Bayesian Analysis hypotheses

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This file contains the code for the final analysis. We analyze the four hypotheses of the final experiment. Additionally, the Cronbach alpha values and code to compare the two groups can be found in this file. The experiment, analysis and result details can be found in Chapter 4.

```
## Loading required package: rjags

## Loading required package: coda

## Linked to JAGS 4.3.0

## Loaded modules: basemod,bugs

##
## Attaching package: 'rstatix'

## The following object is masked from 'package:stats':
##
##     filter

##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union

## Loading required package: ggplot2
```

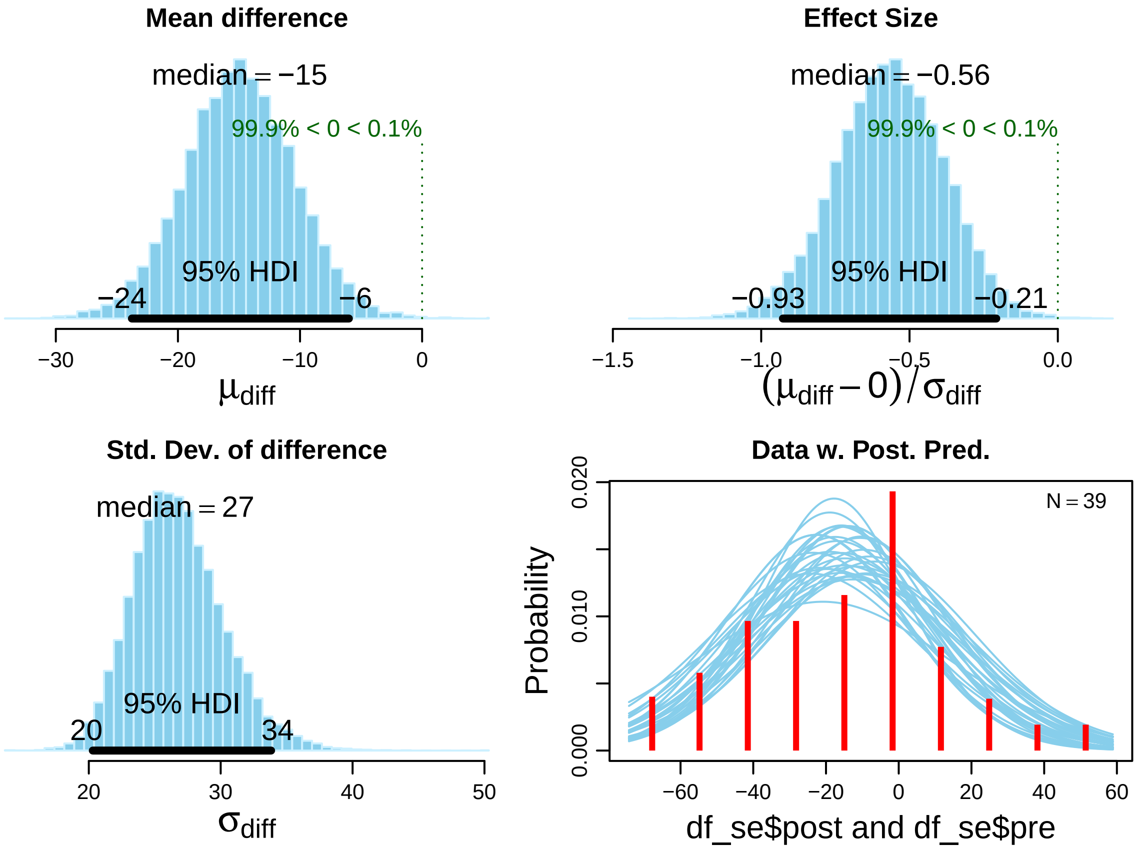
H1: The user's self-efficacy is higher after the conversation with the virtual coach than before the conversation with the virtual coach.

To analyze this hypothesis, we conducted a Bayesian paired t-test. The two measurements that were compared were the pre self-efficacy measurement and post self-efficacy measurement.

```
set.seed(22)

fit1 <- bayes.t.test(df_se$post, df_se$pre, paired = TRUE)
show(fit1)
```

```
##
##  Bayesian estimation supersedes the t test (BEST) - paired samples
##
## data: df_se$post and df_se$pre, n = 39
##
##   Estimates [95% credible interval]
## mean paired difference: -15 [-24, -6]
## sd of the paired differences: 27 [20, 34]
##
## The mean difference is more than 0 by a probability of 0.001
## and less than 0 by a probability of 0.999
```

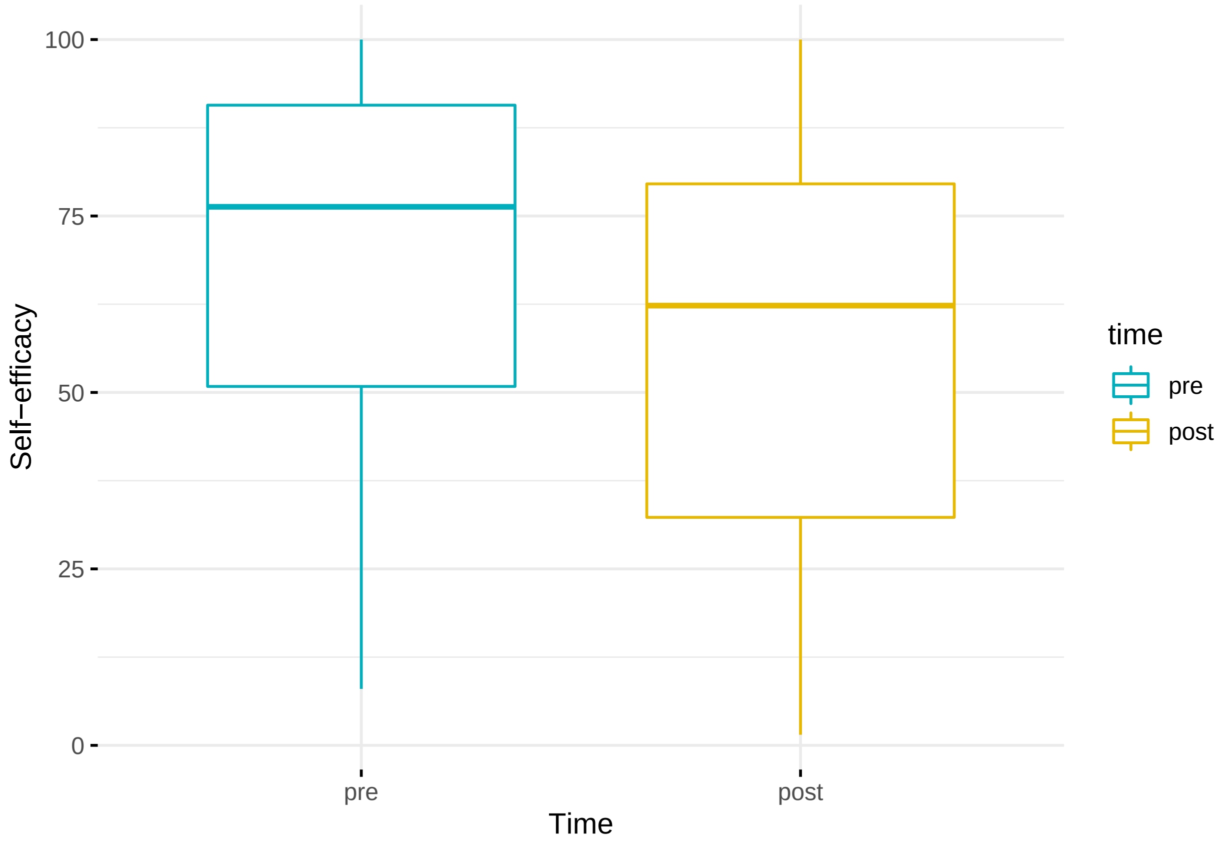
```
plot(fit1)
```



```
df_se_plots %>%
  group_by(time) %>%
  get_summary_stats(se, type = "mean_sd")
```

```
## # A tibble: 2 x 5
##   time  variable     n  mean    sd
##   <chr> <chr>    <dbl> <dbl> <dbl>
## 1 post  se          39  56.7  28.1
## 2 pre   se          39  71.6  25.6
```

```
# Figure 4.2
df_se_plots$time <- factor(df_se_plots$time, c("pre", "post"))
bxp1 <- ggboxplot(
  df_se_plots, x = "time", y = "se",
  ylab = "Self-efficacy", xlab = "Time",
  color = "time", palette = c("#00AFBB", "#E7B800"),
  ggtheme = theme_minimal()
  )
bxp1
```



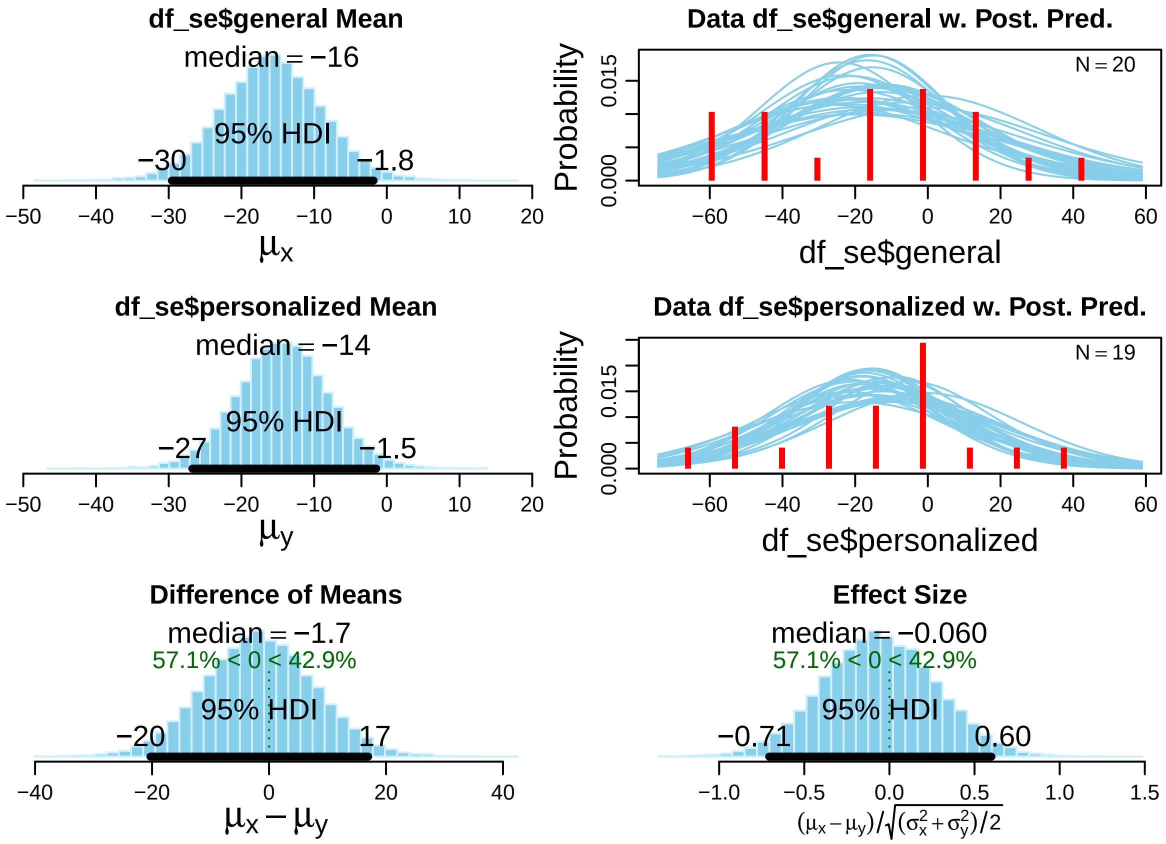
H2: The self-efficacy is higher when people receive personalized examples than when they received general examples.

A Bayesian two-sample t-test was conducted to analyze this hypothesis. The two independent groups were the general and personalized examples groups, and the dependent variable was the change in self-efficacy between the pre and post measurement.

```
set.seed(22)

# Table 4.3
fit2 <- bayes.t.test(df_se$general, df_se$personalized)
show(fit2)
```

```
##
##  Bayesian estimation supersedes the t test (BEST) - two sample
##
## data: df_se$general (n = 20) and df_se$personalized (n = 19)
##
##   Estimates [95% credible interval]
## mean of df_se$general: -16 [-30, -1.8]
## mean of df_se$personalized: -14 [-27, -1.5]
## difference of the means: -1.7 [-20, 17]
## sd of df_se$general: 29 [20, 41]
## sd of df_se$personalized: 26 [17, 37]
##
## The difference of the means is greater than 0 by a probability of 0.429
## and less than 0 by a probability of 0.571
```

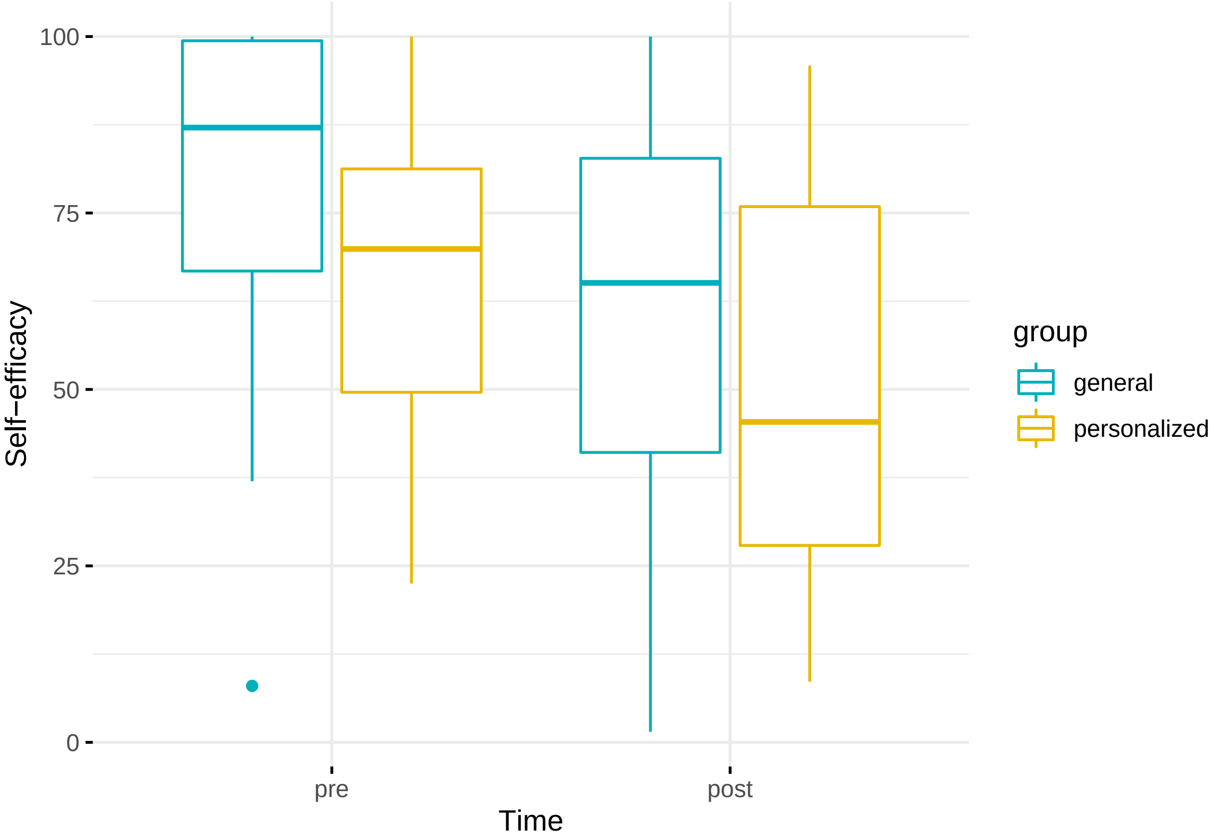
```r
plot(fit2)
```



```r
df_se_plots %>%
  group_by(group, time) %>%
  get_summary_stats(se, type = "mean_sd")
```

```
## # A tibble: 4 x 6
##   group        time  variable     n  mean    sd
##   <chr>        <fct> <chr>    <dbl> <dbl> <dbl>
## 1 general      pre   se          20  77.5  26.2
## 2 general      post  se          20  61.9  28.6
## 3 personalized pre   se          19  65.5  24.0
## 4 personalized post  se          19  51.2  27.2
```

```r
# Figure 4.3
ggboxplot(df_se_plots, x = "time", y = "se", color = "group", ylab = "Self-efficacy", xlab = "Time", gg
          palette = c("#00AFBB", "#E7B800"))
```



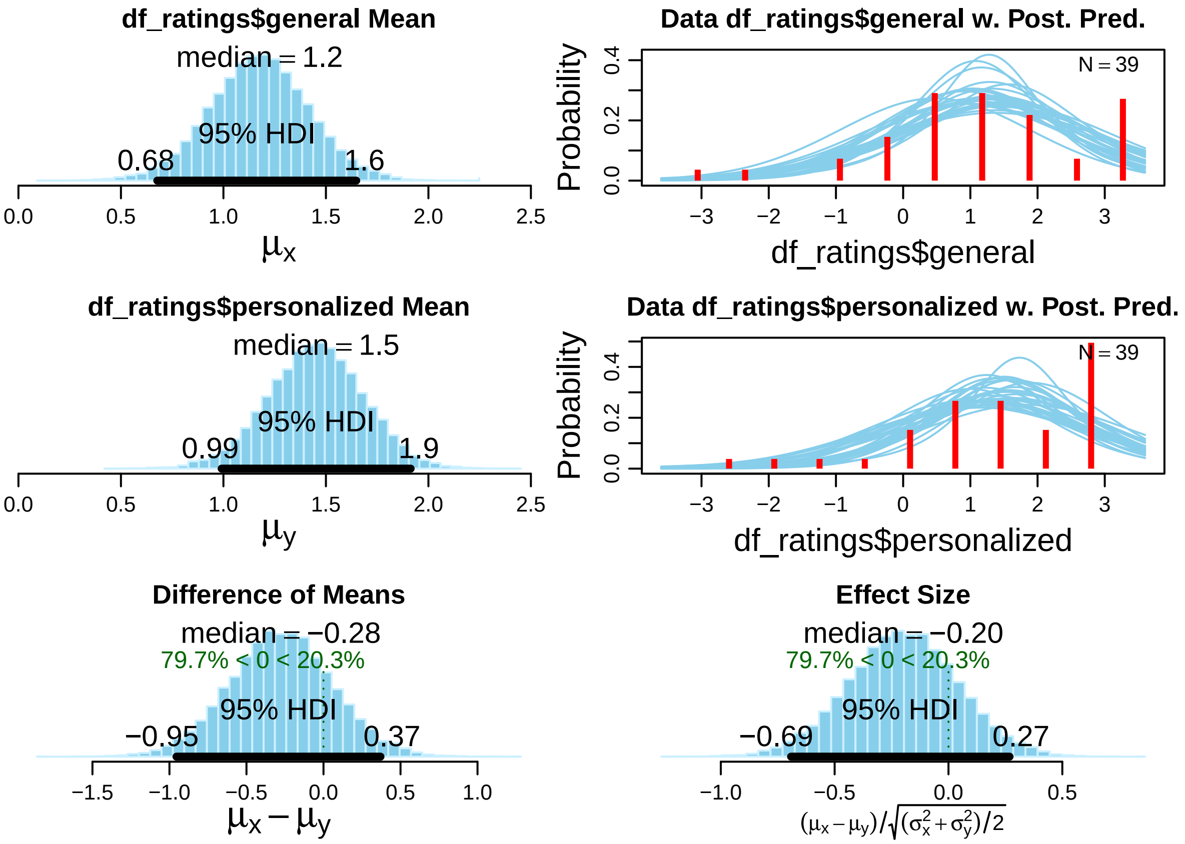
H3: The personalized examples are perceived as more motivating than the general examples.

To check whether the personalized examples are perceived as more motivating than the general examples, a Bayesian two-sample t-test was conducted for the motivation rating measure.

```
set.seed(22)

# Table 4.4
fit3 <- bayes.t.test(df_ratings$general, df_ratings$personalized)
show(fit3)
```

```
##
##  Bayesian estimation supersedes the t test (BEST) - two sample
##
## data: df_ratings$general (n = 39) and df_ratings$personalized (n = 39)
##
##   Estimates [95% credible interval]
## mean of df_ratings$general: 1.2 [0.68, 1.6]
## mean of df_ratings$personalized: 1.5 [0.99, 1.9]
## difference of the means: -0.28 [-0.95, 0.37]
## sd of df_ratings$general: 1.4 [1.0, 1.8]
## sd of df_ratings$personalized: 1.3 [1.0, 1.7]
##
## The difference of the means is greater than 0 by a probability of 0.203
## and less than 0 by a probability of 0.797
```

```
plot(fit3)
```



df_ratings$general Mean

Data df_ratings$general w. Post. Pred.

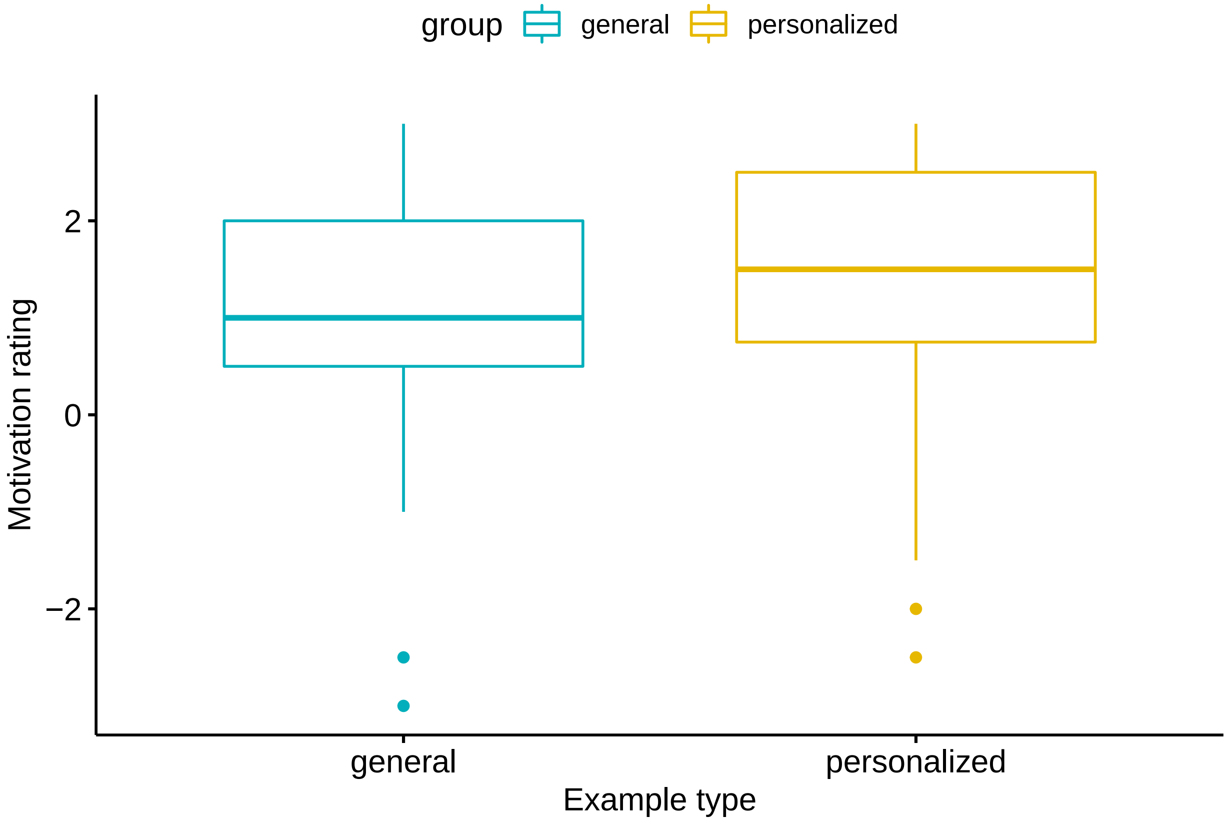
df_ratings$personalized Mean

Data df_ratings$personalized w. Post. Pred.

Difference of Means

Effect Size

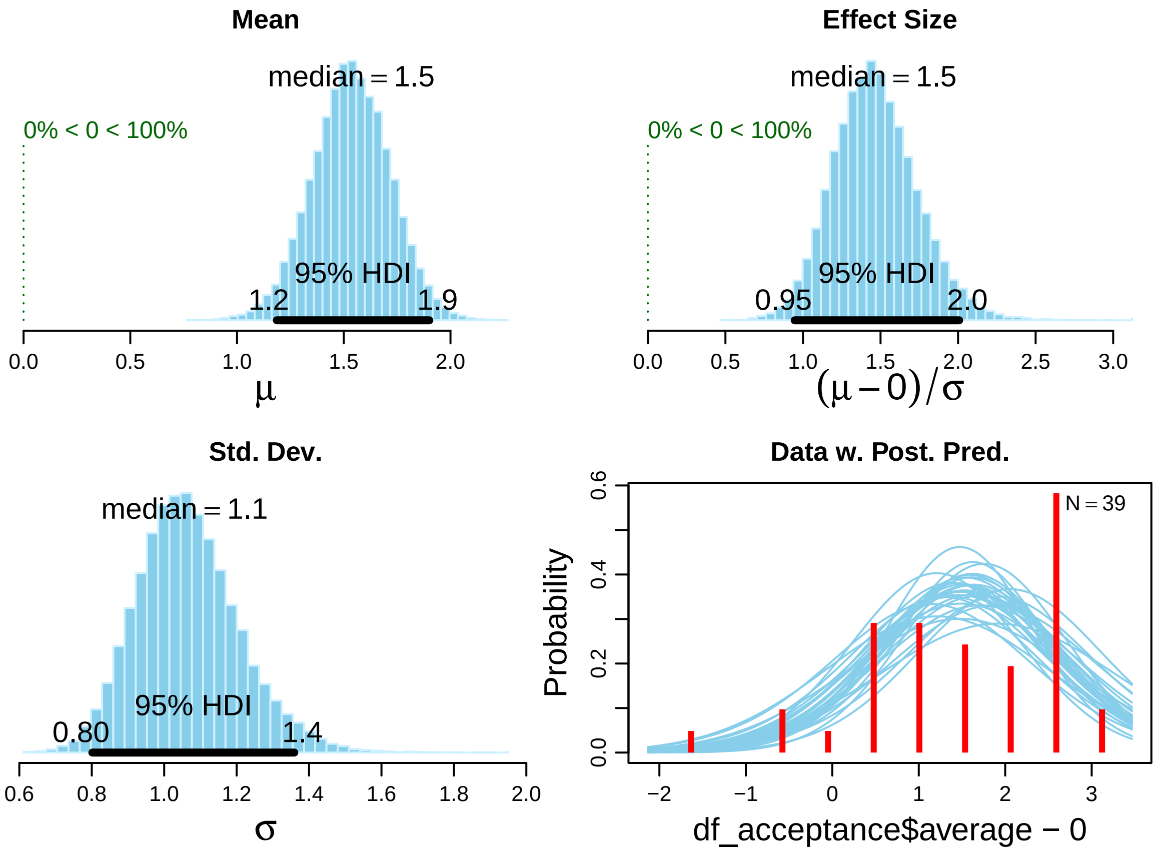
```
df_ratings_plot <- df_ratings %>%
 gather(key = "group", value = "rating", general, personalized) %>%
 convert_as_factor(id, group)

# Figure 4.4
ggboxplot(df_ratings_plot, x = "group", y = "rating",
          color = "group", palette = c("#00AFBB", "#E7B800"),
        ylab = "Motivation rating", xlab = "Example type")
```

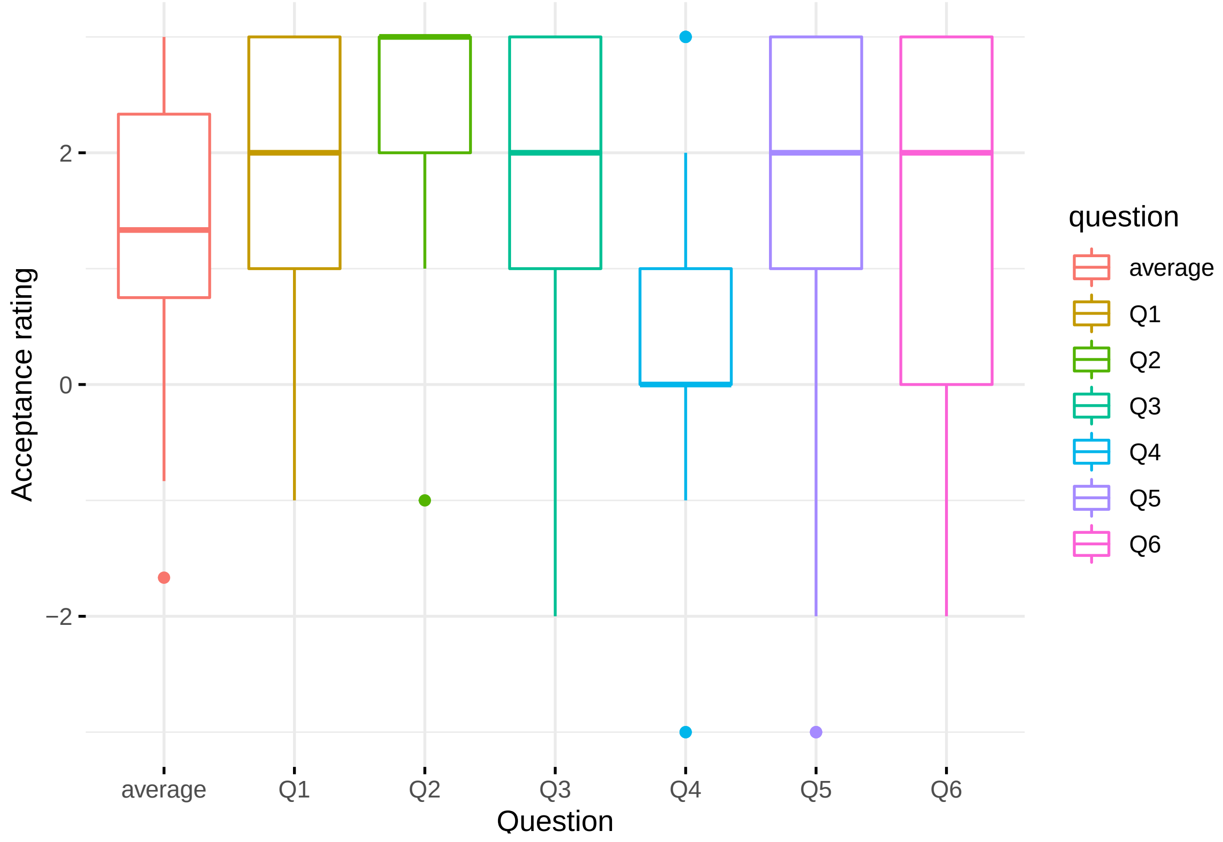


H4: People have a positive attitude towards the virtual coach.

For the last hypothesis, we conducted a Bayesian one-sample t-test of the participants' responses to the acceptance questionnaire.

```
##
##  Bayesian estimation supersedes the t test (BEST) - one sample
##
## data: df_acceptance$average - 0, n = 39
##
##   Estimates [95% credible interval]
## mean of df_acceptance$average - 0: 1.5 [1.2, 1.9]
## sd of df_acceptance$average - 0: 1.1 [0.80, 1.4]
##
## The mean is more than 0 by a probability of >0.999
## and less than 0 by a probability of <0.001
```


Mean
median = 1.5
0% < 0 < 100%
95% HDI
1.2
1.9
0.0
0.5
1.0
1.5
2.0
μ
Effect Size
median = 1.5
0% < 0 < 100%
95% HDI
0.95
2.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
(μ − 0)/σ
Std. Dev.
median = 1.1
95% HDI
0.80
1.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
σ
Data w. Post. Pred.
N = 39
Probability
0.0
0.2
0.4
0.6
−2
−1
0
1
2
3
df_acceptance$average − 0


Acceptance rating
2
0
−2
average
Q1
Q2
Q3
Q4
Q5
Q6
Question
question
average
Q1
Q2
Q3
Q4
Q5
Q6

```
## # A tibble: 7 x 5
##   question variable     n  mean    sd
##   <fct>    <chr>    <dbl> <dbl> <dbl>
## 1 average  rating      39 1.5   1.09
## 2 Q1       rating      39 1.85  1.16
## 3 Q2       rating      39 2.54  0.822
## 4 Q3       rating      39 1.62  1.44
## 5 Q4       rating      39 0.436 1.35
## 6 Q5       rating      39 1.26  1.85
## 7 Q6       rating      39 1.31  1.59
```

```
##
##  Bayesian estimation supersedes the t test (BEST) - one sample
##
## data: df_acceptance$Q1 - 0, n = 39
##
##   Estimates [95% credible interval]
## mean of df_acceptance$Q1 - 0: 1.9 [1.5, 2.3]
## sd of df_acceptance$Q1 - 0: 1.1 [0.86, 1.5]
##
## The mean is more than 0 by a probability of >0.999
## and less than 0 by a probability of <0.001
```

```
##
##  Bayesian estimation supersedes the t test (BEST) - one sample
##
## data: df_acceptance$Q2 - 0, n = 39
##
##   Estimates [95% credible interval]
## mean of df_acceptance$Q2 - 0: 3.0 [3.0, 3.0]
## sd of df_acceptance$Q2 - 0: 0.00088 [0.00082, 0.0011]
##
## The mean is more than 0 by a probability of >0.999
## and less than 0 by a probability of <0.001
```

```
##
##  Bayesian estimation supersedes the t test (BEST) - one sample
##
## data: df_acceptance$Q3 - 0, n = 39
##
##   Estimates [95% credible interval]
## mean of df_acceptance$Q3 - 0: 1.7 [1.2, 2.2]
## sd of df_acceptance$Q3 - 0: 1.4 [1.1, 1.8]
##
## The mean is more than 0 by a probability of >0.999
## and less than 0 by a probability of <0.001
```

```
##
##  Bayesian estimation supersedes the t test (BEST) - one sample
##
## data: df_acceptance$Q4 - 0, n = 39
##
##   Estimates [95% credible interval]
## mean of df_acceptance$Q4 - 0: 0.43 [0.028, 0.87]
## sd of df_acceptance$Q4 - 0: 1.3 [0.85, 1.7]
##
## The mean is more than 0 by a probability of 0.978
## and less than 0 by a probability of 0.022
```

```
##
##  Bayesian estimation supersedes the t test (BEST) - one sample
##
## data: df_acceptance$Q5 - 0, n = 39
##
##   Estimates [95% credible interval]
## mean of df_acceptance$Q5 - 0: 1.4 [0.76, 2.1]
## sd of df_acceptance$Q5 - 0: 1.7 [1.0, 2.3]
##
## The mean is more than 0 by a probability of >0.999
## and less than 0 by a probability of <0.001
```

```
##
##  Bayesian estimation supersedes the t test (BEST) - one sample
##
## data: df_acceptance$Q6 - 0, n = 39
##
##   Estimates [95% credible interval]
## mean of df_acceptance$Q6 - 0: 1.4 [0.82, 1.9]
## sd of df_acceptance$Q6 - 0: 1.6 [1.2, 2.0]
##
## The mean is more than 0 by a probability of >0.999
## and less than 0 by a probability of <0.001
```

Compute the Cronbach alpha value for the acceptance questionnaire

```r
library(ltm)
```

```
## Loading required package: MASS
```

```
##
## Attaching package: 'MASS'
```

```
## The following object is masked from 'package:dplyr':
##
##     select
```

```
## The following object is masked from 'package:rstatix':
##
##     select
```

```
## Loading required package: msm
```

```
## Loading required package: polycor
```

```r
df_acc_questions <- df_acceptance[c("Q1","Q2","Q3","Q4","Q5","Q6")]
cronbach.alpha(df_acc_questions, CI=TRUE)
```

```
##
## Cronbach's alpha for the 'df_acc_questions' data-set
##
## Items: 6
## Sample units: 39
## alpha: 0.866
##
## Bootstrap 95% CI based on 1000 samples
##  2.5% 97.5%
## 0.780 0.919
```

In the following code blocks, we check if there are major differences in variables between the two groups (general and personalized group). We use Bayesian t-tests and Bayesian test of proportions.

```r
set.seed(22)
# Check difference between the two groups for running or walking self-efficacy
bayes.t.test(pre ~ group, data = df_user)
```

```
##
##  Bayesian estimation supersedes the t test (BEST) - two sample
##
## data: group general (n = 20) and group personalized (n = 19)
##
##   Estimates [95% credible interval]
## mean of group general: 75 [61, 90]
## mean of group personalized: 66 [54, 78]
## difference of the means: 9.6 [-9.3, 28]
## sd of group general: 31 [20, 43]
## sd of group personalized: 25 [17, 35]
##
## The difference of the means is greater than 0 by a probability of 0.843
## and less than 0 by a probability of 0.157
```

```r
# Check difference between the two groups for age
bayes.t.test(age ~ group, data = df_user)
```

```
##
##  Bayesian estimation supersedes the t test (BEST) - two sample
##
## data: group general (n = 20) and group personalized (n = 19)
##
##   Estimates [95% credible interval]
## mean of group general: 44 [36, 53]
## mean of group personalized: 38 [31, 46]
## difference of the means: 6.0 [-5.5, 17]
## sd of group general: 18 [13, 26]
## sd of group personalized: 15 [10, 21]
##
## The difference of the means is greater than 0 by a probability of 0.854
## and less than 0 by a probability of 0.146
```

```r
# Check difference between the two groups for Godin leisure time activity score
bayes.t.test(godin_activity ~ group, data = df_user)
```

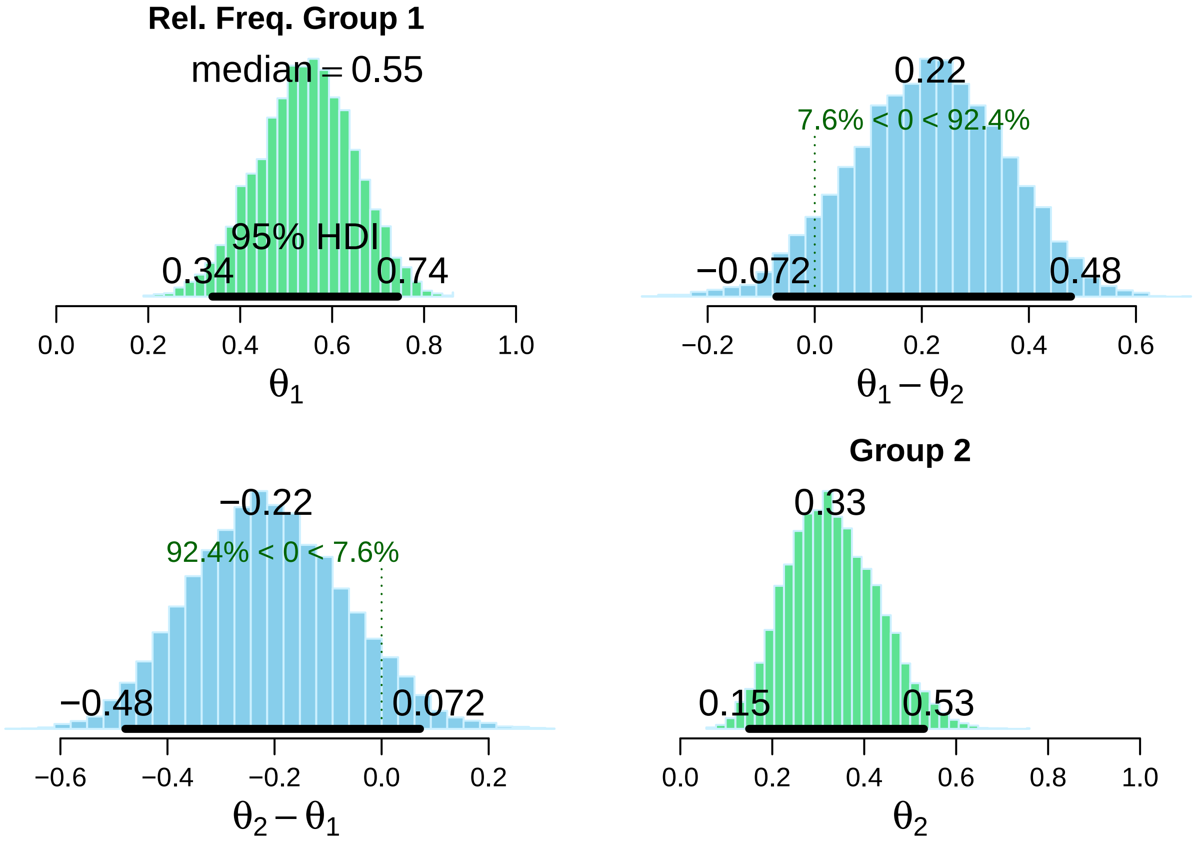
```
##
##  Bayesian estimation supersedes the t test (BEST) - two sample
##
## data: group general (n = 20) and group personalized (n = 19)
##
##   Estimates [95% credible interval]
## mean of group general: 35 [19, 50]
## mean of group personalized: 30 [19, 42]
## difference of the means: 4.3 [-15, 23]
## sd of group general: 32 [21, 46]
## sd of group personalized: 22 [15, 32]
##
```

```
## The difference of the means is greater than 0 by a probability of 0.678
## and less than 0 by a probability of 0.322
```

```
set.seed(22)
# Check difference between the two groups for smoke variable
df_smoker <- read.csv(file =  'smoker.csv', sep=";", dec=",")

smoker <- as.vector(df_smoker[,2])
smoker_sum <- rowSums(df_smoker[,c("Smoker", "Non.smoker")])
fit <- bayes.prop.test(smoker, smoker_sum)
fit
```

```
##
##  Bayesian First Aid proportion test
##
## data: smoker out of smoker_sum
## number of successes:  11,  6
## number of trials:     20, 19
## Estimated relative frequency of success [95% credible interval]:
##   Group 1: 0.55 [0.34, 0.74]
##   Group 2: 0.33 [0.15, 0.53]
## Estimated group difference (Group 1 - Group 2):
##   0.22 [-0.072, 0.48]
## The relative frequency of success is larger for Group 1 by a probability
## of 0.924 and larger for Group 2 by a probability of 0.076 .
```

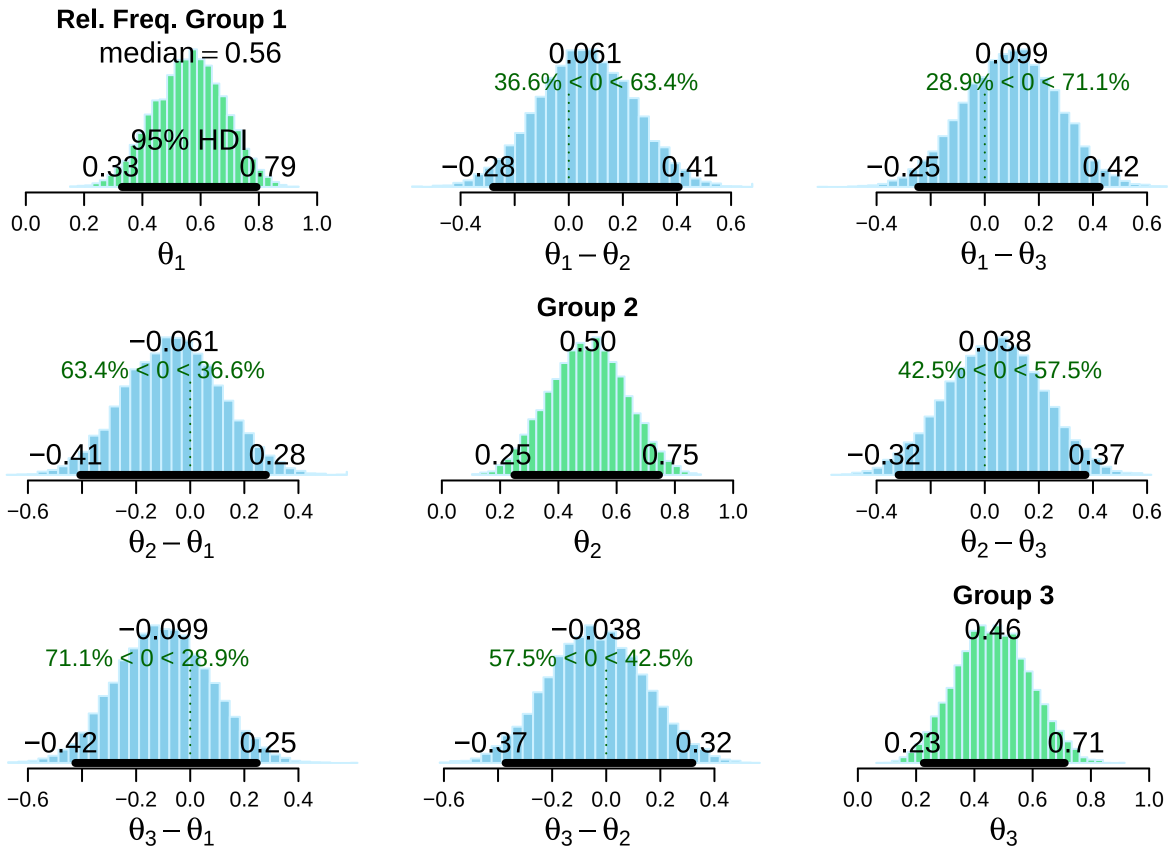
```
plot(fit)
```



```
set.seed(22)
# Check difference between the two groups for weekly exercise variable
df_weekly_exercise <- read.csv(file =  'weekly_exercise.csv', sep=";", dec=",")

weekly_exercise <- as.vector(df_weekly_exercise[,2])
weekly_exercise_sum <- rowSums(df_weekly_exercise[,c("General", "Personalized")])
fit2 <- bayes.prop.test(weekly_exercise, weekly_exercise_sum)
fit2
```

```
##
##  Bayesian First Aid proportion test
##
## data: weekly_exercise out of weekly_exercise_sum
## number of successes:   8,  6,  6
## number of trials:     14, 12, 13
## Estimated relative frequency of success [95% credible interval]:
##   Group 1: 0.56 [0.33, 0.79]
##   Group 2: 0.50 [0.25, 0.75]
##   Group 3: 0.46 [0.23, 0.71]
## Estimated pairwise group differences (row - column) with 95 % cred. intervals:
##               Group
##           2             3
##   1     0.06           0.1
##     [-0.28, 0.41] [-0.25, 0.42]
##   2                   0.04
##                     [-0.32, 0.37]
```

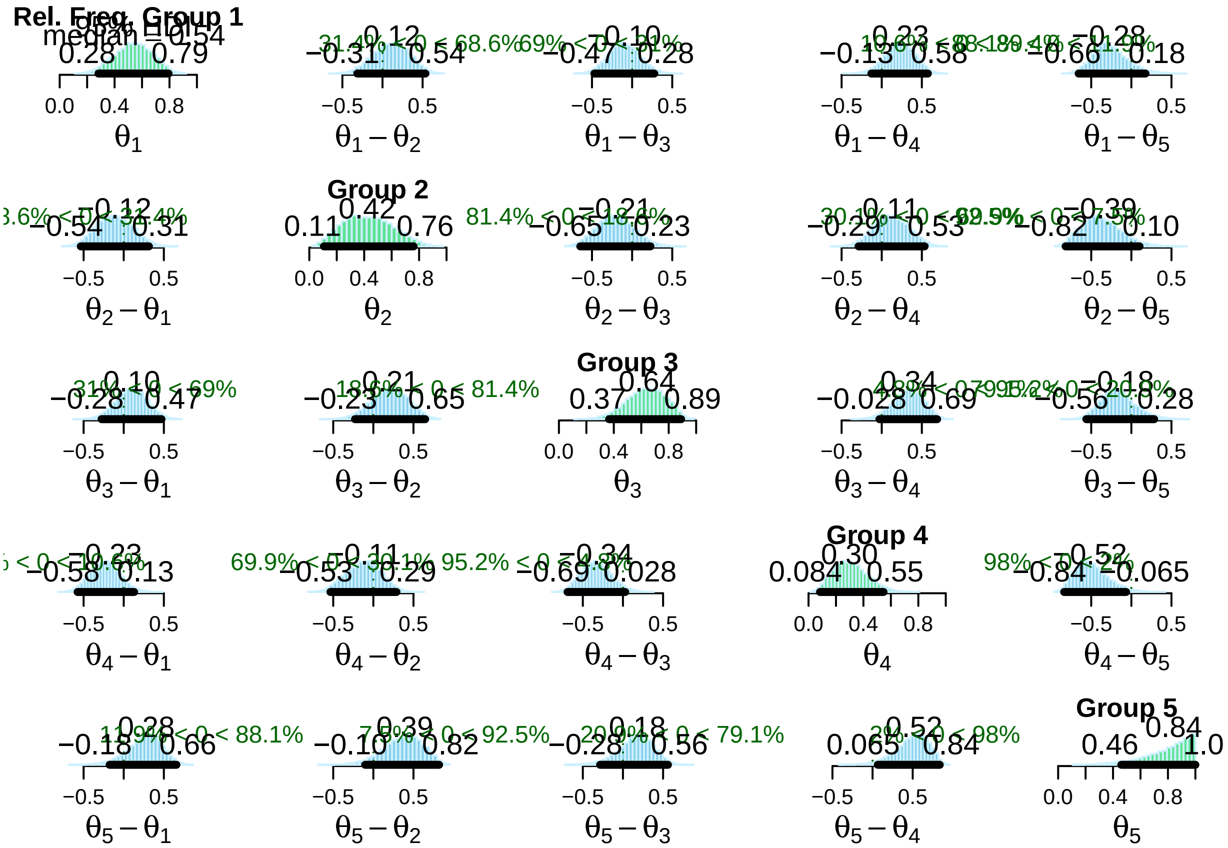
```
plot(fit2)
```



```r
# Check difference between the two groups for the TTM-phase variable
df_ttm_phase <- read.csv(file =  'ttm_phase.csv', sep=";", dec=",")

ttm_phase <- as.vector(df_ttm_phase[,2])
ttm_phase_sum <- rowSums(df_ttm_phase[,c("General", "Personalized")])
fit3 <- bayes.prop.test(ttm_phase, ttm_phase_sum)
fit3
```

```
##
##  Bayesian First Aid proportion test
##
## data: ttm_phase out of ttm_phase_sum
## number of successes:   6,  2,  6,  3,  3
## number of trials:     11,  5,  9, 11,  3
## Estimated relative frequency of success [95% credible interval]:
##   Group 1: 0.54 [0.28, 0.79]
##   Group 2: 0.42 [0.11, 0.76]
##   Group 3: 0.64 [0.37, 0.89]
##   Group 4: 0.30 [0.084, 0.55]
##   Group 5: 0.84 [0.46, 1.0]
## Estimated pairwise group differences (row - column) with 95 % cred. intervals:
##                               Group
##           2               3               4               5
##   1      0.12            -0.1            0.23           -0.28
##     [-0.31, 0.54]   [-0.47, 0.28]   [-0.13, 0.58]   [-0.66, 0.18]
##   2                      -0.21           0.11           -0.39
##                     [-0.65, 0.23]   [-0.29, 0.53]   [-0.82, 0.1]
##   3                                        0.34          -0.18
##                                  [-0.028, 0.69]   [-0.56, 0.28]
##   4                                                      -0.52
##                                                 [-0.84, -0.065]
```

```
plot(fit3)
```


Rel. Freq. Group 1
95% HDI
median = 0.54
θ_1
31.4% < 0 < 68.6%
$\theta_1 - \theta_2$
69% < 0 < 31%
$\theta_1 - \theta_3$
$\theta_1 - \theta_4$
88.1% < 0 < 11.9%
$\theta_1 - \theta_5$
$\theta_2 - \theta_1$
Group 2
θ_2
81.4% < 0 < 18.6%
$\theta_2 - \theta_3$
30.1% < 0 < 69.9%
$\theta_2 - \theta_4$
92.5% < 0 < 7.5%
$\theta_2 - \theta_5$
31% < 0 < 69%
$\theta_3 - \theta_1$
18.6% < 0 < 81.4%
$\theta_3 - \theta_2$
Group 3
θ_3
4.8% < 0 < 95.2%
$\theta_3 - \theta_4$
79.1% < 0 < 20.9%
$\theta_3 - \theta_5$
$\theta_4 - \theta_1$
69.9% < 0 < 30.1%
$\theta_4 - \theta_2$
95.2% < 0 < 4.8%
$\theta_4 - \theta_3$
Group 4
θ_4
98% < 0 < 2%
$\theta_4 - \theta_5$
11.9% < 0 < 88.1%
$\theta_5 - \theta_1$
7.5% < 0 < 92.5%
$\theta_5 - \theta_2$
20.9% < 0 < 79.1%
$\theta_5 - \theta_3$
2% < 0 < 98%
$\theta_5 - \theta_4$
Group 5
θ_5