Statistical Tests on the Mental Model Difficulty Ratings

Required Packages

```
library(ggplot2)
library(haven)
library(easyGgplot2)
library(tidyr)
library(coin)
```

```
## Loading required package: survival
```

Extracting Mental Models

```
ourdf <- read.csv('our_mmq_ratings.csv')
ourdf <- ourdf[, -which(names(ourdf) == "Question.Text")]
ourdf <- ourdf[, -which(names(ourdf) == "Question.Number")]

gcsdf <- read.csv('gcs_mmq_ratings.csv')
gcsdf <- gcsdf[, -which(names(gcsdf) == "Question.Text")]
gcsdf <- gcsdf[, -which(names(gcsdf) == "Question.Number")]

dhdf <- read.csv('datahub_mmq_ratings.csv')
dhdf <- dhdf[, -which(names(dhdf) == "Question.Text")]
dhdf <- dhdf[, -which(names(dhdf) == "Question.Number")]
```

Carrying out the Mann-Whitney U Test

```
our_wilcox_tests <- function(n){
  our_n <- as.numeric(ourdf[n,])
  gcs_n <- as.numeric(gcsdf[n,])
  datahub_n <- as.numeric(dhdf[n,])

  our_vals <- c()
  gcs_vals <- c()
  datahub_vals <- c()
  for (i in 1:5){
    our_times <- our_n[i]
    our_vals <- append(our_vals, rep(i, our_times)); our_vals
    gcs_times <- gcs_n[i]
    gcs_vals <- append(gcs_vals, rep(i, gcs_times)); gcs_vals
    datahub_times <- datahub_n[i]
    datahub_vals <- append(datahub_vals, rep(i, datahub_times)); datahub_vals
  }
  #One-Sided Mann-Whitney U Significance Test for Whether our Median is Less
  #than that of the other mental model's
  w1 <- wilcox.test(our_vals, gcs_vals, alternative = "less")
```

```
  w2 <- wilcox.test(our_vals, datahub_vals, alternative = "less")

  print("Our MM vs GCS MM")
  print(w1)
  print("Our MM vs Datahub MM")
  print(w2)
}
```

```
our_wilcox_tests(1)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 304.5, p-value = 1.472e-05
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 289, p-value = 1.973e-06
## alternative hypothesis: true location shift is less than 0
```

```
our_wilcox_tests(2)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 446.5, p-value = 0.02004
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 434.5, p-value = 0.009427
## alternative hypothesis: true location shift is less than 0
```

```
our_wilcox_tests(3)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 313, p-value = 4.882e-05
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 408, p-value = 0.0006511
## alternative hypothesis: true location shift is less than 0
```

```
our_wilcox_tests(4)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 364.5, p-value = 0.001141
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 308, p-value = 1.066e-05
## alternative hypothesis: true location shift is less than 0
```

```
our_wilcox_tests(5)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
```

```
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 592.5, p-value = 0.2197
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 719.5, p-value = 0.5465
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(6)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 438, p-value = 0.02031
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 553, p-value = 0.1273
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(7)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 367, p-value = 0.03568
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
```

```
##
## data:  our_vals and datahub_vals
## W = 455, p-value = 0.1787
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(8)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties
```

```
## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties
```

```
## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 492, p-value = 0.2165
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 505, p-value = 0.215
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(9)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties
```

```
## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties
```

```
## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 312.5, p-value = 0.04825
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 365, p-value = 0.06548
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(10)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties
```

```
## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
```

```
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 604, p-value = 0.2086
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 654.5, p-value = 0.2239
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(11)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 594, p-value = 0.2962
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 913.5, p-value = 0.98
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(12)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 550.5, p-value = 0.2542
## alternative hypothesis: true location shift is less than 0
##
```

```
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 829.5, p-value = 0.9807
## alternative hypothesis: true location shift is less than 0
```

`our_wilcox_tests(13)`

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 322.5, p-value = 0.01334
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 304.5, p-value = 0.002631
## alternative hypothesis: true location shift is less than 0
```

`our_wilcox_tests(14)`

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 314, p-value = 0.0009313
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 431.5, p-value = 0.04183
## alternative hypothesis: true location shift is less than 0
```

`our_wilcox_tests(15)`

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 534, p-value = 0.1518
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 560.5, p-value = 0.1873
## alternative hypothesis: true location shift is less than 0
```

`our_wilcox_tests(16)`

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 558, p-value = 0.2181
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 548.5, p-value = 0.2343
## alternative hypothesis: true location shift is less than 0
```

`our_wilcox_tests(17)`

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
```

```
## data:  our_vals and gcs_vals
## W = 424.5, p-value = 0.06304
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 486, p-value = 0.1054
## alternative hypothesis: true location shift is less than 0
```

`our_wilcox_tests(18)`

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 458, p-value = 0.0106
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 518, p-value = 0.05281
## alternative hypothesis: true location shift is less than 0
```

`our_wilcox_tests(19)`

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 468.5, p-value = 0.1645
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
```

```
## W = 383.5, p-value = 0.01608
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(20)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties
```

```
## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties
```

```
## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 396.5, p-value = 0.05668
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 301, p-value = 4.631e-05
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(21)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties
```

```
## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties
```

```
## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 642.5, p-value = 0.6099
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 298, p-value = 3.299e-05
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(22)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties
```

```
## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties
```

```
## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 495, p-value = 0.04636
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 469, p-value = 0.00354
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(23)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 641, p-value = 0.3465
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 648.5, p-value = 0.1607
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(24)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 468, p-value = 0.03497
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
```

```
## 
##  Wilcoxon rank sum test with continuity correction
## 
## data:  our_vals and datahub_vals
## W = 535.5, p-value = 0.05224
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(25)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties
```

```
## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties
```

```
## [1] "Our MM vs GCS MM"
## 
##  Wilcoxon rank sum test with continuity correction
## 
## data:  our_vals and gcs_vals
## W = 650.5, p-value = 0.9284
## alternative hypothesis: true location shift is less than 0
## 
## [1] "Our MM vs Datahub MM"
## 
##  Wilcoxon rank sum test with continuity correction
## 
## data:  our_vals and datahub_vals
## W = 739, p-value = 0.9738
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(26)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
## compute exact p-value with ties
```

```
## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties
```

```
## [1] "Our MM vs GCS MM"
## 
##  Wilcoxon rank sum test with continuity correction
## 
## data:  our_vals and gcs_vals
## W = 446.5, p-value = 0.1914
## alternative hypothesis: true location shift is less than 0
## 
## [1] "Our MM vs Datahub MM"
## 
##  Wilcoxon rank sum test with continuity correction
## 
## data:  our_vals and datahub_vals
## W = 605, p-value = 0.3856
## alternative hypothesis: true location shift is less than 0
```

```r
our_wilcox_tests(27)
```

```
## Warning in wilcox.test.default(our_vals, gcs_vals, alternative = "less"): cannot
```

```
## compute exact p-value with ties

## Warning in wilcox.test.default(our_vals, datahub_vals, alternative = "less"):
## cannot compute exact p-value with ties

## [1] "Our MM vs GCS MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and gcs_vals
## W = 384, p-value = 0.002592
## alternative hypothesis: true location shift is less than 0
##
## [1] "Our MM vs Datahub MM"
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  our_vals and datahub_vals
## W = 637, p-value = 0.5094
## alternative hypothesis: true location shift is less than 0
```