Statistical analysis of robot behavior and perception data

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R script for

M. T. Parreira, S. Gillet, K. Winkle and I. Leite, "How Did We Miss This? A Case Study on Unintended Biases in Robot Social Behavior," 2023 18th ACM/IEEE International Conference on Human-Robot Interaction (HRI), Stockholm, Sweden, 2023

Data sources in this repository.

```
## Imports


if (!require("car")) install.packages("car")
```

```
## Loading required package: car
```

```
## Loading required package: carData
```

```
if (!require("pastecs")) install.packages("pastecs")
```

```
## Loading required package: pastecs
```

```
## Warning: package 'pastecs' was built under R version 4.2.2
```

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.2 --
```

```
## v ggplot2 3.3.6     v purrr   0.3.4
## v tibble  3.1.8     v dplyr   1.0.9
## v tidyr   1.2.0     v stringr 1.4.0
## v readr   2.1.2     v forcats 0.5.1
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x tidyr::extract() masks pastecs::extract()
## x dplyr::filter()  masks stats::filter()
## x dplyr::first()   masks pastecs::first()
## x dplyr::lag()     masks stats::lag()
## x dplyr::last()    masks pastecs::last()
## x dplyr::recode()  masks car::recode()
## x purrr::some()    masks car::some()
```

```
library(lme4)
```

```
## Loading required package: Matrix
##
## Attaching package: 'Matrix'
##
## The following objects are masked from 'package:tidyr':
##
```

```
##     expand, pack, unpack
```

```
library(car)
library(pastecs)
```

General Analyses

Perception of Robot

```
questionnaires_org <- read_csv("df_postq.csv")
```

```
## Rows: 90 Columns: 50
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr  (7): Timestamp, What was it like to speak with the robot? Describe posi...
## dbl (43): Participant Number, Thinking aloud has helped me complete the task...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
#filter for 2 cond
questionnaires_org <- questionnaires_org %>% filter(condition != "rubberduck")

questionnaires <- questionnaires_org %>%
  mutate(condition = factor(condition, levels=c('naive','datadriven'))) %>%
  mutate(listening_behavior = as.numeric(listening_behavior))%>%
  mutate(closeness = as.numeric(closeness))%>%
  mutate(competence = as.numeric(competence))%>%
  mutate(warmth = as.numeric(warmth))%>%
  mutate(discomfort = as.numeric(discomfort))

#checking data normality and homogeneity
by(questionnaires[, c("listening_behavior","closeness","competence","warmth","discomfort")], questionnai
```

```
## questionnaires$condition: naive
##              listening_behavior   closeness competence     warmth   discomfort
## median                3.0000000  2.50000000  4.8333333  4.6666667  2.500000000
## mean                  2.9051724  2.59195402  4.5459770  4.3850575  2.655172414
## SE.mean               0.1919780  0.12312808  0.3018707  0.3438512  0.268019331
## CI.mean.0.95          0.3932492  0.25221643  0.6183541  0.7043473  0.549012712
## var                   1.0688116  0.43965517  2.6426519  3.4287767  2.083196497
## std.dev               1.0338334  0.66306498  1.6256235  1.8516956  1.443328271
## coef.var              0.3558596  0.25581665  0.3575961  0.4222740  0.543591167
## skewness             -0.2450445  0.01840162 -0.1648141 -0.2335330  0.659781984
## skew.2SE             -0.2826043  0.02122218 -0.1900764 -0.2693284  0.760911794
## kurtosis             -0.8673683 -1.08754166 -1.2875600 -1.2799240 -0.905183436
## kurt.2SE             -0.5130904 -0.64333364 -0.7616542 -0.7571371 -0.535459903
## normtest.W            0.9660794  0.97092107  0.9503647  0.9279383  0.892703781
## normtest.p            0.4588851  0.58493458  0.1870759  0.0486604  0.006581138
## ------------------------------------------------------------
## questionnaires$condition: datadriven
##              listening_behavior   closeness competence     warmth  discomfort
## median                3.0000000  2.33333333  4.8333333  3.8333333  2.33333333
## mean                  3.0806452  2.37096774  4.8118280  3.8279570  2.83333333
```

```
## SE.mean               0.1388253  0.09393485  0.2533812  0.2884147  0.24416732
## CI.mean.0.95          0.2835191  0.19184056  0.5174734  0.5890214  0.49865620
## var                   0.5974462  0.27353644  1.9902628  2.5786738  1.84814815
## std.dev               0.7729465  0.52300711  1.4107668  1.6058250  1.35946613
## coef.var              0.2509041  0.22058803  0.2931873  0.4194992  0.47981157
## skewness             -0.2734820  0.50579408  0.1257446  0.2425218  0.82918911
## skew.2SE             -0.3251585  0.60136769  0.1495050  0.2883482  0.98587066
## kurtosis             -0.6058372 -0.44618530 -1.0617467 -0.5712341 -0.04665003
## kurt.2SE             -0.3690514 -0.27179801 -0.6467731 -0.3479727 -0.02841731
## normtest.W            0.9784879  0.96707658  0.9645833  0.9778377  0.92303409
## normtest.p            0.7694075  0.44241475  0.3835769  0.7502260  0.02843696
```

```
print("listening_behavior")
```

```
## [1] "listening_behavior"
```

```
leveneTest(questionnaires$listening_behavior,questionnaires$condition)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  2.1433 0.1486
##       58
```

```
print("closeness")
```

```
## [1] "closeness"
```

```
leveneTest(questionnaires$closeness,questionnaires$condition)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  1.9706 0.1657
##       58
```

```
print("competence")
```

```
## [1] "competence"
```

```
leveneTest(questionnaires$competence,questionnaires$condition)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.8933 0.3485
##       58
```

```
print("warmth")
```

```
## [1] "warmth"
```

```
leveneTest(questionnaires$warmth,questionnaires$condition)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.8923 0.3488
##       58
```

```
print("discomfort")
```

```
## [1] "discomfort"
```

```r
leveneTest(questionnaires$discomfort,questionnaires$condition)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.1503 0.6996
##       58
```

```r
#perception of listener behavior (from Murray et al. (2021))
model1 <-aov(listening_behavior ~ condition, data = questionnaires)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: listening_behavior
##              Sum Sq Df  F value Pr(>F)
## (Intercept) 244.761  1 296.6790 <2e-16 ***
## condition     0.461  1   0.5592 0.4576
## Residuals    47.850 58
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
#plot(model1)

#perception of closeness with robot (from Murray et al. (2021))
model1 <-aov(closeness ~ condition, data = questionnaires)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: closeness
##              Sum Sq Df  F value Pr(>F)
## (Intercept) 194.829  1 550.7806 <2e-16 ***
## condition     0.732  1   2.0685 0.1557
## Residuals    20.516 58
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
#plot(model1)

#RoSAS
model1 <-aov(competence ~ condition, data = questionnaires)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: competence
##             Sum Sq Df  F value Pr(>F)
## (Intercept) 599.31  1 259.9813 <2e-16 ***
## condition     1.06  1   0.4594 0.5006
## Residuals   133.70 58
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
#plot(model1)

#RoSAS (not normal)
```

```
model1<-wilcox.test(warmth ~ condition, data = questionnaires, exact = FALSE,
correct= FALSE)
model1
```

```
##
##  Wilcoxon rank sum test
##
## data:  warmth by condition
## W = 543.5, p-value = 0.164
## alternative hypothesis: true location shift is not equal to 0
```

```
#RoSAS (not normal)
model1<-wilcox.test(discomfort ~ condition, data = questionnaires, exact = FALSE,
correct= FALSE)
model1
```

```
##
##  Wilcoxon rank sum test
##
## data:  discomfort by condition
## W = 410, p-value = 0.5585
## alternative hypothesis: true location shift is not equal to 0
```

Controlling for Effect of Gender

Robot Listening Behavior and Robot Perception Analyses

```
questionnaires_org <- read_csv('final_robot_logs.csv')
```

```
## Rows: 60 Columns: 51
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr (15): condition, gender, bc_freqs_per_min_t0, bc_freqs_per_min_vocal_t0,...
## dbl (36): participant, order, bc_count_t0, bc_freq_t0, bc_count_vocal_t0, bc...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
#filter for 2 cond
questionnaires_orgn <- questionnaires_org %>% filter(condition == "naive")
questionnaires_orgd<- questionnaires_org %>% filter(condition == "datadriven")

questionnairesn <- questionnaires_orgn %>%
  mutate(gender = factor(gender)) %>%
  mutate(talk_ratio = as.numeric(talk_ratio))%>%
  mutate(listening_behavior = as.numeric(listening_behavior))%>%
  mutate(closeness = as.numeric(closeness))%>%
  mutate(competence = as.numeric(competence))%>%
  mutate(warmth = as.numeric(warmth))%>%
  mutate(discomfort = as.numeric(discomfort))%>%
  mutate(bc_freq = as.numeric(bc_freq_all))

questionnairesd <- questionnaires_orgd %>%
  mutate(gender = factor(gender)) %>%
  mutate(talk_ratio = as.numeric(talk_ratio))%>%
```

```
  mutate(listening_behavior = as.numeric(listening_behavior))%>%
  mutate(closeness = as.numeric(closeness))%>%
  mutate(competence = as.numeric(competence))%>%
  mutate(warmth = as.numeric(warmth))%>%
  mutate(discomfort = as.numeric(discomfort))%>%
  mutate(bc_freq = as.numeric(bc_freq_all))

#checking stats per gender (NaiveL condition)
by(questionnairesn[, c("bc_freq", "talk_ratio","listening_behavior","closeness","competence","warmth","
```

```
## questionnairesn$gender: Female
##                 bc_freq talk_ratio listening_behavior  closeness competence
## median       2.08883553  1.2871109          3.0000000  2.5000000  5.1666667
## mean         2.18589871  1.5778822          2.9444444  2.5925926  4.6666667
## SE.mean      0.25737783  0.3206889          0.3674655  0.2062135  0.6028482
## CI.mean.0.95 0.59351434  0.7395099          0.8473769  0.4755292  1.3901704
## var          0.59619013  0.9255722          1.2152778  0.3827160  3.2708333
## std.dev      0.77213349  0.9620666          1.1023964  0.6186405  1.8085445
## coef.var     0.35323388  0.6097202          0.3743988  0.2386185  0.3875453
## skewness     1.43898024  0.8134285         -0.2101882  0.6512570 -0.2034848
## skew.2SE     1.00328104  0.5671359         -0.1465468  0.4540672 -0.1418730
## kurtosis     1.10685089 -0.7431266         -0.9294234 -0.7465410 -1.4593891
## kurt.2SE     0.39538624 -0.2654576         -0.3320061 -0.2666773 -0.5213190
## normtest.W   0.77380345  0.8955695          0.9744767  0.9303753  0.9461403
## normtest.p   0.01021893  0.2274250          0.9300716  0.4849279  0.6477980
##                  warmth discomfort
## median        3.83333333  2.3333333
## mean          3.77777778  2.3333333
## SE.mean       0.61988649  0.4303315
## CI.mean.0.95  1.42946081  0.9923462
## var           3.45833333  1.6666667
## std.dev       1.85965947  1.2909944
## coef.var      0.49226280  0.5532833
## skewness      0.02474174  0.7588178
## skew.2SE      0.01725035  0.5290605
## kurtosis     -1.83338560 -0.6077778
## kurt.2SE     -0.65491697 -0.2171087
## normtest.W    0.87663556  0.8978525
## normtest.p    0.14469093  0.2398143
## ------------------------------------------------------------
## questionnairesn$gender: Male
##                  bc_freq talk_ratio listening_behavior  closeness competence
## median        4.32932159 1.13486023          2.8750000  2.5833333  4.5833333
## mean          4.10222617 1.46734585          2.8875000  2.5916667  4.4916667
## SE.mean       0.32307291 0.21322313          0.2304708  0.1560079  0.3540647
## CI.mean.0.95  0.67619938 0.44628113          0.4823809  0.3265282  0.7410660
## var           2.08752214 0.90928203          1.0623355  0.4867690  2.5072368
## std.dev       1.44482599 0.95356281          1.0306966  0.6976883  1.5834257
## coef.var      0.35220535 0.64985552          0.3569512  0.2692045  0.3525252
## skewness     -0.07332227 1.00870969         -0.2462986 -0.1810987 -0.1438882
## skew.2SE     -0.07158933 0.98486928         -0.2404775 -0.1768185 -0.1404875
## kurtosis     -0.80224795 0.18703677         -1.0941428 -1.3656684 -1.4244206
## kurt.2SE     -0.40420254 0.09423612         -0.5512701 -0.6880749 -0.7176764
## normtest.W    0.98329716 0.89762924          0.9545522  0.9487365  0.9408143
```

```
## normtest.p    0.96926647 0.03723542          0.4414902  0.3483177  0.2484200
##                   warmth  discomfort
## median        4.9166667  2.58333333
## mean          4.6583333  2.80000000
## SE.mean       0.4088700  0.33890087
## CI.mean.0.95  0.8557748  0.70932768
## var           3.3434942  2.29707602
## std.dev       1.8285224  1.51561078
## coef.var      0.3925272  0.54128956
## skewness     -0.3639378  0.53117680
## skew.2SE     -0.3553363  0.51862267
## kurtosis     -1.1126684 -1.22387334
## kurt.2SE     -0.5606040 -0.61663319
## normtest.W    0.9209870  0.89656600
## normtest.p    0.1035172  0.03557388
```

```
print("listening_behavior")
```

```
## [1] "listening_behavior"
```

```
leveneTest(questionnairesn$listening_behavior,questionnairesn$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.0571 0.8129
##       27
```

```
print("closeness")
```

```
## [1] "closeness"
```

```
leveneTest(questionnairesn$closeness,questionnairesn$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  1.2261 0.2779
##       27
```

```
print("competence")
```

```
## [1] "competence"
```

```
leveneTest(questionnairesn$competence,questionnairesn$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.0543 0.8175
##       27
```

```
print("warmth")
```

```
## [1] "warmth"
```

```
leveneTest(questionnairesn$warmth,questionnairesn$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.0878 0.7693
##       27
```

```
print("discomfort")
```

```
## [1] "discomfort"
```

```
leveneTest(questionnairesn$discomfort,questionnairesn$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.6878 0.4142
##       27
```

```
print("bc_freq")
```

```
## [1] "bc_freq"
```

```
leveneTest(questionnairesn$bc_freq,questionnairesn$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value  Pr(>F)
## group  1  4.2889 0.04804 *
##       27
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
print("talk_ratio")
```

```
## [1] "talk_ratio"
```

```
leveneTest(questionnairesn$bc_freq,questionnairesn$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value  Pr(>F)
## group  1  4.2889 0.04804 *
##       27
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#checking stats per gender (DataL condition)

by(questionnairesd[, c("bc_freq", "talk_ratio","listening_behavior","closeness","competence","warmth","
```

```
## questionnairesd$gender: Female
##                  bc_freq   talk_ratio listening_behavior  closeness
## median        2.2400922 1.081129e+00          3.5000000  2.3333333
## mean          2.8236437 1.548900e+00          3.2916667  2.3796296
## SE.mean       0.5306233 3.238284e-01          0.1844108  0.1233501
## CI.mean.0.95  1.1195173 6.832182e-01          0.3890728  0.2602459
## var           5.0680998 1.887567e+00          0.6121324  0.2738744
## std.dev       2.2512441 1.373888e+00          0.7823889  0.5233301
## coef.var      0.7972833 8.870088e-01          0.2376878  0.2199208
## skewness      0.7195821 2.280558e+00         -0.8307320  0.2636827
## skew.2SE      0.6709042 2.126284e+00         -0.7745350  0.2458452
## kurtosis     -0.6713821 5.011034e+00          0.2808079 -1.3060430
## kurt.2SE     -0.3234656 2.414269e+00          0.1352906 -0.6292394
## normtest.W    0.9145741 6.819677e-01          0.9247077  0.9422272
## normtest.p    0.1036206 4.964813e-05          0.1566210  0.3162195
##                  competence     warmth discomfort
## median        4.8333333333  3.8333333  2.6666667
```

```
## mean          4.9444444444  3.9166667  2.9259259
## SE.mean       0.3694978830  0.4069677  0.3076199
## CI.mean.0.95  0.7795723895  0.8586268  0.6490214
## var           2.4575163399  2.9812092  1.7033406
## std.dev       1.5676467523  1.7266178  1.3051209
## coef.var      0.3170521521  0.4408386  0.4460540
## skewness      0.0007121276  0.2377440  0.3995598
## skew.2SE      0.0006639539  0.2216612  0.3725305
## kurtosis     -1.2643844809 -0.6514405 -1.1584576
## kurt.2SE     -0.6091686606 -0.3138580 -0.5581341
## normtest.W    0.9502278898  0.9737174  0.9425042
## normtest.p    0.4286029012  0.8639387  0.3196498
## ------------------------------------------------------------
## questionnairesd$gender: Male
##                  bc_freq talk_ratio listening_behavior closeness competence
## median        6.13287905 2.06330193          2.7500000 2.3333333  4.3333333
## mean          6.79650507 2.70007825          2.7884615 2.3589744  4.6282051
## SE.mean       1.10508554 0.54373551          0.1895638 0.1507887  0.3318095
## CI.mean.0.95  2.40777455 1.18469791          0.4130239 0.3285404  0.7229507
## var          15.87578257 3.84342801          0.4671474 0.2955840  1.4312678
## std.dev       3.98444257 1.96046627          0.6834818 0.5436764  1.1963561
## coef.var      0.58624874 0.72607758          0.2451107 0.2304715  0.2584924
## skewness      1.11821991 1.11401446          0.4161778 0.7512835  0.1695492
## skew.2SE      0.90715114 0.90373949          0.3376224 0.6094755  0.1375461
## kurtosis      0.50187737 0.28356561         -0.6575549 0.2426664 -1.3412359
## kurt.2SE      0.21071801 0.11905773         -0.2760807 0.1018858 -0.5631307
## normtest.W    0.87312433 0.86417549          0.9703644 0.9394294  0.9444716
## normtest.p    0.05759946 0.04374719          0.8985901 0.4495558  0.5173418
##                  warmth discomfort
## median        3.8333333 2.33333333
## mean          3.7051282 2.70512821
## SE.mean       0.4109236 0.40918664
## CI.mean.0.95  0.8953256 0.89154110
## var           2.1951567 2.17663818
## std.dev       1.4816061 1.47534341
## coef.var      0.3998799 0.54538761
## skewness      0.1261762 1.21232068
## skew.2SE      0.1023599 0.98349000
## kurtosis     -1.1647714 0.77498422
## kurt.2SE     -0.4890404 0.32538453
## normtest.W    0.9692994 0.86703251
## normtest.p    0.8857819 0.04774531
```

```
print("listening_behavior")
```

```
## [1] "listening_behavior"
```

```
leveneTest(questionnairesd$listening_behavior,questionnairesd$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.1141 0.7379
##       29
```

```
print("closeness")
```

```
## [1] "closeness"
```

```
leveneTest(questionnairesd$closeness,questionnairesd$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.1918 0.6646
##       29
```

```
print("competence")
```

```
## [1] "competence"
```

```
leveneTest(questionnairesd$competence,questionnairesd$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  1.2028 0.2818
##       29
```

```
print("warmth")
```

```
## [1] "warmth"
```

```
leveneTest(questionnairesd$warmth,questionnairesd$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.1651 0.6875
##       29
```

```
print("discomfort")
```

```
## [1] "discomfort"
```

```
leveneTest(questionnairesd$discomfort,questionnairesd$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.0404 0.8422
##       29
```

```
print("bc_freq")
```

```
## [1] "bc_freq"
```

```
leveneTest(questionnairesd$bc_freq,questionnairesd$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  1.6511  0.209
##       29
```

```
print("talk_ratio")
```

```
## [1] "talk_ratio"
```

```
leveneTest(questionnairesd$bc_freq,questionnairesd$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  1.6511  0.209
```

```
##       29
```

```
#bc frequency (NaiveL)
model1 <-aov(bc_freq ~ gender + talk_ratio, data = questionnairesn)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: bc_freq
##             Sum Sq Df F value   Pr(>F)
## (Intercept) 21.302  1 12.4754 0.001563 **
## gender      22.825  1 13.3673 0.001138 **
## talk_ratio   0.037  1  0.0215 0.884531
## Residuals   44.396 26
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#plot(model1)

#bc frequency (DataL)
model1 <-aov(bc_freq ~ gender + talk_ratio, data = questionnairesd)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: bc_freq
##              Sum Sq Df F value   Pr(>F)
## (Intercept)  23.801  1  3.1202 0.088231 .
## gender       57.808  1  7.5782 0.010252 *
## talk_ratio   63.080  1  8.2693 0.007622 **
## Residuals   213.587 28
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#ROBOT PERCEPTION (NaiveL) - listening behavior (from Murray et al. (2021))
model1 <-aov(listening_behavior ~ gender + bc_freq, data = questionnairesn)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: listening_behavior
##             Sum Sq Df F value    Pr(>F)
## (Intercept) 33.943  1 29.9604 9.672e-06 ***
## gender       0.256  1  0.2263    0.6382
## bc_freq      0.451  1  0.3980    0.5336
## Residuals   29.456 26
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#plot(model1)

#ROBOT PERCEPTION (DataL) - listening behavior (from Murray et al. (2021))
model1 <-aov(listening_behavior ~ gender + bc_freq, data = questionnairesd)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
```

```
## Response: listening_behavior
##              Sum Sq Df  F value  Pr(>F)
## (Intercept) 135.123  1 240.0325 2.9e-15 ***
## gender        0.777  1   1.3809  0.2499
## bc_freq       0.250  1   0.4437  0.5108
## Residuals    15.762 28
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#plot(model1)

#ROBOT PERCEPTION (NaiveL) - closeness (from Murray et al. (2021))
model1 <-aov(closeness ~ gender + bc_freq, data = questionnairesn)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: closeness
##              Sum Sq Df F value    Pr(>F)
## (Intercept) 26.7667  1 57.8463 4.503e-08 ***
## gender       0.0960  1  0.2074    0.6526
## bc_freq      0.2796  1  0.6042    0.4440
## Residuals   12.0307 26
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#plot(model1)

#ROBOT PERCEPTION (DataL) - closeness (from Murray et al. (2021))
model1 <-aov(closeness ~ gender + bc_freq, data = questionnairesd)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: closeness
##             Sum Sq Df  F value    Pr(>F)
## (Intercept) 64.300  1 221.8704 7.775e-15 ***
## gender       0.044  1   0.1527    0.6989
## bc_freq      0.088  1   0.3044    0.5855
## Residuals    8.115 28
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#plot(model1)

#ROBOT PERCEPTION (NaiveL) - Competence (from RoSAS)
model1 <-aov(competence ~ gender + bc_freq, data = questionnairesn)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: competence
##             Sum Sq Df F value    Pr(>F)
## (Intercept) 80.533  1 29.1843 1.166e-05 ***
## gender       1.416  1  0.5130    0.4802
## bc_freq      2.058  1  0.7457    0.3957
```

```
## Residuals   71.746 26
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#plot(model1)

#ROBOT PERCEPTION (DataL) - Competence (from RoSAS)
model1 <-aov(competence ~ gender + bc_freq, data = questionnairesd)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: competence
##              Sum Sq Df  F value    Pr(>F)
## (Intercept) 293.214  1 139.3342 2.195e-12 ***
## gender        0.399  1   0.1894    0.6668
## bc_freq       0.030  1   0.0143    0.9057
## Residuals    58.923 28
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#plot(model1)

#ROBOT PERCEPTION (NaiveL) - Warmth (from RoSAS)
model1 <-aov(warmth ~ gender + bc_freq, data = questionnairesn)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: warmth
##             Sum Sq Df F value    Pr(>F)
## (Intercept) 65.435  1 18.6561 0.0002025 ***
## gender       3.211  1  0.9154 0.3474917
## bc_freq      0.000  1  0.0001 0.9939451
## Residuals   91.193 26
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#plot(model1)

#ROBOT PERCEPTION (DataL) - Warmth (from RoSAS)
model1 <-aov(warmth ~ gender + bc_freq, data = questionnairesd)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: warmth
##              Sum Sq Df F value    Pr(>F)
## (Intercept) 195.729  1 71.8540 3.233e-09 ***
## gender        0.000  1  0.0000    0.9950
## bc_freq       0.751  1  0.2757    0.6037
## Residuals    76.271 28
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#plot(model1)

#ROBOT PERCEPTION (NaiveL) - Discomfort (from RoSAS)
model1 <-aov(discomfort ~ gender + bc_freq, data = questionnairesn)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: discomfort
##             Sum Sq Df F value    Pr(>F)
## (Intercept) 30.423  1 14.0209 0.0009071 ***
## gender       1.909  1  0.8798 0.3568878
## bc_freq      0.562  1  0.2589 0.6151344
## Residuals   56.416 26
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#plot(model1)

#ROBOT PERCEPTION (DataL) - Discomfort (from RoSAS)
model1 <-aov(discomfort ~ gender + bc_freq, data = questionnairesd)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: discomfort
##             Sum Sq Df F value    Pr(>F)
## (Intercept) 83.557  1 44.5360 3.049e-07 ***
## gender       1.910  1  1.0183    0.3216
## bc_freq      2.544  1  1.3557    0.2541
## Residuals   52.533 28
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#plot(model1)
```

NaiveL - Analysis of Pitch Distribution

```
questionnaires_org <- read_csv("pitchesnewdf.csv")
```

```
## Rows: 22 Columns: 7
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr (1): gender
## dbl (6): participant, total, total_below_pitch, total_above_pitch, rel_below...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
questionnaires <- questionnaires_org %>%
  mutate(gender = factor(gender))%>%
  mutate(rel_below_pitch = as.numeric(rel_below_pitch)) %>%
  mutate(below_avg_size = as.numeric(below_avg_size))

by(questionnaires[, c("rel_below_pitch","below_avg_size")], questionnaires$gender, stat.desc, basic = F
```

```
## questionnaires$gender: Female
##              rel_below_pitch below_avg_size
## median           0.243279730     1.50277325
## mean             0.238803939     1.50434211
## SE.mean          0.013559529     0.06419866
## CI.mean.0.95     0.034855879     0.16502791
## var              0.001103165     0.02472881
## std.dev          0.033213927     0.15725396
## coef.var         0.139084503     0.10453337
## skewness        -0.061534503     0.04630657
## skew.2SE        -0.036404303     0.02739534
## kurtosis        -1.478930903    -2.17288664
## kurt.2SE        -0.424790561    -0.62411417
## normtest.W       0.980180258     0.84870215
## normtest.p       0.952450184     0.15364171
## ------------------------------------------------------------
## questionnaires$gender: Male
##              rel_below_pitch below_avg_size
## median          0.2830402990   1.7073776583
## mean            0.2989990818   1.7501124495
## SE.mean         0.0136431113   0.0812285617
## CI.mean.0.95    0.0290796034   0.1731345808
## var             0.0029781518   0.1055692677
## std.dev         0.0545724452   0.3249142466
## coef.var        0.1825170995   0.1856533543
## skewness        2.1885356211   1.9814378205
## skew.2SE        1.9391332669   1.7556360321
## kurtosis        4.6349786546   4.1562409061
## kurt.2SE        2.1246285514   1.9051798840
## normtest.W      0.7030959582   0.7517658334
## normtest.p      0.0001825701   0.0006672151
```

```
print("rel_below_pitch")
```

```
## [1] "rel_below_pitch"
```

```
leveneTest(questionnaires$rel_below_pitch,questionnaires$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.0909 0.7661
##       20
```

```
print("below_avgsize")
```

```
## [1] "below_avgsize"
```

```
leveneTest(questionnaires$below_avg_size,questionnaires$gender)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.4153 0.5266
##       20
```

```
#samples below 26th percentile (LowPitch)
model1<-wilcox.test(rel_below_pitch ~ gender, data = questionnaires, exact = FALSE,
correct= FALSE)
```

```
model1
```

```
##
##  Wilcoxon rank sum test
##
## data:  rel_below_pitch by gender
## W = 11, p-value = 0.006378
## alternative hypothesis: true location shift is not equal to 0
```

```
#consecutive duration below 26th percentile (LowPitchDuration)
model1<-wilcox.test(below_avg_size ~ gender, data = questionnaires, exact = FALSE,
correct= FALSE)
model1
```

```
##
##  Wilcoxon rank sum test
##
## data:  below_avg_size by gender
## W = 20, p-value = 0.039
## alternative hypothesis: true location shift is not equal to 0
```

DataL - Principal Component Analysis of State Space

```
questionnaires_org <- read_csv("pitchescompsdf.csv")
```

```
## Rows: 47276 Columns: 35
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr  (1): gender
## dbl (34): PC0, PC1, PC2, PC3, PC4, PC5, PC6, PC7, PC8, PC9, PC10, PC11, PC12...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
questionnaires <- questionnaires_org %>%
  mutate(gender = factor(gender))%>%
  mutate(pc0 = as.numeric(PC0)) %>%
  mutate(pc1 = as.numeric(PC1))

#PC0
model1 <-aov(pc0 ~ gender, data = questionnaires)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: pc0
##             Sum Sq    Df F value    Pr(>F)
## (Intercept)  41804     1 16386.8 < 2.2e-16 ***
## gender        7320     1  2869.3 < 2.2e-16 ***
## Residuals   120598 47274
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#plot(model1)

#PC1
```

```r
model1 <-aov(pc1 ~ gender, data = questionnaires)
Anova(model1, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: pc1
##             Sum Sq    Df F value    Pr(>F)
## (Intercept)    339     1  342.94 < 2.2e-16 ***
## gender        5187     1 5254.87 < 2.2e-16 ***
## Residuals    46667 47274
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
#plot(model1)
```