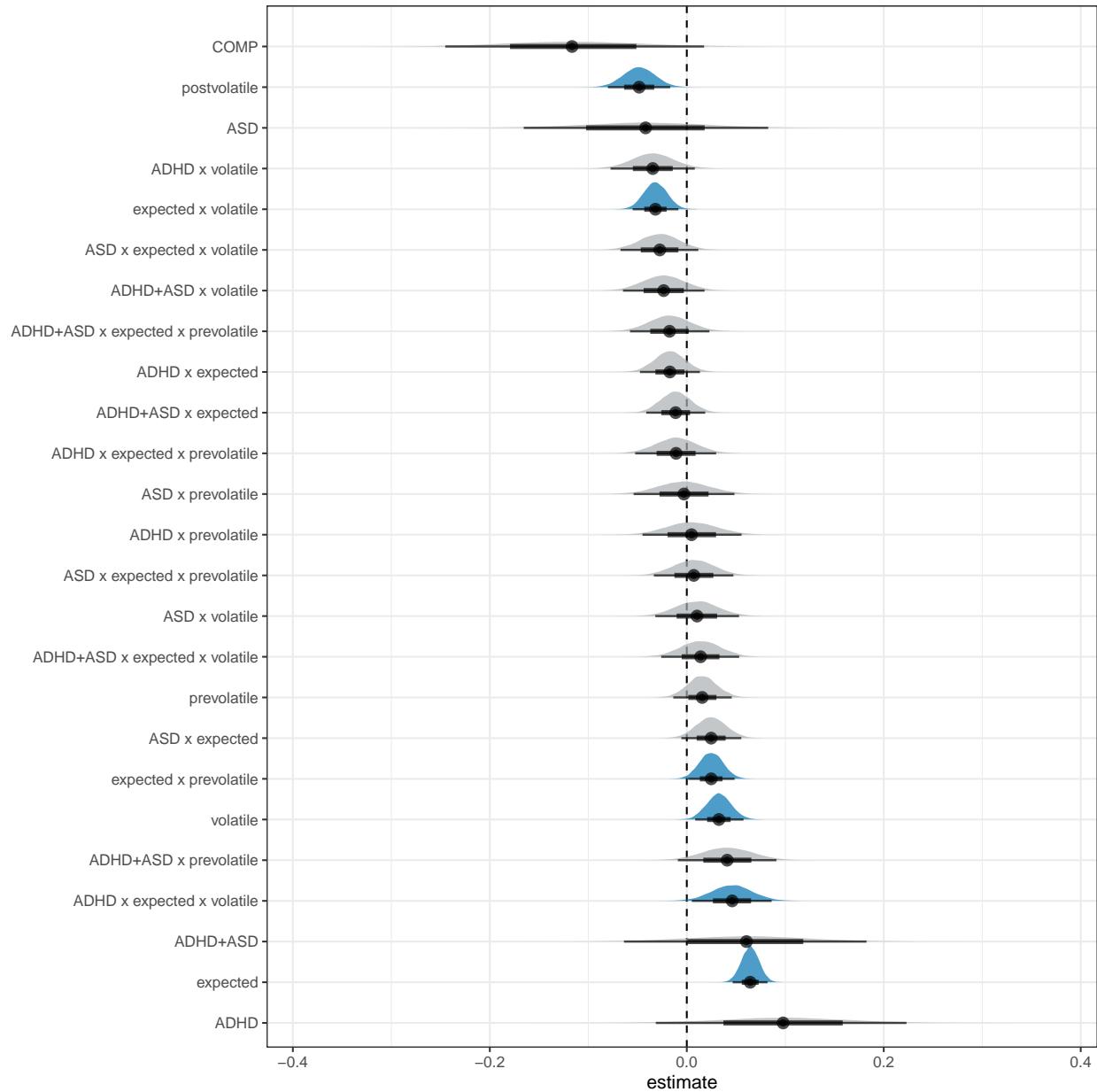
```

```

COMP      = b_Intercept + b_COMP,
`ADHD-ASD` = ADHD - ASD,
`ADHD-COMP` = ADHD - COMP,
`ASD-COMP` = ASD - COMP
)

# plot the posterior distributions
df.m.var %>%
  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", "ADHD"),
    coef = str_replace_all(coef, "diagnosis2", "ASD"),
    coef = str_replace_all(coef, "diagnosis3", "ADHD+ASD"),
    coef = str_replace_all(coef, "expected1", "expected"),
    coef = str_replace_all(coef, "expected2", "unexpected"),
    coef = str_replace_all(coef, "phase1", "prevolatile"),
    coef = str_replace_all(coef, "phase2", "volatile"),
    coef = fct_reorder(coef, desc(estimate))
  ) %>%
  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(c_dark, c_light)) + theme(legend.position = "none")

```



# H1a: COMP < ADHD

```
h1a = hypothesis(m.var, "0 < 2*diagnosis1 + diagnosis2 + diagnosis3")
h1a
```

## Hypothesis Tests for class b:

	Hypothesis	Estimate	Est.Error	CI.Lower	CI.Upper	Evid.Ratio
## 1	$(0) - (2 * \text{diagnosis1} + \text{diagnosis2} + \text{diagnosis3}) < 0$	-0.21	0.11	-0.39	-0.03	39.36

## Post.Prob Star

## 1 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 assume equal prior probabilities.

```

## Exploration

# COMP < BOTH
e1 = hypothesis(m.var, "0 < diagnosis1 + diagnosis2 + 2*diagnosis3",
                alpha = 0.025)
e1

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (0)-(diagnosis1+d... < 0      -0.18      0.11     -0.39      0.03     19.29
##   Post.Prob Star
## 1      0.95
## ---
## '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.

# COMP < ASD
e2 = hypothesis(m.var, "0 < diagnosis1 + 2*diagnosis2 + diagnosis3",
                alpha = 0.025)
e2

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (0)-(diagnosis1+2... < 0      -0.07      0.11     -0.28      0.14      3.05
##   Post.Prob Star
## 1      0.75
## ---
## '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.

## extract predicted differences in ms instead of log data
df.new = df.var %>%
  select(diagnosis, phase, expected) %>%
  distinct() %>%
  mutate(
    condition = paste(diagnosis, phase, expected, sep = "_")
  )
df.ms = as.data.frame(
  fitted(m.var, summary = F,
         newdata = df.new %>% select(diagnosis, phase, expected),
         re_formula = NA))
colnames(df.ms) = df.new$condition

# calculate our difference columns
df.ms = df.ms %>%
  mutate(
    COMP      = rowMeans(across(matches("COMP_.*"))),
    ADHD      = rowMeans(across(matches("ADHD_.*"))),
    ASD       = rowMeans(across(matches("ASD_.*"))),
    BOTH      = rowMeans(across(matches("BOTH_.*"))),
    h1a_COMPvADHD = ADHD - COMP

```

```
)
```

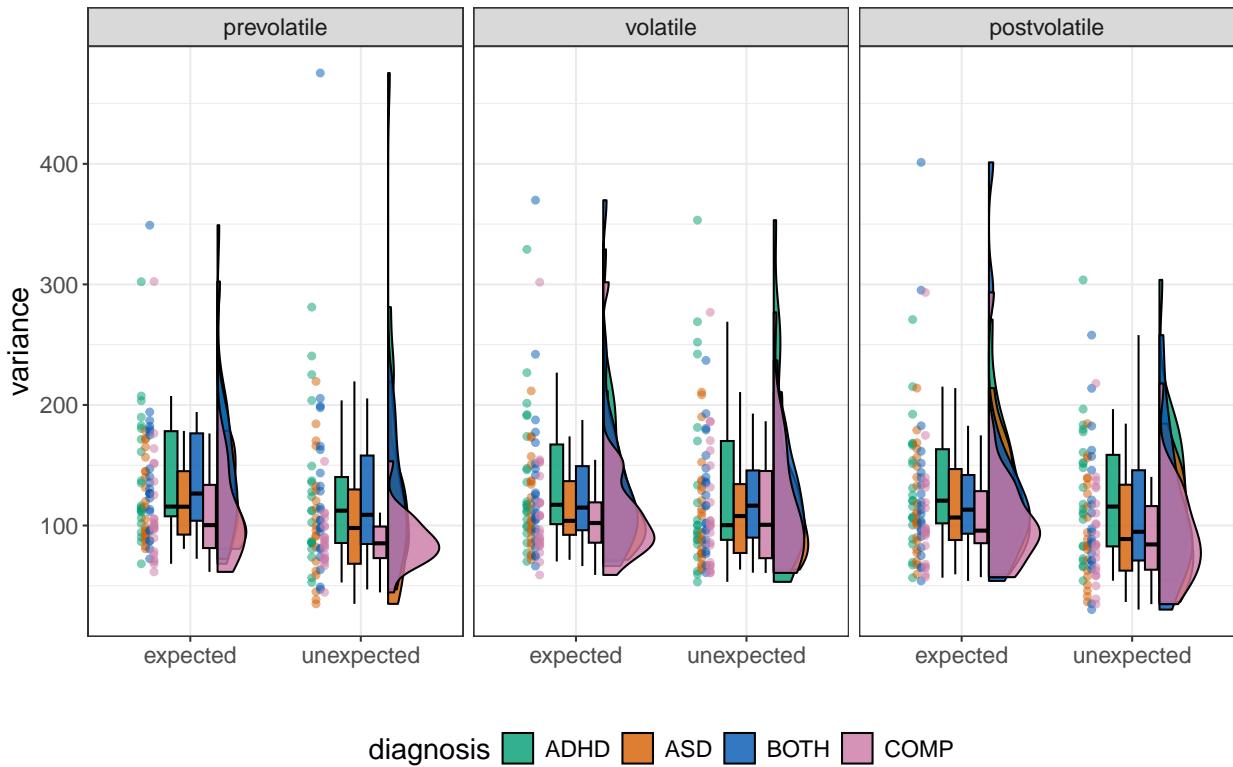
The model supports our hypothesis regarding increased reaction time variance in adults with ADHD compared to adults without any psychiatric diagnoses (*estimate* = -0.21 [-0.39, -0.03], *posterior probability* = 97.52%). Specifically, the model predicts a reaction time variance of 100.5ms [85.85, 117.24] in COMP adults, of 123.91ms [106.2, 143.29] in adults with ADHD, of 108.27ms [93.36, 124.75] in adults with ASD and of 119.47ms [103.55, 137.17] in adults with ADHD and ASD.

## Plots

```
# rain cloud plot

df.var %>%
  ggplot(aes(expected, rt.var, fill = diagnosis, colour = diagnosis)) + #
  geom_rain(rain.side = 'r',
  boxplot.args = list(color = "black", outlier.shape = NA, show.legend = FALSE, alpha = .8),
  violin.args = list(color = "black", outlier.shape = NA, alpha = .8),
  boxplot.args.pos = list(
    position = ggpp::position_dodge_nudge(x = 0, width = 0.3), width = 0.3
  ),
  point.args = list(show_guide = FALSE, alpha = .5),
  violin.args.pos = list(
    width = 0.6, position = position_nudge(x = 0.16)),
  point.args.pos = list(position = ggpp::position_dodge_nudge(x = -0.25, width = 0.1))) +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  #ylim(0, 1) +
  labs(title = "Reaction times variance per subject", x = "", y = "variance") +
  facet_wrap(. ~ phase) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5),
  legend.direction = "horizontal", text = element_text(size = 15))
```

## Reaction times variance per subject



Now, we use line plots to visualise out the different main effects and interaction effects in our data.

```
# two-way interactions
p1 = df.var %>%
  group_by(diagnosis, expected) %>%
  summarise(
    var.mn = mean(rt.var),
    var.se = sd(rt.var) / sqrt(n())
  ) %>%
  ggplot(aes(y = var.mn, x = expected, group = diagnosis, colour = diagnosis)) +
  geom_line(position = position_dodge(0.4), linewidth = 1) +
  geom_errorbar(aes(ymin = var.mn - var.se,
                     ymax = var.mn + var.se), linewidth = 1, width = 0.5,
                position = position_dodge(0.4)) +
  geom_point(position = position_dodge(0.4), size = 5) +
  labs (x = "expectancy", y = "rt var (ms)") +
  ggtitle("Diagnosis x expectancy") +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))
p2 = df.var %>%
  group_by(diagnosis, phase) %>%
  summarise(
    var.mn = mean(rt.var),
    var.se = sd(rt.var) / sqrt(n())
  ) %>%
  ggplot(aes(y = var.mn, x = phase, group = diagnosis, colour = diagnosis)) +
```

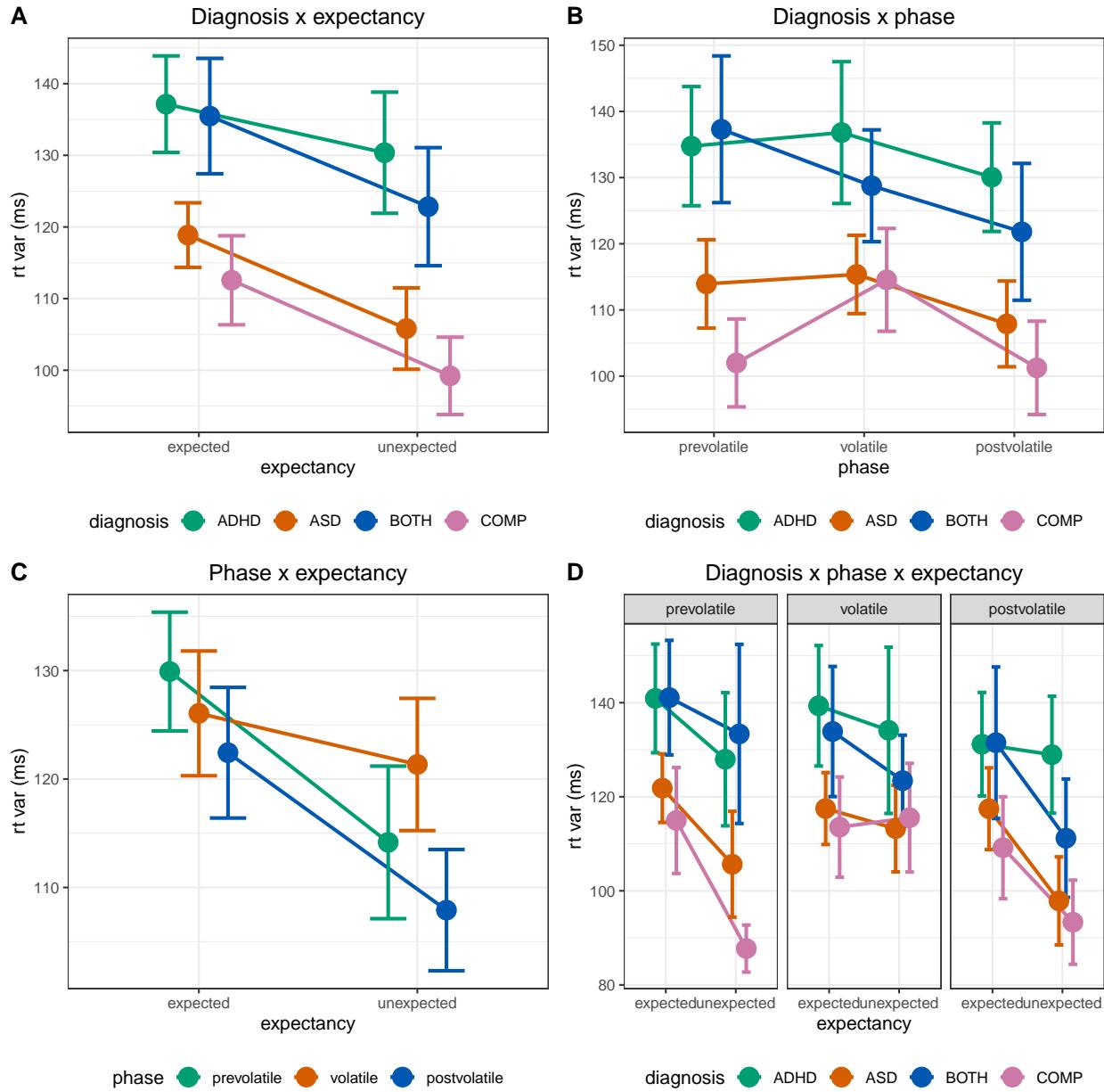
```

geom_line(position = position_dodge(0.4), linewidth = 1) +
geom_errorbar(aes(ymin = var.mn - var.se,
                  ymax = var.mn + var.se), linewidth = 1, width = 0.5,
                  position = position_dodge(0.4)) +
geom_point(position = position_dodge(0.4), size = 5) +
labs (x = "phase", y = "rt var (ms)") +
ggtitle("Diagnosis x phase") +
scale_fill_manual(values = custom.col) +
scale_color_manual(values = custom.col) +
theme_bw() +
theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))
p3 = df.var %>%
  group_by(phase, expected) %>%
  summarise(
    var.mn = mean(rt.var),
    var.se = sd(rt.var) / sqrt(n())
  ) %>%
  ggplot(aes(y = var.mn, x = expected, group = phase, colour = phase)) +
  geom_line(position = position_dodge(0.4), linewidth = 1) +
  geom_errorbar(aes(ymin = var.mn - var.se,
                     ymax = var.mn + var.se), linewidth = 1, width = 0.5,
                     position = position_dodge(0.4)) +
  geom_point(position = position_dodge(0.4), size = 5) +
  labs (x = "expectancy", y = "rt var (ms)") +
  ggtitle("Phase x expectancy") +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))

# three-way interaction
p4 = df.var %>%
  group_by(diagnosis, expected, phase) %>%
  summarise(
    var.mn = mean(rt.var),
    var.se = sd(rt.var) / sqrt(n())
  ) %>%
  ggplot(aes(y = var.mn, x = expected, group = diagnosis, colour = diagnosis)) +
  geom_line(position = position_dodge(0.4), linewidth = 1) +
  geom_errorbar(aes(ymin = var.mn - var.se,
                     ymax = var.mn + var.se), linewidth = 1, width = 0.5,
                     position = position_dodge(0.4)) +
  geom_point(position = position_dodge(0.4), size = 5) +
  labs (x = "expectancy", y = "rt var (ms)") +
  ggtitle("Diagnosis x phase x expectancy") +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  facet_wrap(. ~ phase) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))

ggarrange(p1, p2, p3, p4, ncol = 2, nrow = 2, labels = "AUTO")

```



## Bayes factor analysis

To complement our hypothesis testing using `brms::hypothesis()`, we perform a Bayes Factor (BF) analysis. The BF is the ratio of the marginal likelihoods of the data given two models. We will compare models containing different combinations of population-level effects to the model only containing the intercept on the population-level and all group-level effects. The BF depends on the priors that were used, because it indicates a change in our belief after seeing the data. Therefore, we perform a sensitivity analysis comparing the BF based on our chosen priors with narrower and wider priors.

```
# set the directory in which to save results
sense_dir = file.path(getwd(), "_brms_sens_cache")
main.code = "pal_var"

# rerun the model with more iterations for bridgesampling
```

```

set.seed(2684)
m.var.bf = brm(f.var,
  df.var, prior = priors,
  family = lognormal,
  iter = 40000, warmup = 10000,
  backend = "cmdstanr", threads = threading(8),
  file = file.path(brms_dir, "m_var_bf"),
  save_pars = save_pars(all = TRUE)
)

# describe priors for the sensitivity analysis
pr.descriptions = c("chosen",
  "sdx2", "sdx4", "sdx8",
  "sdx0.5", "sdx0.25", "sdx0.125"
)

# check which have been run already
if (file.exists(file.path(sense_dir, sprintf("df_%s_bf.csv", main.code)))) {
  pr.done = read_csv(
    file.path(sense_dir, sprintf("df_%s_bf.csv", main.code)),
    show_col_types = F) %>%
    select(priors) %>% distinct()
  pr.descriptions = pr.descriptions[!(pr.descriptions %in% pr.done$priors)]
}

# loop through the priors that have not been used before
for (pr.desc in pr.descriptions) {
  tryCatch({
    # use function to compute BF with the described priors
    bf_sens_3int(m.var.bf, "diagnosis", "phase", "expected",
      pr.desc,
      main.code, # prefix for all models and MLL
      file.path("logfiles", "log_PAL-var_bf.txt"), # log file
      sense_dir # where to save the models and MLL
    )
  },
  error = function(err) {
    message(sprintf("Error for %s: %s", pr.desc, err))
  }
)
}

df.var.bf = read_csv(file.path(sense_dir,
  sprintf("df_%s_bf.csv", main.code)),
  show_col_types = F)

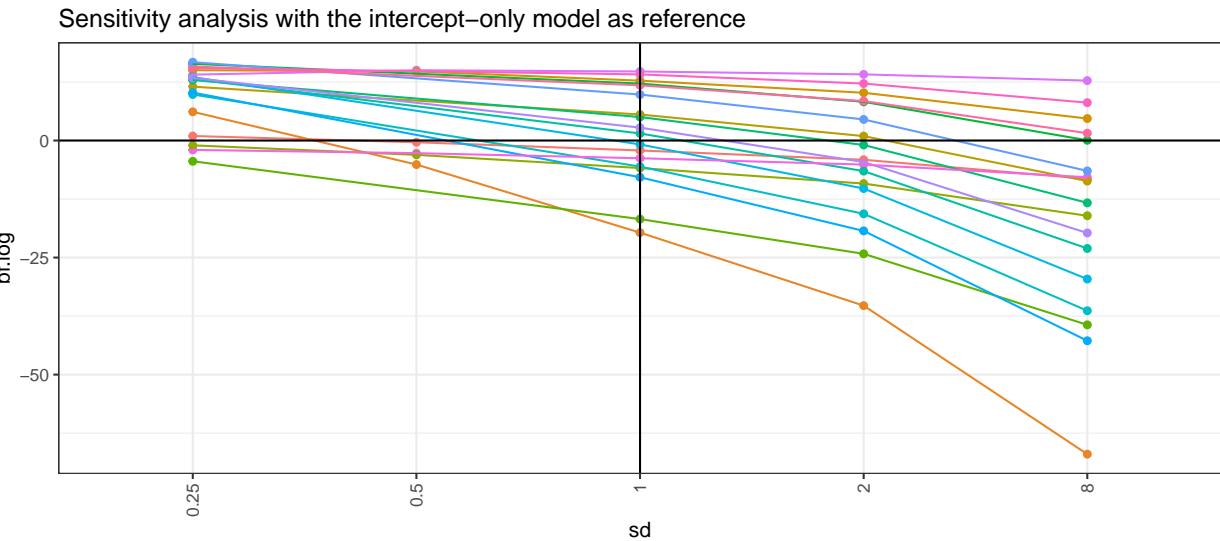
# check the sensitivity analysis result per model
df.var.bf %>%
  filter(`population-level` != "1") %>%
  mutate(
    sd = as.factor(case_when(
      priors == "chosen" ~ "1",
      substr(priors, 1, 3) == "sdx" ~ gsub("sdx", "", priors),

```

```

    T ~ priors)
),
order = case_when(
  priors == "chosen" ~ 1,
  substr(priors, 1, 3) == "sdx" ~ as.numeric(gsub("sdx", "", priors)),
  T ~ 999),
sd = fct_reorder(sd, order)
) %>%
ggplot(aes(y = bf.log,
            x = sd,
            group = `population-level`,
            colour = `population-level`)) +
geom_point() +
geom_line() +
geom_vline(xintercept = "1") +
geom_hline(yintercept = 0) +
ggtitle("Sensitivity analysis with the intercept-only model as reference") +
#scale_colour_manual(values = custom.col) +
theme_bw() +
theme(legend.position = "none",
      axis.text.x = element_text(angle = 90, vjust = 0.5, hjust = 1))

```



```

# focus on the best models
df.best = df.var.bf %>%
ungroup() %>%
filter(priors == "chosen" & !is.na(bf.log)) %>%
mutate(bf.rank = rank(bf.log),
       bf.rank = max(bf.rank) - bf.rank + 1
     ) %>%
filter(bf.rank <= 5)
best = df.best$`population-level`
df.var.bf %>%
filter(`population-level` %in% best) %>%
mutate(
  sd = as.factor(case_when(

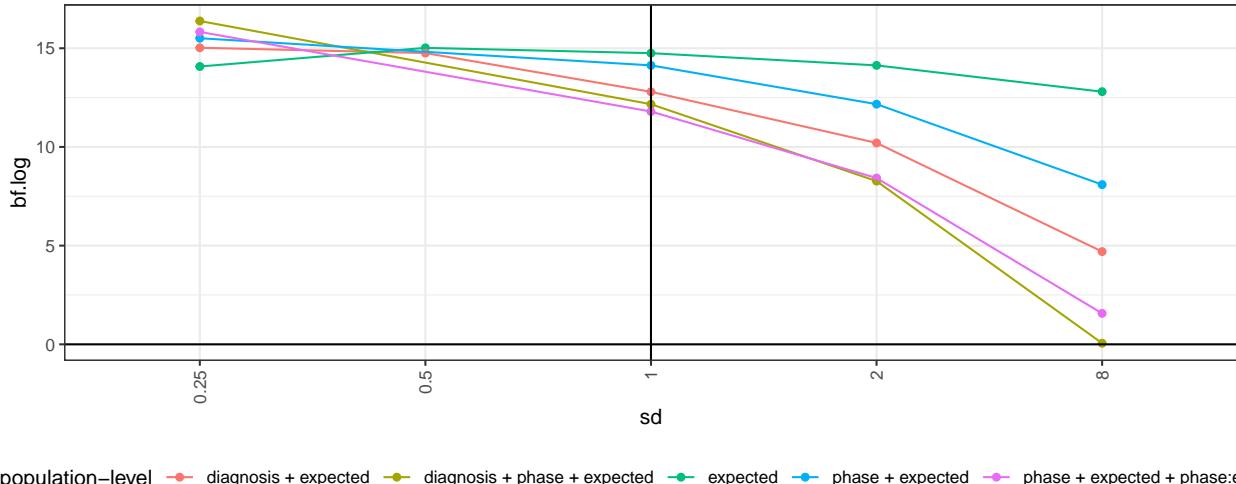
```

```

    priors == "chosen" ~ "1",
    substr(priors, 1, 3) == "sdx" ~ gsub("sdx", "", priors),
    T ~ priors)
),
order = case_when(
  priors == "chosen" ~ 1,
  substr(priors, 1, 3) == "sdx" ~ as.numeric(gsub("sdx", "", priors)),
  T ~ 999),
  sd = fct_reorder(sd, order)
) %>%
ggplot(aes(y = bf.log,
            x = sd,
            group = `population-level`,
            colour = `population-level`)) +
  geom_point() +
  geom_line() +
  geom_vline(xintercept = "1") +
  geom_hline(yintercept = 0) +
  ggtitle("Sensitivity analysis with the intercept-only model as reference") +
  #scale_colour_manual(values = custom.col) +
  theme_bw() +
  theme(legend.position = "bottom",
        axis.text.x = element_text(angle = 90, vjust = 0.5, hjust = 1))

```

Sensitivity analysis with the intercept-only model as reference



population-level | ● diagnosis + expected | ● diagnosis + phase + expected | ● expected | ● phase + expected | ● phase + expected + phase:ex

```

# create a data frame with the comparisons
kable(head(df.var.bf %>% filter(priors == "chosen") %>% select(-priors) %>%
  filter(`population-level` != "1") %>% arrange(desc(bf.log)) %>%
  mutate(
    bf.log.diff = bf.log - lead(bf.log),
    bf.int = interpret_bf(bf.log.diff, log = T)
  )), digits = 3)

```

population-level	bf.log	bf.log.diff	bf.int
expected	14.751	0.619	anecdotal evidence in favour of

population-level	bf.log	bf.log.diff	bf.int
phase + expected	14.132	1.339	moderate evidence in favour of
diagnosis + expected	12.793	0.627	anecdotal evidence in favour of
diagnosis + phase + expected	12.166	0.371	anecdotal evidence in favour of
phase + expected + phase:expected	11.795	1.968	moderate evidence in favour of
diagnosis + phase + expected + phase:expected	9.826	4.268	very strong evidence in favour of

### S1.3 Reaction times in correct trials

In the preregistration, we noted the following population-level effects for the model of the reaction time variances: group, expectancy, phase and difficulty; as well as the group-level predictores subject and trials. We tried both this full model and one without difficulty:

```
rt.cor ~ diagnosis * expected * phase * difficulty + (expected * phase * difficulty | subID) + (diagnosis * expected * phase * difficulty | trl)

rt.cor ~ diagnosis * expected * phase + (expected * phase | subID) + (diagnosis * expected * phase | trl)
```

Unfortunately, they both showed suboptimal posterior fit. They are uploaded to GitHub and can be inspected. Therefore, we aggregated the reaction times for correct trials using the median (see above in the preparation of the data).

```
# figure out slopes for subjects
kable(head(df.pal %>% count(subID, expected)))
```

subID	expected	n
1	expected	9
1	unexpected	9
2	expected	9
2	unexpected	9
3	expected	9
3	unexpected	9

```
kable(head(df.pal %>% count(subID, phase)))
```

subID	phase	n
1	prevolatile	6
1	volatile	6
1	postvolatile	6
2	prevolatile	6
2	volatile	6
2	postvolatile	6

```
kable(head(df.pal %>% count(subID, difficulty)))
```

subID	difficulty	n
1	easy	6
1	medium	6

subID	difficulty	n
1	difficult	6
2	easy	6
2	medium	6
2	difficult	6

```
kable(head(df.pal %>% count(subID, expected, phase)))
```

subID	expected	phase	n
1	expected	prevolatile	3
1	expected	volatile	3
1	expected	postvolatile	3
1	unexpected	prevolatile	3
1	unexpected	volatile	3
1	unexpected	postvolatile	3

```
kable(head(df.pal %>% count(subID, expected, difficulty)))
```

subID	expected	difficulty	n
1	expected	easy	3
1	expected	medium	3
1	expected	difficult	3
1	unexpected	easy	3
1	unexpected	medium	3
1	unexpected	difficult	3

```
kable(head(df.pal %>% count(subID, phase, difficulty)))
```

subID	phase	difficulty	n
1	prevolatile	easy	2
1	prevolatile	medium	2
1	prevolatile	difficult	2
1	volatile	easy	2
1	volatile	medium	2
1	volatile	difficult	2

```
kable(head(df.pal %>% count(subID, expected, phase, difficulty)))
```

subID	expected	phase	difficulty	n
1	expected	prevolatile	easy	1
1	expected	prevolatile	medium	1
1	expected	prevolatile	difficult	1
1	expected	volatile	easy	1
1	expected	volatile	medium	1
1	expected	volatile	difficult	1

```

code = "PAL-rt"

# set the formula
f.pal = brms::bf(rt.cor ~ diagnosis * expected * phase * difficulty +
  (expected + phase + difficulty +
    expected:phase + difficulty:phase + expected:difficulty | subID))

# set informed priors based on previous results
priors = c(
  # informative priors based Lawson et al. and Schad, Betancourt & Vasishth (2019)
  prior(normal(6.0, 0.3), class = Intercept),
  prior(normal(0.0, 0.5), class = sigma),
  prior(normal(0, 0.1), class = sd),
  prior(lkj(2), class = cor),
  prior(normal(100, 100.0), class = ndt), # higher due to aggregation
  # ASD slower overall (Lawson et al., 2017)
  prior(normal(0.02, 0.04), class = b, coef = diagnosis2),
  # faster for expected trials (Lawson et al., 2017)
  prior(normal(-0.02, 0.04), class = b, coef = expected1), # expected
  # faster on easy trials (Lawson et al., 2017)
  prior(normal(-0.02, 0.04), class = b, coef = difficulty1), # easy
  # larger effect of phases in ASD (Shi et al., 2022)
  prior(normal(0.02, 0.04), class = b, coef = diagnosis2:phase2),
  prior(normal(0.02, 0.04), class = b, coef = diagnosis2:phase1),
  # smaller effect of expected in ASD (Lawson et al., 2017)
  prior(normal(0.02, 0.04), class = b, coef = diagnosis2:expected1),
  # all the other interactions
  prior(normal(0.00, 0.04), class = b)
)

```

## Simulation-based calibration

```

if (!(file.exists(file.path(cache_dir, sprintf("df_res_%s.rds", code)))) |
  !(file.exists(file.path(cache_dir, sprintf("df_res_%s.rds", code))))) {
  # simulate some data based on the priors
  gen = SBC_generator_brms(f.pal, data = df.pal, prior = priors,
    thin = 50, warmup = 10000, refresh = 2000,
    generate_lp = TRUE, family = shifted_lognormal, init = 0.1)
  if (!file.exists(file.path(cache_dir, paste0("dat_", code, ".rds")))){
    dat = generate_datasets(gen, nsim)
    saveRDS(dat, file = file.path(cache_dir, paste0("dat_", code, ".rds")))
  } else {
    dat = readRDS(file = file.path(cache_dir, paste0("dat_", code, ".rds")))
  }

  # perform the SBC
  bck = SBC_backend_brms_from_generator(gen, chains = 4, thin = 1,
    warmup = warm, iter = iter,
    init = 0.1)
  # only do it for 250 simulations since it takes so long
  # > this was done with the helper script, seeds are documented there!
  res = compute_SBC(SBC_datasets(dat$variables[1:250,],
    dat$generated[1:250])),

```

```

        bck,
        cache_mode = "results",
        cache_location = file.path(cache_dir, sprintf("res_%s", code, i)))
    write_csv(res$stats, file.path(cache_dir, sprintf("df_res_%s.rds", code)))
    write_csv(res$backend_diagnostics, file.path(cache_dir, sprintf("df_div_%s.rds", code)))
} else {
    # load in the results of the SBC
    df.results = readRDS(file.path(cache_dir, sprintf("df_res_%s.rds", code)))
    df.backend = readRDS(file.path(cache_dir, sprintf("df_div_%s.rds", code)))
}

```

Again, we start by investigating the rhats and the number of divergent samples. This shows that 2 of 500 simulations had at least one parameter that had an rhat of at least 1.05, and 2 models had divergent samples. This suggests that this model performs well and we can continue with our checks by plotting the simulated values to perform prior predictive checks.

```

if (!(file.exists(file.path(cache_dir, sprintf("dvfakemat_%s", code))))) {
    # create a matrix out of generated data
    dvfname = gsub(" ", "", gsub("[\\|~].*", "", f.pal)[1])
    dvfakemat = matrix(NA, nrow=dat[["generated"]][[1]]), length(dat[["generated"]]))
    for (i in 1:length(dat[["generated"]])) {
        dvfakemat[,i] = dat[["generated"]][[i]][dvfname]
    }
    saveRDS(dvfakemat, file.path(cache_dir, sprintf("dvfakemat_%s", code)))
} else {
    dvfakemat = readRDS(file.path(cache_dir, sprintf("dvfakemat_%s", code)))
}

# compute one histogram per simulated data-set
dvfakematH = dvfakemat
dvfakematH[dvfakematH > 2000] = 2000
breaks = seq(0, max(dvfakematH, na.rm=T), length.out = 101)
binwidth = breaks[2] - breaks[1]
histmat = matrix(NA, ncol = dim(dvfakemat)[2], nrow = length(breaks)-1)
for (i in 1:dim(dvfakemat)[2]) {
    histmat[,i] = hist(dvfakematH[,i], breaks = breaks, plot = F)$counts
}
# for each bin, compute quantiles across histograms
probs = seq(0.1, 0.9, 0.1)
quantmat = as.data.frame(matrix(NA, nrow=dim(histmat)[1], ncol = length(probs)))
names(quantmat) = paste0("p", probs)
for (i in 1:dim(histmat)[1]) {
    quantmat[i,] = quantile(histmat[i,], p = probs)
}
quantmat$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 = "Distribution of simulated reaction times", y = "", x = "") +
    theme_bw()

```

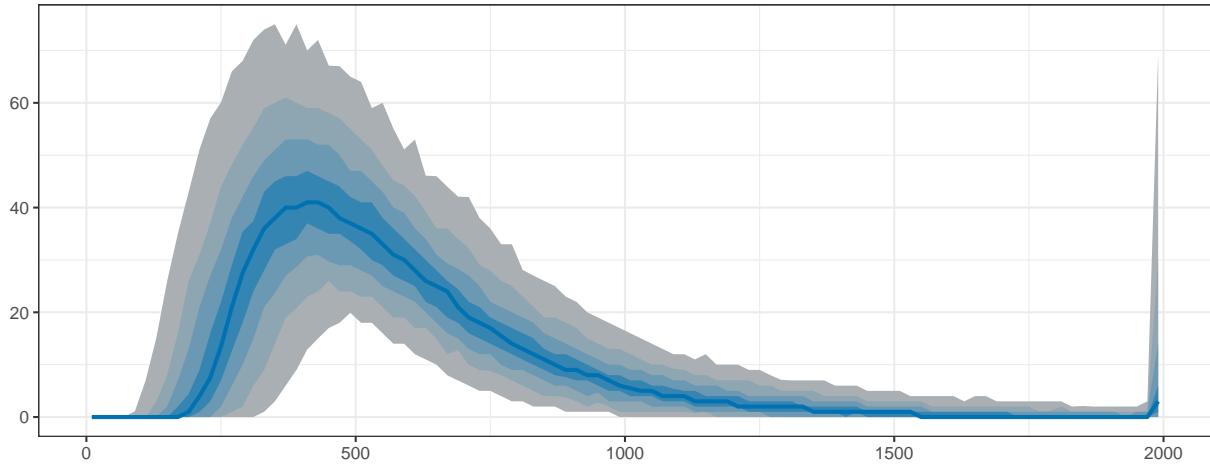
```

tmpM = apply(dvfakemat, 2, mean) # mean
tmpSD = apply(dvfakemat, 2, sd)
p2 = ggplot() +
  stat_bin(aes(x = tmpM), fill = c_dark) +
  labs(x = "Mean discrimination", title = "Means of simulated reaction times") +
  theme_bw()
p3 = ggplot() +
  stat_bin(aes(x = tmpSD), fill = c_dark) +
  labs(x = "SD discrimination", title = "SDs of simulated reaction times") +
  theme_bw()
p = ggarrange(p1,
  ggarrange(p2, p3, ncol = 2, labels = c("B", "C")),
  nrow = 2, labels = "A")
annotate_figure(p, top = text_grob("Prior predictive checks", face = "bold", size = 14))

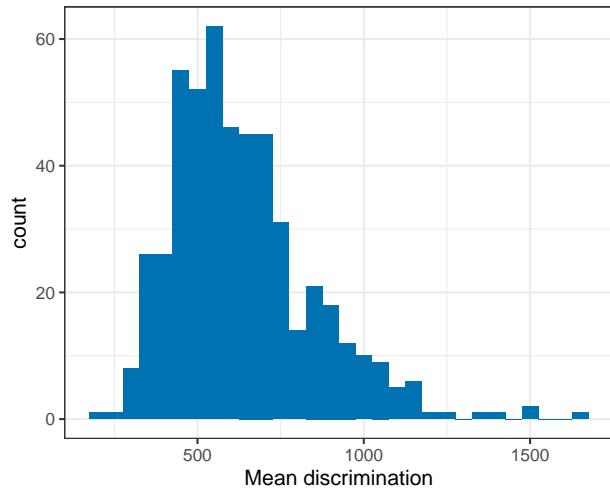
```

### Prior predictive checks

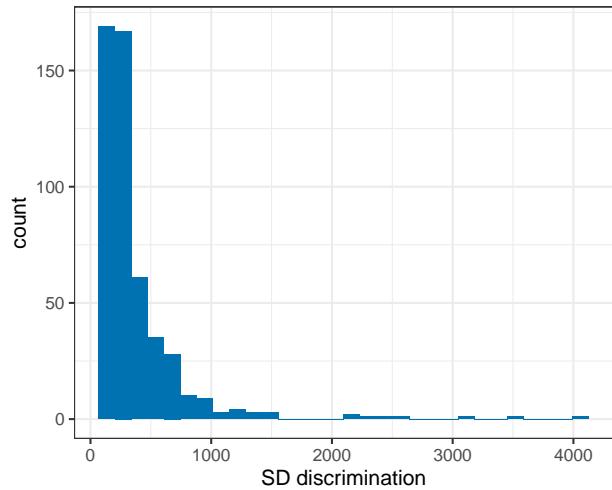
**A** Distribution of simulated reaction times



**B** Means of simulated reaction times



**C** SDs of simulated reaction times



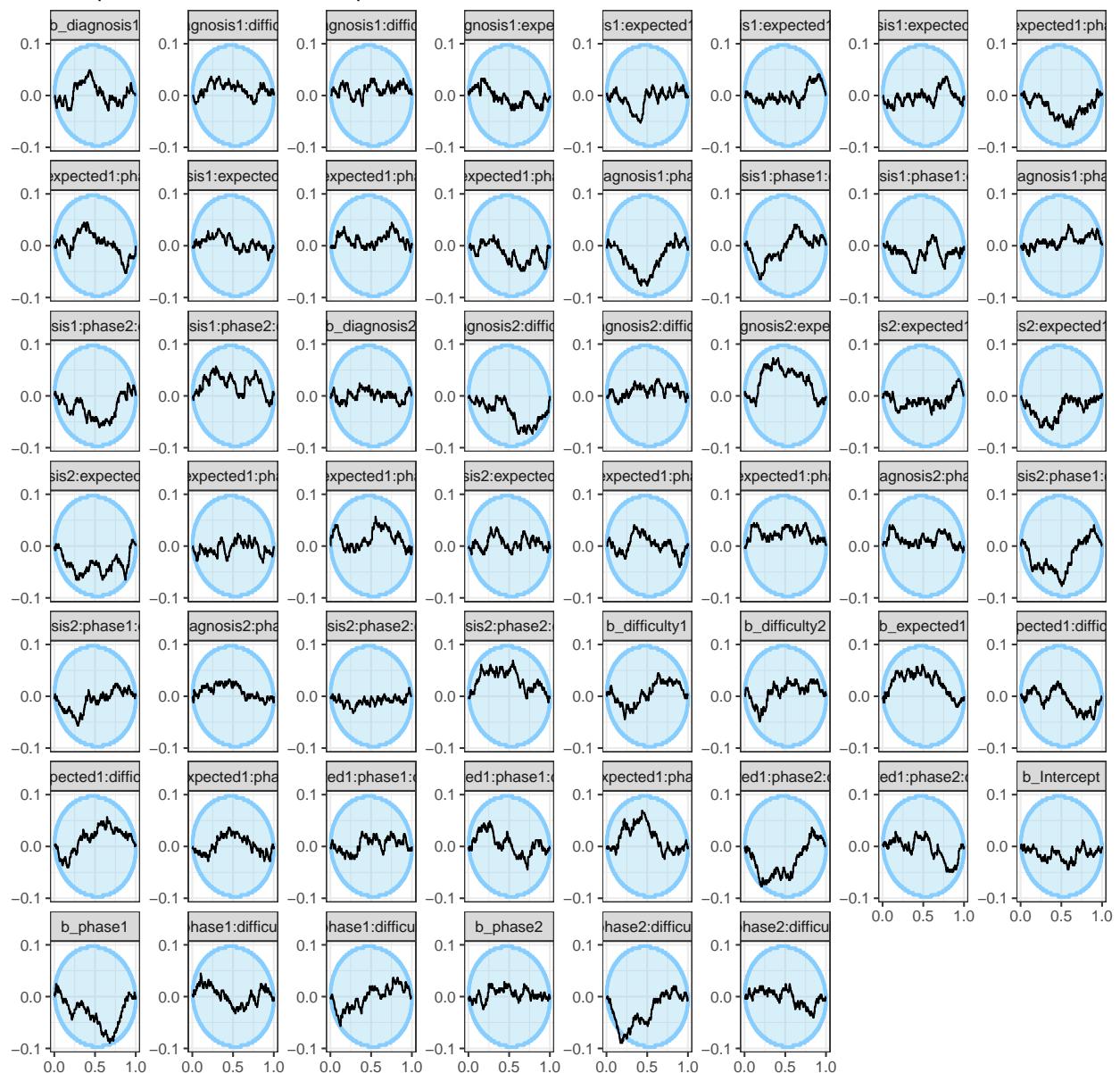
Subfigure A shows the distribution of the simulated data with bluer bands being more likely than greyer bands. Subfigure A shows a distribution that fits our expectations about reaction times in a simple decision

task. The distribution of the means and standard deviations in the simulated datasets also look good. We go ahead with these priors and check the results of the SBC. We only plot the results from the models that had no divergence issues.

```
# 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))
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)) +
  ggtitle("Computational faithfulness: empirical cumulative distribution function")
```

### Computational faithfulness: empirical cumulative distribution function



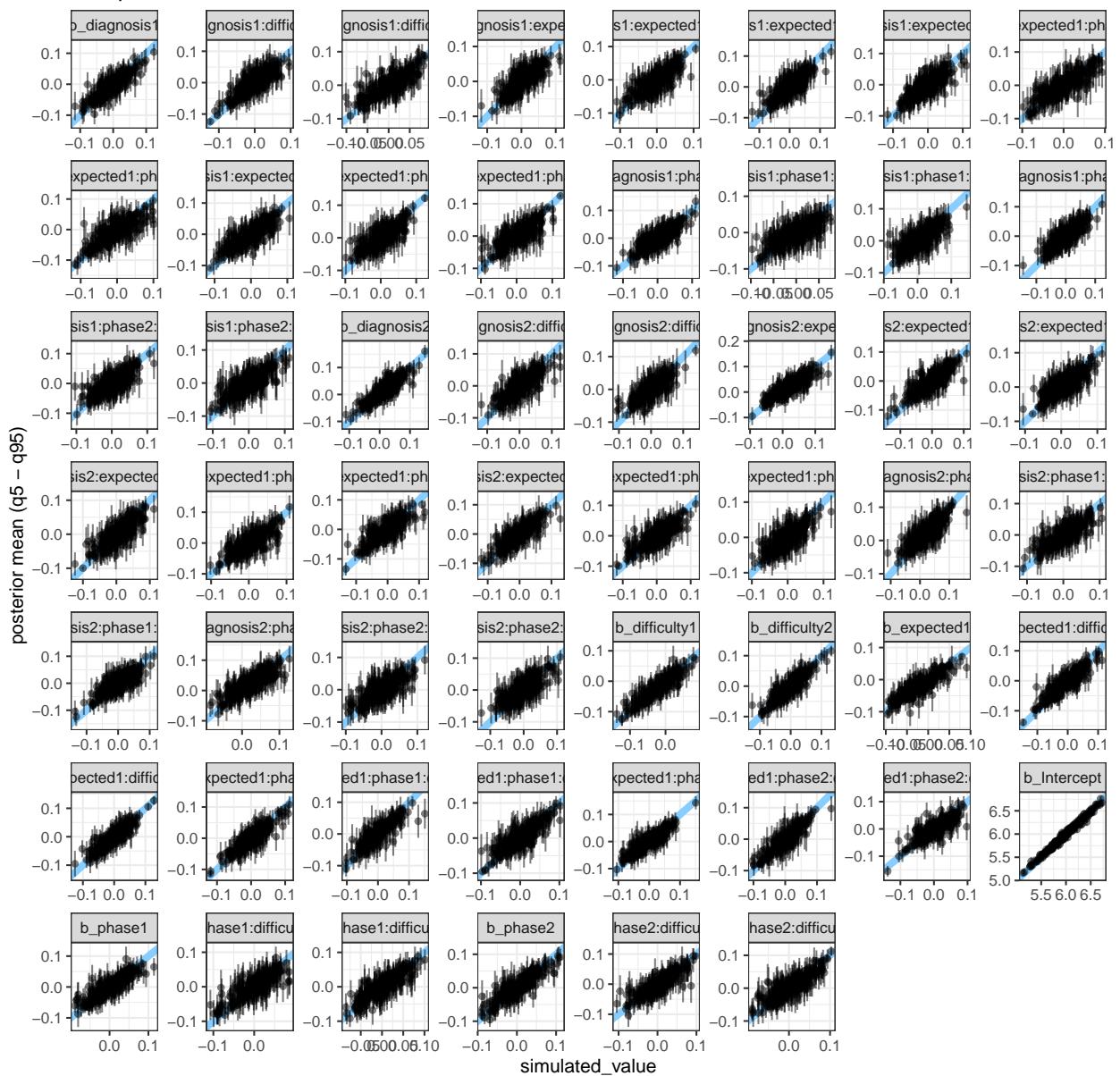
```
plot_rank_hist(df.results.b, bins = 20) + theme_bw() +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3)) +
  ggtitle("Computational faithfulness: rank histograms")
```

### Computational faithfulness: rank histograms



```
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)) +
  ggtitle("Computational faithfulness: simulated and estimated values")
```

### Computational faithfulness: simulated and estimated values

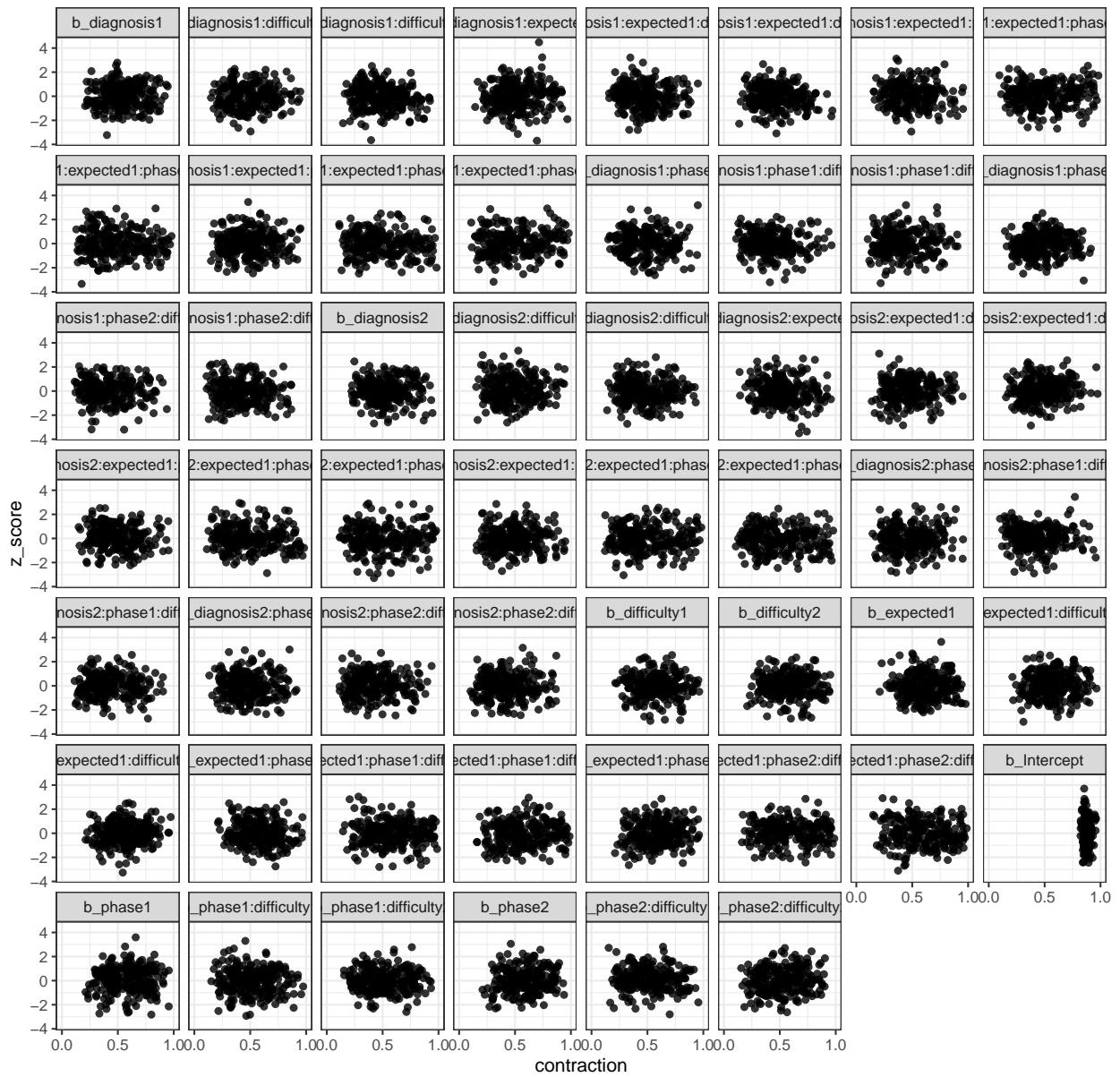


```

plot_contraction(df.results.b,
  prior_sd = setNames(
    c(as.numeric(
      gsub(".*, (.+)\\\".*", "\\"1",
        priors[priors$class == "Intercept",]$prior)),
      rep(0.04, times = (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 = 5)) +
  ggtitle("Computational faithfulness: contraction and z-values")

```

### Computational faithfulness: contraction and z-values



While some of the ECDFs show discrepancies from the theoretical distribution, we judge all evaluated parameters to be acceptable.

### Posterior predictive checks

After having run the SBC, we realised that setting the threshold to Gaussian with a mean of 100ms does not fit well with a model based on aggregated reaction times - they are unlikely to be this low. Therefore, we change the mean of this one prior, but assume that the SBC still holds.

As the next step, we fit the model, check whether there are divergence or rhat issues, and then check whether the chains have converged.

```
# adjust ndt prior
priors = priors %>%
  mutate(
```

```

    prior = if_else(class == "ndt", "normal(250, 100)", prior)
  )

# fit the final model
set.seed(2468)
m.pal = brm(f.pal,
  df.pal, prior = priors,
  family = shifted_lognormal,
  iter = iter, warmup = warm,
  backend = "cmdstanr", threads = threading(8),
  file = file.path(brms_dir, "m_pal"),
  save_pars = save_pars(all = TRUE)
)
rstan::check_hmc_diagnostics(m.pal$fit)

##
## Divergences:
## 0 of 18000 iterations ended with a divergence.

##
## Tree depth:
## 0 of 18000 iterations saturated the maximum tree depth of 10.

##
## Energy:
## E-BFMI indicated no pathological behavior.

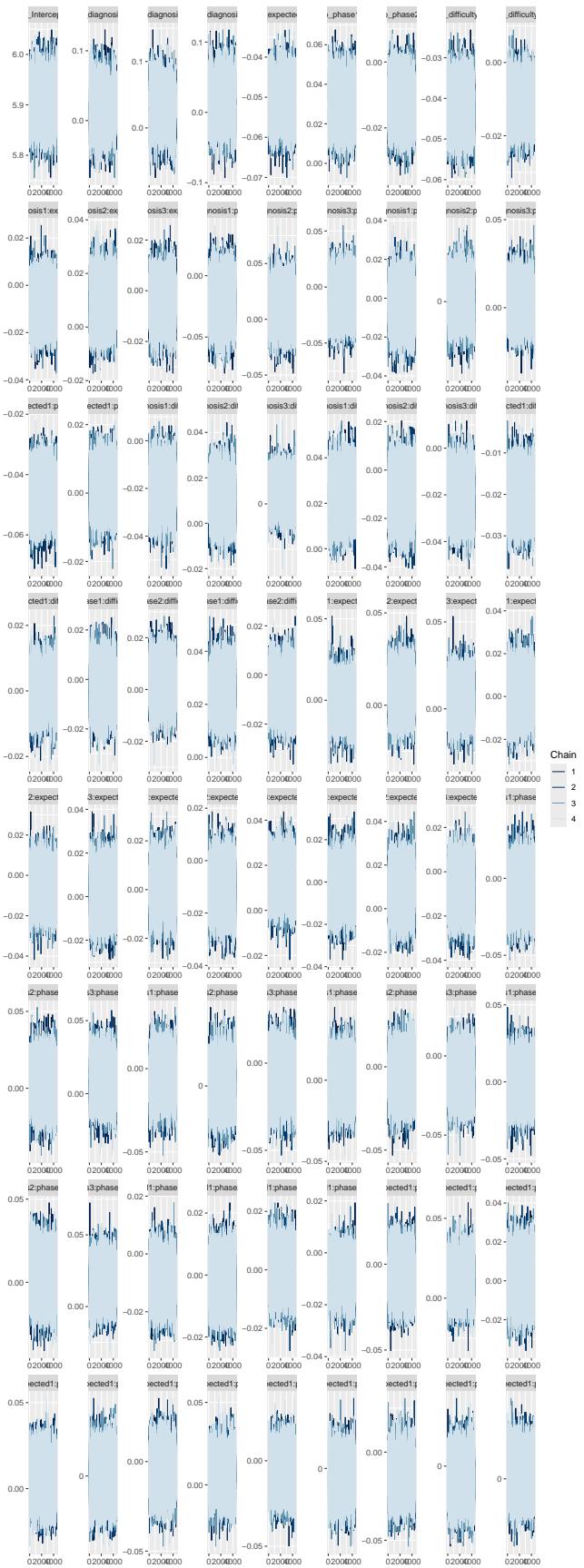
# check that rhats are below 1.01
sum(brms::rhat(m.pal) >= 1.01, na.rm = T)

## [1] 0

# check the trace plots
post.draws = as_draws_df(m.pal)
mcmc_trace(post.draws, regex_pars = "^b_",
  facet_args = list(ncol = 9)) +
  scale_x_continuous(breaks=scales::pretty_breaks(n = 3)) +
  scale_y_continuous(breaks=scales::pretty_breaks(n = 3))

## Scale for x is already present.
## Adding another scale for x, which will replace the existing scale.

```



This model has no pathological behaviour with E-BFMI, no divergent sample and no rhats that are higher or equal to 1.01. Therefore, we go ahead and perform our posterior predictive checks.

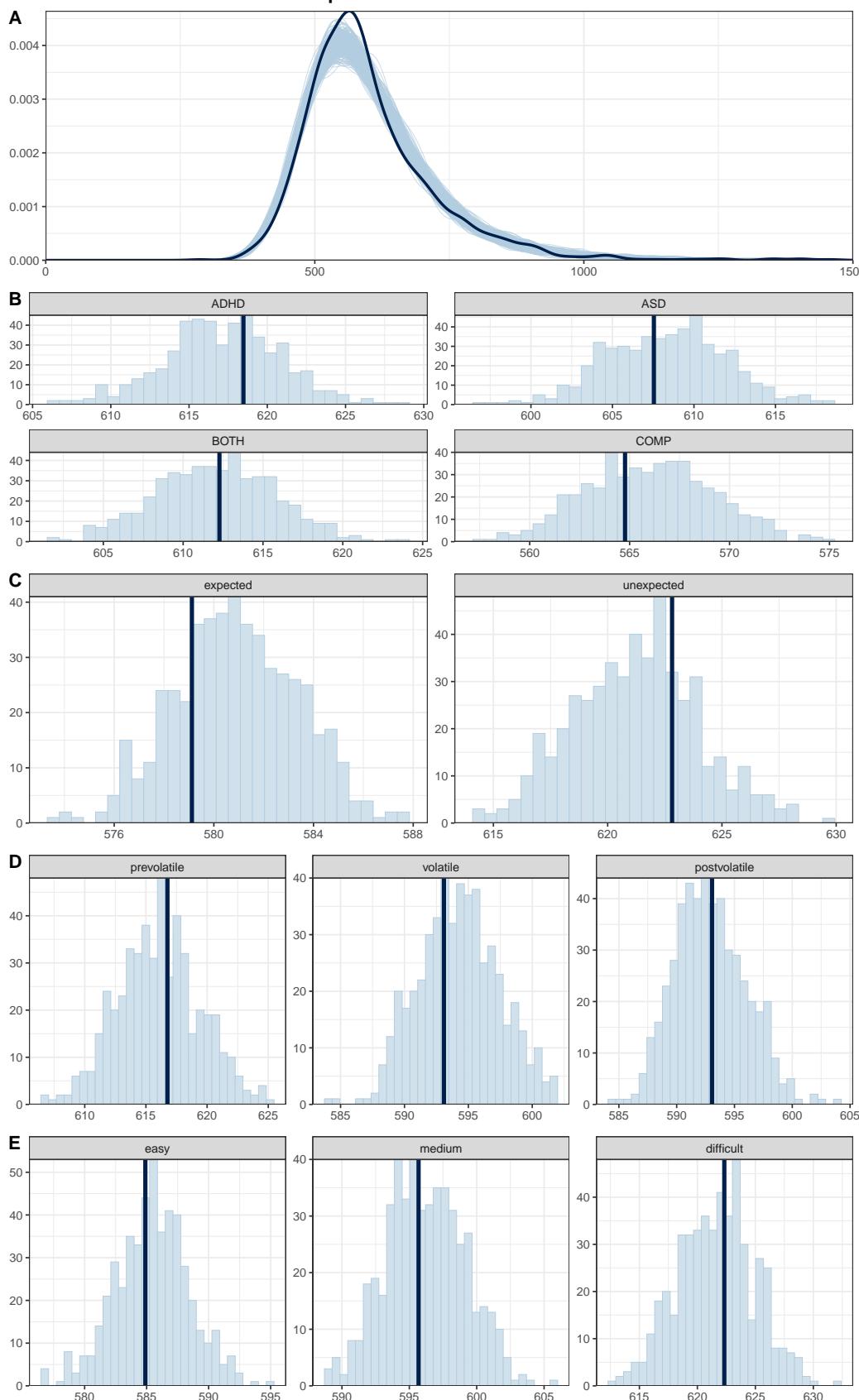
```
# get posterior predictions
post.pred = posterior_predict(m.pal, ndraws = nsim)

# check the fit of the predicted data compared to the real data
p1 = pp_check(m.pal, ndraws = nsim) +
  theme_bw() + theme(legend.position = "none") + xlim(0, 1500)

# distributions of means compared to the real values per group or conditions
p2 = ppc_stat_grouped(df.pal$rt.cor,
                      post.pred,
                      df.pal$diagnosis) +
  theme_bw() + theme(legend.position = "none")
p3 = ppc_stat_grouped(df.pal$rt.cor,
                      post.pred,
                      df.pal$expected) +
  theme_bw() + theme(legend.position = "none")
p4 = ppc_stat_grouped(df.pal$rt.cor,
                      post.pred,
                      df.pal$phase) +
  theme_bw() + theme(legend.position = "none")
p5 = ppc_stat_grouped(df.pal$rt.cor,
                      post.pred,
                      df.pal$difficulty) +
  theme_bw() + theme(legend.position = "none")

p = ggarrange(p1, p2, p3, p4, p5,
              nrow = 5, ncol = 1, labels = "AUTO")
annotate_figure(p, top = text_grob("Posterior predictive checks: reaction times",
                                   face = "bold", size = 14))
```

### Posterior predictive checks: reaction times



The simulated data based on the model fits well with the real data, although there are slight deviations specifically for the predictor expectedness. However, it is much better than for the full model, so we judge this to be acceptable.

## Inferences

Now that we are convinced that we can trust our model, we have a look at its estimate and use the hypothesis function to assess our hypotheses and perform explorative tests.

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

## Family: shifted_lognormal
## Links: mu = identity; sigma = identity; ndt = identity
## Formula: rt.cor ~ diagnosis * expected * phase * difficulty + (expected + phase + difficulty + expect
## Data: df.pal (Number of observations: 1620)
## Draws: 4 chains, each with iter = 6000; warmup = 1500; thin = 1;
##         total post-warmup draws = 18000
##
## Multilevel Hyperparameters:
## ~subID (Number of levels: 90)
##                                         Estimate Est.Error l-95% CI
## sd(Intercept)                         0.23     0.02    0.20
## sd(expected1)                         0.03     0.00    0.02
## sd(phase1)                            0.08     0.01    0.07
## sd(phase2)                            0.03     0.01    0.02
## sd(difficulty1)                      0.01     0.01    0.00
## sd(difficulty2)                      0.02     0.01    0.01
## sd(expected1:phase1)                  0.04     0.01    0.02
## sd(expected1:phase2)                  0.03     0.01    0.01
## sd(phase1:difficulty1)                0.04     0.01    0.02
## sd(phase2:difficulty1)                0.02     0.01    0.00
## sd(phase1:difficulty2)                0.03     0.01    0.00
## sd(phase2:difficulty2)                0.03     0.01    0.01
## sd(expected1:difficulty1)             0.01     0.01    0.00
## sd(expected1:difficulty2)             0.02     0.01    0.01
## cor(Intercept,expected1)              0.02     0.13   -0.23
## cor(Intercept,phase1)                 0.12     0.10   -0.09
## cor(expected1,phase1)                 0.20     0.14   -0.09
## cor(Intercept,phase2)                 -0.16    0.14   -0.43
## cor(expected1,phase2)                 0.19     0.17   -0.16
## cor(phase1,phase2)                   -0.32    0.14   -0.56
## cor(Intercept,difficulty1)            -0.11    0.21   -0.50
## cor(expected1,difficulty1)            -0.06    0.22   -0.49
## cor(phase1,difficulty1)               -0.03    0.21   -0.44
## cor(phase2,difficulty1)               -0.08    0.22   -0.50
## cor(Intercept,difficulty2)            -0.18    0.17   -0.50
## cor(expected1,difficulty2)            -0.24    0.20   -0.60
## cor(phase1,difficulty2)               -0.28    0.18   -0.60
## cor(phase2,difficulty2)               -0.08    0.20   -0.45
## cor(difficulty1,difficulty2)          -0.06    0.24   -0.51
## cor(Intercept,expected1:phase1)       -0.10    0.14   -0.36
## cor(expected1,expected1:phase1)        0.18     0.17   -0.16
## cor(phase1,expected1:phase1)           -0.34    0.14   -0.59
## cor(phase2,expected1:phase1)           0.06     0.18   -0.29
```

## cor(difficulty1,expected1:phase1)	-0.06	0.22	-0.48
## cor(difficulty2,expected1:phase1)	0.03	0.20	-0.36
## cor(Intercept,expected1:phase2)	0.38	0.14	0.08
## cor(expected1,expected1:phase2)	-0.16	0.18	-0.50
## cor(phase1,expected1:phase2)	0.06	0.17	-0.27
## cor(phase2,expected1:phase2)	-0.49	0.16	-0.76
## cor(difficulty1,expected1:phase2)	-0.01	0.22	-0.44
## cor(difficulty2,expected1:phase2)	0.11	0.20	-0.29
## cor(expected1:phase1,expected1:phase2)	-0.14	0.19	-0.48
## cor(Intercept,phase1:difficulty1)	-0.26	0.14	-0.53
## cor(expected1,phase1:difficulty1)	-0.15	0.18	-0.49
## cor(phase1,phase1:difficulty1)	0.09	0.15	-0.21
## cor(phase2,phase1:difficulty1)	-0.03	0.19	-0.39
## cor(difficulty1,phase1:difficulty1)	0.10	0.23	-0.37
## cor(difficulty2,phase1:difficulty1)	0.00	0.21	-0.40
## cor(expected1:phase1,phase1:difficulty1)	-0.14	0.18	-0.48
## cor(expected1:phase2,phase1:difficulty1)	-0.12	0.19	-0.49
## cor(Intercept,phase2:difficulty1)	-0.07	0.19	-0.42
## cor(expected1,phase2:difficulty1)	-0.21	0.21	-0.59
## cor(phase1,phase2:difficulty1)	-0.04	0.20	-0.42
## cor(phase2,phase2:difficulty1)	-0.21	0.21	-0.59
## cor(difficulty1,phase2:difficulty1)	-0.00	0.23	-0.44
## cor(difficulty2,phase2:difficulty1)	0.17	0.22	-0.29
## cor(expected1:phase1,phase2:difficulty1)	0.04	0.21	-0.38
## cor(expected1:phase2,phase2:difficulty1)	0.22	0.21	-0.24
## cor(phase1:difficulty1,phase2:difficulty1)	0.02	0.22	-0.39
## cor(Intercept,phase1:difficulty2)	0.12	0.18	-0.25
## cor(expected1,phase1:difficulty2)	0.20	0.21	-0.22
## cor(phase1,phase1:difficulty2)	0.00	0.19	-0.37
## cor(phase2,phase1:difficulty2)	0.21	0.21	-0.22
## cor(difficulty1,phase1:difficulty2)	-0.12	0.24	-0.56
## cor(difficulty2,phase1:difficulty2)	-0.16	0.22	-0.57
## cor(expected1:phase1,phase1:difficulty2)	-0.04	0.21	-0.43
## cor(expected1:phase2,phase1:difficulty2)	-0.15	0.21	-0.54
## cor(phase1:difficulty1,phase1:difficulty2)	-0.17	0.22	-0.56
## cor(phase2:difficulty1,phase1:difficulty2)	-0.20	0.23	-0.60
## cor(Intercept,phase2:difficulty2)	0.23	0.16	-0.10
## cor(expected1,phase2:difficulty2)	0.17	0.19	-0.23
## cor(phase1,phase2:difficulty2)	-0.06	0.17	-0.39
## cor(phase2,phase2:difficulty2)	0.10	0.20	-0.30
## cor(difficulty1,phase2:difficulty2)	-0.04	0.23	-0.49
## cor(difficulty2,phase2:difficulty2)	-0.18	0.21	-0.57
## cor(expected1:phase1,phase2:difficulty2)	0.09	0.19	-0.30
## cor(expected1:phase2,phase2:difficulty2)	0.04	0.20	-0.36
## cor(phase1:difficulty1,phase2:difficulty2)	-0.23	0.20	-0.59
## cor(phase2:difficulty1,phase2:difficulty2)	-0.19	0.23	-0.60
## cor(phase1:difficulty2,phase2:difficulty2)	0.13	0.22	-0.31
## cor(Intercept,expected1:difficulty1)	0.05	0.22	-0.39
## cor(expected1,expected1:difficulty1)	0.05	0.23	-0.41
## cor(phase1,expected1:difficulty1)	0.04	0.23	-0.41
## cor(phase2,expected1:difficulty1)	0.04	0.23	-0.42
## cor(difficulty1,expected1:difficulty1)	-0.12	0.25	-0.59
## cor(difficulty2,expected1:difficulty1)	-0.03	0.24	-0.49
## cor(expected1:phase1,expected1:difficulty1)	0.09	0.23	-0.38

## cor(expected1:phase2,expected1:difficulty1)	0.01	0.23	-0.44
## cor(phase1:difficulty1,expected1:difficulty1)	0.03	0.23	-0.42
## cor(phase2:difficulty1,expected1:difficulty1)	0.06	0.24	-0.42
## cor(phase1:difficulty2,expected1:difficulty1)	0.03	0.24	-0.44
## cor(phase2:difficulty2,expected1:difficulty1)	0.02	0.24	-0.43
## cor(Intercept,expected1:difficulty2)	-0.01	0.16	-0.32
## cor(expected1,expected1:difficulty2)	0.25	0.19	-0.13
## cor(phase1,expected1:difficulty2)	0.39	0.16	0.06
## cor(phase2,expected1:difficulty2)	0.06	0.19	-0.32
## cor(difficulty1,expected1:difficulty2)	0.00	0.23	-0.44
## cor(difficulty2,expected1:difficulty2)	-0.40	0.20	-0.73
## cor(expected1:phase1,expected1:difficulty2)	-0.00	0.19	-0.37
## cor(expected1:phase2,expected1:difficulty2)	-0.17	0.19	-0.53
## cor(phase1:difficulty1,expected1:difficulty2)	-0.07	0.19	-0.44
## cor(phase2:difficulty1,expected1:difficulty2)	-0.17	0.22	-0.57
## cor(phase1:difficulty2,expected1:difficulty2)	0.12	0.21	-0.30
## cor(phase2:difficulty2,expected1:difficulty2)	0.12	0.21	-0.30
## cor(expected1:difficulty1,expected1:difficulty2)	-0.05	0.24	-0.50
##		u-95% CI	Rhat
## sd(Intercept)	0.27	1.00	2856
## sd(expected1)	0.04	1.00	7481
## sd(phase1)	0.10	1.00	7310
## sd(phase2)	0.05	1.00	7164
## sd(difficulty1)	0.03	1.00	4255
## sd(difficulty2)	0.03	1.00	5984
## sd(expected1:phase1)	0.05	1.00	8529
## sd(expected1:phase2)	0.04	1.00	8720
## sd(phase1:difficulty1)	0.06	1.00	6990
## sd(phase2:difficulty1)	0.04	1.00	4295
## sd(phase1:difficulty2)	0.04	1.00	4189
## sd(phase2:difficulty2)	0.05	1.00	4041
## sd(expected1:difficulty1)	0.02	1.00	5474
## sd(expected1:difficulty2)	0.04	1.00	6138
## cor(Intercept,expected1)	0.28	1.00	18965
## cor(Intercept,phase1)	0.32	1.00	8901
## cor(expected1,phase1)	0.47	1.00	2892
## cor(Intercept,phase2)	0.12	1.00	18148
## cor(expected1,phase2)	0.51	1.00	9169
## cor(phase1,phase2)	-0.03	1.00	14899
## cor(Intercept,difficulty1)	0.32	1.00	28933
## cor(expected1,difficulty1)	0.39	1.00	21720
## cor(phase1,difficulty1)	0.40	1.00	27327
## cor(phase2,difficulty1)	0.37	1.00	19557
## cor(Intercept,difficulty2)	0.17	1.00	24894
## cor(expected1,difficulty2)	0.16	1.00	13825
## cor(phase1,difficulty2)	0.08	1.00	21644
## cor(phase2,difficulty2)	0.32	1.00	16363
## cor(difficulty1,difficulty2)	0.41	1.00	10344
## cor(Intercept,expected1:phase1)	0.17	1.00	17506
## cor(expected1,expected1:phase1)	0.49	1.00	7439
## cor(phase1,expected1:phase1)	-0.07	1.00	15983
## cor(phase2,expected1:phase1)	0.41	1.00	9224
## cor(difficulty1,expected1:phase1)	0.40	1.00	6170
## cor(difficulty2,expected1:phase1)	0.42	1.00	8101

## cor(Intercept,expected1:phase2)	0.64	1.00	22206
## cor(expected1,expected1:phase2)	0.20	1.00	13022
## cor(phase1,expected1:phase2)	0.38	1.00	20778
## cor(phase2,expected1:phase2)	-0.14	1.00	14261
## cor(difficulty1,expected1:phase2)	0.43	1.00	14604
## cor(difficulty2,expected1:phase2)	0.49	1.00	16111
## cor(expected1:phase1,expected1:phase2)	0.25	1.00	16972
## cor(Intercept,phase1:difficulty1)	0.03	1.00	19947
## cor(expected1,phase1:difficulty1)	0.21	1.00	10070
## cor(phase1,phase1:difficulty1)	0.39	1.00	17257
## cor(phase2,phase1:difficulty1)	0.34	1.00	10588
## cor(difficulty1,phase1:difficulty1)	0.53	1.00	6220
## cor(difficulty2,phase1:difficulty1)	0.41	1.00	8293
## cor(expected1:phase1,phase1:difficulty1)	0.22	1.00	12805
## cor(expected1:phase2,phase1:difficulty1)	0.25	1.00	9920
## cor(Intercept,phase2:difficulty1)	0.31	1.00	23181
## cor(expected1,phase2:difficulty1)	0.23	1.00	16041
## cor(phase1,phase2:difficulty1)	0.35	1.00	23381
## cor(phase2,phase2:difficulty1)	0.24	1.00	14377
## cor(difficulty1,phase2:difficulty1)	0.45	1.00	13649
## cor(difficulty2,phase2:difficulty1)	0.57	1.00	11815
## cor(expected1:phase1,phase2:difficulty1)	0.45	1.00	19579
## cor(expected1:phase2,phase2:difficulty1)	0.59	1.00	13165
## cor(phase1:difficulty1,phase2:difficulty1)	0.44	1.00	18556
## cor(Intercept,phase1:difficulty2)	0.46	1.00	23283
## cor(expected1,phase1:difficulty2)	0.58	1.00	14775
## cor(phase1,phase1:difficulty2)	0.38	1.00	23858
## cor(phase2,phase1:difficulty2)	0.58	1.00	13841
## cor(difficulty1,phase1:difficulty2)	0.36	1.00	10089
## cor(difficulty2,phase1:difficulty2)	0.28	1.00	13012
## cor(expected1:phase1,phase1:difficulty2)	0.37	1.00	20006
## cor(expected1:phase2,phase1:difficulty2)	0.28	1.00	14034
## cor(phase1:difficulty1,phase1:difficulty2)	0.28	1.00	12571
## cor(phase2:difficulty1,phase1:difficulty2)	0.28	1.00	10328
## cor(Intercept,phase2:difficulty2)	0.53	1.00	20338
## cor(expected1,phase2:difficulty2)	0.54	1.00	12487
## cor(phase1,phase2:difficulty2)	0.29	1.00	22452
## cor(phase2,phase2:difficulty2)	0.46	1.00	12785
## cor(difficulty1,phase2:difficulty2)	0.41	1.00	10081
## cor(difficulty2,phase2:difficulty2)	0.25	1.00	9716
## cor(expected1:phase1,phase2:difficulty2)	0.46	1.00	16835
## cor(expected1:phase2,phase2:difficulty2)	0.43	1.00	13701
## cor(phase1:difficulty1,phase2:difficulty2)	0.19	1.00	14015
## cor(phase2:difficulty1,phase2:difficulty2)	0.29	1.00	8339
## cor(phase1:difficulty2,phase2:difficulty2)	0.54	1.00	11222
## cor(Intercept,expected1:difficulty1)	0.47	1.00	33288
## cor(expected1,expected1:difficulty1)	0.49	1.00	26393
## cor(phase1,expected1:difficulty1)	0.47	1.00	29631
## cor(phase2,expected1:difficulty1)	0.47	1.00	23764
## cor(difficulty1,expected1:difficulty1)	0.39	1.00	9995
## cor(difficulty2,expected1:difficulty1)	0.44	1.00	20944
## cor(expected1:phase1,expected1:difficulty1)	0.53	1.00	18001
## cor(expected1:phase2,expected1:difficulty1)	0.46	1.00	23210
## cor(phase1:difficulty1,expected1:difficulty1)	0.46	1.00	21030

## cor(phase2:difficulty1,expected1:difficulty1)	0.51	1.00	14379
## cor(phase1:difficulty2,expected1:difficulty1)	0.48	1.00	17098
## cor(phase2:difficulty2,expected1:difficulty1)	0.47	1.00	18923
## cor(Intercept,expected1:difficulty2)	0.30	1.00	28157
## cor(expected1,expected1:difficulty2)	0.59	1.00	10983
## cor(phase1,expected1:difficulty2)	0.67	1.00	16883
## cor(phase2,expected1:difficulty2)	0.42	1.00	15766
## cor(difficulty1,expected1:difficulty2)	0.44	1.00	9749
## cor(difficulty2,expected1:difficulty2)	0.04	1.00	7834
## cor(expected1:phase1,expected1:difficulty2)	0.37	1.00	16236
## cor(expected1:phase2,expected1:difficulty2)	0.22	1.00	14644
## cor(phase1:difficulty1,expected1:difficulty2)	0.32	1.00	18071
## cor(phase2:difficulty1,expected1:difficulty2)	0.28	1.00	11930
## cor(phase1:difficulty2,expected1:difficulty2)	0.52	1.00	15095
## cor(phase2:difficulty2,expected1:difficulty2)	0.51	1.00	15050
## cor(expected1:difficulty1,expected1:difficulty2)	0.42	1.00	13178
##		Tail_ESS	
## sd(Intercept)	5862		
## sd(expected1)	9174		
## sd(phase1)	12662		
## sd(phase2)	9347		
## sd(difficulty1)	7392		
## sd(difficulty2)	6047		
## sd(expected1:phase1)	9238		
## sd(expected1:phase2)	9521		
## sd(phase1:difficulty1)	7279		
## sd(phase2:difficulty1)	5112		
## sd(phase1:difficulty2)	4702		
## sd(phase2:difficulty2)	2793		
## sd(expected1:difficulty1)	8408		
## sd(expected1:difficulty2)	4798		
## cor(Intercept,expected1)	14369		
## cor(Intercept,phase1)	12476		
## cor(expected1,phase1)	5556		
## cor(Intercept,phase2)	14623		
## cor(expected1,phase2)	12169		
## cor(phase1,phase2)	13901		
## cor(Intercept,difficulty1)	11981		
## cor(expected1,difficulty1)	13268		
## cor(phase1,difficulty1)	13644		
## cor(phase2,difficulty1)	13471		
## cor(Intercept,difficulty2)	14508		
## cor(expected1,difficulty2)	14526		
## cor(phase1,difficulty2)	13387		
## cor(phase2,difficulty2)	14306		
## cor(difficulty1,difficulty2)	14749		
## cor(Intercept,expected1:phase1)	14717		
## cor(expected1,expected1:phase1)	11721		
## cor(phase1,expected1:phase1)	15226		
## cor(phase2,expected1:phase1)	13146		
## cor(difficulty1,expected1:phase1)	9708		
## cor(difficulty2,expected1:phase1)	11967		
## cor(Intercept,expected1:phase2)	13851		
## cor(expected1,expected1:phase2)	13747		

## cor(phase1,expected1:phase2)	14317
## cor(phase2,expected1:phase2)	12968
## cor(difficulty1,expected1:phase2)	14199
## cor(difficulty2,expected1:phase2)	15432
## cor(expected1:phase1,expected1:phase2)	14828
## cor(Intercept,phase1:difficulty1)	14040
## cor(expected1,phase1:difficulty1)	13409
## cor(phase1,phase1:difficulty1)	14670
## cor(phase2,phase1:difficulty1)	14189
## cor(difficulty1,phase1:difficulty1)	10529
## cor(difficulty2,phase1:difficulty1)	11800
## cor(expected1:phase1,phase1:difficulty1)	15086
## cor(expected1:phase2,phase1:difficulty1)	14532
## cor(Intercept,phase2:difficulty1)	13262
## cor(expected1,phase2:difficulty1)	13963
## cor(phase1,phase2:difficulty1)	14399
## cor(phase2,phase2:difficulty1)	12482
## cor(difficulty1,phase2:difficulty1)	13883
## cor(difficulty2,phase2:difficulty1)	13606
## cor(expected1:phase1,phase2:difficulty1)	14444
## cor(expected1:phase2,phase2:difficulty1)	13734
## cor(phase1:difficulty1,phase2:difficulty1)	15247
## cor(Intercept,phase1:difficulty2)	13194
## cor(expected1,phase1:difficulty2)	13909
## cor(phase1,phase1:difficulty2)	13647
## cor(phase2,phase1:difficulty2)	13263
## cor(difficulty1,phase1:difficulty2)	12879
## cor(difficulty2,phase1:difficulty2)	13941
## cor(expected1:phase1,phase1:difficulty2)	15500
## cor(expected1:phase2,phase1:difficulty2)	14711
## cor(phase1:difficulty1,phase1:difficulty2)	13441
## cor(phase2:difficulty1,phase1:difficulty2)	13628
## cor(Intercept,phase2:difficulty2)	12729
## cor(expected1,phase2:difficulty2)	13198
## cor(phase1,phase2:difficulty2)	14680
## cor(phase2,phase2:difficulty2)	14117
## cor(difficulty1,phase2:difficulty2)	12425
## cor(difficulty2,phase2:difficulty2)	13542
## cor(expected1:phase1,phase2:difficulty2)	15511
## cor(expected1:phase2,phase2:difficulty2)	14597
## cor(phase1:difficulty1,phase2:difficulty2)	14144
## cor(phase2:difficulty1,phase2:difficulty2)	13046
## cor(phase1:difficulty2,phase2:difficulty2)	12661
## cor(Intercept,expected1:difficulty1)	12937
## cor(expected1,expected1:difficulty1)	13793
## cor(phase1,expected1:difficulty1)	13501
## cor(phase2,expected1:difficulty1)	14402
## cor(difficulty1,expected1:difficulty1)	13654
## cor(difficulty2,expected1:difficulty1)	13893
## cor(expected1:phase1,expected1:difficulty1)	14417
## cor(expected1:phase2,expected1:difficulty1)	15342
## cor(phase1:difficulty1,expected1:difficulty1)	14581
## cor(phase2:difficulty1,expected1:difficulty1)	15251
## cor(phase1:difficulty2,expected1:difficulty1)	15282

```

## cor(phase2:difficulty2,expected1:difficulty1)      15692
## cor(Intercept,expected1:difficulty2)             14540
## cor(expected1,expected1:difficulty2)             13160
## cor(phase1,expected1:difficulty2)                12322
## cor(phase2,expected1:difficulty2)                15623
## cor(difficulty1,expected1:difficulty2)           13289
## cor(difficulty2,expected1:difficulty2)           9666
## cor(expected1:phase1,expected1:difficulty2)       15347
## cor(expected1:phase2,expected1:difficulty2)       13483
## cor(phase1:difficulty1,expected1:difficulty2)     16018
## cor(phase2:difficulty1,expected1:difficulty2)     13293
## cor(phase1:difficulty2,expected1:difficulty2)     15431
## cor(phase2:difficulty2,expected1:difficulty2)     13954
## cor(expected1:difficulty1,expected1:difficulty2)   15185
##
## Regression Coefficients:
##                               Estimate Est.Error 1-95% CI u-95% CI
## Intercept                  5.91     0.04    5.83    5.98
## diagnosis1                 0.02     0.03   -0.03    0.07
## diagnosis2                 0.03     0.03   -0.02    0.09
## diagnosis3                 0.02     0.03   -0.04    0.07
## expected1                 -0.05    0.00   -0.06   -0.04
## phase1                      0.03    0.01    0.01    0.05
## phase2                     -0.01    0.01   -0.02   -0.00
## difficulty1                -0.04    0.00   -0.05   -0.03
## difficulty2                -0.01    0.00   -0.02   -0.00
## diagnosis1:expected1      -0.01    0.01   -0.02    0.01
## diagnosis2:expected1      0.01     0.01   -0.00    0.02
## diagnosis3:expected1      -0.00    0.01   -0.02    0.01
## diagnosis1:phase1          -0.02   0.02   -0.05    0.01
## diagnosis2:phase1          0.01   0.02   -0.02    0.04
## diagnosis3:phase1          -0.01   0.01   -0.04    0.02
## diagnosis1:phase2          -0.00   0.01   -0.02    0.02
## diagnosis2:phase2          0.00   0.01   -0.02    0.02
## diagnosis3:phase2          0.00   0.01   -0.01    0.02
## expected1:phase1           -0.05   0.01   -0.06   -0.03
## expected1:phase2           0.00   0.01   -0.01    0.01
## diagnosis1:difficulty1    -0.02   0.01   -0.04   -0.00
## diagnosis2:difficulty1    0.01   0.01   -0.00    0.03
## diagnosis3:difficulty1    0.01   0.01   -0.01    0.02
## diagnosis1:difficulty2    0.02   0.01    0.01    0.04
## diagnosis2:difficulty2    -0.01   0.01   -0.03    0.01
## diagnosis3:difficulty2    -0.02   0.01   -0.04   -0.00
## expected1:difficulty1     -0.02   0.00   -0.03   -0.01
## expected1:difficulty2     -0.00   0.01   -0.01    0.01
## phase1:difficulty1         -0.00   0.01   -0.02    0.01
## phase2:difficulty1         0.00   0.01   -0.01    0.02
## phase1:difficulty2         0.02   0.01    0.01    0.04
## phase2:difficulty2         -0.01   0.01   -0.02    0.01
## diagnosis1:expected1:phase1 -0.00   0.01   -0.02    0.02
## diagnosis2:expected1:phase1 0.01   0.01   -0.01    0.03
## diagnosis3:expected1:phase1 0.01   0.01   -0.01    0.02
## diagnosis1:expected1:phase2 0.00   0.01   -0.02    0.02
## diagnosis2:expected1:phase2 -0.01   0.01   -0.02    0.01

```

## diagnosis3:expected1:phase2	0.00	0.01	-0.02	0.02
## diagnosis1:expected1:difficulty1	0.00	0.01	-0.01	0.02
## diagnosis2:expected1:difficulty1	-0.01	0.01	-0.03	0.00
## diagnosis3:expected1:difficulty1	0.01	0.01	-0.00	0.03
## diagnosis1:expected1:difficulty2	-0.00	0.01	-0.02	0.02
## diagnosis2:expected1:difficulty2	0.01	0.01	-0.01	0.03
## diagnosis3:expected1:difficulty2	-0.01	0.01	-0.03	0.01
## diagnosis1:phase1:difficulty1	-0.01	0.01	-0.03	0.02
## diagnosis2:phase1:difficulty1	0.00	0.01	-0.02	0.03
## diagnosis3:phase1:difficulty1	0.01	0.01	-0.01	0.03
## diagnosis1:phase2:difficulty1	-0.00	0.01	-0.03	0.02
## diagnosis2:phase2:difficulty1	0.00	0.01	-0.02	0.02
## diagnosis3:phase2:difficulty1	-0.01	0.01	-0.03	0.01
## diagnosis1:phase1:difficulty2	0.00	0.01	-0.02	0.02
## diagnosis2:phase1:difficulty2	-0.01	0.01	-0.03	0.02
## diagnosis3:phase1:difficulty2	0.00	0.01	-0.02	0.02
## diagnosis1:phase2:difficulty2	-0.01	0.01	-0.03	0.02
## diagnosis2:phase2:difficulty2	0.00	0.01	-0.02	0.02
## diagnosis3:phase2:difficulty2	0.02	0.01	-0.01	0.04
## expected1:phase1:difficulty1	-0.01	0.01	-0.02	0.00
## expected1:phase2:difficulty1	-0.00	0.01	-0.01	0.01
## expected1:phase1:difficulty2	0.00	0.01	-0.01	0.01
## expected1:phase2:difficulty2	-0.01	0.01	-0.02	0.00
## diagnosis1:expected1:phase1:difficulty1	-0.01	0.01	-0.03	0.02
## diagnosis2:expected1:phase1:difficulty1	0.01	0.01	-0.01	0.03
## diagnosis3:expected1:phase1:difficulty1	0.00	0.01	-0.02	0.02
## diagnosis1:expected1:phase2:difficulty1	0.01	0.01	-0.01	0.03
## diagnosis2:expected1:phase2:difficulty1	-0.00	0.01	-0.02	0.02
## diagnosis3:expected1:phase2:difficulty1	-0.00	0.01	-0.02	0.02
## diagnosis1:expected1:phase1:difficulty2	0.01	0.01	-0.01	0.03
## diagnosis2:expected1:phase1:difficulty2	-0.01	0.01	-0.03	0.01
## diagnosis3:expected1:phase1:difficulty2	-0.00	0.01	-0.02	0.02
## diagnosis1:expected1:phase2:difficulty2	-0.01	0.01	-0.03	0.01
## diagnosis2:expected1:phase2:difficulty2	-0.01	0.01	-0.03	0.01
## diagnosis3:expected1:phase2:difficulty2	0.00	0.01	-0.02	0.02
##		Rhat	Bulk_ESS	Tail_ESS
## Intercept	1.00	2661	5819	
## diagnosis1	1.00	2930	5477	
## diagnosis2	1.00	2431	4786	
## diagnosis3	1.00	2670	5263	
## expected1	1.00	14025	14622	
## phase1	1.00	7141	10612	
## phase2	1.00	15633	15040	
## difficulty1	1.00	23341	15599	
## difficulty2	1.00	23067	14517	
## diagnosis1:expected1	1.00	14562	14155	
## diagnosis2:expected1	1.00	14452	13537	
## diagnosis3:expected1	1.00	15072	13967	
## diagnosis1:phase1	1.00	7948	10949	
## diagnosis2:phase1	1.00	8075	11199	
## diagnosis3:phase1	1.00	8335	11401	
## diagnosis1:phase2	1.00	15944	13669	
## diagnosis2:phase2	1.00	15022	14334	
## diagnosis3:phase2	1.00	14754	14425	

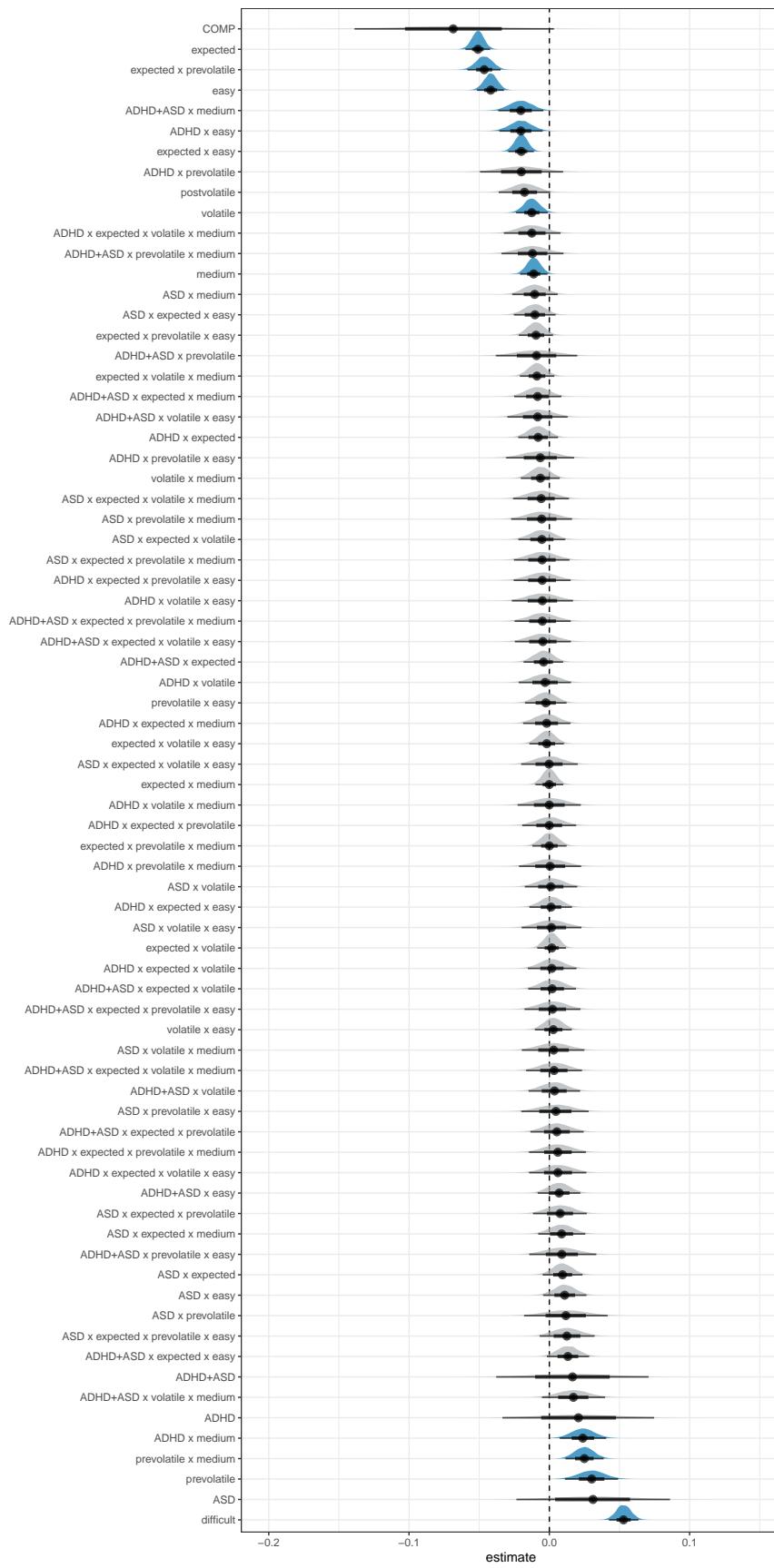
## expected1:phase1	1.00	15276	14970
## expected1:phase2	1.00	14638	13666
## diagnosis1:difficulty1	1.00	22542	14994
## diagnosis2:difficulty1	1.00	23362	15115
## diagnosis3:difficulty1	1.00	22341	14746
## diagnosis1:difficulty2	1.00	19671	15529
## diagnosis2:difficulty2	1.00	20317	14488
## diagnosis3:difficulty2	1.00	19230	14511
## expected1:difficulty1	1.00	28914	14887
## expected1:difficulty2	1.00	22237	15425
## phase1:difficulty1	1.00	15198	15367
## phase2:difficulty1	1.00	22344	14326
## phase1:difficulty2	1.00	20487	14161
## phase2:difficulty2	1.00	16877	14766
## diagnosis1:expected1:phase1	1.00	15118	14695
## diagnosis2:expected1:phase1	1.00	15370	14617
## diagnosis3:expected1:phase1	1.00	14730	14149
## diagnosis1:expected1:phase2	1.00	19119	15070
## diagnosis2:expected1:phase2	1.00	18142	14652
## diagnosis3:expected1:phase2	1.00	16940	13964
## diagnosis1:expected1:difficulty1	1.00	23155	15466
## diagnosis2:expected1:difficulty1	1.00	22542	14479
## diagnosis3:expected1:difficulty1	1.00	21847	14532
## diagnosis1:expected1:difficulty2	1.00	18001	15211
## diagnosis2:expected1:difficulty2	1.00	17993	14809
## diagnosis3:expected1:difficulty2	1.00	18446	14712
## diagnosis1:phase1:difficulty1	1.00	16157	13405
## diagnosis2:phase1:difficulty1	1.00	15439	14860
## diagnosis3:phase1:difficulty1	1.00	16619	14940
## diagnosis1:phase2:difficulty1	1.00	18120	14244
## diagnosis2:phase2:difficulty1	1.00	18797	14850
## diagnosis3:phase2:difficulty1	1.00	18357	14998
## diagnosis1:phase1:difficulty2	1.00	19398	15122
## diagnosis2:phase1:difficulty2	1.00	20290	15188
## diagnosis3:phase1:difficulty2	1.00	18918	14982
## diagnosis1:phase2:difficulty2	1.00	17264	14384
## diagnosis2:phase2:difficulty2	1.00	17973	14267
## diagnosis3:phase2:difficulty2	1.00	17406	15250
## expected1:phase1:difficulty1	1.00	24306	14342
## expected1:phase2:difficulty1	1.00	24116	14787
## expected1:phase1:difficulty2	1.00	25324	14184
## expected1:phase2:difficulty2	1.00	24141	15208
## diagnosis1:expected1:phase1:difficulty1	1.00	19924	14996
## diagnosis2:expected1:phase1:difficulty1	1.00	19241	15105
## diagnosis3:expected1:phase1:difficulty1	1.00	19096	15632
## diagnosis1:expected1:phase2:difficulty1	1.00	19299	14432
## diagnosis2:expected1:phase2:difficulty1	1.00	19473	14916
## diagnosis3:expected1:phase2:difficulty1	1.00	19048	15284
## diagnosis1:expected1:phase1:difficulty2	1.00	19780	14956
## diagnosis2:expected1:phase1:difficulty2	1.00	19700	15546
## diagnosis3:expected1:phase1:difficulty2	1.00	19721	14962
## diagnosis1:expected1:phase2:difficulty2	1.00	19234	14041
## diagnosis2:expected1:phase2:difficulty2	1.00	18734	14459
## diagnosis3:expected1:phase2:difficulty2	1.00	18292	14897

```

## Further Distributional Parameters:
## Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma      0.13     0.01     0.12    0.14 1.00    5483   10330
## ndt       216.55    10.38   194.46   234.99 1.00    9267   11437
##
## 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).
# get the estimates and compute group comparisons
df.m.pal = post.draws %>%
  select(starts_with("b_")) %>%
  mutate(
    b_COMP      = - b_diagnosis1 - b_diagnosis2 - b_diagnosis3,
    b_postvolatile = - b_phase1 - b_phase2,
    b_difficult   = - b_difficulty1 - b_difficulty2
  )

# plot the posterior distributions
df.m.pal %>%
  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", "ADHD"),
    coef = str_replace_all(coef, "diagnosis2", "ASD"),
    coef = str_replace_all(coef, "diagnosis3", "ADHD+ASD"),
    coef = str_replace_all(coef, "expected1", "expected"),
    coef = str_replace_all(coef, "expected2", "unexpected"),
    coef = str_replace_all(coef, "phase1", "prevolatile"),
    coef = str_replace_all(coef, "phase2", "volatile"),
    coef = str_replace_all(coef, "difficulty1", "easy"),
    coef = str_replace_all(coef, "difficulty2", "medium"),
    coef = fct_reorder(coef, desc(estimate))
  ) %>%
  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(c_dark, c_light)) + theme(legend.position = "none")

```



```

## create design matrix to figure out how to set comparisons for hypotheses
df.des = cbind(df.pal,
               model.matrix(~ diagnosis * expected * phase * difficulty,
                            data = df.pal)) %>%
  select(-subID, -rt.cor, -rt.use, -acc) %>% distinct()

# H1b: COMP(unexp-exp) > ASD(unexp-exp)
as.data.frame(t(df.des %>%
  filter((diagnosis == "ASD" | diagnosis == "COMP")) %>%
  group_by(diagnosis, expected) %>%
  summarise(across(where(is.numeric), ~ mean(.x))) %>%
  group_by(diagnosis) %>%
  summarise(across(where(is.numeric), ~ diff(.x))) %>%
  select(where(is.numeric)) %>%
  map_df(~ diff(.x))) %>%
  filter(V1 != 0) # COMP - ASD

## V1
## diagnosis1:expected1 2
## diagnosis2:expected1 4
## diagnosis3:expected1 2

h1b = hypothesis(m.pal, "0 <
                      diagnosis1:expected1 + 2*diagnosis2:expected1+ diagnosis3:expected1")
h1b

## Hypothesis Tests for class b:
##          Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (0)-(diagnosis1:e... < 0     -0.01      0.01    -0.03     0.01     2.52
##   Post.Prob Star
## 1       0.72
## ---
## '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.

# H1c: COMP(unexp-exp) != ADHD(unexp-exp)
as.data.frame(t(df.des %>%
  filter((diagnosis == "ADHD" | diagnosis == "COMP")) %>%
  group_by(diagnosis, expected) %>%
  summarise(across(where(is.numeric), ~ mean(.x))) %>%
  group_by(diagnosis) %>%
  summarise(across(where(is.numeric), ~ diff(.x))) %>%
  select(where(is.numeric)) %>%
  map_df(~ diff(.x))) %>%
  filter(V1 != 0) # COMP - ADHD

## V1
## diagnosis1:expected1 4
## diagnosis2:expected1 2
## diagnosis3:expected1 2

h1c = hypothesis(m.pal, "0 >
                      2*diagnosis1:expected1 + diagnosis2:expected1+ diagnosis3:expected1",
                      alpha = 0.025)

```

```

h1c

## Hypothesis Tests for class b:
##          Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (0)-(2*diagnosis1... > 0     0.01      0.01    -0.01     0.03     4.43
##   Post.Prob Star
## 1      0.82
## ---
## '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.

# H1d: COMP(volatible-prevolatile) < ASD(volatible-prevolatile)
as.data.frame(t(df.des %>%
  filter((diagnosis == "ASD" | diagnosis == "COMP") & phase != "postvolatile") %>%
  group_by(diagnosis, phase) %>%
  summarise(across(where(is.numeric), ~ mean(.x))) %>%
  group_by(diagnosis) %>%
  summarise(across(where(is.numeric), ~ diff(.x))) %>% # volatile - prevolatile
  select(where(is.numeric)) %>%
  map_df(~ diff(.x))) %>%
  filter(V1 != 0) # COMP - ADHD

##          V1
## diagnosis1:phase1  1
## diagnosis2:phase1  2
## diagnosis3:phase1  1
## diagnosis1:phase2 -1
## diagnosis2:phase2 -2
## diagnosis3:phase2 -1

h1d = hypothesis(m.pal,
                  "(diagnosis1:phase1 + 2*diagnosis2:phase1 + diagnosis3:phase1) -
                   (diagnosis1:phase2 + 2*diagnosis2:phase2 + diagnosis3:phase2) <
                   0")
h1d

## Hypothesis Tests for class b:
##          Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 ((diagnosis1:phas... < 0    -0.01     0.03    -0.07     0.05     1.46
##   Post.Prob Star
## 1      0.59
## ---
## '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.

## exploration: prevolatile phase

# prevolatile: COMP(unexpected - expected) != ASD(unexpected - expected)
as.data.frame(t(df.des %>%
  filter((diagnosis == "ASD" | diagnosis == "COMP") & phase == "prevolatile") %>%
  group_by(diagnosis, expected) %>%
  summarise(across(where(is.numeric), ~ mean(.x))) %>%

```

```

group_by(diagnosis) %>%
  summarise(across(where(is.numeric), ~ diff(.x))) %>%
  select(where(is.numeric)) %>%
  map_df(~ diff(.x))) %>%
  filter(V1 != 0) # COMP - ASD

##                                     V1
## diagnosis1:expected1      2
## diagnosis2:expected1      4
## diagnosis3:expected1      2
## diagnosis1:expected1:phase1 2
## diagnosis2:expected1:phase1 4
## diagnosis3:expected1:phase1 2

e1.1 = hypothesis(m.pal,
  "0 < diagnosis1:expected1 +
   2*diagnosis2:expected1 +
   diagnosis3:expected1 +
   diagnosis1:expected1:phase1 +
   2*diagnosis2:expected1:phase1 +
   diagnosis3:expected1:phase1",
  alpha = 0.025)
e1.1

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (0)-(diagnosis1:e... < 0     -0.03      0.02    -0.07     0.01      9.27
##   Post.Prob Star
## 1       0.9
## ---
## '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.

# prevolatile: COMP(unexpected - expected) != ADHD(unexpected - expected)
e1.2 = hypothesis(m.pal,
  "0 < 2*diagnosis1:expected1 +
   diagnosis2:expected1 +
   diagnosis3:expected1 +
   2*diagnosis1:expected1:phase1 +
   diagnosis2:expected1:phase1 +
   diagnosis3:expected1:phase1",
  alpha = 0.025)
e1.2

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (0)-(2*diagnosis1... < 0       0      0.02    -0.04     0.04      1.18
##   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.

```

```

# prevolatile: COMP(unexpected - expected) != BOTH(unexpected - expected)
e1.3 = hypothesis(m.pal,
                  "0 < diagnosis1:expected1 +
                    diagnosis2:expected1 +
                    2*diagnosis3:expected1 +
                    diagnosis1:expected1:phase1 +
                    diagnosis2:expected1:phase1 +
                    2*diagnosis3:expected1:phase1",
                  alpha = 0.025)
e1.3

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (0)-(diagnosis1:e... < 0      -0.01      0.02     -0.05     0.03      2.44
##   Post.Prob Star
## 1       0.71
## ---
## '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.

## exploration: task effects

# expected versus unexpected
e2.1 = hypothesis(m.pal, "0 > 2*expected1", alpha = 0.025)
e2.1

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (0)-(2*expected1) > 0      0.1       0.01      0.08      0.12      Inf
##   Post.Prob Star
## 1       1     *
## ---
## '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.

# volatile versus prevolatile
e2.2 = hypothesis(m.pal, "0 < phase1 - phase2", alpha = 0.025)
e2.2

## Hypothesis Tests for class b:
##                               Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio
## 1 (0)-(phase1-phase2) < 0     -0.04      0.01     -0.07     -0.02      2999
##   Post.Prob Star
## 1       1     *
## ---
## '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.

# volatile versus postvolatile
e2.3 = hypothesis(m.pal, "0 < phase1 + 2*phase2", alpha = 0.025)

```

```
e2.3
```

```
## Hypothesis Tests for class b:  
## Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio  
## 1 (0)-(phase1+2*pha... < 0     -0.01      0.01    -0.03     0.02      1.99  
##   Post.Prob Star  
## 1      0.67  
## ---  
## '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.  
# difficult versus medium  
e2.4 = hypothesis(m.pal, "0 < -difficulty1 - 2*difficulty2", alpha = 0.025)  
e2.4
```

```
## Hypothesis Tests for class b:  
## Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio  
## 1 (0)-(-difficulty1... < 0     -0.06      0.01    -0.08    -0.05      Inf  
##   Post.Prob Star  
## 1      1      *  
## ---  
## '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.  
# medium versus easy  
e2.5 = hypothesis(m.pal, "0 < -difficulty1 + difficulty2", alpha = 0.025)  
e2.5
```

```
## Hypothesis Tests for class b:  
## Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio  
## 1 (0)-(-difficulty1... < 0     -0.03      0.01    -0.05    -0.01      17999  
##   Post.Prob Star  
## 1      1      *  
## ---  
## '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.  
# difficult versus easy  
e2.6 = hypothesis(m.pal, "0 < -2*difficulty1 - difficulty2", alpha = 0.025)  
e2.6
```

```
## Hypothesis Tests for class b:  
## Hypothesis Estimate Est.Error CI.Lower CI.Upper Evid.Ratio  
## 1 (0)-(-2*difficult... < 0     -0.09      0.01    -0.11    -0.08      Inf  
##   Post.Prob Star  
## 1      1      *  
## ---  
## '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.
```

```

## extract predicted differences in ms instead of log data
df.new = df.pal %>%
  select(diagnosis, phase, expected, difficulty) %>%
  distinct() %>%
  mutate(
    condition = paste(diagnosis, phase, expected, difficulty, sep = "_")
  )
df.ms = as.data.frame(
  fitted(m.pal, summary = F,
         newdata = df.new %>% select(diagnosis, phase, expected, difficulty),
         re_formula = NA))
colnames(df.ms) = df.new$condition

# calculate our difference columns
df.ms = df.ms %>%
  mutate(
    COMP_expected      = rowMeans(across(matches("COMP_.*_expected_*"))),
    COMP_unexpected    = rowMeans(across(matches("COMP_.*_unexpected_*"))),
    ADHD_expected      = rowMeans(across(matches("ADHD_.*_expected_*"))),
    ADHD_unexpected    = rowMeans(across(matches("ADHD_.*_unexpected_*"))),
    ASD_expected       = rowMeans(across(matches("ASD_.*_expected_*"))),
    ASD_unexpected     = rowMeans(across(matches("ASD_.*_unexpected_*"))),
    COMP_unexp_exp     = COMP_unexpected - COMP_expected,
    ADHD_unexp_exp     = ADHD_unexpected - ADHD_expected,
    ASD_unexp_exp      = ASD_unexpected - ASD_expected,
    `h1b_COMP-ASD unexpected-expected` = COMP_unexp_exp - ASD_unexp_exp,
    `h1c_COMP-ADHD unexpected-expected` = COMP_unexp_exp - ADHD_unexp_exp,
    ASD_prevolatile    = rowMeans(across(matches("ASD_prevolatile_*"))),
    ASD_volatile        = rowMeans(across(matches("ASD_volatile_*"))),
    COMP_prevolatile   = rowMeans(across(matches("COMP_prevolatile_*"))),
    COMP_volatile       = rowMeans(across(matches("COMP_volatile_*"))),
    `h1d_ASD-COMP volatile-prevolatile` =
      (ASD_volatile - ASD_prevolatile) - (COMP_volatile - COMP_prevolatile),
    COMP_pre_unexp     = rowMeans(across(matches("COMP_prevolatile_unexpected_*"))),
    COMP_pre_exp       = rowMeans(across(matches("COMP_prevolatile_expected_*"))),
    BOTH_pre_unexp    = rowMeans(across(matches("BOTH_prevolatile_unexpected_*"))),
    BOTH_pre_exp      = rowMeans(across(matches("BOTH_prevolatile_expected_*"))),
    ADHD_pre_unexp    = rowMeans(across(matches("ADHD_prevolatile_unexpected_*"))),
    ADHD_pre_exp      = rowMeans(across(matches("ADHD_prevolatile_expected_*"))),
    ASD_pre_unexp     = rowMeans(across(matches("ASD_prevolatile_unexpected_*"))),
    ASD_pre_exp       = rowMeans(across(matches("ASD_prevolatile_expected_*"))),
    `e11_prevolatile COMP-ASD unexpected-expected` =
      (COMP_pre_unexp - COMP_pre_exp) - (ASD_pre_unexp - ASD_pre_exp),
    `e12_prevolatile COMP-ADHD unexpected-expected` =
      (COMP_pre_unexp - COMP_pre_exp) - (ADHD_pre_unexp - ADHD_pre_exp),
    `e13_prevolatile COMP-BOTH unexpected-expected` =
      (COMP_pre_unexp - COMP_pre_exp) - (BOTH_pre_unexp - BOTH_pre_exp),
    `e21_unexpected-expected`      = rowMeans(across(matches(".*_unexpected_*")))-
      rowMeans(across(matches(".*_expected_*"))),
    `e22_volatile-prevolatile`     = rowMeans(across(matches(".*_volatile_*")))-
      rowMeans(across(matches(".*_prevolatile_*"))),
    `e23_volatile-postvolatile`    = rowMeans(across(matches(".*_volatile_*")))-
      rowMeans(across(matches(".*_postvolatile_*"))),

```

```

`e24_difficult-medium`      = rowMeans(across(matches(".*_difficult")))) -
  rowMeans(across(matches(".*_medium"))),
`e25_medium-easy`         = rowMeans(across(matches(".*_medium")))) -
  rowMeans(across(matches(".*_easy"))),
`e26_difficult-easy`       = rowMeans(across(matches(".*_difficult")))) -
  rowMeans(across(matches(".*_easy")))
}

lower_ci = function(var) {
  unname(quantile(var, probs = 0.025))
}
upper_ci = function(var) {
  unname(quantile(var, probs = 0.975))
}

kable(df.ms %>%
  select(starts_with("e") | starts_with("h")) %>%
  summarise_all(list(lower_ci = lower_ci, mean = mean, upper_ci = upper_ci)) %>%
  t %>%
  as.data.frame %>%
  rownames_to_column() %>%
  separate(rownames, into = c("id", "comparison", "stat"), sep = "_") %>%
  rename("ms" = "V1") %>%
  arrange(comparison))

```

			stat	ms
id	comparison			
h1d	ASD-COMP volatile-prevolatile	lower	-23.963606	
h1d	ASD-COMP volatile-prevolatile	mean	2.106422	
h1d	ASD-COMP volatile-prevolatile	upper	28.144343	
h1c	COMP-ADHD unexpected-expected	lower	-27.763293	
h1c	COMP-ADHD unexpected-expected	mean	-10.073131	
h1c	COMP-ADHD unexpected-expected	upper	7.492892	
h1b	COMP-ASD unexpected-expected	lower	-15.229914	
h1b	COMP-ASD unexpected-expected	mean	2.059633	
h1b	COMP-ASD unexpected-expected	upper	19.302371	
e26	difficult-easy	lower	4.557815	
e26	difficult-easy	mean	10.983815	
e26	difficult-easy	upper	17.447520	
e24	difficult-medium	lower	16.699729	
e24	difficult-medium	mean	23.538397	
e24	difficult-medium	upper	30.390444	
e25	medium-easy	lower	5.000009	
e25	medium-easy	mean	10.827733	
e25	medium-easy	upper	16.718270	
e12	prevolatile COMP-ADHD unexpected-expected	lower	-35.023845	
e12	prevolatile COMP-ADHD unexpected-expected	mean	-2.284466	
e12	prevolatile COMP-ADHD unexpected-expected	upper	30.988588	
e11	prevolatile COMP-ASD unexpected-expected	lower	-19.078207	
e11	prevolatile COMP-ASD unexpected-expected	mean	14.024309	
e11	prevolatile COMP-ASD unexpected-expected	upper	46.738001	
e13	prevolatile COMP-BOTH unexpected-expected	lower	-28.580904	
e13	prevolatile COMP-BOTH unexpected-expected	mean	4.083189	
e13	prevolatile COMP-BOTH unexpected-expected	upper	36.461674	

id	comparison	stat	ms
e21	unexpected-expected	lower	31.592044
e21	unexpected-expected	mean	38.064796
e21	unexpected-expected	upper	44.517399
e23	volatile-postvolatile	lower	-6.718441
e23	volatile-postvolatile	mean	1.979182
e23	volatile-postvolatile	upper	10.791888
e22	volatile-prevolatile	lower	-27.140222
e22	volatile-prevolatile	mean	-17.227706
e22	volatile-prevolatile	upper	-7.605370

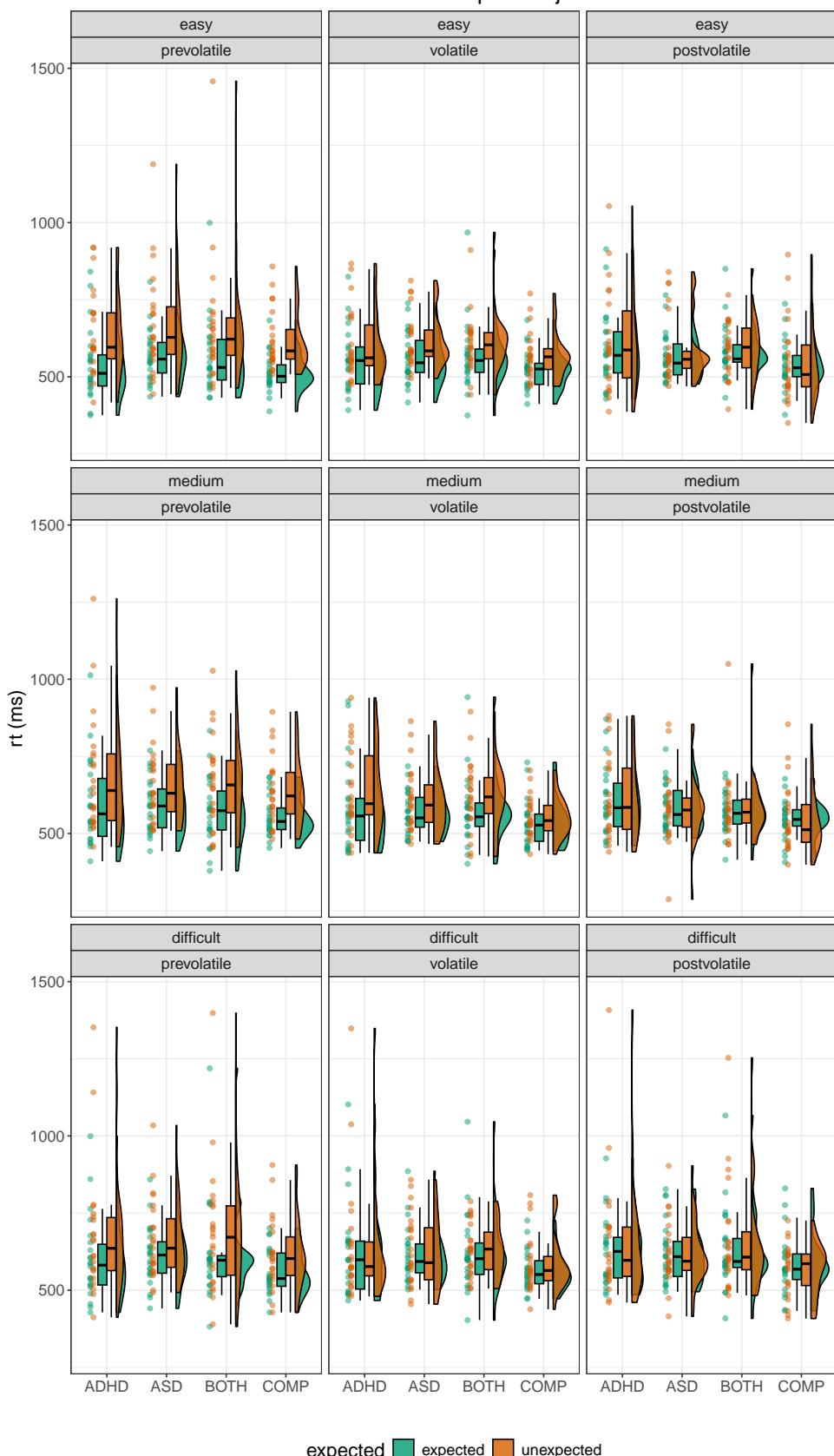
The model does not support our hypothesis, neither regarding a decreased difference in reaction time to expected and unexpected outcomes in adults with ASD compared to adults without any psychiatric diagnoses (*estimate* = -0.01 [-0.03, 0.01], *posterior probability* = 71.56%) nor a difference in reaction time to expected and unexpected outcomes in adults with ASD compared to adults without any psychiatric diagnoses (*estimate* = 0.01 [-0.01, 0.03], *posterior probability* = 81.57%).

## Plots

```
# rain cloud plot including all factors

df.pal %>%
  ggplot(aes(diagnosis, rt.cor, fill = expected, colour = expected)) +
  geom_rain(rain.side = 'r',
  boxplot.args = list(color = "black", outlier.shape = NA, show.legend = FALSE, alpha = .8),
  violin.args = list(color = "black", outlier.shape = NA, alpha = .8),
  boxplot.args.pos = list(
    position = ggpp::position_dodgeNudge(x = 0, width = 0.3), width = 0.3
  ),
  point.args = list(show_guide = FALSE, alpha = .5),
  violin.args.pos = list(
    width = 0.6, position = position_nudge(x = 0.16)),
  point.args.pos = list(position = ggpp::position_dodgeNudge(x = -0.25, width = 0.1))) +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  #ylim(0, 1) +
  labs(title = "Reaction times per subject", x = "", y = "rt (ms)") +
  facet_wrap(difficulty ~ phase) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5),
        legend.direction = "horizontal", text = element_text(size = 15))
```

Reaction times per subject

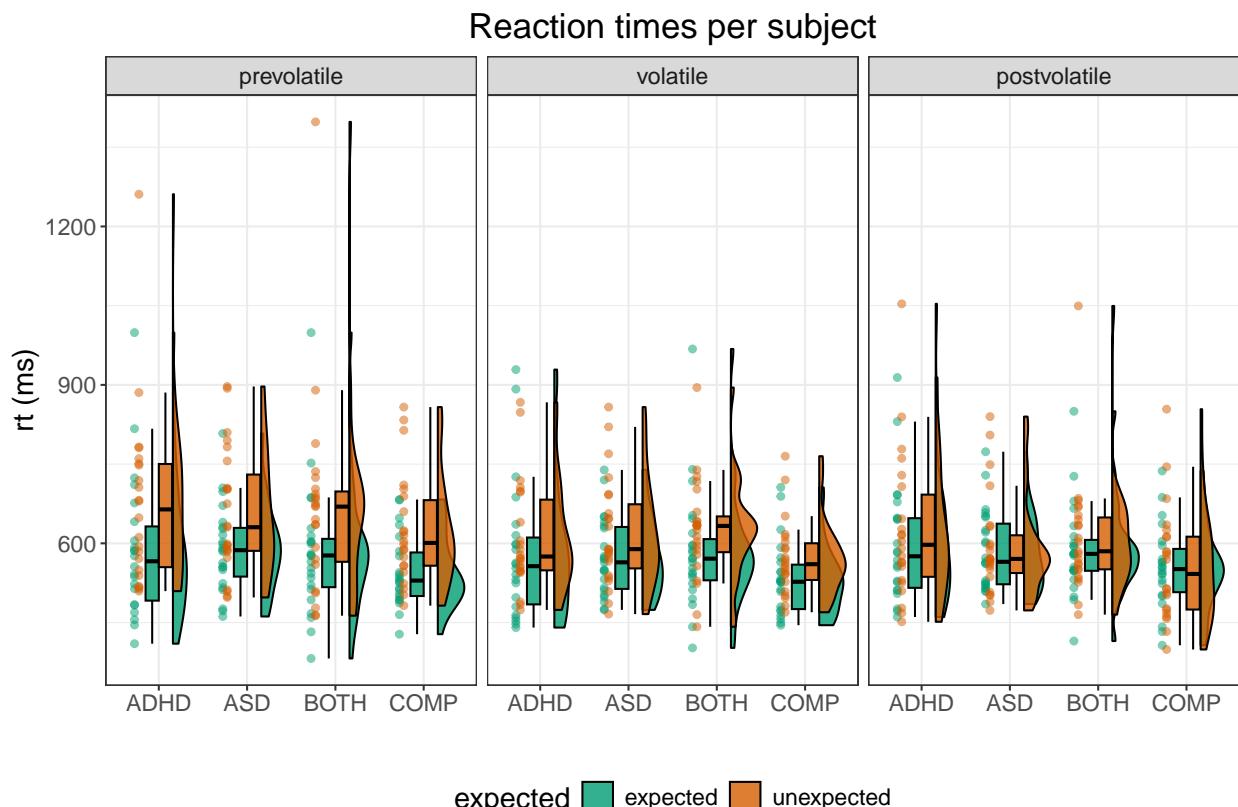


```

# rain cloud plot excluding difficulty

df.pal %>%
  group_by(subID, diagnosis, expected, phase) %>%
  summarise(
    rt.cor = median(rt.cor, na.rm = T)
  ) %>%
  ggplot(aes(diagnosis, rt.cor, fill = expected, colour = expected)) +
  geom_rain(rain.side = 'r',
  boxplot.args = list(color = "black", outlier.shape = NA, show.legend = FALSE, alpha = .8),
  violin.args = list(color = "black", outlier.shape = NA, alpha = .8),
  boxplot.args.pos = list(
    position = ggpp::position_dodgenudge(x = 0, width = 0.3), width = 0.3
  ),
  point.args = list(show_guide = FALSE, alpha = .5),
  violin.args.pos = list(
    width = 0.6, position = position_nudge(x = 0.16)),
  point.args.pos = list(position = ggpp::position_dodgenudge(x = -0.25, width = 0.1))) +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  #ylim(0, 1) +
  labs(title = "Reaction times per subject", x = "", y = "rt (ms)") +
  facet_wrap(. ~ phase) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5),
        legend.direction = "horizontal", text = element_text(size = 15))

```

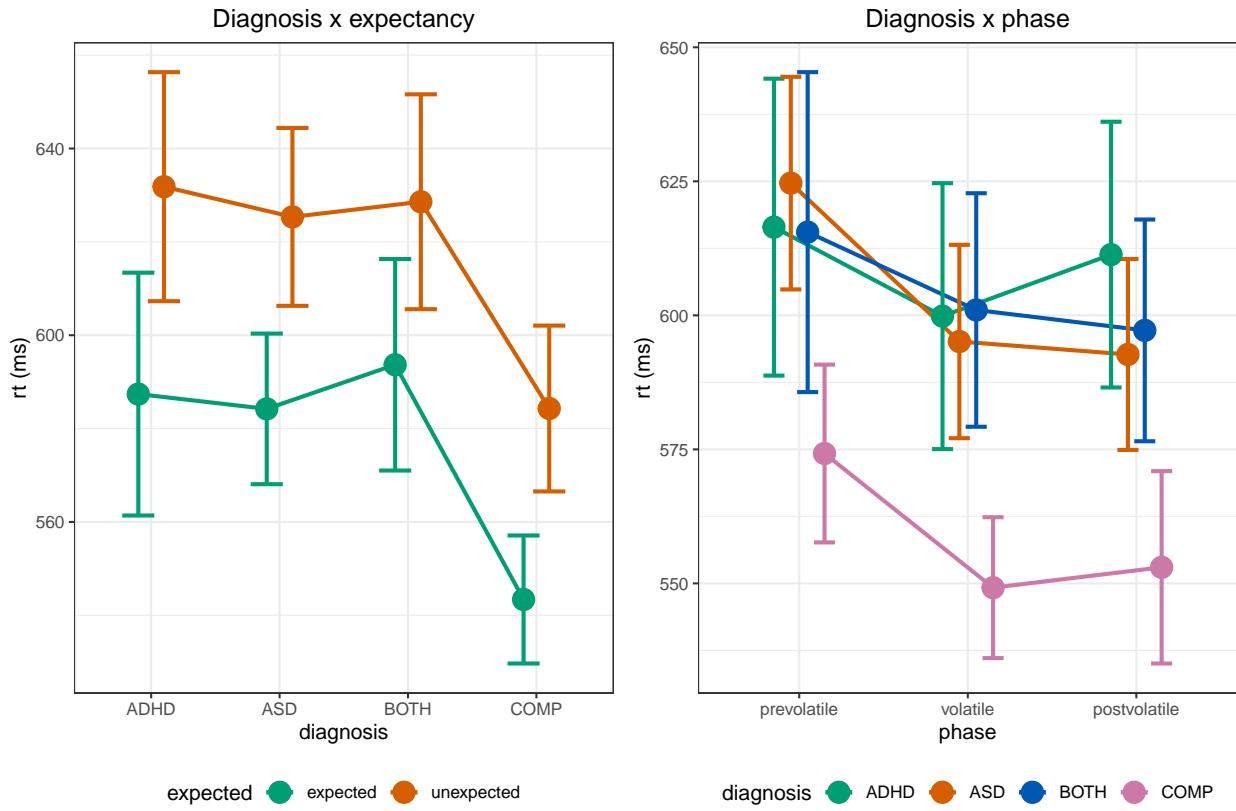


```

# two-way interactions
p1 = df.pal %>%
  group_by(subID, diagnosis, expected) %>%
  summarise(
    rt.cor = median(rt.cor, na.rm = T)
  ) %>%
  group_by(diagnosis, expected) %>%
  summarise(
    rt.mn = mean(rt.cor),
    rt.se = sd(rt.cor) / sqrt(n())
  ) %>%
  ggplot(aes(y = rt.mn, x = diagnosis, group = expected, colour = expected)) +
  geom_line(position = position_dodge(0.4), linewidth = 1) +
  geom_errorbar(aes(ymin = rt.mn - rt.se,
                     ymax = rt.mn + rt.se), linewidth = 1, width = 0.5,
                 position = position_dodge(0.4)) +
  geom_point(position = position_dodge(0.4), size = 5) +
  labs (x = "diagnosis", y = "rt (ms)") +
  ggtitle("Diagnosis x expectancy") +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))
p2 = df.pal %>%
  group_by(subID, diagnosis, phase) %>%
  summarise(
    rt.cor = median(rt.cor, na.rm = T)
  ) %>%
  group_by(diagnosis, phase) %>%
  summarise(
    rt.mn = mean(rt.cor),
    rt.se = sd(rt.cor) / sqrt(n())
  ) %>%
  ggplot(aes(y = rt.mn, x = phase, group = diagnosis, colour = diagnosis)) +
  geom_line(position = position_dodge(0.4), linewidth = 1) +
  geom_errorbar(aes(ymin = rt.mn - rt.se,
                     ymax = rt.mn + rt.se), linewidth = 1, width = 0.5,
                 position = position_dodge(0.4)) +
  geom_point(position = position_dodge(0.4), size = 5) +
  labs (x = "phase", y = "rt (ms)") +
  ggtitle("Diagnosis x phase") +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))

ggarrange(p1, p2, ncol = 2)

```



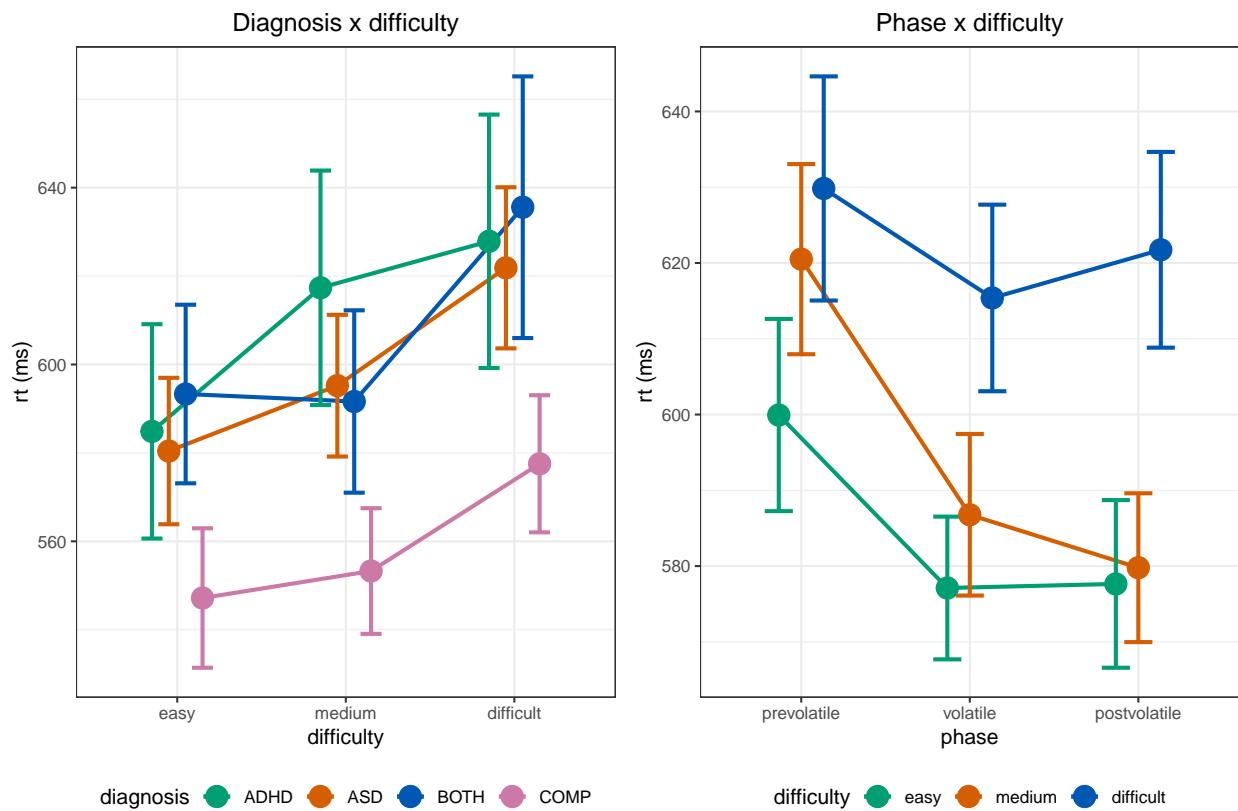
```
p3 = df.pal %>%
  group_by(subID, diagnosis, difficulty) %>%
  summarise(
    rt.cor = median(rt.cor, na.rm = T)
  ) %>%
  group_by(diagnosis, difficulty) %>%
  summarise(
    rt.mn = mean(rt.cor),
    rt.se = sd(rt.cor) / sqrt(n())
  ) %>%
  ggplot(aes(y = rt.mn, x = difficulty, group = diagnosis, colour = diagnosis)) +
  geom_line(position = position_dodge(0.4), linewidth = 1) +
  geom_errorbar(aes(ymax = rt.mn + rt.se,
                    ymin = rt.mn - rt.se,
                    position = position_dodge(0.4))) +
  geom_point(position = position_dodge(0.4), size = 5) +
  labs(x = "difficulty", y = "rt (ms)") +
  ggtitle("Diagnosis x difficulty") +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))
p4 = df.pal %>%
  group_by(subID, phase, difficulty) %>%
  summarise(
    rt.cor = median(rt.cor, na.rm = T)
  ) %>%
```

```

group_by(phase, difficulty) %>%
summarise(
  rt.mn = mean(rt.cor),
  rt.se = sd(rt.cor) / sqrt(n())
) %>%
ggplot(aes(y = rt.mn, x = phase, group = difficulty, colour = difficulty)) +
geom_line(position = position_dodge(0.4), linewidth = 1) +
geom_errorbar(aes(ymin = rt.mn - rt.se,
                  ymax = rt.mn + rt.se), linewidth = 1, width = 0.5,
               position = position_dodge(0.4)) +
geom_point(position = position_dodge(0.4), size = 5) +
labs (x = "phase", y = "rt (ms)") +
ggtitle("Phase x difficulty") +
scale_fill_manual(values = custom.col) +
scale_color_manual(values = custom.col) +
theme_bw() +
theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))

ggarrange(p3, p4, ncol = 2)

```



```

p5 = df.pal %>%
group_by(subID, expected, phase) %>%
summarise(
  rt.cor = median(rt.cor, na.rm = T)
) %>%
group_by(phase, expected) %>%

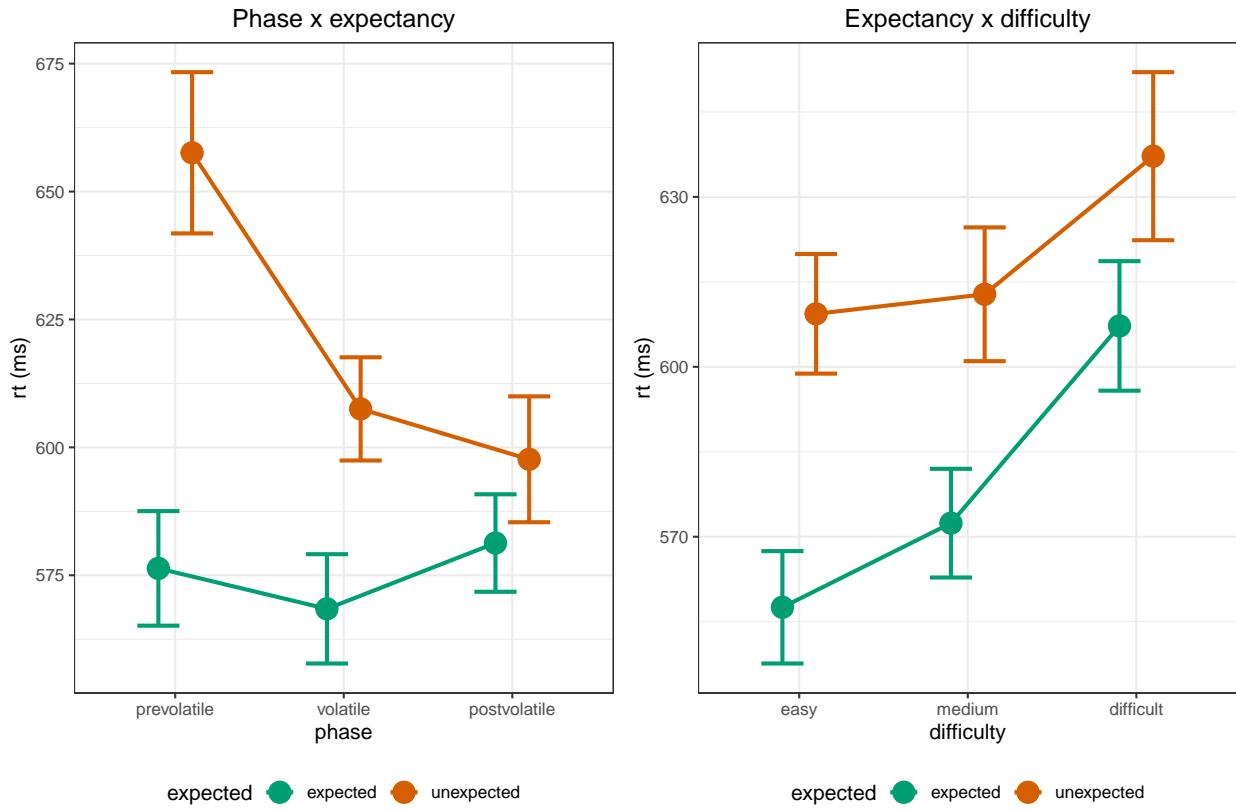
```

```

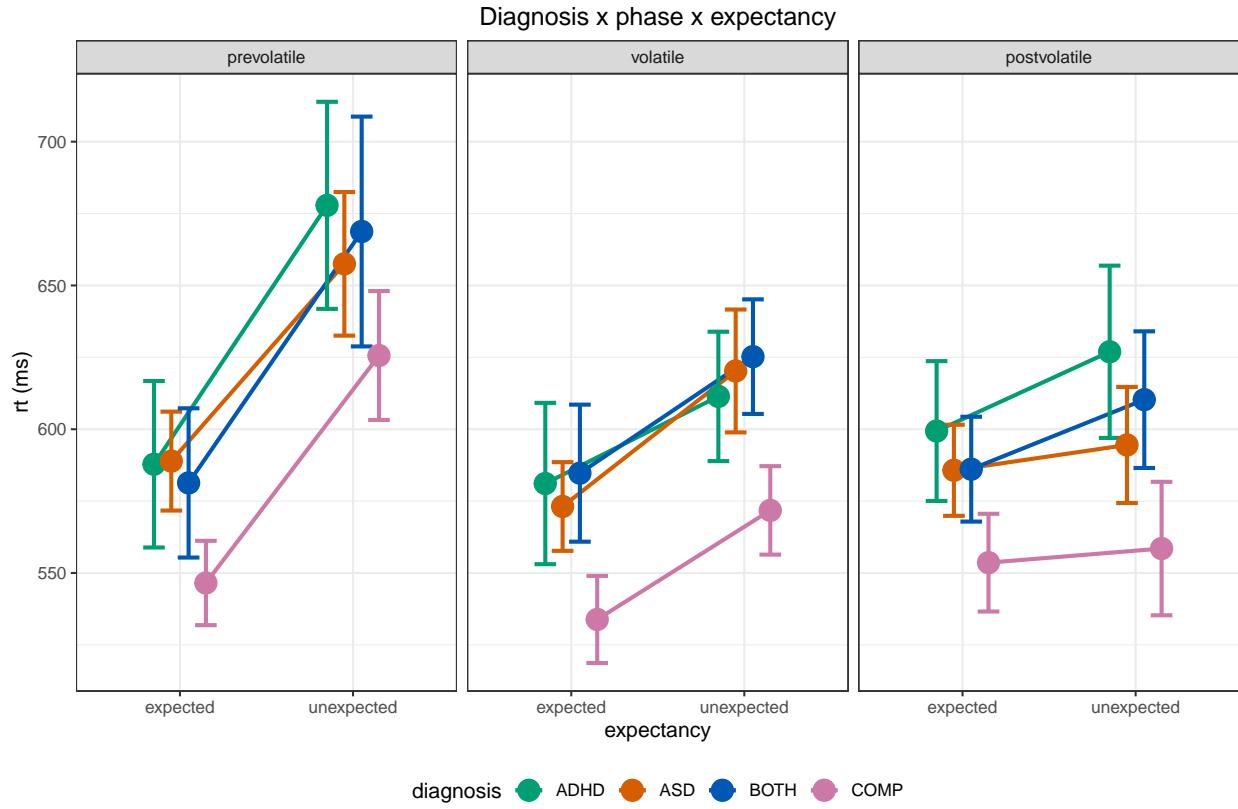
summarise(
  rt.mn = mean(rt.cor),
  rt.se = sd(rt.cor) / sqrt(n())
) %>%
ggplot(aes(y = rt.mn, x = phase, group = expected, colour = expected)) +
  geom_line(position = position_dodge(0.4), linewidth = 1) +
  geom_errorbar(aes(ymin = rt.mn - rt.se,
                     ymax = rt.mn + rt.se), linewidth = 1, width = 0.5,
                position = position_dodge(0.4)) +
  geom_point(position = position_dodge(0.4), size = 5) +
  labs (x = "phase", y = "rt (ms)") +
  ggtitle("Phase x expectancy") +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))
p6 = df.pal %>%
  group_by(subID, expected, difficulty) %>%
  summarise(
    rt.cor = median(rt.cor, na.rm = T)
  ) %>%
  group_by(expected, difficulty) %>%
  summarise(
    rt.mn = mean(rt.cor),
    rt.se = sd(rt.cor) / sqrt(n())
  ) %>%
ggplot(aes(y = rt.mn, x = difficulty, group = expected, colour = expected)) +
  geom_line(position = position_dodge(0.4), linewidth = 1) +
  geom_errorbar(aes(ymin = rt.mn - rt.se,
                     ymax = rt.mn + rt.se), linewidth = 1, width = 0.5,
                position = position_dodge(0.4)) +
  geom_point(position = position_dodge(0.4), size = 5) +
  labs (x = "difficulty", y = "rt (ms)") +
  ggtitle("Expectancy x difficulty") +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))

ggarrange(p5, p6, ncol = 2)

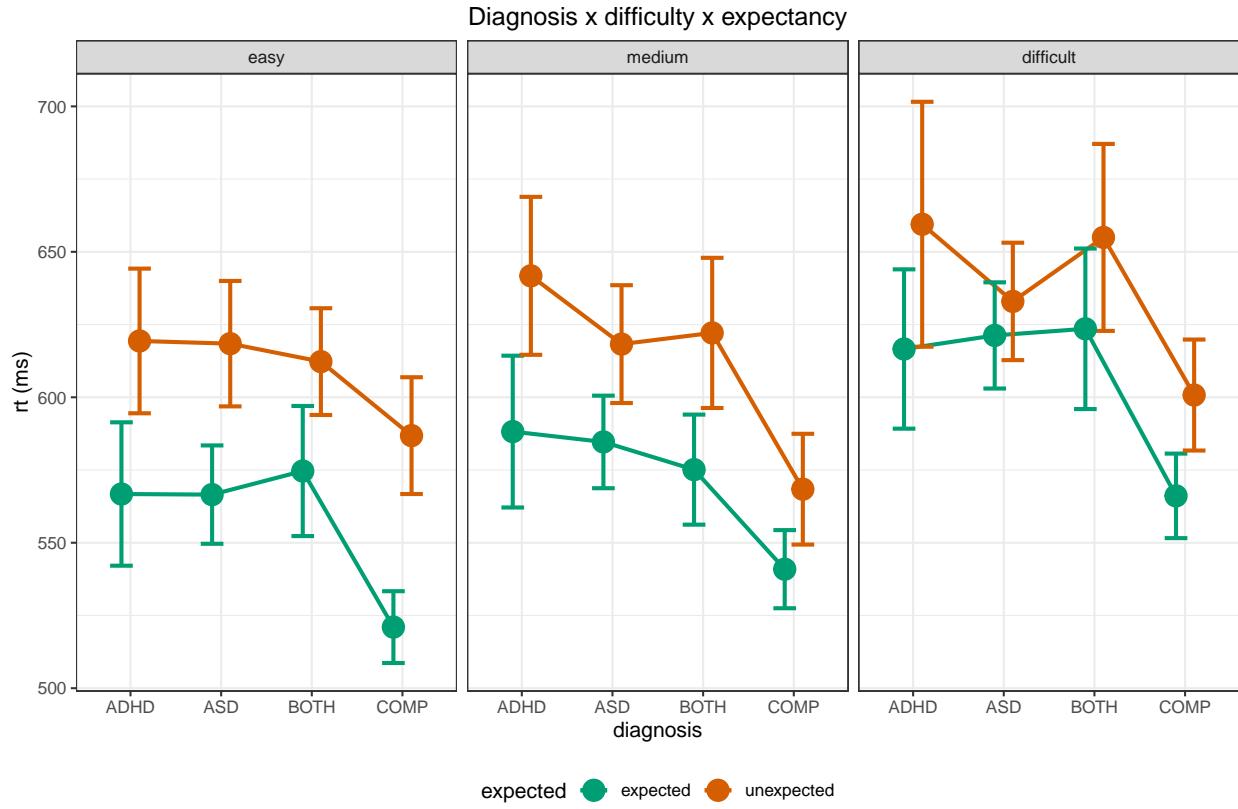
```



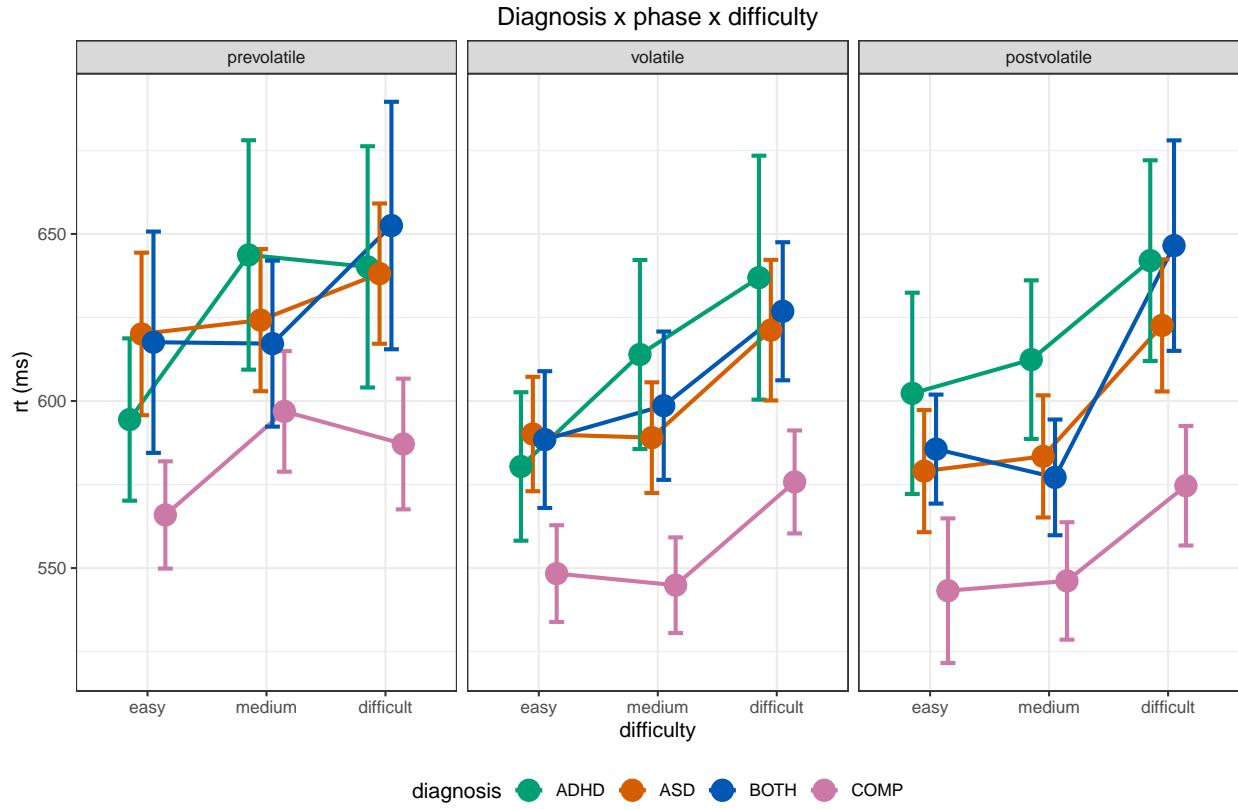
```
# three-way interaction
df.pal %>%
  group_by(subID, diagnosis, expected, phase) %>%
  summarise(
    rt.cor = median(rt.cor, na.rm = T)
  ) %>%
  group_by(diagnosis, expected, phase) %>%
  summarise(
    rt.mn = mean(rt.cor),
    rt.se = sd(rt.cor) / sqrt(n())
  ) %>%
  ggplot(aes(y = rt.mn, x = expected, group = diagnosis, colour = diagnosis)) +
  geom_line(position = position_dodge(0.4), linewidth = 1) +
  geom_errorbar(aes(ymin = rt.mn - rt.se,
                     ymax = rt.mn + rt.se), linewidth = 1, width = 0.5,
                position = position_dodge(0.4)) +
  geom_point(position = position_dodge(0.4), size = 5) +
  labs (x = "expectancy", y = "rt (ms)") +
  ggtitle("Diagnosis x phase x expectancy") +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  facet_wrap(. ~ phase) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))
```



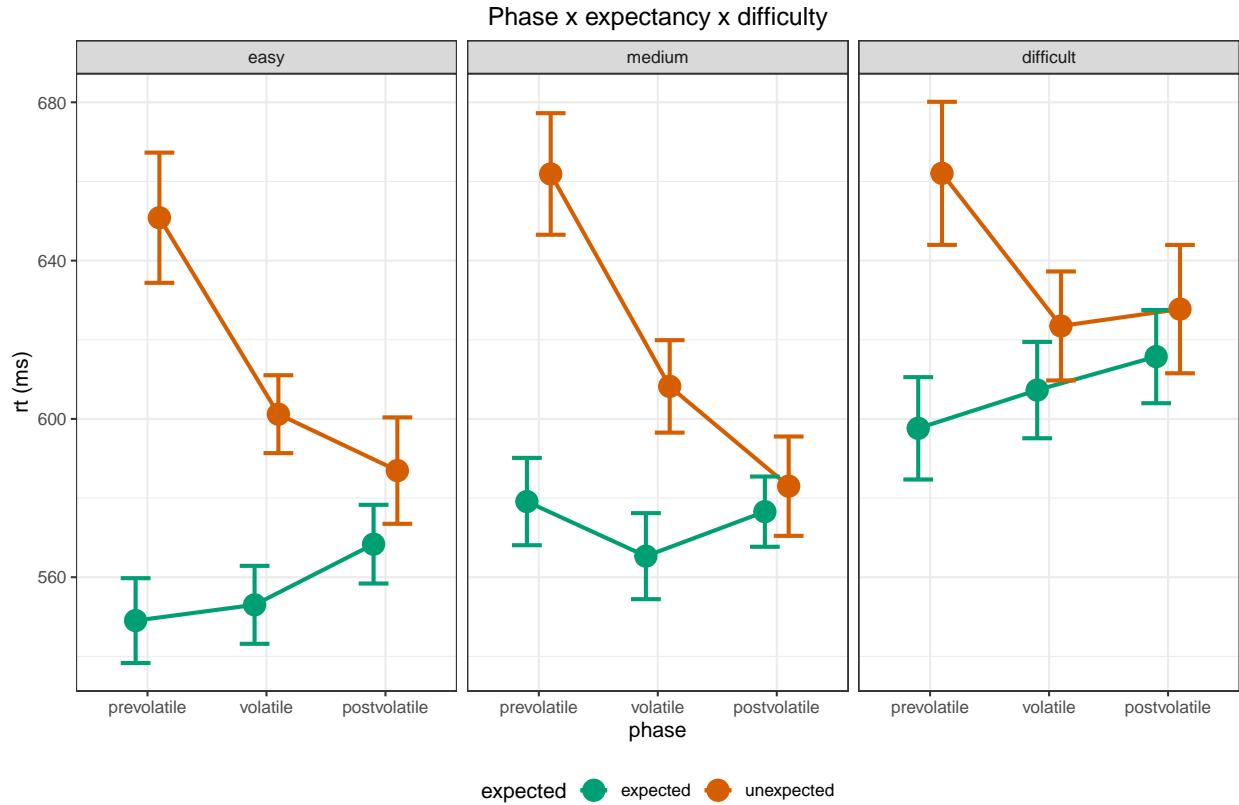
```
df.pal %>%
  group_by(subID, diagnosis, expected, difficulty) %>%
  summarise(
    rt.cor = median(rt.cor, na.rm = T)
  ) %>%
  group_by(diagnosis, expected, difficulty) %>%
  summarise(
    rt.mn = mean(rt.cor),
    rt.se = sd(rt.cor) / sqrt(n())
  ) %>%
  ggplot(aes(y = rt.mn, x = diagnosis, group = expected, colour = expected)) +
  geom_line(position = position_dodge(0.4), linewidth = 1) +
  geom_errorbar(aes(ymax = rt.mn + rt.se,
                    ymin = rt.mn - rt.se,
                    position = position_dodge(0.4))) +
  geom_point(position = position_dodge(0.4), size = 5) +
  labs (x = "diagnosis", y = "rt (ms)") +
  ggtitle("Diagnosis x difficulty x expectancy") +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  facet_wrap(. ~ difficulty) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))
```



```
df.pal %>%
  group_by(subID, diagnosis, phase, difficulty) %>%
  summarise(
    rt.cor = median(rt.cor, na.rm = T)
  ) %>%
  group_by(diagnosis, difficulty, phase) %>%
  summarise(
    rt.mn = mean(rt.cor),
    rt.se = sd(rt.cor) / sqrt(n())
  ) %>%
  ggplot(aes(y = rt.mn, x = difficulty, group = diagnosis, colour = diagnosis)) +
  geom_line(position = position_dodge(0.4), linewidth = 1) +
  geom_errorbar(aes(ymax = rt.mn + rt.se,
                    ymin = rt.mn - rt.se,
                    position = position_dodge(0.4))) +
  geom_point(position = position_dodge(0.4), size = 5) +
  labs (x = "difficulty", y = "rt (ms)") +
  ggtitle("Diagnosis x phase x difficulty") +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  facet_wrap(. ~ phase) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))
```



```
df.pal %>%
  group_by(subID, expected, phase, difficulty) %>%
  summarise(
    rt.cor = median(rt.cor, na.rm = T)
  ) %>%
  group_by(expected, phase, difficulty) %>%
  summarise(
    rt.mn = mean(rt.cor),
    rt.se = sd(rt.cor) / sqrt(n())
  ) %>%
  ggplot(aes(y = rt.mn, x = phase, group = expected, colour = expected)) +
  geom_line(position = position_dodge(0.4), linewidth = 1) +
  geom_errorbar(aes(ymax = rt.mn + rt.se,
                    ymin = rt.mn - rt.se,
                    position = position_dodge(0.4))) +
  geom_point(position = position_dodge(0.4), size = 5) +
  labs (x = "phase", y = "rt (ms)") +
  ggtitle("Phase x expectancy x difficulty") +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  facet_wrap(. ~ difficulty) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))
```



## Bayes factor analysis

```
# set the directory in which to save results
sense_dir = file.path(getwd(), "_brms_sens_cache")
main.code = "pal_rt"

# rerun the model with more iterations for bridgesampling
set.seed(5544)
m.pal.bf = brm(f.pal,
  df.pal, prior = priors,
  family = shifted_lognormal,
  iter = 40000, warmup = 10000,
  backend = "cmdstanr", threads = threading(8),
  file = file.path(brms_dir, "m_pal_bf"), silent = 2,
  save_pars = save_pars(all = TRUE)
)

# first, run it only for the chosen parameters to determine the best models
tryCatch({
  # check if it has been run before
  if (!file.exists(file.path(sense_dir,
    sprintf("df_%s_bf.csv", main.code)))) {
    # use function to compute BF with the described priors
    bf_sens_4int(m.pal.bf, "diagnosis", "expected", "phase", "difficulty",
      "chosen",
      main.code, # prefix for all models and MLL
    )
  }
})
```

```

        file.path("logfiles", "log_PAL_bf.txt"), # log file
        sense_dir, # where to save the models and MLL
        reps = 5
    )
}
},
error = function(err) {
  message(sprintf("Error for %s: %s", "chosen", err))
}
)

# since there are 167 models in total, we focus on the 20 best models for the
# sensitivity analysis
df.pal.bf = read_csv(file.path(sense_dir,
                               sprintf("df_%s_bf.csv", main.code)),
                      show_col_types = F) %>%
ungroup() %>%
filter(priors == "chosen" & !is.na(bf.log)) %>%
mutate(bf.rank = rank(bf.log),
       bf.rank = max(bf.rank) - bf.rank + 1
      ) %>%
filter(bf.rank <= 20)
fixed = df.pal.bf$`population-level`

# and describe the priors we want to use in our sensitivity analysis
pr.descriptions = c(
  "sdx2",     "sdx4",     "sdx8",
  "sdx0.5",   "sdx0.25",  "sdx0.125"
)

# check if they have been run already
pr.done = read_csv(file.path(sense_dir,
                            sprintf("df_%s_bf.csv", main.code)),
                   show_col_types = F) %>%
select(priors) %>% distinct()
pr.descriptions = pr.descriptions[!(pr.descriptions %in% pr.done$priors)]

# loop through the priors that have not been used before
for (pr.desc in pr.descriptions) {
  tryCatch({
    # use function to compute BF with the described priors
    bf_sens_fixed(m.pal.bf, fixed,
                  pr.desc,
                  main.code, # prefix for all models and MLL
                  file.path("logfiles", "log_PAL_bf.txt"), # log file
                  sense_dir # where to save the models and MLL
    )
  },
  error = function(err) {
    message(sprintf("Error for %s: %s", pr.desc, err))
  }
)
}

```

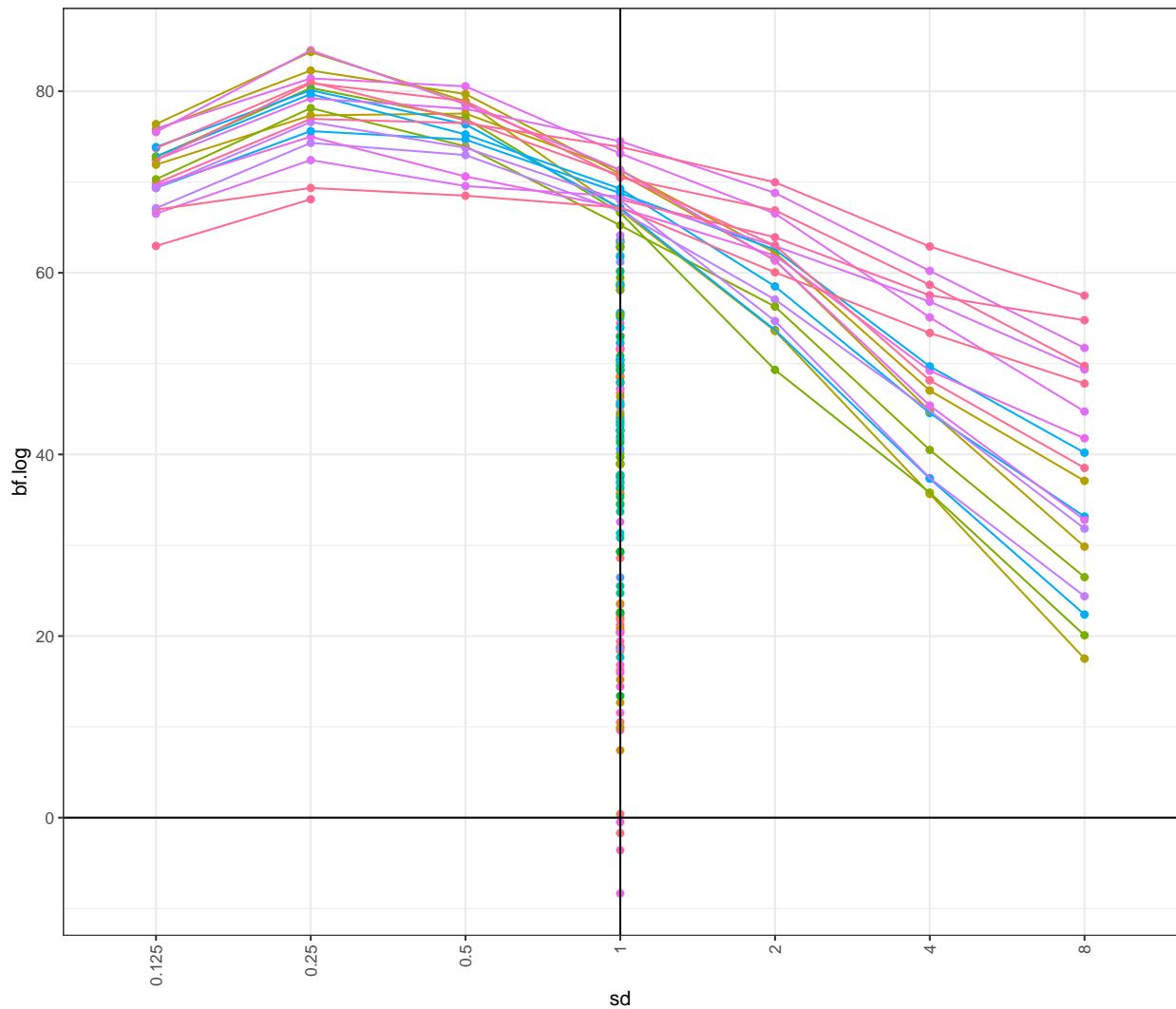
```

df.pal.bf = read_csv(file.path(sense_dir,
                               sprintf("df_%s_bf.csv", main.code)),
                     show_col_types = F)

# check the sensitivity analysis result per model
df.pal.bf %>%
  filter(`population-level` != "1") %>%
  mutate(
    sd = as.factor(case_when(
      priors == "chosen" ~ "1",
      substr(priors, 1, 3) == "sdx" ~ gsub("sdx", "", priors),
      T ~ priors)
    ),
    order = case_when(
      priors == "chosen" ~ 1,
      substr(priors, 1, 3) == "sdx" ~ as.numeric(gsub("sdx", "", priors)),
      T ~ 999),
    sd = fct_reorder(sd, order)
  ) %>%
  ggplot(aes(y = bf.log,
             x = sd,
             group = `population-level`,
             colour = `population-level`)) +
  geom_point() +
  geom_line() +
  geom_vline(xintercept = "1") +
  geom_hline(yintercept = 0) +
  ggtitle("Sensitivity analysis with the intercept-only model as reference") +
  #scale_colour_manual(values = custom.col) +
  theme_bw() +
  theme(legend.position = "none",
        axis.text.x = element_text(angle = 90, vjust = 0.5, hjust = 1))

```

### Sensitivity analysis with the intercept–only model as reference



There seems to be a bit of a change between the best few models from the chosen prior to narrower or wider priors, let's inspect this more closely.

```
# choose the top 4 models for closer inspection
df.pal.bf.best = df.pal.bf %>%
  drop_na() %>%
  # choose the best models based on the chosen priors
  filter(priors == "chosen") %>%
  mutate(
    bf.rank = max(rank(bf.log)) - rank(bf.log) + 1
  ) %>%
  filter(bf.rank < 6) %>%
  # add a model number to make plotting easier
  mutate(
    model.nr = paste("model", bf.rank)
  ) %>%
  select(`population-level`, model.nr) %>%
  # merge with the other data again
  merge(., df.pal.bf)
```

```

kable(df.pal.bf.best %>%
      select(-`population-level`) %>%
      pivot_wider(names_from = priors, values_from = bf.log) %>%
      arrange(desc(chosen)) %>%
      relocate(model.nr, `sdx0.125`, `sdx0.25`, `sdx0.5`, `chosen`, `sdx2`, `sdx4`, `sdx8`)
)

```

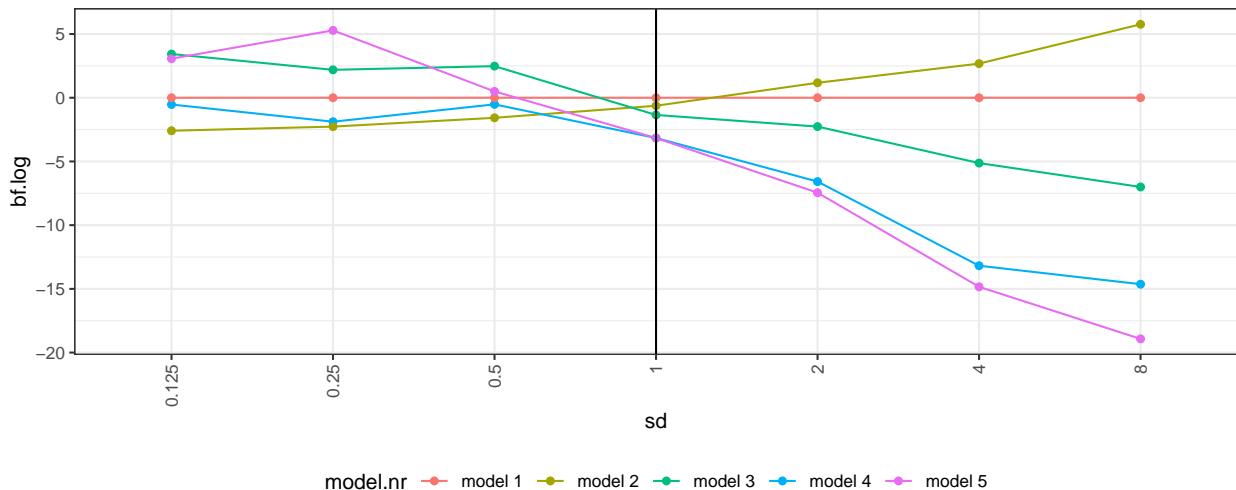
model.nr	sdx0.125	sdx0.25	sdx0.5	chosen	sdx2	sdx4	sdx8
model 1	72.4367	79.2156	78.0568	74.4847	68.7962	60.2180	51.7267
model 2	69.8482	76.9495	76.4820	73.8563	69.9708	62.8958	57.4885
model 3	75.8675	81.4059	80.5378	73.1331	66.5321	55.0912	44.7257
model 4	71.9045	77.3350	77.5374	71.3240	62.2166	47.0348	37.0936
model 5	75.5027	84.5011	78.5547	71.3230	61.3441	45.3799	32.8017

```

# use the model which is best at chosen priors as comparison model
df.pal.bf.best %>%
  group_by(priors) %>%
  mutate(bf.log = bf.log - bf.log[model.nr == "model 1"]) %>%
  ungroup() %>%
  mutate(
    sd = as.factor(case_when(
      priors == "chosen" ~ "1",
      substr(priors, 1, 3) == "sdx" ~ gsub("sdx", "", priors),
      T ~ priors
    )),
    order = case_when(
      priors == "chosen" ~ 1,
      substr(priors, 1, 3) == "sdx" ~ as.numeric(gsub("sdx", "", priors)),
      T ~ 999,
      sd = fct_reorder(sd, order)
    ) %>%
    ggplot(aes(y = bf.log,
               x = sd,
               group = model.nr ,
               colour = model.nr)) +
    geom_point() +
    geom_line() +
    geom_vline(xintercept = "1") +
    ggtitle("Sensitivity analysis with the model 1 as reference") +
    theme_bw() +
    theme(legend.position = "bottom",
          axis.text.x = element_text(angle = 90, vjust = 0.5, hjust = 1))

```

### Sensitivity analysis with the model 1 as reference



```
kable(df.pal.bf.best %>% filter(priors == "chosen") %>% select(-priors) %>%
  filter(`population-level` != "1") %>% arrange(desc(bf.log)) %>%
  mutate(
    bf.log.diff = bf.log - lead(bf.log),
    bf.int = interpret_bf(bf.log.diff, log = T)
  ))
```

population-level	model.nr	bf.log	bf.log.diff	bf.int
diagnosis + expected + phase + difficulty + expected:phase + expected:difficulty	1	74.484	70.6284	anecdotal evidence in favour of
expected + phase + difficulty + expected:phase + expected:difficulty	2	73.856	30.7232	anecdotal evidence in favour of
diagnosis + expected + phase + difficulty + expected:phase + expected:difficulty + phase:difficulty	3	73.133	11.8091	moderate evidence in favour of
diagnosis + expected + phase + difficulty + diagnosis:difficulty + expected:phase + expected:difficulty	4	71.324	0.0010	anecdotal evidence in favour of
diagnosis + expected + phase + difficulty + expected:phase + expected:difficulty + phase:difficulty + expected:phase:difficulty	5	71.3230	NA	

```
# check out which model is which
kable(df.pal.bf.best %>%
  select(model.nr, `population-level`) %>% distinct() %>%
  arrange(model.nr))
```

model.nr	population-level
1	diagnosis + expected + phase + difficulty + expected:phase + expected:difficulty
2	expected + phase + difficulty + expected:phase + expected:difficulty

---

model.nr	population-level
----------	------------------

---

model	diagnosis + expected + phase + difficulty + expected:phase + expected:difficulty + phase:difficulty
-------	---

3

model	diagnosis + expected + phase + difficulty + diagnosis:difficulty + expected:phase +
-------	---

4      expected:difficulty

model	diagnosis + expected + phase + difficulty + expected:phase + expected:difficulty + phase:difficulty
-------	---

5      + expected:phase:difficulty

---

None of the best five models includes a relevant interaction with the diagnostic group. Therefore, this conventional analysis of reaction time does not suggest any differences in probabilistic learning.

## S1.4 Exploration of reaction times in all non-outlier trials

Since other studies have also used all non-outlier trials regardless of accuracy, we compute the above described model on these RTs as well.

```
# fit the final model
set.seed(2468)
m.use = brm(rt.use ~ diagnosis * expected * phase * difficulty +
             (expected + phase + difficulty +
              expected:phase + difficulty:phase + expected:difficulty | subID),
             df.pal, prior = priors,
             family = shifted_lognormal,
             iter = iter, warmup = warm,
             backend = "cmdstanr", threads = threading(8),
             file = file.path(brms_dir, "m_pal_rtuse"),
             save_pars = save_pars(all = TRUE)
            )
rstan::check_hmc_diagnostics(m.use$fit)

##
## Divergences:
## 0 of 18000 iterations ended with a divergence.

##
## Tree depth:
## 0 of 18000 iterations saturated the maximum tree depth of 10.

##
## Energy:
## E-BFMI indicated no pathological behavior.

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

## [1] 0

# print the model summary
summary(m.use)

## Family: shifted_lognormal
## Links: mu = identity; sigma = identity; ndt = identity
## Formula: rt.use ~ diagnosis * expected * phase * difficulty + (expected + phase + difficulty + expected:phase + difficulty:phase + expected:difficulty | subID)
## Data: df.pal (Number of observations: 1620)
```

```

##   Draws: 4 chains, each with iter = 6000; warmup = 1500; thin = 1;
##             total post-warmup draws = 18000
##
## Multilevel Hyperparameters:
## ~subID (Number of levels: 90)
##                                     Estimate Est.Error l-95% CI
## sd(Intercept)                      0.24     0.02    0.20
## sd(expected1)                      0.02     0.01    0.00
## sd(phase1)                         0.08     0.01    0.07
## sd(phase2)                         0.03     0.01    0.02
## sd(difficulty1)                   0.01     0.01    0.00
## sd(difficulty2)                   0.02     0.01    0.00
## sd(expected1:phase1)              0.02     0.01    0.01
## sd(expected1:phase2)              0.02     0.01    0.00
## sd(phase1:difficulty1)            0.04     0.01    0.02
## sd(phase2:difficulty1)            0.02     0.01    0.00
## sd(phase1:difficulty2)            0.02     0.01    0.00
## sd(phase2:difficulty2)            0.04     0.01    0.02
## sd(expected1:difficulty1)        0.01     0.00    0.00
## sd(expected1:difficulty2)        0.02     0.01    0.00
## cor(Intercept,expected1)          -0.08    0.18    -0.41
## cor(Intercept,phase1)             0.12    0.10    -0.09
## cor(expected1,phase1)             0.19    0.18    -0.19
## cor(Intercept,phase2)             -0.04    0.14    -0.32
## cor(expected1,phase2)             0.10    0.21    -0.34
## cor(phase1,phase2)               -0.28    0.15    -0.56
## cor(Intercept,difficulty1)       -0.23    0.21    -0.60
## cor(expected1,difficulty1)       -0.01    0.23    -0.46
## cor(phase1,difficulty1)          -0.05    0.21    -0.45
## cor(phase2,difficulty1)          -0.15    0.23    -0.55
## cor(Intercept,difficulty2)       -0.17    0.20    -0.52
## cor(expected1,difficulty2)       -0.12    0.23    -0.54
## cor(phase1,difficulty2)          -0.25    0.20    -0.60
## cor(phase2,difficulty2)          -0.01    0.22    -0.43
## cor(difficulty1,difficulty2)     0.00    0.24    -0.44
## cor(Intercept,expected1:phase1)  -0.07    0.17    -0.39
## cor(expected1,expected1:phase1)  0.03    0.22    -0.40
## cor(phase1,expected1:phase1)     -0.32    0.17    -0.62
## cor(phase2,expected1:phase1)     -0.03    0.21    -0.43
## cor(difficulty1,expected1:phase1) 0.01    0.23    -0.43
## cor(difficulty2,expected1:phase1) 0.07    0.22    -0.36
## cor(Intercept,expected1:phase2)  0.24    0.18    -0.15
## cor(expected1,expected1:phase2)  -0.09    0.22    -0.50
## cor(phase1,expected1:phase2)     0.02    0.19    -0.35
## cor(phase2,expected1:phase2)     -0.36    0.21    -0.70
## cor(difficulty1,expected1:phase2) 0.02    0.23    -0.42
## cor(difficulty2,expected1:phase2) 0.03    0.22    -0.41
## cor(expected1:phase1,expected1:phase2) -0.02    0.22    -0.43
## cor(Intercept,phase1:difficulty1) -0.25    0.14    -0.52
## cor(expected1,phase1:difficulty1) 0.03    0.21    -0.37
## cor(phase1,phase1:difficulty1)   0.14    0.15    -0.17
## cor(phase2,phase1:difficulty1)   -0.03    0.19    -0.41
## cor(difficulty1,phase1:difficulty1) 0.09    0.23    -0.38
## cor(difficulty2,phase1:difficulty1) 0.03    0.22    -0.39

```

## cor(expected1:phase1,phase1:difficulty1)	-0.14	0.20	-0.52
## cor(expected1:phase2,phase1:difficulty1)	-0.08	0.21	-0.48
## cor(Intercept,phase2:difficulty1)	-0.16	0.20	-0.52
## cor(expected1,phase2:difficulty1)	-0.05	0.23	-0.49
## cor(phase1,phase2:difficulty1)	-0.08	0.20	-0.46
## cor(phase2,phase2:difficulty1)	-0.10	0.22	-0.52
## cor(difficulty1,phase2:difficulty1)	0.06	0.24	-0.41
## cor(difficulty2,phase2:difficulty1)	0.12	0.23	-0.35
## cor(expected1:phase1,phase2:difficulty1)	0.08	0.23	-0.37
## cor(expected1:phase2,phase2:difficulty1)	0.11	0.23	-0.36
## cor(phase1:difficulty1,phase2:difficulty1)	-0.02	0.22	-0.44
## cor(Intercept,phase1:difficulty2)	0.05	0.20	-0.35
## cor(expected1,phase1:difficulty2)	0.08	0.23	-0.38
## cor(phase1,phase1:difficulty2)	0.01	0.20	-0.39
## cor(phase2,phase1:difficulty2)	0.14	0.23	-0.33
## cor(difficulty1,phase1:difficulty2)	-0.09	0.24	-0.54
## cor(difficulty2,phase1:difficulty2)	-0.11	0.23	-0.54
## cor(expected1:phase1,phase1:difficulty2)	-0.06	0.23	-0.49
## cor(expected1:phase2,phase1:difficulty2)	-0.09	0.23	-0.52
## cor(phase1:difficulty1,phase1:difficulty2)	-0.10	0.23	-0.52
## cor(phase2:difficulty1,phase1:difficulty2)	-0.14	0.24	-0.57
## cor(Intercept,phase2:difficulty2)	0.27	0.14	-0.01
## cor(expected1,phase2:difficulty2)	0.10	0.21	-0.33
## cor(phase1,phase2:difficulty2)	-0.04	0.15	-0.34
## cor(phase2,phase2:difficulty2)	0.05	0.19	-0.33
## cor(difficulty1,phase2:difficulty2)	-0.12	0.23	-0.53
## cor(difficulty2,phase2:difficulty2)	-0.23	0.22	-0.61
## cor(expected1:phase1,phase2:difficulty2)	0.08	0.20	-0.32
## cor(expected1:phase2,phase2:difficulty2)	0.12	0.21	-0.30
## cor(phase1:difficulty1,phase2:difficulty2)	-0.17	0.19	-0.52
## cor(phase2:difficulty1,phase2:difficulty2)	-0.16	0.23	-0.57
## cor(phase1:difficulty2,phase2:difficulty2)	0.08	0.22	-0.36
## cor(Intercept,expected1:difficulty1)	0.09	0.24	-0.39
## cor(expected1,expected1:difficulty1)	0.02	0.24	-0.45
## cor(phase1,expected1:difficulty1)	0.04	0.23	-0.42
## cor(phase2,expected1:difficulty1)	0.01	0.24	-0.45
## cor(difficulty1,expected1:difficulty1)	-0.07	0.25	-0.53
## cor(difficulty2,expected1:difficulty1)	-0.02	0.24	-0.48
## cor(expected1:phase1,expected1:difficulty1)	0.02	0.24	-0.44
## cor(expected1:phase2,expected1:difficulty1)	0.03	0.24	-0.44
## cor(phase1:difficulty1,expected1:difficulty1)	0.03	0.24	-0.44
## cor(phase2:difficulty1,expected1:difficulty1)	0.02	0.24	-0.46
## cor(phase1:difficulty2,expected1:difficulty1)	-0.01	0.24	-0.47
## cor(phase2:difficulty2,expected1:difficulty1)	0.01	0.24	-0.44
## cor(Intercept,expected1:difficulty2)	-0.02	0.18	-0.36
## cor(expected1,expected1:difficulty2)	0.16	0.22	-0.30
## cor(phase1,expected1:difficulty2)	0.36	0.19	-0.06
## cor(phase2,expected1:difficulty2)	-0.07	0.21	-0.47
## cor(difficulty1,expected1:difficulty2)	-0.01	0.23	-0.46
## cor(difficulty2,expected1:difficulty2)	-0.29	0.24	-0.68
## cor(expected1:phase1,expected1:difficulty2)	-0.04	0.22	-0.45
## cor(expected1:phase2,expected1:difficulty2)	-0.02	0.22	-0.44
## cor(phase1:difficulty1,expected1:difficulty2)	-0.07	0.21	-0.47
## cor(phase2:difficulty1,expected1:difficulty2)	-0.08	0.23	-0.51

## cor(phase1:difficulty2,expected1:difficulty2)	0.06	0.23	-0.39
## cor(phase2:difficulty2,expected1:difficulty2)	0.13	0.21	-0.30
## cor(expected1:difficulty1,expected1:difficulty2)	-0.08	0.25	-0.54
##	u-95%	CI	Rhat
## sd(Intercept)	0.28	1.00	2016
## sd(expected1)	0.03	1.00	2555
## sd(phase1)	0.10	1.00	5670
## sd(phase2)	0.05	1.00	3112
## sd(difficulty1)	0.03	1.00	4286
## sd(difficulty2)	0.03	1.00	3195
## sd(expected1:phase1)	0.04	1.00	4753
## sd(expected1:phase2)	0.03	1.00	2762
## sd(phase1:difficulty1)	0.06	1.00	6502
## sd(phase2:difficulty1)	0.04	1.00	2875
## sd(phase1:difficulty2)	0.04	1.00	2974
## sd(phase2:difficulty2)	0.06	1.00	5613
## sd(expected1:difficulty1)	0.02	1.00	7151
## sd(expected1:difficulty2)	0.03	1.00	4804
## cor(Intercept,expected1)	0.28	1.00	17272
## cor(Intercept,phase1)	0.31	1.00	5750
## cor(expected1,phase1)	0.53	1.00	1222
## cor(Intercept,phase2)	0.25	1.00	13694
## cor(expected1,phase2)	0.50	1.00	4262
## cor(phase1,phase2)	0.05	1.00	11038
## cor(Intercept,difficulty1)	0.24	1.00	12961
## cor(expected1,difficulty1)	0.44	1.00	14038
## cor(phase1,difficulty1)	0.37	1.00	18307
## cor(phase2,difficulty1)	0.32	1.00	13367
## cor(Intercept,difficulty2)	0.25	1.00	14732
## cor(expected1,difficulty2)	0.34	1.00	7567
## cor(phase1,difficulty2)	0.18	1.00	13752
## cor(phase2,difficulty2)	0.42	1.00	13536
## cor(difficulty1,difficulty2)	0.47	1.00	9510
## cor(Intercept,expected1:phase1)	0.26	1.00	15663
## cor(expected1,expected1:phase1)	0.45	1.00	5095
## cor(phase1,expected1:phase1)	0.04	1.00	14282
## cor(phase2,expected1:phase1)	0.37	1.00	11451
## cor(difficulty1,expected1:phase1)	0.46	1.00	8748
## cor(difficulty2,expected1:phase1)	0.49	1.00	9388
## cor(Intercept,expected1:phase2)	0.57	1.00	13776
## cor(expected1,expected1:phase2)	0.35	1.00	7315
## cor(phase1,expected1:phase2)	0.39	1.00	15505
## cor(phase2,expected1:phase2)	0.12	1.00	5176
## cor(difficulty1,expected1:phase2)	0.46	1.00	12450
## cor(difficulty2,expected1:phase2)	0.45	1.00	12500
## cor(expected1:phase1,expected1:phase2)	0.42	1.00	13042
## cor(Intercept,phase1:difficulty1)	0.03	1.00	15675
## cor(expected1,phase1:difficulty1)	0.44	1.00	5204
## cor(phase1,phase1:difficulty1)	0.43	1.00	13980
## cor(phase2,phase1:difficulty1)	0.35	1.00	7226
## cor(difficulty1,phase1:difficulty1)	0.51	1.00	5101
## cor(difficulty2,phase1:difficulty1)	0.45	1.00	6500
## cor(expected1:phase1,phase1:difficulty1)	0.28	1.00	6737
## cor(expected1:phase2,phase1:difficulty1)	0.33	1.00	7166

## cor(Intercept,phase2:difficulty1)	0.27	1.00	15437
## cor(expected1,phase2:difficulty1)	0.41	1.00	11545
## cor(phase1,phase2:difficulty1)	0.33	1.00	17374
## cor(phase2,phase2:difficulty1)	0.35	1.00	11916
## cor(difficulty1,phase2:difficulty1)	0.50	1.00	10629
## cor(difficulty2,phase2:difficulty1)	0.55	1.00	9787
## cor(expected1:phase1,phase2:difficulty1)	0.50	1.00	12243
## cor(expected1:phase2,phase2:difficulty1)	0.53	1.00	9544
## cor(phase1:difficulty1,phase2:difficulty1)	0.43	1.00	13701
## cor(Intercept,phase1:difficulty2)	0.43	1.00	19093
## cor(expected1,phase1:difficulty2)	0.52	1.00	10317
## cor(phase1,phase1:difficulty2)	0.41	1.00	19241
## cor(phase2,phase1:difficulty2)	0.55	1.00	9999
## cor(difficulty1,phase1:difficulty2)	0.39	1.00	8913
## cor(difficulty2,phase1:difficulty2)	0.36	1.00	10078
## cor(expected1:phase1,phase1:difficulty2)	0.39	1.00	13384
## cor(expected1:phase2,phase1:difficulty2)	0.37	1.00	10128
## cor(phase1:difficulty1,phase1:difficulty2)	0.37	1.00	12352
## cor(phase2:difficulty1,phase1:difficulty2)	0.35	1.00	8561
## cor(Intercept,phase2:difficulty2)	0.53	1.00	16648
## cor(expected1,phase2:difficulty2)	0.49	1.00	5397
## cor(phase1,phase2:difficulty2)	0.26	1.00	14644
## cor(phase2,phase2:difficulty2)	0.41	1.00	7624
## cor(difficulty1,phase2:difficulty2)	0.34	1.00	5051
## cor(difficulty2,phase2:difficulty2)	0.23	1.00	4437
## cor(expected1:phase1,phase2:difficulty2)	0.46	1.00	8301
## cor(expected1:phase2,phase2:difficulty2)	0.52	1.00	7230
## cor(phase1:difficulty1,phase2:difficulty2)	0.21	1.00	10482
## cor(phase2:difficulty1,phase2:difficulty2)	0.31	1.00	6875
## cor(phase1:difficulty2,phase2:difficulty2)	0.51	1.00	7432
## cor(Intercept,expected1:difficulty1)	0.53	1.00	22663
## cor(expected1,expected1:difficulty1)	0.48	1.00	21005
## cor(phase1,expected1:difficulty1)	0.49	1.00	24596
## cor(phase2,expected1:difficulty1)	0.47	1.00	20325
## cor(difficulty1,expected1:difficulty1)	0.42	1.00	14764
## cor(difficulty2,expected1:difficulty1)	0.45	1.00	17245
## cor(expected1:phase1,expected1:difficulty1)	0.48	1.00	18140
## cor(expected1:phase2,expected1:difficulty1)	0.49	1.00	16000
## cor(phase1:difficulty1,expected1:difficulty1)	0.49	1.00	17353
## cor(phase2:difficulty1,expected1:difficulty1)	0.48	1.00	13519
## cor(phase1:difficulty2,expected1:difficulty1)	0.45	1.00	14865
## cor(phase2:difficulty2,expected1:difficulty1)	0.47	1.00	18171
## cor(Intercept,expected1:difficulty2)	0.34	1.00	19887
## cor(expected1,expected1:difficulty2)	0.56	1.00	5382
## cor(phase1,expected1:difficulty2)	0.67	1.00	12163
## cor(phase2,expected1:difficulty2)	0.35	1.00	13215
## cor(difficulty1,expected1:difficulty2)	0.45	1.00	9560
## cor(difficulty2,expected1:difficulty2)	0.23	1.00	5067
## cor(expected1:phase1,expected1:difficulty2)	0.39	1.00	13631
## cor(expected1:phase2,expected1:difficulty2)	0.41	1.00	14253
## cor(phase1:difficulty1,expected1:difficulty2)	0.35	1.00	16180
## cor(phase2:difficulty1,expected1:difficulty2)	0.38	1.00	11489
## cor(phase1:difficulty2,expected1:difficulty2)	0.49	1.00	13311
## cor(phase2:difficulty2,expected1:difficulty2)	0.52	1.00	14802

## cor(expected1:difficulty1,expected1:difficulty2)	0.42	1.00	11514
## Tail_ESS			
## sd(Intercept)	4222		
## sd(expected1)	2666		
## sd(phase1)	9882		
## sd(phase2)	2140		
## sd(difficulty1)	5586		
## sd(difficulty2)	3044		
## sd(expected1:phase1)	3922		
## sd(expected1:phase2)	2058		
## sd(phase1:difficulty1)	7953		
## sd(phase2:difficulty1)	4258		
## sd(phase1:difficulty2)	4460		
## sd(phase2:difficulty2)	6427		
## sd(expected1:difficulty1)	7363		
## sd(expected1:difficulty2)	3837		
## cor(Intercept,expected1)	12160		
## cor(Intercept,phase1)	9520		
## cor(expected1,phase1)	2084		
## cor(Intercept,phase2)	13477		
## cor(expected1,phase2)	6958		
## cor(phase1,phase2)	8230		
## cor(Intercept,difficulty1)	10868		
## cor(expected1,difficulty1)	14545		
## cor(phase1,difficulty1)	12468		
## cor(phase2,difficulty1)	13434		
## cor(Intercept,difficulty2)	11012		
## cor(expected1,difficulty2)	10456		
## cor(phase1,difficulty2)	10669		
## cor(phase2,difficulty2)	13665		
## cor(difficulty1,difficulty2)	13007		
## cor(Intercept,expected1:phase1)	13293		
## cor(expected1,expected1:phase1)	10212		
## cor(phase1,expected1:phase1)	10980		
## cor(phase2,expected1:phase1)	13421		
## cor(difficulty1,expected1:phase1)	12299		
## cor(difficulty2,expected1:phase1)	12917		
## cor(Intercept,expected1:phase2)	9394		
## cor(expected1,expected1:phase2)	10453		
## cor(phase1,expected1:phase2)	13307		
## cor(phase2,expected1:phase2)	5389		
## cor(difficulty1,expected1:phase2)	12928		
## cor(difficulty2,expected1:phase2)	14410		
## cor(expected1:phase1,expected1:phase2)	13832		
## cor(Intercept,phase1:difficulty1)	13050		
## cor(expected1,phase1:difficulty1)	9530		
## cor(phase1,phase1:difficulty1)	14051		
## cor(phase2,phase1:difficulty1)	11668		
## cor(difficulty1,phase1:difficulty1)	7570		
## cor(difficulty2,phase1:difficulty1)	10226		
## cor(expected1:phase1,phase1:difficulty1)	9211		
## cor(expected1:phase2,phase1:difficulty1)	11176		
## cor(Intercept,phase2:difficulty1)	11267		
## cor(expected1,phase2:difficulty1)	12744		

```

## cor(phase1,phase2:difficulty1)           13335
## cor(phase2,phase2:difficulty1)           12758
## cor(difficulty1,phase2:difficulty1)      13035
## cor(difficulty2,phase2:difficulty1)      11821
## cor(expected1:phase1,phase2:difficulty1) 13885
## cor(expected1:phase2,phase2:difficulty1) 12099
## cor(phase1:difficulty1,phase2:difficulty1) 14714
## cor(Intercept,phase1:difficulty2)        11843
## cor(expected1,phase1:difficulty2)         12128
## cor(phase1,phase1:difficulty2)            13603
## cor(phase2,phase1:difficulty2)            12163
## cor(difficulty1,phase1:difficulty2)       12675
## cor(difficulty2,phase1:difficulty2)       12614
## cor(expected1:phase1,phase1:difficulty2)   14015
## cor(expected1:phase2,phase1:difficulty2)   13232
## cor(phase1:difficulty1,phase1:difficulty2) 12446
## cor(phase2:difficulty1,phase1:difficulty2) 13105
## cor(Intercept,phase2:difficulty2)         13778
## cor(expected1,phase2:difficulty2)          8884
## cor(phase1,phase2:difficulty2)             13339
## cor(phase2,phase2:difficulty2)             11574
## cor(difficulty1,phase2:difficulty2)        9045
## cor(difficulty2,phase2:difficulty2)        7077
## cor(expected1:phase1,phase2:difficulty2)    12240
## cor(expected1:phase2,phase2:difficulty2)    9523
## cor(phase1:difficulty1,phase2:difficulty2) 13564
## cor(phase2:difficulty1,phase2:difficulty2) 11080
## cor(phase1:difficulty2,phase2:difficulty2) 11170
## cor(Intercept,expected1:difficulty1)       12037
## cor(expected1,expected1:difficulty1)        13611
## cor(phase1,expected1:difficulty1)           13342
## cor(phase2,expected1:difficulty1)           13832
## cor(difficulty1,expected1:difficulty1)      12979
## cor(difficulty2,expected1:difficulty1)      14167
## cor(expected1:phase1,expected1:difficulty1) 13617
## cor(expected1:phase2,expected1:difficulty1) 14690
## cor(phase1:difficulty1,expected1:difficulty1) 14183
## cor(phase2:difficulty1,expected1:difficulty1) 13892
## cor(phase1:difficulty2,expected1:difficulty1) 14792
## cor(phase2:difficulty2,expected1:difficulty1) 14580
## cor(Intercept,expected1:difficulty2)        11951
## cor(expected1,expected1:difficulty2)         7595
## cor(phase1,expected1:difficulty2)            8330
## cor(phase2,expected1:difficulty2)            12885
## cor(difficulty1,expected1:difficulty2)       13211
## cor(difficulty2,expected1:difficulty2)       8547
## cor(expected1:phase1,expected1:difficulty2) 14135
## cor(expected1:phase2,expected1:difficulty2) 14484
## cor(phase1:difficulty1,expected1:difficulty2) 14284
## cor(phase2:difficulty1,expected1:difficulty2) 14826
## cor(phase1:difficulty2,expected1:difficulty2) 13822
## cor(phase2:difficulty2,expected1:difficulty2) 14984
## cor(expected1:difficulty1,expected1:difficulty2) 14329
##

```

	Estimate	Est.Error	l-95% CI	u-95% CI
## Regression Coefficients:				
##				
## Intercept	5.91	0.04	5.83	6.00
## diagnosis1	0.02	0.03	-0.04	0.07
## diagnosis2	0.03	0.03	-0.02	0.09
## diagnosis3	0.01	0.03	-0.04	0.07
## expected1	-0.04	0.00	-0.05	-0.04
## phase1	0.03	0.01	0.01	0.05
## phase2	-0.01	0.01	-0.02	-0.00
## difficulty1	-0.04	0.00	-0.05	-0.03
## difficulty2	-0.01	0.00	-0.02	-0.00
## diagnosis1:expected1	-0.00	0.01	-0.01	0.01
## diagnosis2:expected1	0.00	0.01	-0.01	0.02
## diagnosis3:expected1	-0.00	0.01	-0.01	0.01
## diagnosis1:phase1	-0.03	0.02	-0.06	0.00
## diagnosis2:phase1	0.01	0.02	-0.02	0.04
## diagnosis3:phase1	-0.00	0.01	-0.03	0.03
## diagnosis1:phase2	-0.00	0.01	-0.02	0.02
## diagnosis2:phase2	0.00	0.01	-0.02	0.02
## diagnosis3:phase2	-0.00	0.01	-0.02	0.02
## expected1:phase1	-0.04	0.01	-0.05	-0.03
## expected1:phase2	0.00	0.00	-0.01	0.01
## diagnosis1:difficulty1	-0.02	0.01	-0.03	0.00
## diagnosis2:difficulty1	0.01	0.01	-0.01	0.02
## diagnosis3:difficulty1	0.01	0.01	-0.00	0.03
## diagnosis1:difficulty2	0.02	0.01	0.01	0.04
## diagnosis2:difficulty2	-0.01	0.01	-0.02	0.01
## diagnosis3:difficulty2	-0.03	0.01	-0.04	-0.01
## expected1:difficulty1	-0.02	0.00	-0.03	-0.01
## expected1:difficulty2	0.00	0.00	-0.01	0.01
## phase1:difficulty1	-0.01	0.01	-0.02	0.01
## phase2:difficulty1	0.00	0.01	-0.01	0.02
## phase1:difficulty2	0.02	0.01	0.01	0.04
## phase2:difficulty2	-0.00	0.01	-0.02	0.01
## diagnosis1:expected1:phase1	0.00	0.01	-0.01	0.02
## diagnosis2:expected1:phase1	0.01	0.01	-0.01	0.03
## diagnosis3:expected1:phase1	-0.00	0.01	-0.02	0.01
## diagnosis1:expected1:phase2	-0.00	0.01	-0.02	0.01
## diagnosis2:expected1:phase2	-0.01	0.01	-0.02	0.01
## diagnosis3:expected1:phase2	0.01	0.01	-0.01	0.03
## diagnosis1:expected1:difficulty1	-0.00	0.01	-0.02	0.01
## diagnosis2:expected1:difficulty1	-0.01	0.01	-0.02	0.01
## diagnosis3:expected1:difficulty1	0.01	0.01	-0.01	0.02
## diagnosis1:expected1:difficulty2	-0.00	0.01	-0.02	0.01
## diagnosis2:expected1:difficulty2	0.00	0.01	-0.01	0.02
## diagnosis3:expected1:difficulty2	-0.00	0.01	-0.02	0.01
## diagnosis1:phase1:difficulty1	-0.02	0.01	-0.04	0.01
## diagnosis2:phase1:difficulty1	0.01	0.01	-0.01	0.04
## diagnosis3:phase1:difficulty1	0.01	0.01	-0.02	0.03
## diagnosis1:phase2:difficulty1	-0.00	0.01	-0.02	0.02
## diagnosis2:phase2:difficulty1	0.00	0.01	-0.02	0.02
## diagnosis3:phase2:difficulty1	-0.01	0.01	-0.03	0.01
## diagnosis1:phase1:difficulty2	-0.00	0.01	-0.02	0.02
## diagnosis2:phase1:difficulty2	-0.01	0.01	-0.03	0.01

## diagnosis3:phase1:difficulty2	-0.00	0.01	-0.03	0.02
## diagnosis1:phase2:difficulty2	0.00	0.01	-0.02	0.03
## diagnosis2:phase2:difficulty2	0.01	0.01	-0.02	0.03
## diagnosis3:phase2:difficulty2	0.01	0.01	-0.01	0.04
## expected1:phase1:difficulty1	-0.01	0.01	-0.02	0.00
## expected1:phase2:difficulty1	-0.00	0.01	-0.01	0.01
## expected1:phase1:difficulty2	-0.00	0.01	-0.01	0.01
## expected1:phase2:difficulty2	-0.01	0.01	-0.02	0.00
## diagnosis1:expected1:phase1:difficulty1	0.00	0.01	-0.02	0.02
## diagnosis2:expected1:phase1:difficulty1	0.01	0.01	-0.01	0.03
## diagnosis3:expected1:phase1:difficulty1	0.00	0.01	-0.02	0.02
## diagnosis1:expected1:phase2:difficulty1	0.00	0.01	-0.02	0.02
## diagnosis2:expected1:phase2:difficulty1	0.00	0.01	-0.02	0.02
## diagnosis3:expected1:phase2:difficulty1	-0.01	0.01	-0.03	0.01
## diagnosis1:expected1:phase1:difficulty2	0.01	0.01	-0.01	0.03
## diagnosis2:expected1:phase1:difficulty2	-0.00	0.01	-0.02	0.02
## diagnosis3:expected1:phase1:difficulty2	-0.01	0.01	-0.03	0.01
## diagnosis1:expected1:phase2:difficulty2	-0.01	0.01	-0.03	0.01
## diagnosis2:expected1:phase2:difficulty2	-0.01	0.01	-0.03	0.01
## diagnosis3:expected1:phase2:difficulty2	0.01	0.01	-0.01	0.03
##	Rhat	Bulk_ESS	Tail_ESS	
## Intercept	1.00	1730	4745	
## diagnosis1	1.00	1920	4082	
## diagnosis2	1.00	1821	3695	
## diagnosis3	1.00	1813	3714	
## expected1	1.00	16117	13497	
## phase1	1.00	5220	8780	
## phase2	1.00	12983	13534	
## difficulty1	1.00	15260	13656	
## difficulty2	1.00	19463	14630	
## diagnosis1:expected1	1.00	15109	12506	
## diagnosis2:expected1	1.00	15619	13499	
## diagnosis3:expected1	1.00	16213	14154	
## diagnosis1:phase1	1.00	5636	8934	
## diagnosis2:phase1	1.00	5510	8725	
## diagnosis3:phase1	1.00	5725	9627	
## diagnosis1:phase2	1.00	11890	13046	
## diagnosis2:phase2	1.00	10937	13345	
## diagnosis3:phase2	1.00	11717	12959	
## expected1:phase1	1.00	14200	14074	
## expected1:phase2	1.00	18159	14291	
## diagnosis1:difficulty1	1.00	15332	14442	
## diagnosis2:difficulty1	1.00	15715	13896	
## diagnosis3:difficulty1	1.00	15840	13587	
## diagnosis1:difficulty2	1.00	13952	13979	
## diagnosis2:difficulty2	1.00	14665	13901	
## diagnosis3:difficulty2	1.00	13716	13655	
## expected1:difficulty1	1.00	21076	15241	
## expected1:difficulty2	1.00	18862	14430	
## phase1:difficulty1	1.00	11191	12745	
## phase2:difficulty1	1.00	16365	14555	
## phase1:difficulty2	1.00	15415	14127	
## phase2:difficulty2	1.00	11999	13288	
## diagnosis1:expected1:phase1	1.00	14174	13639	

```

## diagnosis2:expected1:phase1      1.00    13919    13850
## diagnosis3:expected1:phase1      1.00    13127    12941
## diagnosis1:expected1:phase2      1.00    14496    14407
## diagnosis2:expected1:phase2      1.00    14489    14469
## diagnosis3:expected1:phase2      1.00    13801    13893
## diagnosis1:expected1:difficulty1 1.00    17011    14346
## diagnosis2:expected1:difficulty1 1.00    15362    13792
## diagnosis3:expected1:difficulty1 1.00    16473    13863
## diagnosis1:expected1:difficulty2 1.00    13878    13361
## diagnosis2:expected1:difficulty2 1.00    13896    13978
## diagnosis3:expected1:difficulty2 1.00    14102    14265
## diagnosis1:phase1:difficulty1    1.00    11130    11657
## diagnosis2:phase1:difficulty1    1.00    10195    11649
## diagnosis3:phase1:difficulty1    1.00    10735    12917
## diagnosis1:phase2:difficulty1    1.00    13174    13788
## diagnosis2:phase2:difficulty1    1.00    13440    13567
## diagnosis3:phase2:difficulty1    1.00    13061    14118
## diagnosis1:phase1:difficulty2    1.00    14038    13762
## diagnosis2:phase1:difficulty2    1.00    12307    12692
## diagnosis3:phase1:difficulty2    1.00    13023    14373
## diagnosis1:phase2:difficulty2    1.00    11708    13036
## diagnosis2:phase2:difficulty2    1.00    11090    13154
## diagnosis3:phase2:difficulty2    1.00    11038    12251
## expected1:phase1:difficulty1     1.00    15967    13909
## expected1:phase2:difficulty1     1.00    16188    14010
## expected1:phase1:difficulty2     1.00    15335    14242
## expected1:phase2:difficulty2     1.00    15815    14317
## diagnosis1:expected1:phase1:difficulty1 1.00    12647    13041
## diagnosis2:expected1:phase1:difficulty1 1.00    12619    13425
## diagnosis3:expected1:phase1:difficulty1 1.00    12977    12232
## diagnosis1:expected1:phase2:difficulty1 1.00    12694    12849
## diagnosis2:expected1:phase2:difficulty1 1.00    13263    14366
## diagnosis3:expected1:phase2:difficulty1 1.00    12170    12995
## diagnosis1:expected1:phase1:difficulty2 1.00    12461    13777
## diagnosis2:expected1:phase1:difficulty2 1.00    12457    13301
## diagnosis3:expected1:phase1:difficulty2 1.00    13287    13572
## diagnosis1:expected1:phase2:difficulty2 1.00    12591    13358
## diagnosis2:expected1:phase2:difficulty2 1.00    12600    13937
## diagnosis3:expected1:phase2:difficulty2 1.00    12853    13725
##
## Further Distributional Parameters:
##           Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sigma      0.13      0.01     0.12     0.14 1.00      4128     7712
## ndt       212.10    11.83   187.08   233.35 1.00      5825     8479
##
## 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).
# compare the fixed effects between both models
effects = as.data.frame(fixef(m.pal)) %>%
  mutate(model = "cor") %>%
  rownames_to_column(., var = "fixed effect") %>%
  merge(., as.data.frame(fixef(m.use))) %>%

```

```

mutate(model = "use") %>%
rownames_to_column(., var = "fixed effect"),
  all = T) %>%
select(model, `fixed effect`, Estimate) %>%
pivot_wider(names_from = model, values_from = c(Estimate)) %>%
mutate(
  Estimate.diff = cor - use
)

kable(effects)

```

fixed effect	use	cor	Estimate.diff
diagnosis1	0.0160305	0.0208257	0.0047952
diagnosis1:difficulty1	-0.0152346	-0.0202866	-0.0050519
diagnosis1:difficulty2	0.0232305	0.0239342	0.0007036
diagnosis1:expected1	-0.0020182	-0.0080076	-0.0059895
diagnosis1:expected1:difficulty1	-0.0045934	0.0011407	0.0057341
diagnosis1:expected1:difficulty2	-0.0020800	-0.0019117	0.0001683
diagnosis1:expected1:phase1	0.0031739	-0.0000719	-0.0032459
diagnosis1:expected1:phase1:difficulty1	0.0037546	-0.0051538	-0.0089084
diagnosis1:expected1:phase1:difficulty2	0.0074234	0.0060690	-0.0013544
diagnosis1:expected1:phase2	-0.0045406	0.0018260	0.0063666
diagnosis1:expected1:phase2:difficulty1	0.0034878	0.0061304	0.0026426
diagnosis1:expected1:phase2:difficulty2	-0.0125092	-0.0123857	0.0001234
diagnosis1:phase1	-0.0271165	-0.0199222	0.0071943
diagnosis1:phase1:difficulty1	-0.0164401	-0.0064664	0.0099737
diagnosis1:phase1:difficulty2	-0.0003568	0.0005862	0.0009431
diagnosis1:phase2	-0.0016191	-0.0030865	-0.0014674
diagnosis1:phase2:difficulty1	-0.0005597	-0.0049369	-0.0043772
diagnosis1:phase2:difficulty2	0.0035350	-0.0000382	-0.0035732
diagnosis2	0.0316581	0.0309340	-0.0007241
diagnosis2:difficulty1	0.0066220	0.0109889	0.0043669
diagnosis2:difficulty2	-0.0057267	-0.0104102	-0.0046835
diagnosis2:expected1	0.0040875	0.0094331	0.0053456
diagnosis2:expected1:difficulty1	-0.0056077	-0.0103183	-0.0047105
diagnosis2:expected1:difficulty2	0.0044707	0.0087610	0.0042903
diagnosis2:expected1:phase1	0.0097832	0.0076629	-0.0021203
diagnosis2:expected1:phase1:difficulty1	0.0072642	0.0125615	0.0052973
diagnosis2:expected1:phase1:difficulty2	-0.0018248	-0.0052012	-0.0033764
diagnosis2:expected1:phase2	-0.0051722	-0.0053017	-0.0001296
diagnosis2:expected1:phase2:difficulty1	0.0045965	-0.0001899	-0.0047864
diagnosis2:expected1:phase2:difficulty2	-0.0117300	-0.0058574	0.0058726
diagnosis2:phase1	0.0141532	0.0117758	-0.0023774
diagnosis2:phase1:difficulty1	0.0137690	0.0044184	-0.0093506
diagnosis2:phase1:difficulty2	-0.0098694	-0.0054126	0.0044569
diagnosis2:phase2	0.0025945	0.0010793	-0.0015152
diagnosis2:phase2:difficulty1	0.0009623	0.0015290	0.0005667
diagnosis2:phase2:difficulty2	0.0057657	0.0030157	-0.0027500
diagnosis3	0.0147218	0.0165024	0.0017806
diagnosis3:difficulty1	0.0123957	0.0069778	-0.0054179
diagnosis3:difficulty2	-0.0250665	-0.0203600	0.0047065
diagnosis3:expected1	-0.0011207	-0.0041570	-0.0030364
diagnosis3:expected1:difficulty1	0.0091217	0.0132378	0.0041161

fixed effect	use	cor	Estimate.diff
diagnosis3:expected1:difficulty2	-0.0017783	-0.0083723	-0.0065940
diagnosis3:expected1:phase1	-0.0031130	0.0053877	0.0085007
diagnosis3:expected1:phase1:difficulty1	0.0012655	0.0022258	0.0009604
diagnosis3:expected1:phase1:difficulty2	-0.0083082	-0.0048754	0.0034328
diagnosis3:expected1:phase2	0.0096356	0.0020228	-0.0076128
diagnosis3:expected1:phase2:difficulty1	-0.0071217	-0.0046146	0.0025071
diagnosis3:expected1:phase2:difficulty2	0.0061392	0.0032754	-0.0028638
diagnosis3:phase1	-0.0024007	-0.0091461	-0.0067454
diagnosis3:phase1:difficulty1	0.0067041	0.0090339	0.0023298
diagnosis3:phase1:difficulty2	-0.0047899	-0.0119835	-0.0071937
diagnosis3:phase2	-0.0002878	0.0035756	0.0038634
diagnosis3:phase2:difficulty1	-0.0098692	-0.0082901	0.0015791
diagnosis3:phase2:difficulty2	0.0144615	0.0171624	0.0027010
difficulty1	-0.0431570	-0.0418193	0.0013377
difficulty2	-0.0102083	-0.0111177	-0.0009094
expected1	-0.0435172	-0.0509429	-0.0074256
expected1:difficulty1	-0.0234677	-0.0200669	0.0034008
expected1:difficulty2	0.0005227	-0.0000421	-0.0005648
expected1:phase1	-0.0387839	-0.0464322	-0.0076483
expected1:phase1:difficulty1	-0.0075735	-0.0095197	-0.0019463
expected1:phase1:difficulty2	-0.0023415	0.0000350	0.0023765
expected1:phase2	0.0000150	0.0016810	0.0016660
expected1:phase2:difficulty1	-0.0007777	-0.0018808	-0.0011031
expected1:phase2:difficulty2	-0.0087070	-0.0088048	-0.0000979
Intercept	5.9137150	5.9054759	-0.0082391
phase1	0.0297910	0.0301318	0.0003408
phase1:difficulty1	-0.0078720	-0.0025580	0.0053140
phase1:difficulty2	0.0232080	0.0249524	0.0017444
phase2	-0.0126536	-0.0124811	0.0001725
phase2:difficulty1	0.0025871	0.0028634	0.0002763
phase2:difficulty2	-0.0037692	-0.0063421	-0.0025729

## S1.4 Exploration of association type

Now, we explore if there were any differences between the tone-valence associations at the beginning.

```
# check normal distribution
df_tp %>% group_by(diagnosis, tone_pic, expected) %>%
  shapiro_test(rt.cor) %>%
  mutate(
    sig = if_else(p < 0.05, "*", ""))
  )

## # A tibble: 16 x 7
##   diagnosis tone_pic     expected variable statistic      p sig
##   <fct>     <chr>       <fct>    <chr>     <dbl>    <dbl> <chr>
## 1 ADHD      highneg_lowpos expected  rt.cor      0.909  0.0450  "*"
## 2 ADHD      highneg_lowpos unexpected rt.cor      0.794  0.000402  "*"
## 3 ADHD      highpos_lowneg expected  rt.cor      0.874  0.00930  "*"
## 4 ADHD      highpos_lowneg unexpected rt.cor      0.904  0.0363  "*"
## 5 ASD       highneg_lowpos expected  rt.cor      0.883  0.0115  "*"
## 6 ASD       highneg_lowpos unexpected rt.cor      0.945  0.235   ""
```

```

##  7 ASD      highpos_lowneg expected   rt.cor      0.959 0.445    ""
##  8 ASD      highpos_lowneg unexpected rt.cor      0.886 0.0134   **"
##  9 BOTH     highneg_lowpos expected   rt.cor      0.859 0.00395   **"
## 10 BOTH    highneg_lowpos unexpected rt.cor      0.911 0.0421   **"
## 11 BOTH     highpos_lowneg expected   rt.cor      0.842 0.00192   **"
## 12 BOTH     highpos_lowneg unexpected rt.cor      0.884 0.0121   **"
## 13 COMP     highneg_lowpos expected   rt.cor      0.928 0.109    ""
## 14 COMP     highneg_lowpos unexpected rt.cor      0.872 0.00861   **"
## 15 COMP     highpos_lowneg expected   rt.cor      0.921 0.0784   ""
## 16 COMP     highpos_lowneg unexpected rt.cor      0.955 0.390    ""

# rank transform the data
df.tp = df.tp %>%
  ungroup() %>%
  mutate(
    rrt.cor = rank(rt.cor),
    tone_pic = as.factor(tone_pic)
  )

# run the ANOVA
aov.tp = anovaBF(rrt.cor ~ diagnosis * tone_pic * expected, data = df.tp)
bf.tp = extractBF(aov.tp, logbf = T)
kable(head(bf.tp %>% arrange(desc(bf.tp))))

```

	bf	error	time	code
diagnosis + tone_pic + expected	10.458971	0.0148163	Mon Apr 21 17:37:47 2025	4bbf44d45328
diagnosis + tone_pic + expected + tone_pic:expected	9.490657	0.0331604	Mon Apr 21 17:37:47 2025	4bbf50ea6606
tone_pic + expected	9.080089	0.0084332	Mon Apr 21 17:37:47 2025	4bbf37f80cab
tone_pic + expected + tone_pic:expected	8.043344	0.0122361	Mon Apr 21 17:37:47 2025	4bbf72619c94
diagnosis + expected	7.438287	0.0378826	Mon Apr 21 17:37:47 2025	4bbf1eed561c
diagnosis + tone_pic + expected + diagnosis:expected	7.255477	0.1088670	Mon Apr 21 17:37:47 2025	4bbf5f2ea24d

The best model contains all three main effects suggesting that while certain combinations were associated with faster and others with slower reaction times, this was independent of the diagnostic status and expectancy.

## S1.5 Explorative analysis of errors

Last but not least, we are going to explore possible differences with regards to mean accuracies using a Bayesian ANOVA.

```

# check normal distribution
df.pal %>% group_by(diagnosis, phase, expected, difficulty) %>%
  shapiro_test(acc) %>%
  mutate(
    sig = if_else(p < 0.05, "*", "")
  )

## # A tibble: 72 x 8

```

```

##      diagnosis phase      expected difficulty variable statistic      p sig
##      <fct>     <fct>      <fct>    <fct>    <chr>      <dbl>    <dbl> <chr>
## 1 ADHD      prevolatile expected     easy     acc      0.753 1.00e-4 *
## 2 ADHD      prevolatile expected   medium    acc      0.707 2.40e-5 *
## 3 ADHD      prevolatile expected  difficult  acc      0.848 3.11e-3 *
## 4 ADHD      prevolatile unexpected easy     acc      0.768 1.67e-4 *
## 5 ADHD      prevolatile unexpected medium    acc      0.603 1.43e-6 *
## 6 ADHD      prevolatile unexpected difficult acc      0.642 3.89e-6 *
## 7 ADHD      volatile    expected     easy     acc      0.794 3.99e-4 *
## 8 ADHD      volatile    expected   medium    acc      0.836 1.90e-3 *
## 9 ADHD      volatile    expected  difficult  acc      0.837 1.99e-3 *
## 10 ADHD     volatile   unexpected easy     acc      0.756 1.10e-4 *
## # i 62 more rows

# rank transform the data
df.acc = df.pal %>%
  ungroup() %>%
  mutate(
    racc = rank(acc)
  )

# run the ANOVA
if (!file.exists(file.path(brms_dir, "aov_acc.rds"))){
  aov.acc = anovaBF(racc ~ diagnosis * phase * expected * difficulty, data = df.acc)
  saveRDS(aov.acc, file = file.path(brms_dir, "aov_acc.rds"))
} else {
  aov.acc = readRDS(file.path(brms_dir, "aov_acc.rds"))
}

bf.acc = extractBF(aov.acc, logbf = T)
kable(head(bf.acc %>% arrange(desc(bf))))

```

	bf	error	time	code
diagnosis + expected + difficulty	61.99468	0.0147572	Fri Jan 31 13:34:33 2025	25e1017cb0c6f
diagnosis + difficulty	59.71508	0.0105499	Fri Jan 31 13:34:33 2025	25e102598c793
diagnosis + expected + difficulty + expected:difficulty	59.08581	0.0244052	Fri Jan 31 13:34:55 2025	25e1037d1b4f1
diagnosis + expected + difficulty + diagnosis:difficulty	58.71545	0.0165925	Fri Jan 31 13:34:36 2025	25e107f137933
expected + difficulty	57.67953	0.0113627	Fri Jan 31 13:34:33 2025	25e107eb14701
diagnosis + expected + diagnosis:expected + difficulty	57.66487	0.0372488	Fri Jan 31 13:34:33 2025	25e105446e94a

```

# print overall accuracy rates for all the effects included in the best model
df.acc.diagnosis = df.acc %>%
  group_by(diagnosis) %>%
  summarise(mean_accuracy = mean(acc, na.rm = T),
            sd_accuracy = sd(acc, na.rm = T))
df.acc.diagnosis

```

```
## # A tibble: 4 x 3
```

```

## diagnosis mean_accuracy sd_accuracy
## <fct>          <dbl>      <dbl>
## 1 ADHD           90.2       12.8
## 2 ASD            88.8       14.1
## 3 BOTH           90.7       12.7
## 4 COMP           92.9       11.1

df.acc %>%
  group_by(expected) %>%
  summarise(mean_accuracy = mean(acc, na.rm = T),
            sd_accuracy = sd(acc, na.rm = T))

## # A tibble: 2 x 3
##   expected  mean_accuracy  sd_accuracy
##   <fct>          <dbl>        <dbl>
## 1 expected       92.2        8.81
## 2 unexpected     89.1       15.7

df.acc %>%
  group_by(difficulty) %>%
  summarise(mean_accuracy = mean(acc, na.rm = T),
            sd_accuracy = sd(acc, na.rm = T))

## # A tibble: 3 x 3
##   difficulty  mean_accuracy  sd_accuracy
##   <fct>          <dbl>        <dbl>
## 1 easy           93.1        11.6
## 2 medium         92.6        11.5
## 3 difficult      86.3        14.0

```

Accuracies were generally high, with a grand average of 90.66% accurate responses across diagnostic groups. Accuracies seems to have differed between diagnostic groups. Let's do some plotting to figure out where our differences lie.

## Plots

```

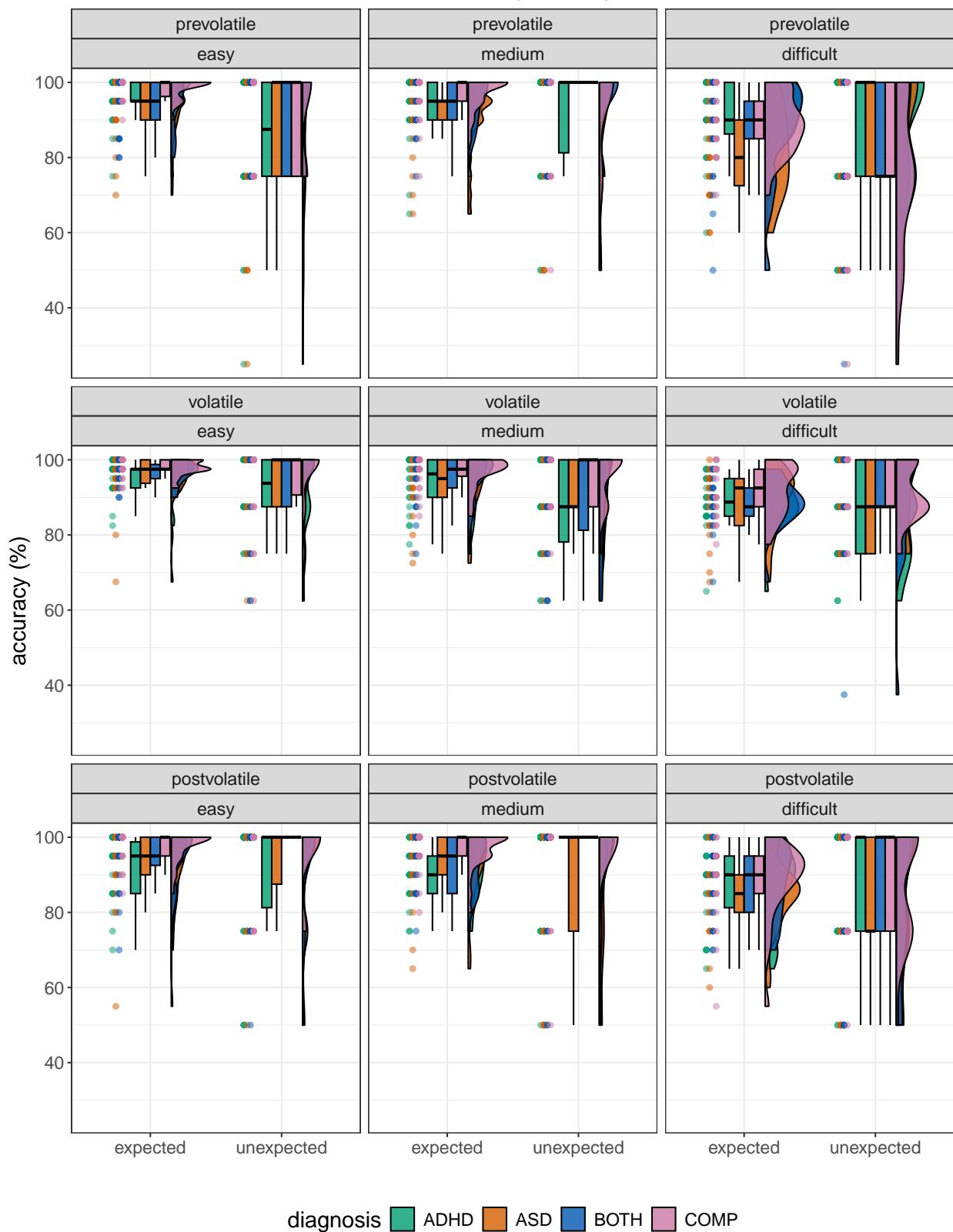
# rain cloud plot including all factors

df.acc %>%
  ggplot(aes(expected, acc, fill = diagnosis, colour = diagnosis)) +
  geom_rain(rain.side = 'r',
            boxplot.args = list(color = "black", outlier.shape = NA, show.legend = FALSE, alpha = .8),
            violin.args = list(color = "black", outlier.shape = NA, alpha = .8),
            boxplot.args.pos = list(
              position = ggpp::position_dodgenudge(x = 0, width = 0.3), width = 0.3
            ),
            point.args = list(show_guide = FALSE, alpha = .5),
            violin.args.pos = list(
              width = 0.6, position = position_nudge(x = 0.16)),
            point.args.pos = list(position = ggpp::position_dodgenudge(x = -0.25, width = 0.1))) +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  labs(title = "Accuracies per subject", x = "", y = "accuracy (%)") +
  facet_wrap(phase ~ difficulty) +
  theme_bw() +

```

```
theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5),
      legend.direction = "horizontal", text = element_text(size = 15))
```

### Accuracies per subject



```

# plot as line plot without the phases
df.acc %>%
  group_by(subID, diagnosis, expected, difficulty) %>%
  summarise(
    acc = mean(acc, na.rm = T)
  ) %>%
  group_by(diagnosis, expected, difficulty) %>%
  summarise(
    acc.mn = mean(acc),
    acc.se = sd(acc) / sqrt(n())
  ) %>%
  ggplot(aes(y = acc.mn, x = difficulty, group = expected, colour = expected)) +
  geom_line(position = position_dodge(0.4), linewidth = 1) +
  geom_errorbar(aes(ymin = acc.mn - acc.se,
                     ymax = acc.mn + acc.se), linewidth = 1, width = 0.5,
                 position = position_dodge(0.4)) +
  geom_point(position = position_dodge(0.4), size = 5) +
  facet_wrap(. ~ diagnosis) +
  ylim(75,100) +
  labs (x = "difficulty", y = "accuracy") +
  scale_fill_manual(values = custom.col) +
  scale_color_manual(values = custom.col) +
  theme_bw() +
  theme(legend.position = "bottom", plot.title = element_text(hjust = 0.5))

```

