# Getting Started with the Graded Response Model (GRM): A gentle introduction and tutorial in R

Rizqy Amelia Zein1,2 and Hanif Akhtar3,4

1Department of Psychology, Universitas Airlangga

2Department of Psychology, Ludwig-Maximilians-Universität

3Doctoral School of Psychology, ELTE Eötvös Loránd University

4Faculty of Psychology, Universitas Muhammadiyah Malang

# Author Note

Rizqy Amelia Zein  https://orcid.org/0000-0001-7840-0299

Hanif Akhtar  https://orcid.org/0000-0002-1388-7347

We declare we have no competing interests. The first author receives a PhD scholarship from the German Academic Exchange Service (Deutscher Akademischer Austauschdienst, DAAD).

Correspondence concerning this article should be addressed to Rizqy Amelia Zein, Department of Psychology, Universitas Airlangga, Jalan Airlangga 4-6, Surabaya, Jawa Timur, Indonesia 60286, Email: amelia.zein@psikologi.unair.ac.id

# Abstract

This tutorial paper introduces the Graded Response Model (GRM), a tool for testing measurement precision under the Item Response Theory (IRT) paradigm. Addressing common problems of measurement imprecision and lack of construct validity, the tutorial guides researchers through a one-dimensional GRM analysis in the R environment, using psych, mirt, and ggmirt packages. GRM is specifically designed to examine the psychometric properties of psychological scales with polytomous items. The tutorial illustrates the procedure using data from the Open Psychometrics Database on the Right-Wing Authoritarianism (RWA) scale, outlining the theoretical underpinnings of GRM, and steps for data preparation, model fitting, interpretation of results, and dealing with common issues and anomalies that may typically arise in the process.

*Keywords*: graded response model, item response theory, mirt, ggmirt, psych, R

# Getting Started with the Graded Response Model (GRM): A gentle introduction and tutorial in R

Measurement, undoubtedly, is an important foundation of scientific research. Measurement process start with defining the construct being studied and then determine the assumptions

# A Brief Overview of Item Response Theory

# Graded Response Model

# Assumptions and Key Concepts

# Disclosure

To maximise reproducibility of our analysis, we wrote the article as a Quarto (.qmd) document, where we integrate the R codes used in the analysis as well as its outputs. We also include the complete R script for the example we used as a supplementary document. The Quarto file (and its corresponding .docx and .pdf output) and R script are publicly available on (a Github repository)[https://github.com/rameliaz/grm-tutorial-paper].

# An Illustrative Example of Graded Response Model: The Right Wing Authoritarianism (RWA) Scale

To demonstrate the procedure of running a graded response model, we

## A Brief Overview of the Altemeyer’s RWA Scale

## Step 1: Preparation

install.packages("tidyverse", "psych", "devtools", "mirt", "caret", dependencies=TRUE)  
library(tidyverse); library(psych); library(mirt); library(caret)

Blabla

# devtools::install\_github("masurp/ggmirt")  
library(ggmirt)

Blabla

ds <- read.csv("data/data.csv")

Blabla

str(ds)

Blabla

rwa <- subset(ds, select = Q1:Q22)  
str(rwa)

Blabla

## Step 2: Inspecting Key Descriptive Statistics

psych::describe(rwa)

As we see in Table 1, nddasjdhajskdhaks

unfav <- c("Q4","Q6","Q8","Q9","Q11","Q13","Q15","Q18","Q20","Q21") # Now we create a vector defining which items will be coded reversely.  
rwa <- rwa %>%   
 mutate(across(all\_of(unfav), ~ 9 - .))# We simply subtract the scores from 9 (the maximum) to reverse code the unfavorable items.

Kok ada nilai 0-nya? padahal kan skor minimalnya 1. Coba kita hitung frekuensi nilai 0 di tiap item.

zero <- colSums(rwa == 0) / nrow(rwa) \* 100 # Computing the frequency of "0" in each column.  
print(zero) # The proportion of "0" for each item.

rwa <- rwa %>%  
 mutate\_all(~na\_if(., 0)) %>% # Replacing 0 with NA in all columns.  
 drop\_na() # Removing cases with any NA values.

Now let’s look again at the descriptive statistics after we removed all NA cases.

psych::describe(rwa)

## Step 3: Examining Dimensionality

irt.fa(rwa, nfactors = 1, fm = "minres")

fa.parallel(rwa, nfactors = 1, fm="minres", fa="fa", cor = "poly")

cor <- cor(rwa,method="pearson") # First, creating a (pearson) correlation matrix.  
efa <- fa(rwa, nfactors=1, fm="minres") # Now, running exploratory factor analysis.   
print(efa) # Print the results.

Scree plot

Now lets do parallel analysis

pa <- fa.parallel(rwa, fm="minres", fa="fa") # Running a parallel analysis.

pa$fa.values # Seeing the eigenvalues of each factor.

## Step 4: Model Estimation, Parameters, and Fit Statistics

model <- 'rwa = 1-22'

fit <- mirt(data=rwa, 1, model=model, itemtype="graded", SE=T, verbose=F)

coefs <- coef(fit, IRTpars=T, simplify=T) # Storing model parameters in a data frame.  
print(coefs) # Yielding model parameters: item discriminations (a) and threshold (b).

summary(fit)

lhalalala

M2(fit, type="C2")

lhalalala

According to our analysis, the model does not fit the data well (*M*(209) = 7843.760331, *p* = , *RMSEA* = 0.1491097, )

item.fit <- itemfit(fit)

## Step 5: Model Residuals

ld <- residuals(fit, type = "LD") # Running local dependency statistics  
up <- which(upper.tri(ld), arr.ind = T) # Extracting values only on the upper side of the diagonal.  
lar <- up[ld[up] > 0.2 | ld[up] < -0.2, ] # Defining unusually large residuals (>0.2).

lhalalala

for (i in 1:nrow(lar)) {  
 row <- lar[i, 1]  
 col <- lar[i, 2]  
 value <- ld[row, col]  
 cat(sprintf("A large residual correlation is found between item %d and item %d: %f\n", row, col, value))  
} # Now we detect the problematic pairs.

lhalalala

q3 <- residuals(fit, type = "Q3") # Running Yen's Q3 statistics  
findCorrelation(q3, cutoff = 0.2, verbose = T) # Detecting problematic correlation pairs.

## Step 6: IRT Plots

Now spit out the

tracePlot(fit, facet=T, title = "Category Probability Functions of RWA Scale") + labs(color="Response Options")

lhalalala

itemInfoPlot(fit, facet=T, title = "Item Information Curves of the RWA Scale")

lhalalala

itemInfoPlot(fit, facet=T, theta\_range = c(-6,6), title = "Item Information Curves of the RWA Scale")#

lhalalala

testInfoPlot(fit, title="Test Information Curve of the RWA Scale")

## Step 7: Computing Reliability

theta\_se <- fscores(fit, full.scores.SE = T) # Extracting the estimated theta score of each participant.  
e\_rel <- empirical\_rxx(theta\_se) # Then use the estimated theta to calculate empirical reliability.

lhalalala

m\_rel <- marginal\_rxx(fit)

lhalalala

omega(rwa)

# Conclusions

# References

Table 1

Descriptive Statistics of RWA Scale

| Item | Mean | SD | Minimum | Maximum | Range | n |
| --- | --- | --- | --- | --- | --- | --- |
| Q1 | 5.03 | 2.27 | 1 | 9 | 8 | 1,644 |
| Q2 | 4.48 | 2.65 | 1 | 9 | 8 | 1,644 |
| Q3 | 5.38 | 2.87 | 1 | 9 | 8 | 1,644 |
| Q4 | 4.57 | 2.57 | 1 | 9 | 8 | 1,644 |
| Q5 | 4.89 | 2.28 | 1 | 9 | 8 | 1,644 |
| Q6 | 4.24 | 2.33 | 1 | 8 | 7 | 1,644 |
| Q7 | 5.63 | 2.71 | 1 | 9 | 8 | 1,644 |
| Q8 | 4.88 | 2.35 | 1 | 9 | 8 | 1,644 |
| Q9 | 3.71 | 2.29 | 1 | 9 | 8 | 1,644 |
| Q10 | 6.13 | 2.47 | 1 | 9 | 8 | 1,644 |
| Q11 | 3.91 | 2.30 | 1 | 9 | 8 | 1,644 |
| Q12 | 6.36 | 2.09 | 1 | 9 | 8 | 1,644 |
| Q13 | 5.04 | 2.42 | 1 | 9 | 8 | 1,644 |
| Q14 | 5.91 | 2.63 | 1 | 9 | 8 | 1,644 |
| Q15 | 4.80 | 2.25 | 1 | 9 | 8 | 1,644 |
| Q16 | 4.61 | 2.55 | 1 | 9 | 8 | 1,644 |
| Q17 | 5.54 | 2.53 | 1 | 9 | 8 | 1,644 |
| Q18 | 3.71 | 2.45 | 1 | 8 | 7 | 1,644 |
| Q19 | 5.28 | 2.46 | 1 | 9 | 8 | 1,644 |
| Q20 | 3.89 | 2.35 | 1 | 9 | 8 | 1,644 |
| Q21 | 5.80 | 2.22 | 1 | 9 | 8 | 1,644 |
| Q22 | 5.60 | 2.54 | 1 | 9 | 8 | 1,644 |

*Note*. SD = Standard Deviation

Table 2

Descriptive Statistics of RWA Scale

| Item | Mean | SD | Minimum | Maximum | Range | n |
| --- | --- | --- | --- | --- | --- | --- |
| Q1 | 5.03 | 2.27 | 1 | 9 | 8 | 1,644 |
| Q2 | 4.48 | 2.65 | 1 | 9 | 8 | 1,644 |
| Q3 | 5.38 | 2.87 | 1 | 9 | 8 | 1,644 |
| Q4 | 4.57 | 2.57 | 1 | 9 | 8 | 1,644 |
| Q5 | 4.89 | 2.28 | 1 | 9 | 8 | 1,644 |
| Q6 | 4.24 | 2.33 | 1 | 8 | 7 | 1,644 |
| Q7 | 5.63 | 2.71 | 1 | 9 | 8 | 1,644 |
| Q8 | 4.88 | 2.35 | 1 | 9 | 8 | 1,644 |
| Q9 | 3.71 | 2.29 | 1 | 9 | 8 | 1,644 |
| Q10 | 6.13 | 2.47 | 1 | 9 | 8 | 1,644 |
| Q11 | 3.91 | 2.30 | 1 | 9 | 8 | 1,644 |
| Q12 | 6.36 | 2.09 | 1 | 9 | 8 | 1,644 |
| Q13 | 5.04 | 2.42 | 1 | 9 | 8 | 1,644 |
| Q14 | 5.91 | 2.63 | 1 | 9 | 8 | 1,644 |
| Q15 | 4.80 | 2.25 | 1 | 9 | 8 | 1,644 |
| Q16 | 4.61 | 2.55 | 1 | 9 | 8 | 1,644 |
| Q17 | 5.54 | 2.53 | 1 | 9 | 8 | 1,644 |
| Q18 | 3.71 | 2.45 | 1 | 8 | 7 | 1,644 |
| Q19 | 5.28 | 2.46 | 1 | 9 | 8 | 1,644 |
| Q20 | 3.89 | 2.35 | 1 | 9 | 8 | 1,644 |
| Q21 | 5.80 | 2.22 | 1 | 9 | 8 | 1,644 |
| Q22 | 5.60 | 2.54 | 1 | 9 | 8 | 1,644 |

*Note*. SD = Standard Deviation, Descriptive Statistics After Reversing Unfavorable Items

Table 3

Percentge of Zero in Each Item

| Item | Percentage |
| --- | --- |
| Q1 | 0.13 |
| Q2 | 0.07 |
| Q3 | 0.24 |
| Q4 | 58.51 |
| Q5 | 0.13 |
| Q6 | 52.17 |
| Q7 | 0.14 |
| Q8 | 30.55 |
| Q9 | 43.57 |
| Q10 | 0.17 |
| Q11 | 52.05 |
| Q12 | 0.32 |
| Q13 | 39.93 |
| Q14 | 0.21 |
| Q15 | 30.49 |
| Q16 | 0.10 |
| Q17 | 0.13 |
| Q18 | 63.73 |
| Q19 | 0.11 |
| Q20 | 46.45 |
| Q21 | 27.85 |
| Q22 | 0.11 |

Table 4

Descriptive Statistics of RWA Scale

| Item | Mean | SD | Minimum | Maximum | Range | n |
| --- | --- | --- | --- | --- | --- | --- |
| Q1 | 5.03 | 2.27 | 1 | 9 | 8 | 1,644 |
| Q2 | 4.48 | 2.65 | 1 | 9 | 8 | 1,644 |
| Q3 | 5.38 | 2.87 | 1 | 9 | 8 | 1,644 |
| Q4 | 4.57 | 2.57 | 1 | 9 | 8 | 1,644 |
| Q5 | 4.89 | 2.28 | 1 | 9 | 8 | 1,644 |
| Q6 | 4.24 | 2.33 | 1 | 8 | 7 | 1,644 |
| Q7 | 5.63 | 2.71 | 1 | 9 | 8 | 1,644 |
| Q8 | 4.88 | 2.35 | 1 | 9 | 8 | 1,644 |
| Q9 | 3.71 | 2.29 | 1 | 9 | 8 | 1,644 |
| Q10 | 6.13 | 2.47 | 1 | 9 | 8 | 1,644 |
| Q11 | 3.91 | 2.30 | 1 | 9 | 8 | 1,644 |
| Q12 | 6.36 | 2.09 | 1 | 9 | 8 | 1,644 |
| Q13 | 5.04 | 2.42 | 1 | 9 | 8 | 1,644 |
| Q14 | 5.91 | 2.63 | 1 | 9 | 8 | 1,644 |
| Q15 | 4.80 | 2.25 | 1 | 9 | 8 | 1,644 |
| Q16 | 4.61 | 2.55 | 1 | 9 | 8 | 1,644 |
| Q17 | 5.54 | 2.53 | 1 | 9 | 8 | 1,644 |
| Q18 | 3.71 | 2.45 | 1 | 8 | 7 | 1,644 |
| Q19 | 5.28 | 2.46 | 1 | 9 | 8 | 1,644 |
| Q20 | 3.89 | 2.35 | 1 | 9 | 8 | 1,644 |
| Q21 | 5.80 | 2.22 | 1 | 9 | 8 | 1,644 |
| Q22 | 5.60 | 2.54 | 1 | 9 | 8 | 1,644 |

*Note*. SD = Standard Deviation, Descriptive Statistics After Reversing Unfavorable Items

Figure 1

Scree Plot

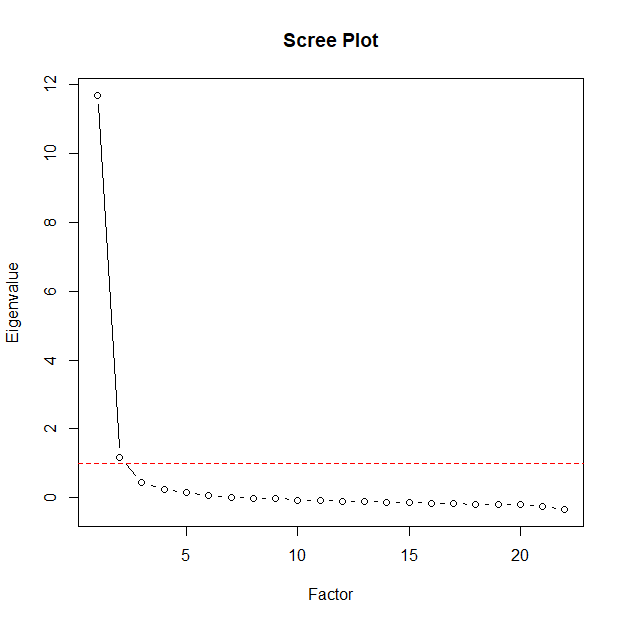


Figure 2

Parallel Analysis

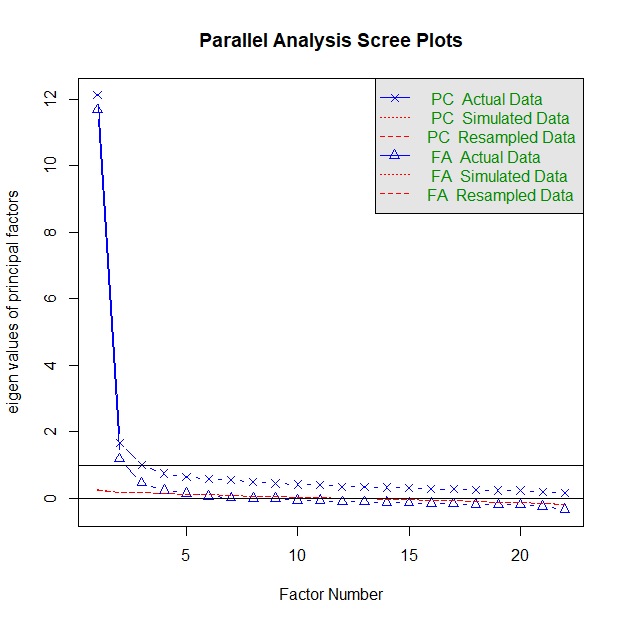


Table 5

Descriptive Statistics of RWA Scale

| Item | α | β1 | β2 | β3 | β4 | β5 | β6 | β7 | β8 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Q1 | 1.17 | -3.23 | -1.81 | -0.88 | -0.41 | 0.12 | 0.70 | 1.65 | 2.64 |
| Q2 | 1.93 | -1.47 | -0.63 | -0.24 | -0.02 | 0.33 | 0.77 | 1.18 | 1.77 |
| Q3 | 3.36 | -1.43 | -0.84 | -0.53 | -0.37 | -0.16 | 0.15 | 0.46 | 0.82 |
| Q4 | 1.97 | -1.17 | -0.69 | -0.49 | -0.15 | 0.23 | 0.67 | 1.11 | 4.41 |
| Q5 | 1.67 | -2.48 | -1.37 | -0.65 | -0.19 | 0.21 | 0.73 | 1.32 | 2.17 |
| Q6 | 1.59 | -1.43 | -0.76 | -0.39 | 0.10 | 0.55 | 1.09 | 1.78 |  |
| Q7 | 3.49 | -1.69 | -1.00 | -0.66 | -0.42 | -0.26 | 0.06 | 0.41 | 0.87 |
| Q8 | 1.55 | -1.88 | -1.17 | -0.81 | -0.21 | 0.18 | 0.63 | 1.22 | 5.73 |
| Q9 | 1.75 | -1.20 | -0.49 | 0.17 | 0.52 | 0.88 | 1.33 | 1.84 | 4.55 |
| Q10 | 3.40 | -2.02 | -1.30 | -0.96 | -0.70 | -0.49 | -0.06 | 0.28 | 0.77 |
| Q11 | 1.87 | -1.18 | -0.53 | -0.05 | 0.32 | 0.71 | 1.26 | 1.81 | 4.39 |
| Q12 | 2.49 | -2.75 | -1.88 | -1.38 | -1.03 | -0.66 | -0.09 | 0.42 | 1.02 |
| Q13 | 2.03 | -1.71 | -1.12 | -0.61 | -0.30 | 0.02 | 0.39 | 0.88 | 4.55 |
| Q14 | 2.99 | -1.81 | -1.16 | -0.84 | -0.63 | -0.39 | -0.02 | 0.36 | 0.78 |
| Q15 | 1.85 | -1.99 | -1.17 | -0.57 | -0.20 | 0.18 | 0.64 | 1.31 | 4.56 |
| Q16 | 2.10 | -1.56 | -0.83 | -0.34 | -0.05 | 0.27 | 0.71 | 1.18 | 1.70 |
| Q17 | 3.08 | -1.81 | -1.07 | -0.73 | -0.47 | -0.19 | 0.23 | 0.63 | 1.06 |
| Q18 | 1.81 | -0.83 | -0.27 | 0.06 | 0.34 | 0.76 | 1.23 | 1.76 |  |
| Q19 | 3.07 | -1.89 | -1.14 | -0.63 | -0.32 | -0.07 | 0.38 | 0.79 | 1.25 |
| Q20 | 1.59 | -1.24 | -0.54 | 0.02 | 0.31 | 0.76 | 1.29 | 1.86 | 5.66 |
| Q21 | 2.52 | -2.04 | -1.53 | -1.08 | -0.64 | -0.33 | -0.02 | 0.35 | 4.43 |
| Q22 | 2.87 | -1.95 | -1.16 | -0.78 | -0.46 | -0.22 | 0.19 | 0.58 | 0.99 |

*Note*. SD = Standard Deviation, Descriptive Statistics After Reversing Unfavorable Items

Table 6

Descriptive Statistics of RWA Scale

| Item | S\_X2 | df.S\_X2 | RMSEA.S\_X2 | p.S\_X2 |
| --- | --- | --- | --- | --- |
| Q1 | 681.44 | 639.00 | 0.01 | 0.12 |
| Q2 | 603.40 | 584.00 | 0.00 | 0.28 |
| Q3 | 545.40 | 448.00 | 0.01 | 0.00 |
| Q4 | 494.56 | 532.00 | 0.00 | 0.88 |
| Q5 | 611.84 | 586.00 | 0.01 | 0.22 |
| Q6 | 552.66 | 601.00 | 0.00 | 0.92 |
| Q7 | 480.44 | 408.00 | 0.01 | 0.01 |
| Q8 | 576.91 | 590.00 | 0.00 | 0.64 |
| Q9 | 576.31 | 542.00 | 0.01 | 0.15 |
| Q10 | 437.15 | 413.00 | 0.01 | 0.20 |
| Q11 | 504.45 | 553.00 | 0.00 | 0.93 |
| Q12 | 432.40 | 452.00 | 0.00 | 0.74 |
| Q13 | 558.98 | 544.00 | 0.00 | 0.32 |
| Q14 | 489.53 | 452.00 | 0.01 | 0.11 |
| Q15 | 569.58 | 555.00 | 0.00 | 0.33 |
| Q16 | 571.00 | 569.00 | 0.00 | 0.47 |
| Q17 | 489.44 | 464.00 | 0.01 | 0.20 |
| Q18 | 532.11 | 540.00 | 0.00 | 0.59 |
| Q19 | 502.27 | 443.00 | 0.01 | 0.03 |
| Q20 | 573.68 | 582.00 | 0.00 | 0.59 |
| Q21 | 425.75 | 451.00 | 0.00 | 0.80 |
| Q22 | 506.01 | 469.00 | 0.01 | 0.12 |

*Note*. SD = Standard Deviation, Descriptive Statistics After Reversing Unfavorable Items

Figure 3

Category Probability Functions of RWA Scale

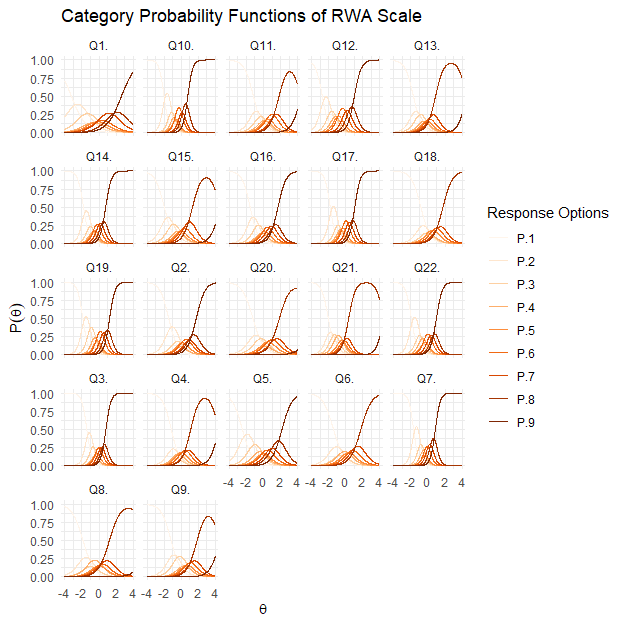


Figure 4

Item Information Curves of the RWA Scale

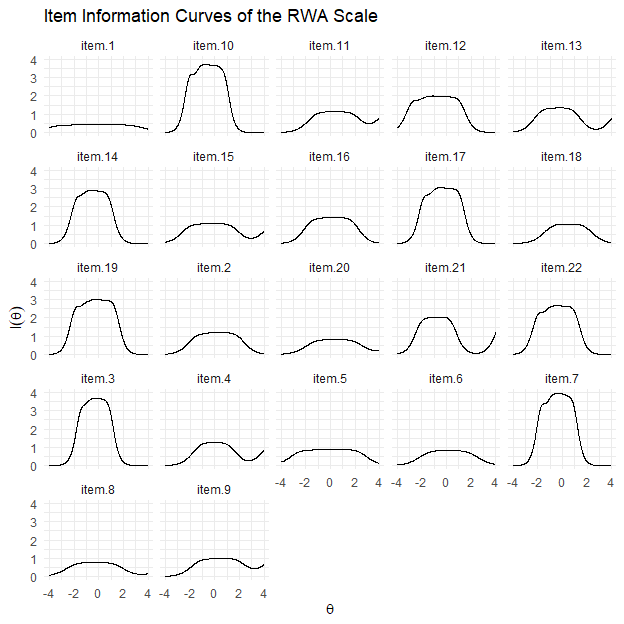


Figure 5

Item Information Curves of the RWA Scale Ranging from -6 to +6 Standard Deviation

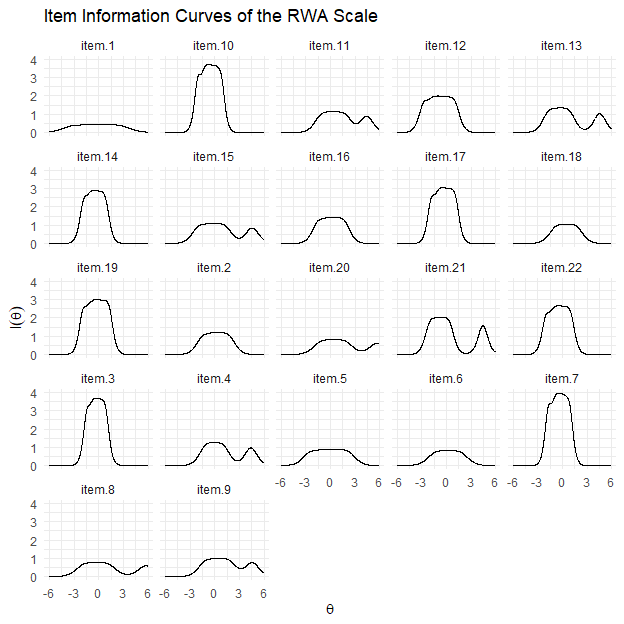


Figure 6

Test Information Curve of the RWA Scale

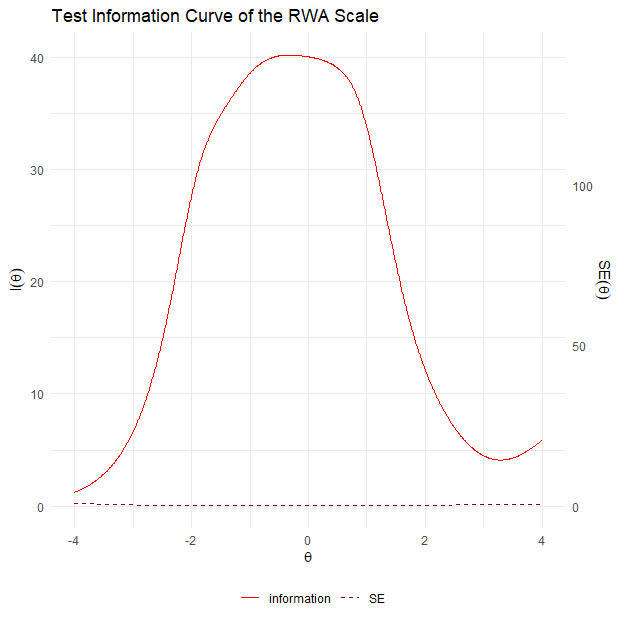


Figure 7

Reliability of the RWA Scale Given to the θ Level

