IRT and CFA

Below, I will analyze the same dataset using both Item Response Theory (IRT) and Confirmatory Factor Analysis (CFA) to compare and contrast between the two.

The Data

The 2015-2016 NHANES Mental Health - Depression Screener.

Originally a rating scale (0, Not at all; 1, several days; 2, more than half the days; 3, nearly everyday)

Q1: "Have little interest in doing things"

Q2: "Feeling down, depressed, or hopeless"

Q3: "Trouble sleeping or sleeping too much"

Q4: "Feeling tired or having little energy"

Q5: "Poor appetite or overeating"

Q6: "Feeling bad about yourself"

Q7: "Trouble concentrating on things"

Q8: "Moving or speaking slowly or too fast"

Q9: "Thought you would be better off dead"

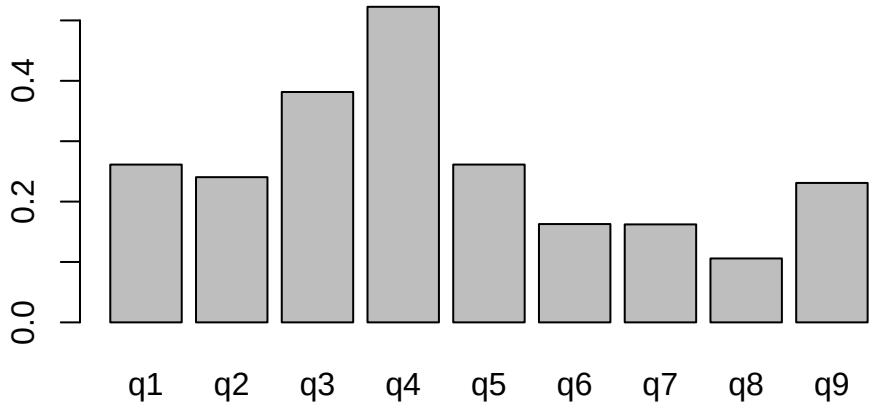
Q10: "Difficulty these problems have caused"

Looking at the questions, we clearly see that Q10 does not fit in with the rest. It violates the assumption of local independence (A participant's answer to Q10 depends on their answers to the other questions). In light of that, I had Q10 dropped from the data set.

Import Dataset

I opted to dichotomize the data by having any value above 0 changed to a 1.

```
Warning: The `value` argument of `names<-` must have the same length as `x` as of tibble
3.0.0.
```



This graph shows mean number of endorsements an answer received. Here, we can see that q4 ("Feeling tired or having little energy") had the most positive answers, while q9 ("Thought you would be better off dead") had very few endorsements.

Fit 1PL Model

Here, I fitted a 1PL (1-parameter logistic) model to estimate item difficulty based on how many people answered the items.

```
pl1 <- rasch(ds_dich)
kable(summary(pl1)$coefficients, digits=2)
```

	value	std.err	z.vals
Dffclt.q1	0.84	0.03	32.08
Dffclt.q2	0.92	0.03	34.44
Dffclt.q3	0.39	0.02	16.73
Dffclt.q4	-0.07	0.02	-3.27
Dffclt.q5	0.84	0.03	32.08
Dffclt.q6	1.29	0.03	41.90
Dffclt.q7	1.30	0.03	41.96
Dffclt.q8	1.65	0.04	45.67
Dffclt.q9	1.27	0.03	41.15
Dscrmn	2.04	0.04	57.81

Every item was fixed to have a discrimination parameter of 2.04.

Fit 2PL Model

Next, I fitted a 2PL model to estimate each item's discriminatory parameter.

```
pl2 <- ltm(ds_dich ~ z1)

kable(summary(pl2)$coefficients, digits=2)
```

	value	std.err	z.vals
Dffclt.q1	0.83	0.03	29.54
Dffclt.q2	0.81	0.02	33.91
Dffclt.q3	0.45	0.03	16.09
Dffclt.q4	-0.07	0.02	-3.03
Dffclt.q5	0.96	0.04	26.90
Dffclt.q6	1.18	0.03	38.60
Dffclt.q7	1.32	0.04	34.26
Dffclt.q8	1.67	0.05	34.05
Dffclt.q9	1.18	0.03	38.23
Dscrmn.q1	2.12	0.09	24.65
Dscrmn.q2	3.15	0.15	21.25
Dscrmn.q3	1.57	0.06	25.26
Dscrmn.q4	1.91	0.08	24.51
Dscrmn.q5	1.54	0.06	24.31
Dscrmn.q6	2.65	0.12	22.06
Dscrmn.q7	1.96	0.09	22.87

	value	std.err	z.vals
Dscrmn.q8	1.98	0.10	20.50
Dscrmn.q9	2.67	0.14	19.57

Here, I test to see if PL2 has a significantly better fit than PL1, by evaluating their model characteristics within an ANOVA.

```
anova(pl1, pl2)
```

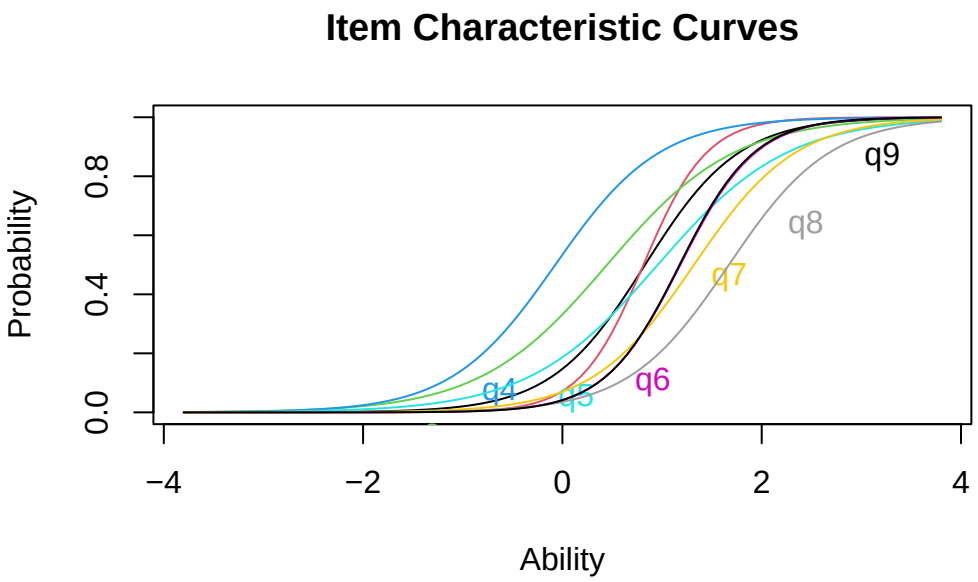
```
 Likelihood Ratio Table
         AIC      BIC   log.Lik    LRT df p.value
pl1 39736.28 39802.82 -19858.14
pl2 39516.84 39636.61 -19740.42 235.44  8  <0.001
```

The significant p-value in this chart tells us that the 2PL is a better fit to the data the 1PL. The fit of the model has been improved by estimating the discriminatory parameter of each item, instead of fixing it to one value.

Item Characteristic Curves

Below, I plotted the item characteristic curves of the 10 items to better see the discriminability across items

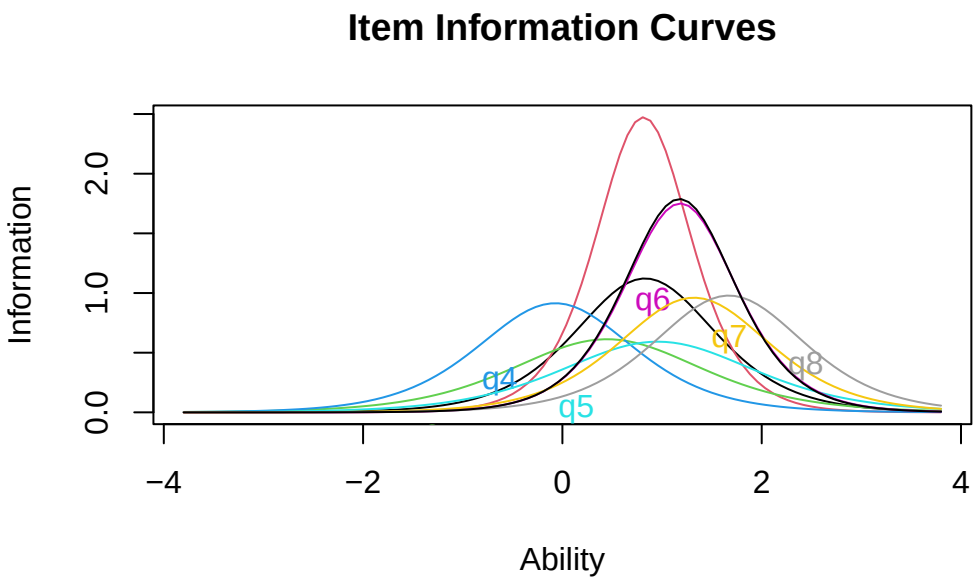
```
plot(pl2, type = c("ICC"))
```



In the ICCs, we can better see the probability of endorsing an answer at varying ability levels. We see that q4 ("Feeling tired or having little energy") has a range of abilities endorsing it, while with q9 ("Thought you would be better off dead"), only individuals with the highest depression level endorse it.

Item Information Curves

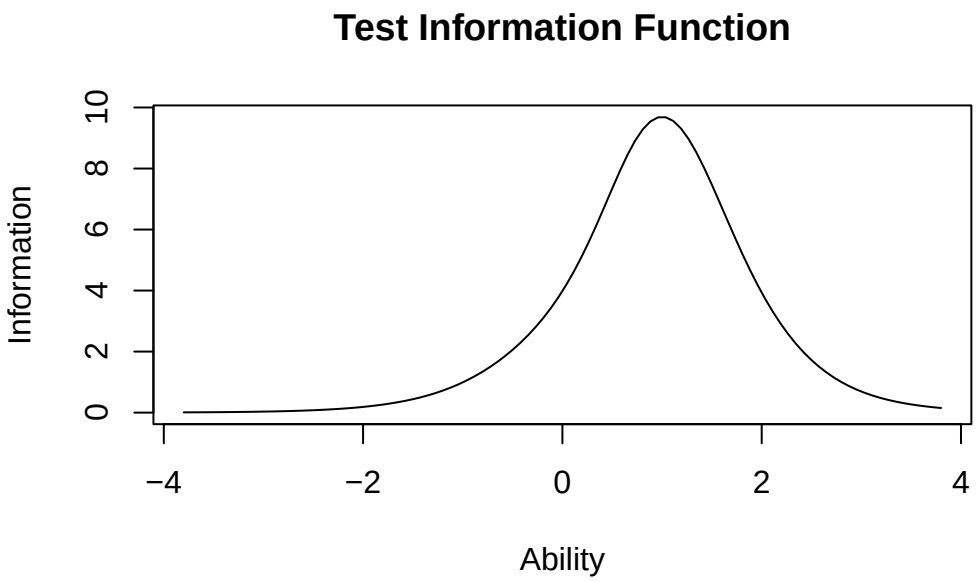
```
plot(pl2, type = c("IIC"))
```



The IICs demonstrate that items range in how much information they provide about an individuals depression level for different ability levels. The red curve, q10, gives us a the most information at moderate depression levels. In contrast, q4 (the blue curve), gives us very low information because of how a range of depression levels it covers.

Sum of all IIC Curves

```
plot(pl2, type = c("IIC"), items = c(0))
```



The test information function shows that the items as a whole provide the most information about low-to-moderate depression levels, and less about extreme high or low depression levels. This is desirable, as it is not important to discriminate between those with very low or very high depression. It is important to discriminate between those of moderate depression levels, which is what the test information function tells us it does.

Confirmatory Factor Analysis

```
mod <-
  "depression =~ q1 + q2 + q3 + q4 + q5 +
                 q6 + q7 + q8 + q9
"


cfafit <- cfa(mod, data = ds_dich,
              ordered = c("q1", "q2", "q3", "q4", "q5",
                          "q6", "q7", "q8", "q9"),
              estimator = "WLSMV",
              check.gradient = TRUE
              )
```

```r
summary(cfafit, fit.measures = TRUE, standardized = TRUE)
```

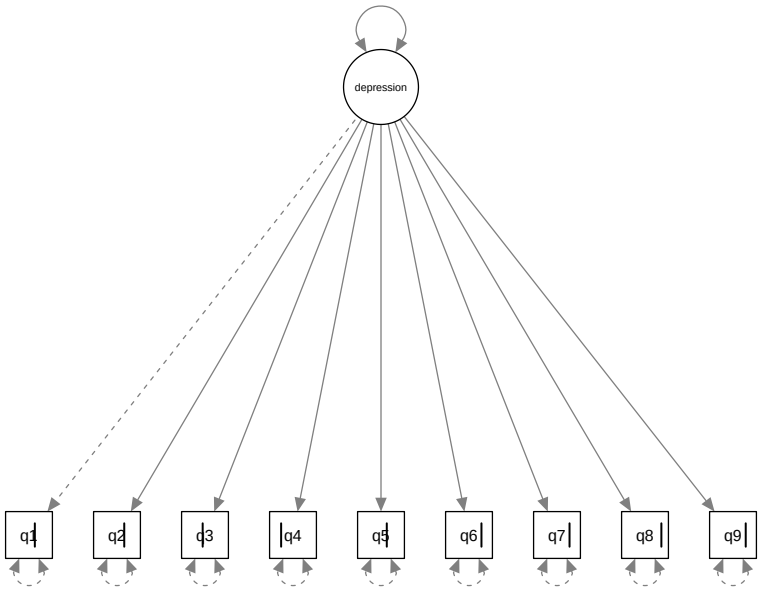
```
lavaan 0.6.15 ended normally after 16 iterations

  Estimator                                         DWLS
  Optimization method                           NLMINB
  Number of model parameters                        18

                                                  Used       Total
  Number of observations                          3560        5735

Model Test User Model:
                                              Standard      Scaled
  Test Statistic                               113.874     164.224
  Degrees of freedom                                27          27
  P-value (Chi-square)                           0.000       0.000
  Scaling correction factor                                  0.699
  Shift parameter                                            1.417
    simple second-order correction

Model Test Baseline Model:

  Test statistic                             11058.349    8374.673
  Degrees of freedom                                36          36
  P-value                                        0.000       0.000
  Scaling correction factor                                  1.322

User Model versus Baseline Model:

  Comparative Fit Index (CFI)                    0.992       0.984
  Tucker-Lewis Index (TLI)                       0.989       0.978

  Robust Comparative Fit Index (CFI)                         0.929
  Robust Tucker-Lewis Index (TLI)                            0.905

Root Mean Square Error of Approximation:

  RMSEA                                          0.030       0.038
  90 Percent confidence interval - lower         0.024       0.032
  90 Percent confidence interval - upper         0.036       0.043
  P-value H_0: RMSEA <= 0.050                    1.000       1.000
  P-value H_0: RMSEA >= 0.080                    0.000       0.000
```

```
  Robust RMSEA                                               0.095
  90 Percent confidence interval - lower                     0.082
  90 Percent confidence interval - upper                     0.108
  P-value H_0: Robust RMSEA <= 0.050                         0.000
  P-value H_0: Robust RMSEA >= 0.080                         0.972

Standardized Root Mean Square Residual:

  SRMR                                             0.040     0.040

Parameter Estimates:

  Standard errors                           Robust.sem
  Information                                 Expected
  Information saturated (h1) model        Unstructured

Latent Variables:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
  depression =~
    q1                1.000                               0.649    0.649
    q2                1.299    0.041   31.349    0.000    0.843    0.843
    q3                0.597    0.037   16.252    0.000    0.387    0.387
    q4                0.490    0.035   13.971    0.000    0.318    0.318
    q5                0.725    0.039   18.741    0.000    0.471    0.471
    q6                1.225    0.042   29.188    0.000    0.795    0.795
    q7                1.010    0.042   24.287    0.000    0.656    0.656
    q8                1.023    0.045   22.879    0.000    0.664    0.664
    q9                1.244    0.041   30.433    0.000    0.808    0.808

Intercepts:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
   .q1                0.000                               0.000    0.000
   .q2                0.000                               0.000    0.000
   .q3                0.000                               0.000    0.000
   .q4                0.000                               0.000    0.000
   .q5                0.000                               0.000    0.000
   .q6                0.000                               0.000    0.000
   .q7                0.000                               0.000    0.000
   .q8                0.000                               0.000    0.000
   .q9                0.000                               0.000    0.000
    depression        0.000                               0.000    0.000
```

```
Thresholds:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
    q1|t1             0.317    0.021   14.823    0.000    0.317    0.317
    q2|t1             0.398    0.022   18.416    0.000    0.398    0.398
    q3|t1            -0.125    0.021   -5.931    0.000   -0.125   -0.125
    q4|t1            -0.685    0.023  -29.915    0.000   -0.685   -0.685
    q5|t1             0.314    0.021   14.689    0.000    0.314    0.314
    q6|t1             0.726    0.023   31.353    0.000    0.726    0.726
    q7|t1             0.730    0.023   31.512    0.000    0.730    0.730
    q8|t1             1.034    0.026   40.319    0.000    1.034    1.034
    q9|t1             0.743    0.023   31.956    0.000    0.743    0.743

Variances:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
   .q1                0.578                              0.578    0.578
   .q2                0.289                              0.289    0.289
   .q3                0.850                              0.850    0.850
   .q4                0.899                              0.899    0.899
   .q5                0.778                              0.778    0.778
   .q6                0.368                              0.368    0.368
   .q7                0.570                              0.570    0.570
   .q8                0.559                              0.559    0.559
   .q9                0.347                              0.347    0.347
    depression        0.422    0.024   17.817    0.000    1.000    1.000

Scales y*:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
    q1                1.000                              1.000    1.000
    q2                1.000                              1.000    1.000
    q3                1.000                              1.000    1.000
    q4                1.000                              1.000    1.000
    q5                1.000                              1.000    1.000
    q6                1.000                              1.000    1.000
    q7                1.000                              1.000    1.000
    q8                1.000                              1.000    1.000
    q9                1.000                              1.000    1.000
```

The thresholds of the CFA have a similar pattern to that of the difficulty ability of each item. Similarly, the factor loadings of the CFA seem similar to the discrimination parameters from the IRT.

```r
semPlot::semPaths(cfafit, nCharNodes = 0, intercepts = FALSE)
```



Check Modification Indices

Next, I checked the modification indices for the assumption of *local independence* for any theoretical justification of adding covariances to the model.

```
modindices(cfafit) %>% dplyr::arrange(desc(mi)) %>% head()
```

```
  lhs op rhs     mi    epc sepc.lv sepc.all sepc.nox
1  q2 ~~  q6 44.620  0.181   0.181    0.555    0.555
2  q7 ~~  q8 23.083  0.146   0.146    0.259    0.259
3  q1 ~~  q2 15.106  0.104   0.104    0.254    0.254
4  q2 ~~  q8 11.415 -0.111  -0.111   -0.275   -0.275
5  q2 ~~  q7 10.357 -0.097  -0.097   -0.239   -0.239
6  q1 ~~  q6  9.408 -0.091  -0.091   -0.198   -0.198
```

Some of the modification indices are high (e.g., q7~~q8), and the SEPC's are moderate.

For example

q7: "Trouble concentrating on things"

q8: "Moving or speaking slowly or too fast"

These do not seem to be particularly closely related.

q2: "Feeling down, depressed, or hopeless"

q6: "Feeling bad about yourself"

Also, not closely related. Therefore, I did not add any of them to the model.

Compare discrimination's with factor loadings

TODO: add link/citation to sources; find formula for converting factor loadings to discriminations

Below I take a better look at the difference between my CFA's factor loadings and 2PL's discrimination abilities.

TODO: it would be helpful to explain the equation

```
model_loadings <- inspect(cfafit, what = "std")[["lambda"]]
# model_loadings

discrims <- pl2$coefficients[, 2]
# for (i in discrims) {
#   print(i / sqrt(3.29 + i**2))
# }
# cbind(loadings = model_loadings,
#       discrims_to_loadings = discrims / sqrt(3.29 + discrims^2))

D <- 1.7



df_loadings <- cbind(loadings = model_loadings,
                     discrims_to_loadings = (discrims / D) / (sqrt(1 + ((discrims / D)^2))

df_loadings <- df_loadings %>% as.data.frame() %>%
  dplyr::rename(cfa_loadings = depression)


df_loadings %>% as.data.frame() %>%
  dplyr::mutate(dif = cfa_loadings-discrims_to_loadings, rat = cfa_loadings/discrims_to_lo
```

```
   cfa_loadings discrims_to_loadings         dif       rat
q1    0.6492553            0.7799653 -0.13070996 0.8324157
```

```
q2    0.8433758            0.8797338 -0.03635799 0.9586716
q3    0.3874317            0.6774524 -0.29002068 0.5718951
q4    0.3183363            0.7474467 -0.42911037 0.4258984
q5    0.4710028            0.6712054 -0.20020264 0.7017267
q6    0.7950571            0.8413632 -0.04630604 0.9449631
q7    0.6560013            0.7555258 -0.09952453 0.8682712
q8    0.6643714            0.7585119 -0.09414051 0.8758879
q9    0.8079155            0.8439462 -0.03603075 0.9573068
```

Pretty much identical! As expected, the 2PL model is roughly equivalent to the dichotomous CFA.

Graded Response Model

```
suppressMessages({
  grm1 <- ltm::grm(ds)
})
```

```
mod2 <-
  "depression =~ q1 + q2 + q3 + q4 + q5 +
                 q6 + q7 + q8 + q9

"


cfafit2 <- cfa(mod2, data = ds,
               ordered = c("q1", "q2", "q3", "q4", "q5",
                           "q6", "q7", "q8", "q9"),
               estimator = "WLSMV",
               check.gradient = TRUE
               )

summary(cfafit2, fit.measures = TRUE, standardized = TRUE)
```

```
lavaan 0.6.15 ended normally after 15 iterations

  Estimator                                         DWLS
  Optimization method                           NLMINB
  Number of model parameters                        36
```

```
                                                  Used       Total
  Number of observations                          3560        5735

Model Test User Model:
                                                Standard      Scaled
  Test Statistic                                 172.086     304.384
  Degrees of freedom                                  27          27
  P-value (Chi-square)                             0.000       0.000
  Scaling correction factor                                    0.568
  Shift parameter                                              1.542
    simple second-order correction

Model Test Baseline Model:

  Test statistic                               20075.503   12223.139
  Degrees of freedom                                  36          36
  P-value                                          0.000       0.000
  Scaling correction factor                                    1.644

User Model versus Baseline Model:

  Comparative Fit Index (CFI)                      0.993       0.977
  Tucker-Lewis Index (TLI)                         0.990       0.970

  Robust Comparative Fit Index (CFI)                           0.947
  Robust Tucker-Lewis Index (TLI)                              0.929

Root Mean Square Error of Approximation:

  RMSEA                                            0.039       0.054
  90 Percent confidence interval - lower           0.033       0.048
  90 Percent confidence interval - upper           0.045       0.059
  P-value H_0: RMSEA <= 0.050                      1.000       0.124
  P-value H_0: RMSEA >= 0.080                      0.000       0.000

  Robust RMSEA                                                 0.085
  90 Percent confidence interval - lower                       0.076
  90 Percent confidence interval - upper                       0.094
  P-value H_0: Robust RMSEA <= 0.050                           0.000
  P-value H_0: Robust RMSEA >= 0.080                           0.807

Standardized Root Mean Square Residual:
```

```
  SRMR                                           0.036       0.036

Parameter Estimates:

  Standard errors                             Robust.sem
  Information                                   Expected
  Information saturated (h1) model          Unstructured

Latent Variables:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
  depression =~
    q1                1.000                               0.636    0.636
    q2                1.299    0.034   37.857    0.000    0.825    0.825
    q3                0.785    0.031   25.439    0.000    0.499    0.499
    q4                0.811    0.027   30.076    0.000    0.516    0.516
    q5                0.828    0.033   25.433    0.000    0.526    0.526
    q6                1.256    0.035   35.851    0.000    0.798    0.798
    q7                1.081    0.035   30.769    0.000    0.687    0.687
    q8                1.038    0.040   25.857    0.000    0.660    0.660
    q9                1.253    0.035   35.399    0.000    0.796    0.796

Intercepts:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
   .q1                0.000                               0.000    0.000
   .q2                0.000                               0.000    0.000
   .q3                0.000                               0.000    0.000
   .q4                0.000                               0.000    0.000
   .q5                0.000                               0.000    0.000
   .q6                0.000                               0.000    0.000
   .q7                0.000                               0.000    0.000
   .q8                0.000                               0.000    0.000
   .q9                0.000                               0.000    0.000
    depression        0.000                               0.000    0.000

Thresholds:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
    q1|t1             0.317    0.021   14.823    0.000    0.317    0.317
    q1|t2             1.095    0.026   41.643    0.000    1.095    1.095
    q1|t3             1.511    0.033   46.448    0.000    1.511    1.511
    q2|t1             0.398    0.022   18.416    0.000    0.398    0.398
    q2|t2             1.269    0.028   44.563    0.000    1.269    1.269
    q2|t3             1.708    0.037   46.184    0.000    1.708    1.708
    q3|t1            -0.125    0.021   -5.931    0.000   -0.125   -0.125
```

```
    q3|t2             0.788    0.024   33.436    0.000    0.788    0.788
    q3|t3             1.191    0.027   43.416    0.000    1.191    1.191
    q4|t1            -0.685    0.023  -29.915    0.000   -0.685   -0.685
    q4|t2             0.672    0.023   29.433    0.000    0.672    0.672
    q4|t3             1.167    0.027   43.010    0.000    1.167    1.167
    q5|t1             0.314    0.021   14.689    0.000    0.314    0.314
    q5|t2             1.110    0.026   41.956    0.000    1.110    1.110
    q5|t3             1.506    0.032   46.436    0.000    1.506    1.506
    q6|t1             0.726    0.023   31.353    0.000    0.726    0.726
    q6|t2             1.414    0.031   45.997    0.000    1.414    1.414
    q6|t3             1.779    0.039   45.725    0.000    1.779    1.779
    q7|t1             0.730    0.023   31.512    0.000    0.730    0.730
    q7|t2             1.361    0.030   45.576    0.000    1.361    1.361
    q7|t3             1.684    0.036   46.296    0.000    1.684    1.684
    q8|t1             1.034    0.026   40.319    0.000    1.034    1.034
    q8|t2             1.616    0.035   46.500    0.000    1.616    1.616
    q8|t3             1.950    0.044   43.899    0.000    1.950    1.950
    q9|t1             0.743    0.023   31.956    0.000    0.743    0.743
    q9|t2             1.742    0.038   45.984    0.000    1.742    1.742
    q9|t3             2.246    0.058   38.857    0.000    2.246    2.246

Variances:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
   .q1                0.596                              0.596    0.596
   .q2                0.319                              0.319    0.319
   .q3                0.751                              0.751    0.751
   .q4                0.734                              0.734    0.734
   .q5                0.723                              0.723    0.723
   .q6                0.363                              0.363    0.363
   .q7                0.528                              0.528    0.528
   .q8                0.565                              0.565    0.565
   .q9                0.366                              0.366    0.366
    depression        0.404    0.020   20.181    0.000    1.000    1.000

Scales y*:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
    q1                1.000                              1.000    1.000
    q2                1.000                              1.000    1.000
    q3                1.000                              1.000    1.000
    q4                1.000                              1.000    1.000
    q5                1.000                              1.000    1.000
    q6                1.000                              1.000    1.000
    q7                1.000                              1.000    1.000
```

```
    q8                1.000                                 1.000    1.000
    q9                1.000                                 1.000    1.000
```

```
grm1
```

```
Call:
ltm::grm(data = ds)

Coefficients:
    Extrmt1  Extrmt2  Extrmt3  Dscrmn
q1    0.848    1.737    2.255   2.010
q2    0.815    1.683    2.176   3.005
q3    0.425    1.487    2.035   1.649
q4   -0.075    1.248    1.854   1.919
q5    0.916    1.920    2.495   1.620
q6    1.154    1.886    2.332   2.716
q7    1.269    2.022    2.458   2.064
q8    1.668    2.399    2.858   1.944
q9    1.170    2.298    2.942   2.604

Log.Lik: -29008.19
```

```
df_coefs_disc <- summary(grm1)$coefficients %>% as.data.frame() %>%
  t() %>%
  as.data.frame()
df_coefs_disc
```

```
           Extrmt1  Extrmt2  Extrmt3   Dscrmn
value    0.84837401 1.736511 2.254968 2.010166
value.1  0.81463616 1.682865 2.176234 3.004799
value.2  0.42471955 1.487429 2.035148 1.648679
value.3 -0.07520555 1.247610 1.853513 1.919487
value.4  0.91610521 1.920134 2.494968 1.620451
value.5  1.15370059 1.885854 2.331579 2.715873
value.6  1.26898328 2.022465 2.457971 2.064210
value.7  1.66830928 2.399041 2.858246 1.944252
value.8  1.16995362 2.298242 2.942208 2.603596
```

```
pl2
```

```
Call:
ltm(formula = ds_dich ~ z1)

Coefficients:
    Dffclt  Dscrmn
q1   0.830   2.119
q2   0.813   3.145
q3   0.448   1.566
q4  -0.071   1.913
q5   0.957   1.539
q6   1.184   2.646
q7   1.321   1.961
q8   1.671   1.979
q9   1.176   2.675

Log.Lik: -19740.42
```

```
AIC(grm1)
```

```
[1] 58088.38
```

```
logLik(cfafit2)
```

```
Warning in logLik(cfafit2): lavaan WARNING: logLik only available if estimator
is ML

'log Lik.' NA (df=36)
```

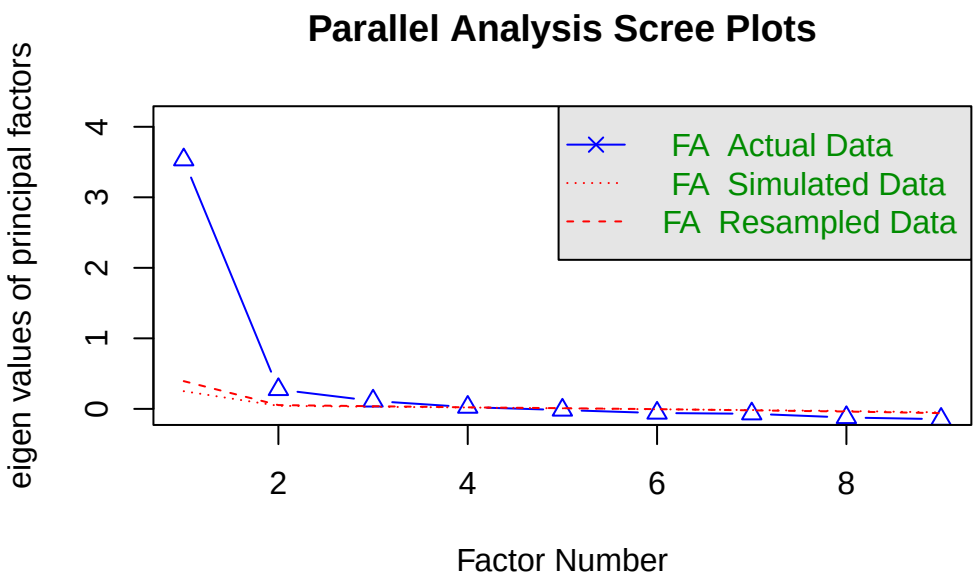
Rating Scale Model

```
library(TAM)
```

```
Warning: package 'TAM' was built under R version 4.3.3
```

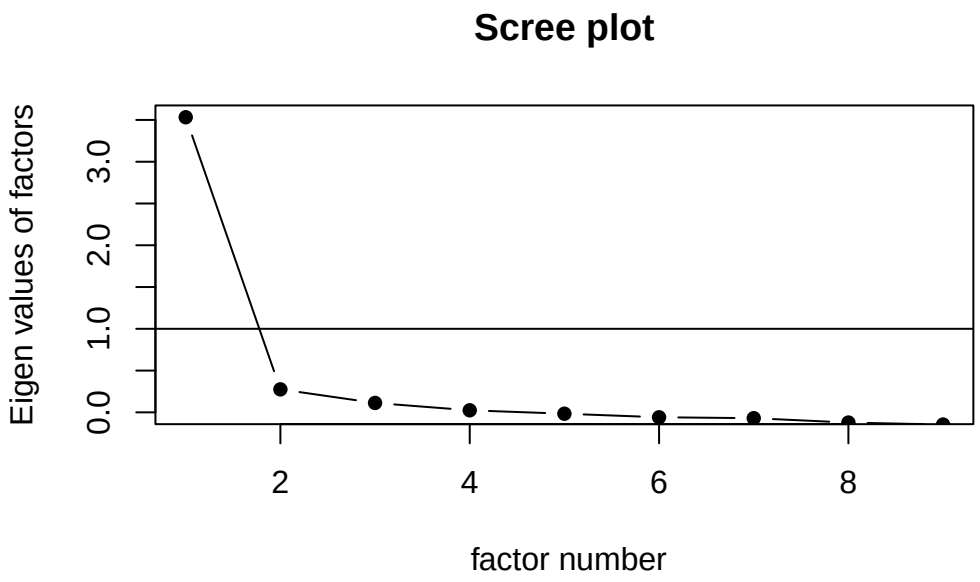
```
Loading required package: CDM

Warning: package 'CDM' was built under R version 4.3.3

Loading required package: mvtnorm

**********************************
** CDM 8.2-6 (2022-08-25 15:43:23)
** Cognitive Diagnostic Models  **
**********************************

* TAM 4.2-21 (2024-02-19 18:52:08)
```

```r
fa.parallel(ds, fa="fa")
```




```
Parallel analysis suggests that the number of factors =  3  and the number of components =  1
```

```r
scree(ds, pc=FALSE)
```




```
myTAM <- tam.mml(ds,
                 irtmodel = "RSM")
```

```
.................................................
Processing Data      2024-03-21 15:50:11.15034
    * Response Data: 5735 Persons and  9 Items
    * Numerical integration with 21 nodes
    * Created Design Matrices   ( 2024-03-21 15:50:11.162252 )
    * Calculated Sufficient Statistics   ( 2024-03-21 15:50:11.167652 )
.................................................
Iteration 1     2024-03-21 15:50:11.171467
E Step
M Step Intercepts   |----
  Deviance = 80217.4562
  Maximum item intercept parameter change: 0.902138
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.022278
.................................................
Iteration 2     2024-03-21 15:50:11.180781
E Step
M Step Intercepts   |----
```

```
  Deviance = 67216.9631 | Absolute change: 13000.49 | Relative change: 0.1934109
  Maximum item intercept parameter change: 0.818814
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.053984
..................................................
Iteration 3     2024-03-21 15:50:11.192602
E Step
M Step Intercepts   |----
  Deviance = 61497.6654 | Absolute change: 5719.298 | Relative change: 0.09300024
  Maximum item intercept parameter change: 0.51591
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.109163
..................................................
Iteration 4     2024-03-21 15:50:11.198452
E Step
M Step Intercepts   |----
  Deviance = 60208.2521 | Absolute change: 1289.413 | Relative change: 0.02141589
  Maximum item intercept parameter change: 0.339079
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.101806
..................................................
Iteration 5     2024-03-21 15:50:11.203965
E Step
M Step Intercepts   |----
  Deviance = 59917.6671 | Absolute change: 290.585 | Relative change: 0.00484974
  Maximum item intercept parameter change: 0.067947
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.074151
..................................................
Iteration 6     2024-03-21 15:50:11.209587
E Step
M Step Intercepts   |----
  Deviance = 59866.0429 | Absolute change: 51.6243 | Relative change: 0.00086233
  Maximum item intercept parameter change: 0.041483
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.067699
..................................................
Iteration 7     2024-03-21 15:50:11.216295
```

```
E Step
M Step Intercepts   |----
  Deviance = 59835.3046 | Absolute change: 30.7383 | Relative change: 0.00051372
  Maximum item intercept parameter change: 0.024542
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.062233
................................................
Iteration 8     2024-03-21 15:50:11.221368
E Step
M Step Intercepts   |----
  Deviance = 59818.5744 | Absolute change: 16.7301 | Relative change: 0.00027968
  Maximum item intercept parameter change: 0.022508
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.047813
................................................
Iteration 9     2024-03-21 15:50:11.226924
E Step
M Step Intercepts   |----
  Deviance = 59805.3162 | Absolute change: 13.2582 | Relative change: 0.00022169
  Maximum item intercept parameter change: 0.021523
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.03958
................................................
Iteration 10     2024-03-21 15:50:11.236112
E Step
M Step Intercepts   |----
  Deviance = 59795.0031 | Absolute change: 10.3131 | Relative change: 0.00017247
  Maximum item intercept parameter change: 0.01891
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.033557
................................................
Iteration 11     2024-03-21 15:50:11.240582
E Step
M Step Intercepts   |----
  Deviance = 59786.9733 | Absolute change: 8.0298 | Relative change: 0.00013431
  Maximum item intercept parameter change: 0.018042
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.028496
```

```
................................................
Iteration 12     2024-03-21 15:50:11.247245
E Step
M Step Intercepts   |----
  Deviance = 59780.2069 | Absolute change: 6.7664 | Relative change: 0.00011319
  Maximum item intercept parameter change: 0.015858
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.02531
................................................
Iteration 13     2024-03-21 15:50:11.252576
E Step
M Step Intercepts   |----
  Deviance = 59774.9331 | Absolute change: 5.2738 | Relative change: 8.823e-05
  Maximum item intercept parameter change: 0.014347
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.021991
................................................
Iteration 14     2024-03-21 15:50:11.257859
E Step
M Step Intercepts   |----
  Deviance = 59770.48 | Absolute change: 4.4531 | Relative change: 7.45e-05
  Maximum item intercept parameter change: 0.013404
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.01961
................................................
Iteration 15     2024-03-21 15:50:11.263365
E Step
M Step Intercepts   |----
  Deviance = 59766.7726 | Absolute change: 3.7074 | Relative change: 6.203e-05
  Maximum item intercept parameter change: 0.012297
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.017672
................................................
Iteration 16     2024-03-21 15:50:11.273672
E Step
M Step Intercepts   |----
  Deviance = 59763.72 | Absolute change: 3.0525 | Relative change: 5.108e-05
  Maximum item intercept parameter change: 0.011103
  Maximum item slope parameter change: 0
```

```
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.015952
................................................
Iteration 17     2024-03-21 15:50:11.278046
E Step
M Step Intercepts   |----
  Deviance = 59761.1664 | Absolute change: 2.5537 | Relative change: 4.273e-05
  Maximum item intercept parameter change: 0.010189
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.014476
................................................
Iteration 18     2024-03-21 15:50:11.283446
E Step
M Step Intercepts   |----
  Deviance = 59759.039 | Absolute change: 2.1274 | Relative change: 3.56e-05
  Maximum item intercept parameter change: 0.009277
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.013151
................................................
Iteration 19     2024-03-21 15:50:11.288623
E Step
M Step Intercepts   |----
  Deviance = 59757.2508 | Absolute change: 1.7882 | Relative change: 2.992e-05
  Maximum item intercept parameter change: 0.008528
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.01199
................................................
Iteration 20     2024-03-21 15:50:11.293923
E Step
M Step Intercepts   |----
  Deviance = 59755.7458 | Absolute change: 1.505 | Relative change: 2.519e-05
  Maximum item intercept parameter change: 0.007808
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.010958
................................................
Iteration 21     2024-03-21 15:50:11.304985
E Step
M Step Intercepts   |----
  Deviance = 59754.4986 | Absolute change: 1.2472 | Relative change: 2.087e-05
```

```
  Maximum item intercept parameter change: 0.007507
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.00994
................................................
Iteration 22     2024-03-21 15:50:11.309471
E Step
M Step Intercepts   |----
  Deviance = 59753.4397 | Absolute change: 1.0589 | Relative change: 1.772e-05
  Maximum item intercept parameter change: 0.006733
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.009063
................................................
Iteration 23     2024-03-21 15:50:11.313581
E Step
M Step Intercepts   |----
  Deviance = 59752.518 | Absolute change: 0.9217 | Relative change: 1.543e-05
  Maximum item intercept parameter change: 0.006156
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.008441
................................................
Iteration 24     2024-03-21 15:50:11.318805
E Step
M Step Intercepts   |----
  Deviance = 59751.7578 | Absolute change: 0.7602 | Relative change: 1.272e-05
  Maximum item intercept parameter change: 0.005515
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.00772
................................................
Iteration 25     2024-03-21 15:50:11.324514
E Step
M Step Intercepts   |----
  Deviance = 59751.1183 | Absolute change: 0.6394 | Relative change: 1.07e-05
  Maximum item intercept parameter change: 0.005578
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.007026
................................................
Iteration 26     2024-03-21 15:50:11.336516
E Step
```

```
M Step Intercepts   |----
  Deviance = 59750.5563 | Absolute change: 0.562 | Relative change: 9.41e-06
  Maximum item intercept parameter change: 0.004831
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.00658
................................................
Iteration 27     2024-03-21 15:50:11.340756
E Step
M Step Intercepts   |----
  Deviance = 59750.0899 | Absolute change: 0.4664 | Relative change: 7.81e-06
  Maximum item intercept parameter change: 0.004331
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.006036
................................................
Iteration 28     2024-03-21 15:50:11.344826
E Step
M Step Intercepts   |----
  Deviance = 59749.699 | Absolute change: 0.3909 | Relative change: 6.54e-06
  Maximum item intercept parameter change: 0.004055
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.005491
................................................
Iteration 29     2024-03-21 15:50:11.348889
E Step
M Step Intercepts   |----
  Deviance = 59749.3595 | Absolute change: 0.3396 | Relative change: 5.68e-06
  Maximum item intercept parameter change: 0.003715
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.005103
................................................
Iteration 30     2024-03-21 15:50:11.354173
E Step
M Step Intercepts   |----
  Deviance = 59749.0747 | Absolute change: 0.2848 | Relative change: 4.77e-06
  Maximum item intercept parameter change: 0.00347
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.004669
................................................
```

```
Iteration 31     2024-03-21 15:50:11.363226
E Step
M Step Intercepts   |----
  Deviance = 59748.8273 | Absolute change: 0.2473 | Relative change: 4.14e-06
  Maximum item intercept parameter change: 0.003175
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.004351
................................................
Iteration 32     2024-03-21 15:50:11.367479
E Step
M Step Intercepts   |----
  Deviance = 59748.6198 | Absolute change: 0.2075 | Relative change: 3.47e-06
  Maximum item intercept parameter change: 0.002966
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.003985
................................................
Iteration 33     2024-03-21 15:50:11.371091
E Step
M Step Intercepts   |----
  Deviance = 59748.4395 | Absolute change: 0.1803 | Relative change: 3.02e-06
  Maximum item intercept parameter change: 0.002713
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.003717
................................................
Iteration 34     2024-03-21 15:50:11.385005
E Step
M Step Intercepts   |----
  Deviance = 59748.2882 | Absolute change: 0.1513 | Relative change: 2.53e-06
  Maximum item intercept parameter change: 0.002535
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.003406
................................................
Iteration 35     2024-03-21 15:50:11.388812
E Step
M Step Intercepts   |----
  Deviance = 59748.1566 | Absolute change: 0.1316 | Relative change: 2.2e-06
  Maximum item intercept parameter change: 0.00232
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
```

```
  Maximum variance parameter change: 0.003177
.................................................
Iteration 36     2024-03-21 15:50:11.393032
E Step
M Step Intercepts   |----
  Deviance = 59748.0461 | Absolute change: 0.1105 | Relative change: 1.85e-06
  Maximum item intercept parameter change: 0.002168
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.002911
.................................................
Iteration 37     2024-03-21 15:50:11.397444
E Step
M Step Intercepts   |----
  Deviance = 59747.9501 | Absolute change: 0.0961 | Relative change: 1.61e-06
  Maximum item intercept parameter change: 0.001984
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.002716
.................................................
Iteration 38     2024-03-21 15:50:11.402107
E Step
M Step Intercepts   |----
  Deviance = 59747.8693 | Absolute change: 0.0807 | Relative change: 1.35e-06
  Maximum item intercept parameter change: 0.001854
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.00249
.................................................
Iteration 39     2024-03-21 15:50:11.40691
E Step
M Step Intercepts   |----
  Deviance = 59747.7991 | Absolute change: 0.0702 | Relative change: 1.18e-06
  Maximum item intercept parameter change: 0.001697
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.002323
.................................................
Iteration 40     2024-03-21 15:50:11.412412
E Step
M Step Intercepts   |----
  Deviance = 59747.7401 | Absolute change: 0.059 | Relative change: 9.9e-07
  Maximum item intercept parameter change: 0.001586
```

```
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.00213
................................................
Iteration 41     2024-03-21 15:50:11.417092
E Step
M Step Intercepts   |----
  Deviance = 59747.6887 | Absolute change: 0.0514 | Relative change: 8.6e-07
  Maximum item intercept parameter change: 0.001452
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.001988
................................................
Iteration 42     2024-03-21 15:50:11.426791
E Step
M Step Intercepts   |----
  Deviance = 59747.6455 | Absolute change: 0.0432 | Relative change: 7.2e-07
  Maximum item intercept parameter change: 0.001358
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.001822
................................................
Iteration 43     2024-03-21 15:50:11.43084
E Step
M Step Intercepts   |---
  Deviance = 59747.6079 | Absolute change: 0.0376 | Relative change: 6.3e-07
  Maximum item intercept parameter change: 0.001233
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.001701
................................................
Iteration 44     2024-03-21 15:50:11.43547
E Step
M Step Intercepts   |---
  Deviance = 59747.5765 | Absolute change: 0.0314 | Relative change: 5.3e-07
  Maximum item intercept parameter change: 0.001207
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.001552
................................................
Iteration 45     2024-03-21 15:50:11.440541
E Step
M Step Intercepts   |---
```

```
  Deviance = 59747.5485 | Absolute change: 0.028 | Relative change: 4.7e-07
  Maximum item intercept parameter change: 0.001097
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.001465
.................................................
Iteration 46     2024-03-21 15:50:11.446454
E Step
M Step Intercepts   |---
  Deviance = 59747.5242 | Absolute change: 0.0242 | Relative change: 4.1e-07
  Maximum item intercept parameter change: 0.001019
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.001372
.................................................
Iteration 47     2024-03-21 15:50:11.451054
E Step
M Step Intercepts   |---
  Deviance = 59747.5036 | Absolute change: 0.0206 | Relative change: 3.4e-07
  Maximum item intercept parameter change: 0.000944
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.001277
.................................................
Iteration 48     2024-03-21 15:50:11.461522
E Step
M Step Intercepts   |--
  Deviance = 59747.486 | Absolute change: 0.0176 | Relative change: 3e-07
  Maximum item intercept parameter change: 0.000822
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.001186
.................................................
Iteration 49     2024-03-21 15:50:11.465691
E Step
M Step Intercepts   |---
  Deviance = 59747.4717 | Absolute change: 0.0143 | Relative change: 2.4e-07
  Maximum item intercept parameter change: 0.000825
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.001072
.................................................
Iteration 50     2024-03-21 15:50:11.469308
```

```
E Step
M Step Intercepts   |--
  Deviance = 59747.4587 | Absolute change: 0.013 | Relative change: 2.2e-07
  Maximum item intercept parameter change: 0.000712
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.00101
................................................
Iteration 51     2024-03-21 15:50:11.474321
E Step
M Step Intercepts   |--
  Deviance = 59747.4482 | Absolute change: 0.0105 | Relative change: 1.8e-07
  Maximum item intercept parameter change: 0.000667
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000918
................................................
Iteration 52     2024-03-21 15:50:11.479462
E Step
M Step Intercepts   |--
  Deviance = 59747.4392 | Absolute change: 0.009 | Relative change: 1.5e-07
  Maximum item intercept parameter change: 0.00062
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000845
................................................
Iteration 53     2024-03-21 15:50:11.483967
E Step
M Step Intercepts   |--
  Deviance = 59747.4315 | Absolute change: 0.0077 | Relative change: 1.3e-07
  Maximum item intercept parameter change: 0.000574
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000781
................................................
Iteration 54     2024-03-21 15:50:11.489542
E Step
M Step Intercepts   |--
  Deviance = 59747.4248 | Absolute change: 0.0066 | Relative change: 1.1e-07
  Maximum item intercept parameter change: 0.000531
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000723
```

```
................................................
Iteration 55     2024-03-21 15:50:11.498598
E Step
M Step Intercepts   |--
  Deviance = 59747.4192 | Absolute change: 0.0057 | Relative change: 9e-08
  Maximum item intercept parameter change: 0.000491
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000669
................................................
Iteration 56     2024-03-21 15:50:11.502836
E Step
M Step Intercepts   |--
  Deviance = 59747.4144 | Absolute change: 0.0048 | Relative change: 8e-08
  Maximum item intercept parameter change: 0.000454
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000619
................................................
Iteration 57     2024-03-21 15:50:11.506904
E Step
M Step Intercepts   |--
  Deviance = 59747.4102 | Absolute change: 0.0041 | Relative change: 7e-08
  Maximum item intercept parameter change: 0.000419
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000572
................................................
Iteration 58     2024-03-21 15:50:11.51182
E Step
M Step Intercepts   |--
  Deviance = 59747.4067 | Absolute change: 0.0035 | Relative change: 6e-08
  Maximum item intercept parameter change: 0.000387
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000529
................................................
Iteration 59     2024-03-21 15:50:11.51691
E Step
M Step Intercepts   |--
  Deviance = 59747.4037 | Absolute change: 0.003 | Relative change: 5e-08
  Maximum item intercept parameter change: 0.000358
  Maximum item slope parameter change: 0
```

```
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000489
................................................
Iteration 60     2024-03-21 15:50:11.525671
E Step
M Step Intercepts   |--
  Deviance = 59747.4012 | Absolute change: 0.0026 | Relative change: 4e-08
  Maximum item intercept parameter change: 0.00033
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000452
................................................
Iteration 61     2024-03-21 15:50:11.529878
E Step
M Step Intercepts   |--
  Deviance = 59747.399 | Absolute change: 0.0022 | Relative change: 4e-08
  Maximum item intercept parameter change: 0.000305
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000418
................................................
Iteration 62     2024-03-21 15:50:11.533974
E Step
M Step Intercepts   |--
  Deviance = 59747.3971 | Absolute change: 0.0019 | Relative change: 3e-08
  Maximum item intercept parameter change: 0.000282
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000386
................................................
Iteration 63     2024-03-21 15:50:11.538043
E Step
M Step Intercepts   |--
  Deviance = 59747.3955 | Absolute change: 0.0016 | Relative change: 3e-08
  Maximum item intercept parameter change: 0.000261
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000357
................................................
Iteration 64     2024-03-21 15:50:11.542242
E Step
M Step Intercepts   |--
  Deviance = 59747.3941 | Absolute change: 0.0014 | Relative change: 2e-08
```

```
  Maximum item intercept parameter change: 0.000241
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000329
................................................
Iteration 65     2024-03-21 15:50:11.549613
E Step
M Step Intercepts   |--
  Deviance = 59747.393 | Absolute change: 0.0012 | Relative change: 2e-08
  Maximum item intercept parameter change: 0.000222
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000304
................................................
Iteration 66     2024-03-21 15:50:11.553627
E Step
M Step Intercepts   |--
  Deviance = 59747.392 | Absolute change: 0.001 | Relative change: 2e-08
  Maximum item intercept parameter change: 0.000206
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000281
................................................
Iteration 67     2024-03-21 15:50:11.5573
E Step
M Step Intercepts   |--
  Deviance = 59747.3912 | Absolute change: 8e-04 | Relative change: 1e-08
  Maximum item intercept parameter change: 0.00019
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.00026
................................................
Iteration 68     2024-03-21 15:50:11.56133
E Step
M Step Intercepts   |--
  Deviance = 59747.3904 | Absolute change: 7e-04 | Relative change: 1e-08
  Maximum item intercept parameter change: 0.000175
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.00024
................................................
Iteration 69     2024-03-21 15:50:11.569537
E Step
```

```
M Step Intercepts   |--
  Deviance = 59747.3898 | Absolute change: 6e-04 | Relative change: 1e-08
  Maximum item intercept parameter change: 0.000162
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000222
................................................
Iteration 70     2024-03-21 15:50:11.573537
E Step
M Step Intercepts   |--
  Deviance = 59747.3893 | Absolute change: 5e-04 | Relative change: 1e-08
  Maximum item intercept parameter change: 0.00015
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000205
................................................
Iteration 71     2024-03-21 15:50:11.577412
E Step
M Step Intercepts   |--
  Deviance = 59747.3888 | Absolute change: 4e-04 | Relative change: 1e-08
  Maximum item intercept parameter change: 0.000138
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000189
................................................
Iteration 72     2024-03-21 15:50:11.58985
E Step
M Step Intercepts   |--
  Deviance = 59747.3885 | Absolute change: 4e-04 | Relative change: 1e-08
  Maximum item intercept parameter change: 0.000128
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000175
................................................
Iteration 73     2024-03-21 15:50:11.595452
E Step
M Step Intercepts   |--
  Deviance = 59747.3881 | Absolute change: 3e-04 | Relative change: 1e-08
  Maximum item intercept parameter change: 0.000118
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000162
................................................
```

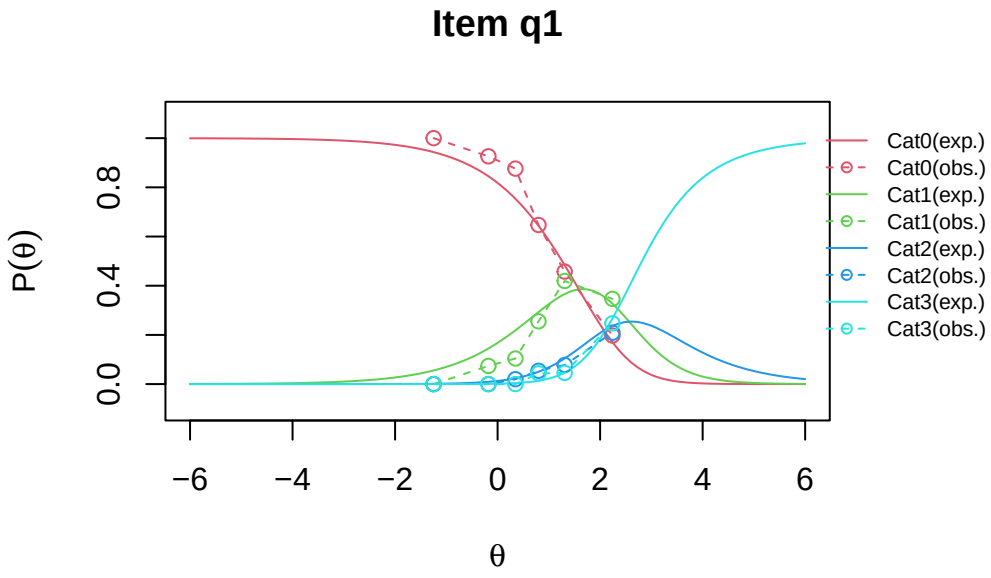
```
Iteration 74     2024-03-21 15:50:11.600506
E Step
M Step Intercepts   |-
  Deviance = 59747.3879 | Absolute change: 3e-04 | Relative change: 0
  Maximum item intercept parameter change: 9.5e-05
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000149
................................................
Iteration 75     2024-03-21 15:50:11.604973
E Step
M Step Intercepts   |-
  Deviance = 59747.3876 | Absolute change: 2e-04 | Relative change: 0
  Maximum item intercept parameter change: 8.9e-05
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000131
................................................
Iteration 76     2024-03-21 15:50:11.610207
E Step
M Step Intercepts   |-
  Deviance = 59747.3875 | Absolute change: 2e-04 | Relative change: 0
  Maximum item intercept parameter change: 8.4e-05
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000118
................................................
Iteration 77     2024-03-21 15:50:11.61575
E Step
M Step Intercepts   |-
  Deviance = 59747.3873 | Absolute change: 2e-04 | Relative change: 0
  Maximum item intercept parameter change: 7.9e-05
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
  Maximum variance parameter change: 0.000108
................................................
Iteration 78     2024-03-21 15:50:11.620439
E Step
M Step Intercepts   |-
  Deviance = 59747.3872 | Absolute change: 1e-04 | Relative change: 0
  Maximum item intercept parameter change: 7.4e-05
  Maximum item slope parameter change: 0
  Maximum regression parameter change: 0
```

```
  Maximum variance parameter change: 1e-04
................................................
Item Parameters
   xsi.index xsi.label     est
1          1        q1  2.0910
2          2        q2  2.2917
3          3        q3  1.5453
4          4        q4  1.1931
5          5        q5  2.0990
6          6        q6  2.6890
7          7        q7  2.6369
8          8        q8  3.1383
9          9        q9  2.8599
10        10      Cat1 -0.5049
11        11      Cat2  0.4748
................................
Regression Coefficients
     [,1]
[1,]    0

Variance:
      [,1]
[1,] 1.918


EAP Reliability:
[1] 0.654

------------------------------
Start:  2024-03-21 15:50:11.148496
End:  2024-03-21 15:50:11.649271
Time difference of 0.5007751 secs
```

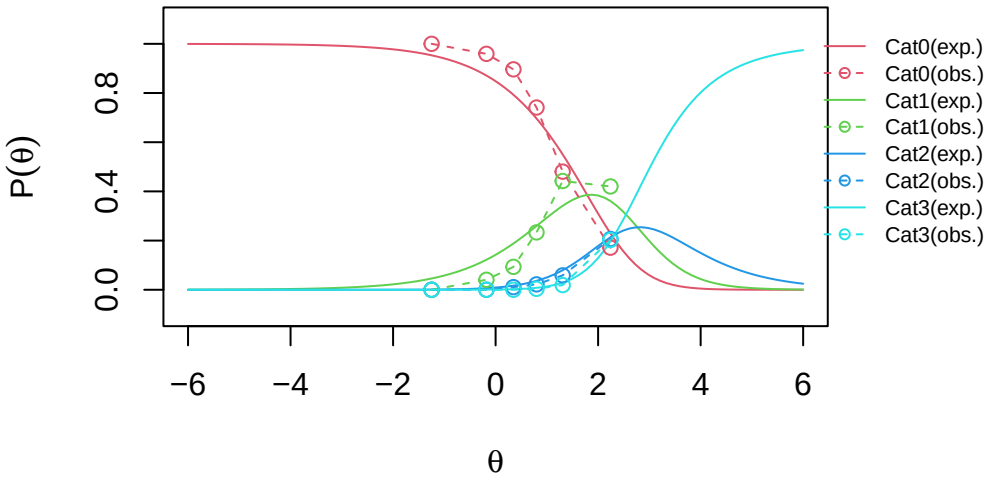
```r
plot(myTAM,
     type = "items",
     export = FALSE,
     package = "graphics",
     observed = TRUE,
     low = -6,
     high = 6)
```

```
Iteration in WLE/MLE estimation  1   | Maximal change  2.9239
```

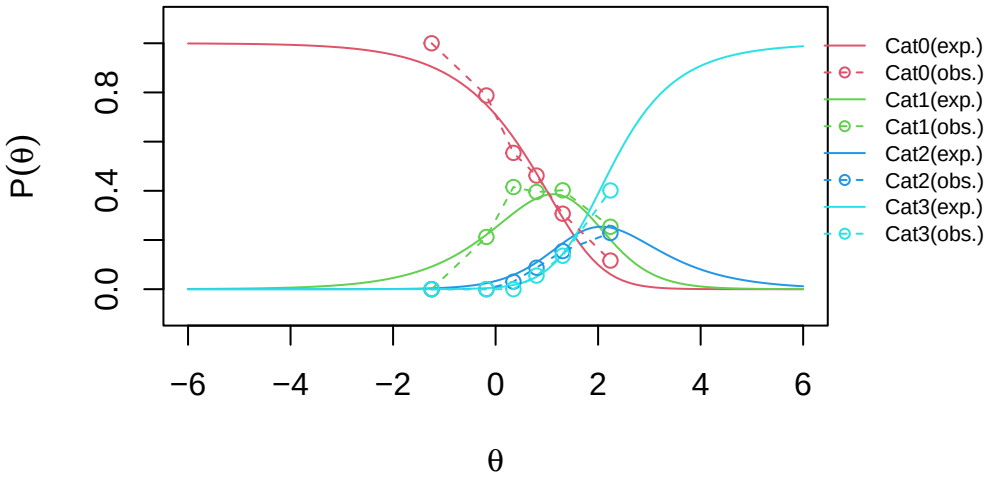
```
Iteration in WLE/MLE estimation  2   | Maximal change  2.8413
Iteration in WLE/MLE estimation  3   | Maximal change  1.1
Iteration in WLE/MLE estimation  4   | Maximal change  0.4911
Iteration in WLE/MLE estimation  5   | Maximal change  0.1645
Iteration in WLE/MLE estimation  6   | Maximal change  0.0147
Iteration in WLE/MLE estimation  7   | Maximal change  3e-04
Iteration in WLE/MLE estimation  8   | Maximal change  0
----
 WLE Reliability= 0.42
```



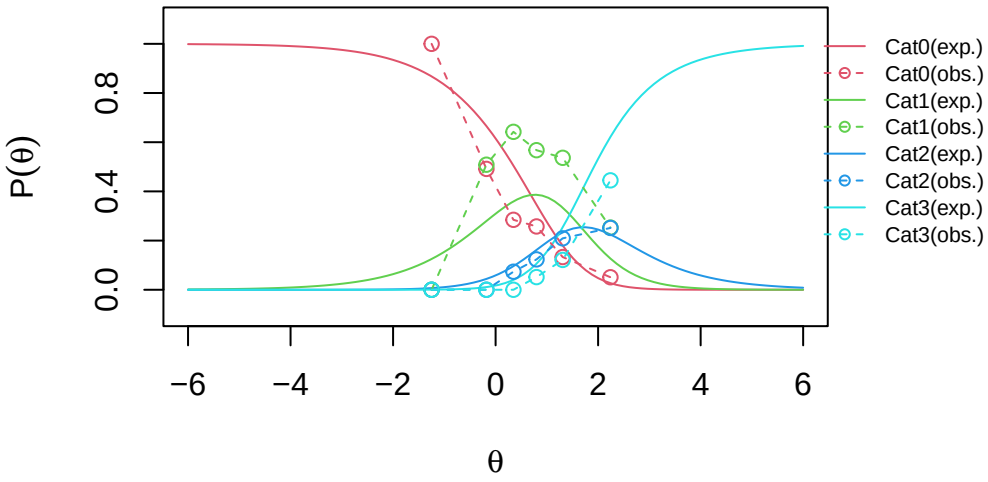
Item q2



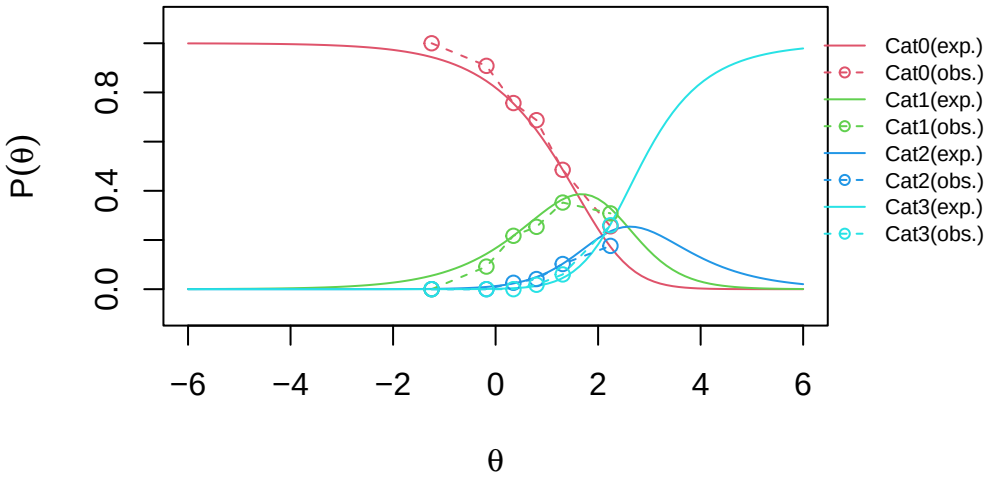
Item q3

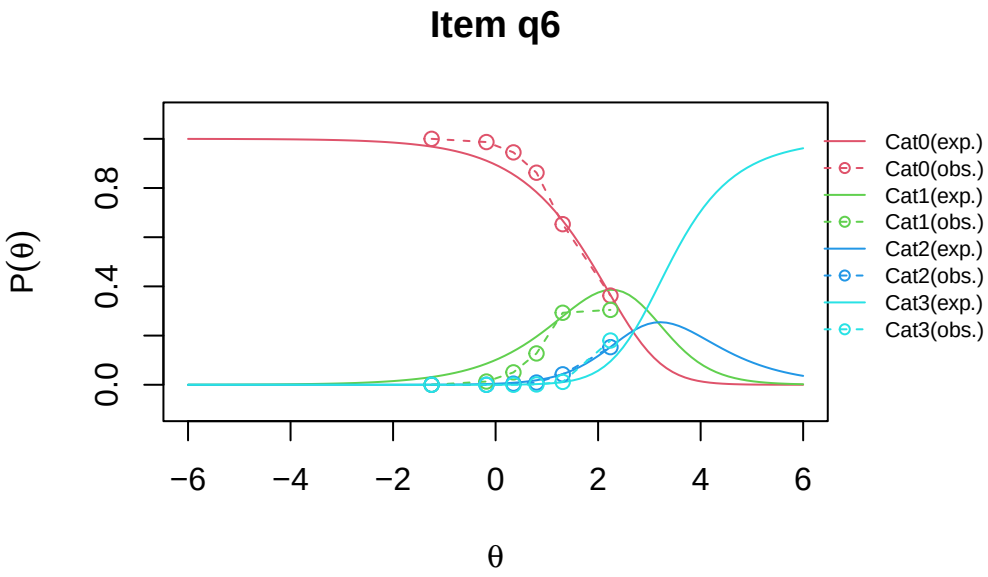


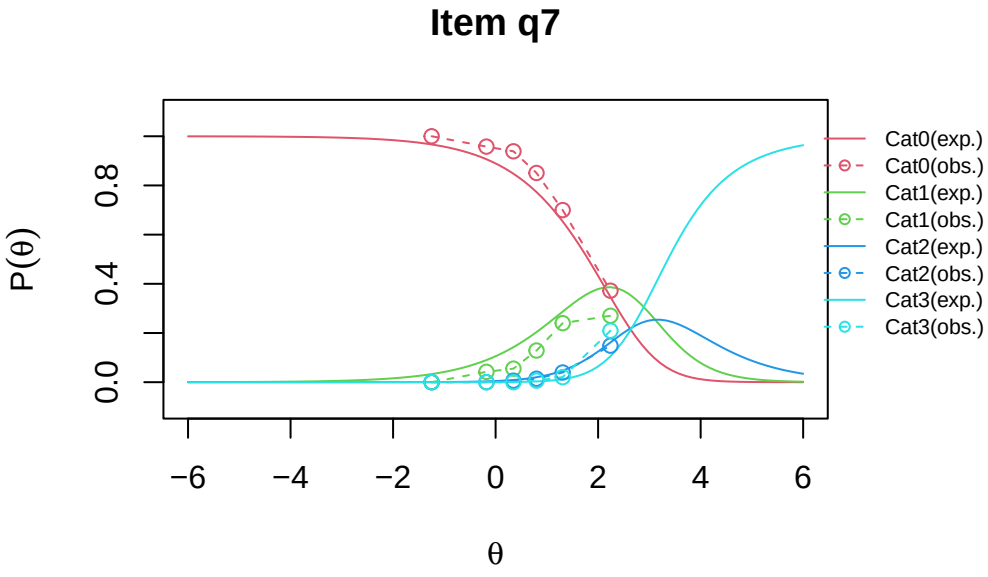
Item q4



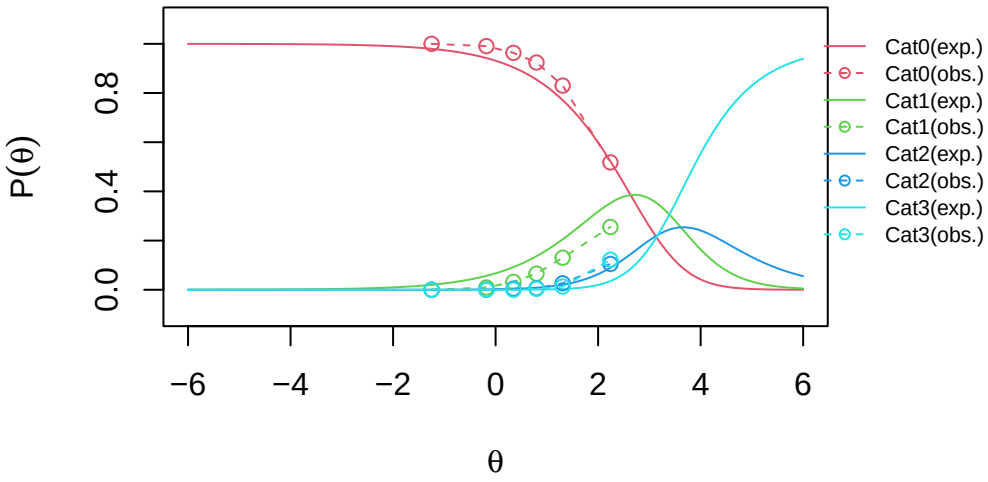
Item q5



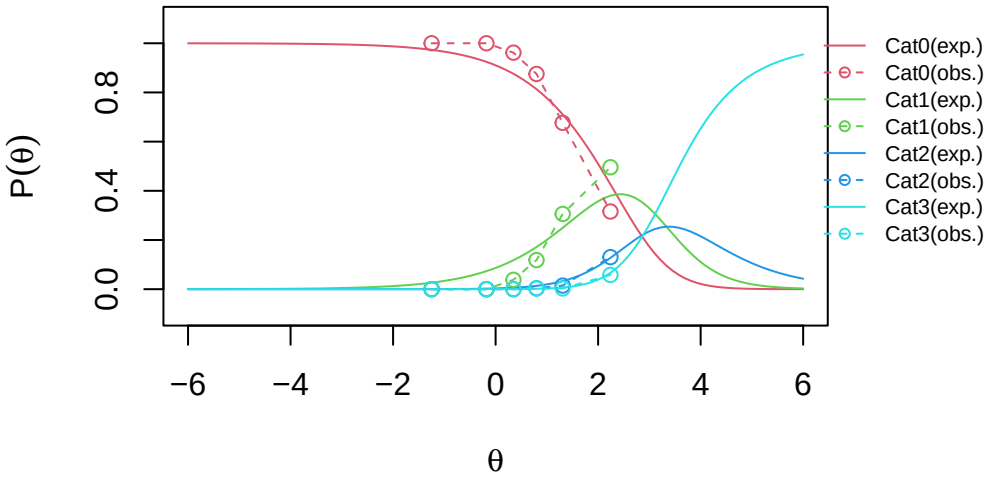

Item q6
P(θ)
0.0
0.4
0.8
−6
−4
−2
0
2
4
6
θ
Cat0(exp.)
Cat0(obs.)
Cat1(exp.)
Cat1(obs.)
Cat2(exp.)
Cat2(obs.)
Cat3(exp.)
Cat3(obs.)


Item q7
P(θ)
0.0
0.4
0.8
−6
−4
−2
0
2
4
6
θ
Cat0(exp.)
Cat0(obs.)
Cat1(exp.)
Cat1(obs.)
Cat2(exp.)
Cat2(obs.)
Cat3(exp.)
Cat3(obs.)

Item q8

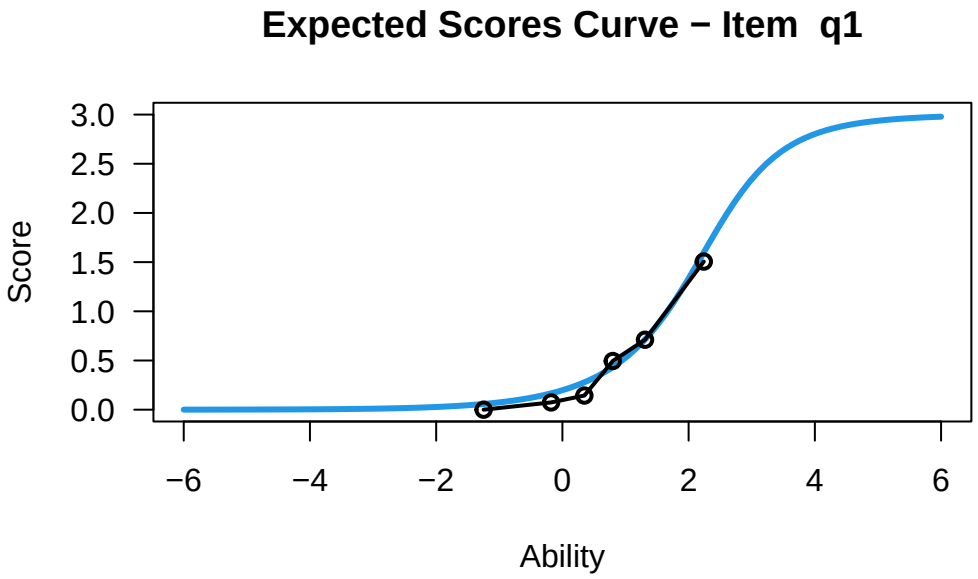


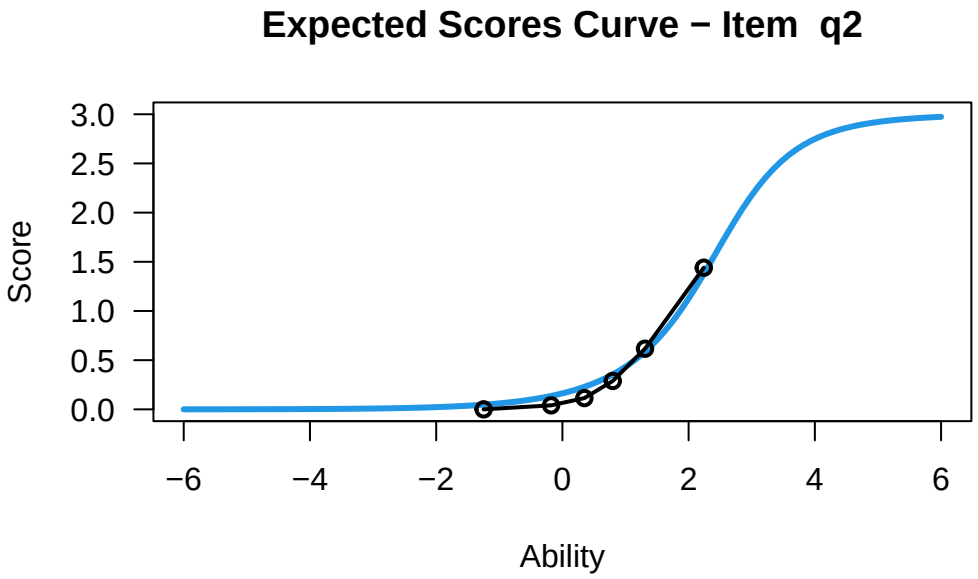
Item q9

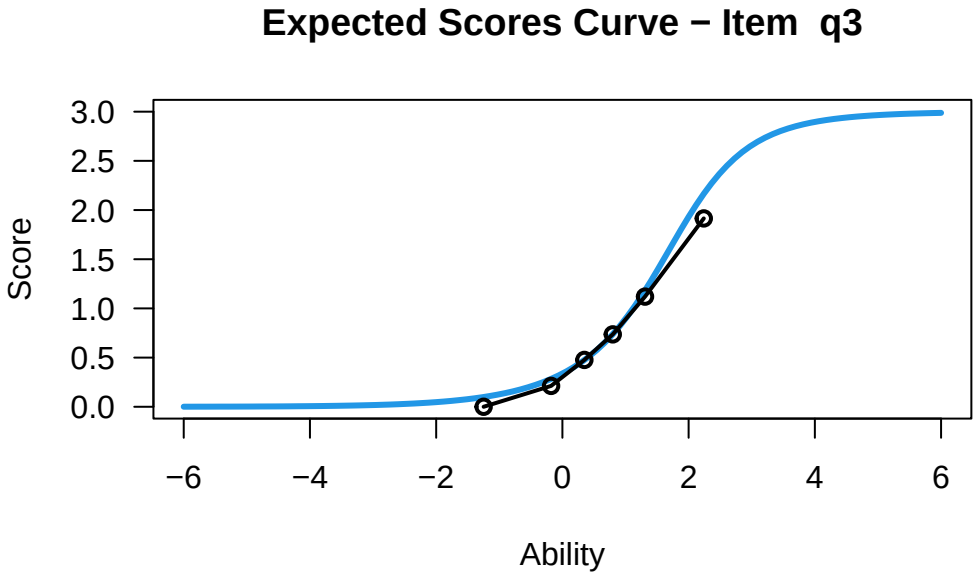


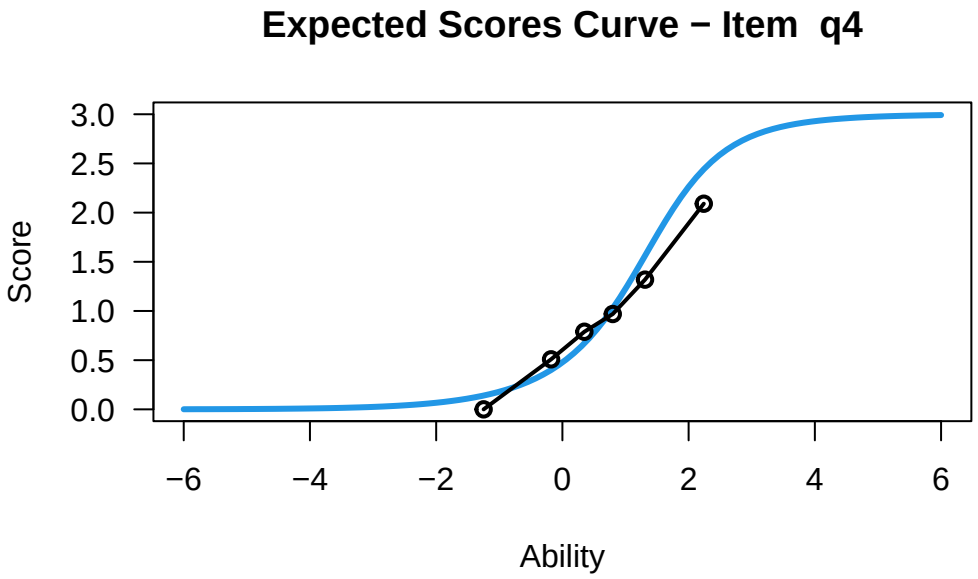
```r
plot(myTAM,
     type = "expected",
     ngroups = 6,
     low  = -6,
     high = 6,
     package = "lattice", overlay = FALSE)
```

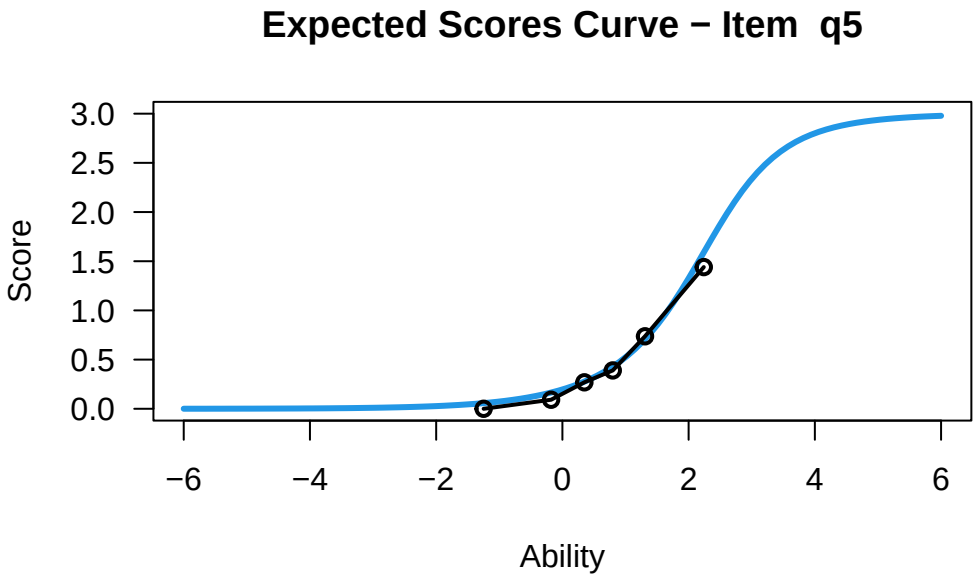
```
Iteration in WLE/MLE estimation  1   | Maximal change  2.9239
Iteration in WLE/MLE estimation  2   | Maximal change  2.8413
Iteration in WLE/MLE estimation  3   | Maximal change  1.1
Iteration in WLE/MLE estimation  4   | Maximal change  0.4911
Iteration in WLE/MLE estimation  5   | Maximal change  0.1645
Iteration in WLE/MLE estimation  6   | Maximal change  0.0147
Iteration in WLE/MLE estimation  7   | Maximal change  3e-04
Iteration in WLE/MLE estimation  8   | Maximal change  0
----
 WLE Reliability= 0.42
```

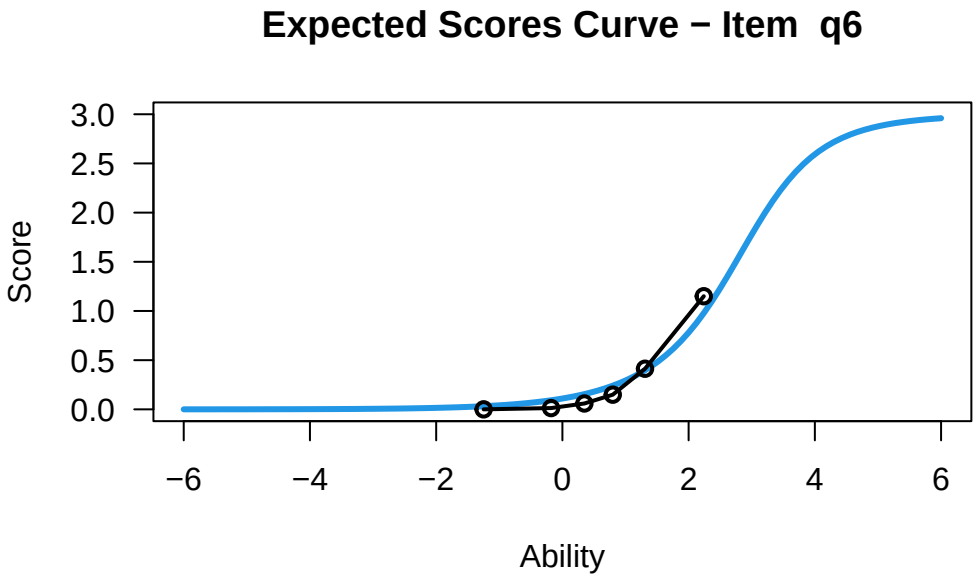


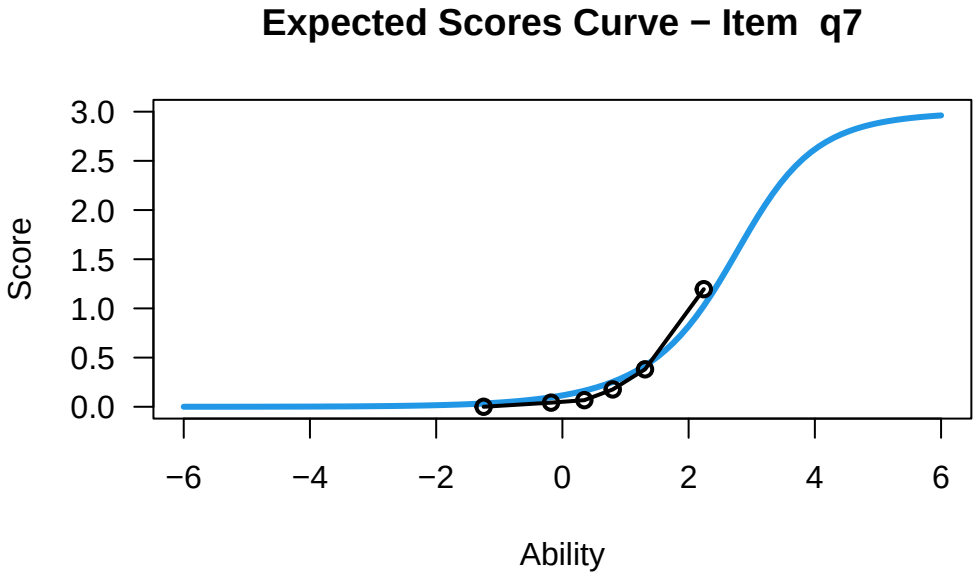

Expected Scores Curve − Item q2
Score
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−6
−4
−2
0
2
4
6
Ability

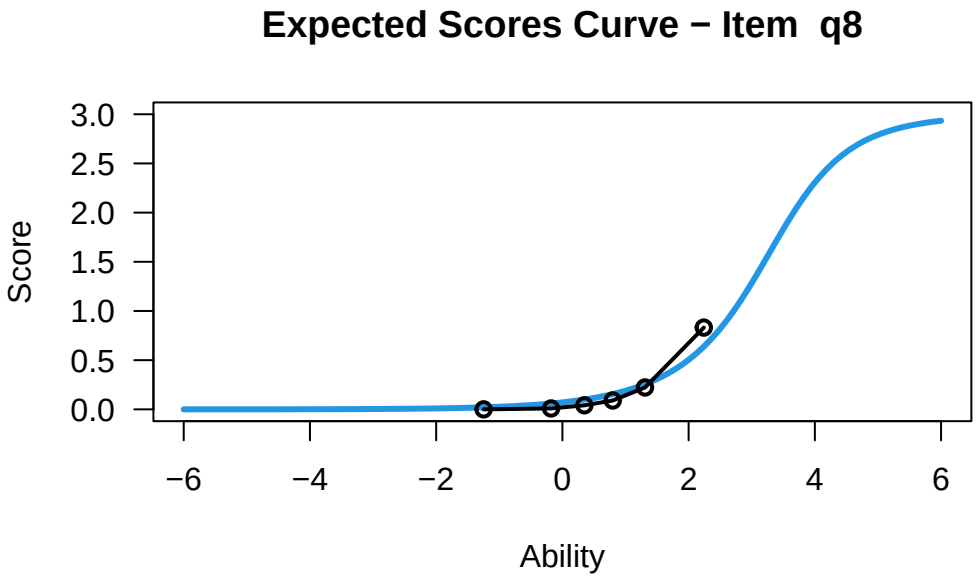

Expected Scores Curve − Item q3
Score
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−6
−4
−2
0
2
4
6
Ability

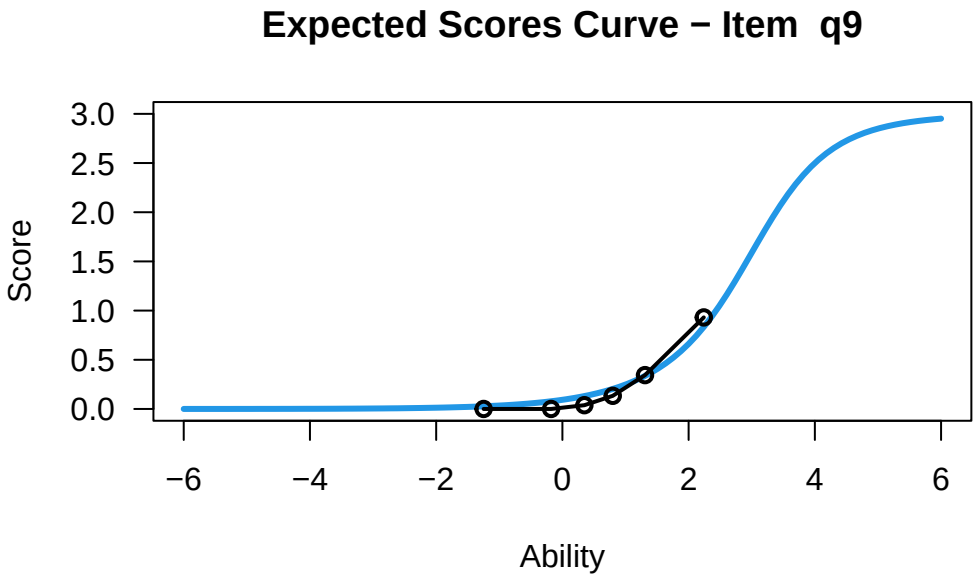

Expected Scores Curve − Item q4
Score
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−6
−4
−2
0
2
4
6
Ability


Expected Scores Curve − Item q5
Score
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−6
−4
−2
0
2
4
6
Ability


Expected Scores Curve − Item q6
Score
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−6
−4
−2
0
2
4
6
Ability


Expected Scores Curve − Item q7
Score
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−6
−4
−2
0
2
4
6
Ability






```
.................................................
 Plots exported in png format into folder:
 C:/Users/alex/Downloads/Plots
```

Conclusion

The IRT analysis showed that the questions were all positive, that the discrimination parameters were all good, that the IIC suggests that the scale is overall reliable, but the reliability peaks on low-moderate depression. But in a screening tool, this is probably what we want.

The factor analysis gave broadly similar results to the IRT analysis, but not identical. The model fit was not perfect, suggesting that it was not unidimensional, which might be a problem. The modification indices suggested some additional covariances, but there did not seem to be strong theoretical foundation for adding those to the model.

I wanted to try running a CFA using Maximum Likelihood with categorical data, as this might have given more similar results to the IRT. Lavaan does not support it, it is my understanding that Mplus does; but I don't have access to that.

A drawback of this analysis is that I dichotomized the variables to simplify the analysis. The results might have been different if this was not done.

Extension: Graded response model (GRM), Rating scale model (RSM)

TODO: Create a GitHub repository for this analysis

TODO: Look into measurement invariance (CFA) and differential item functioning (IRT)