Evaluating the effectiveness of each response option with the nominal response model

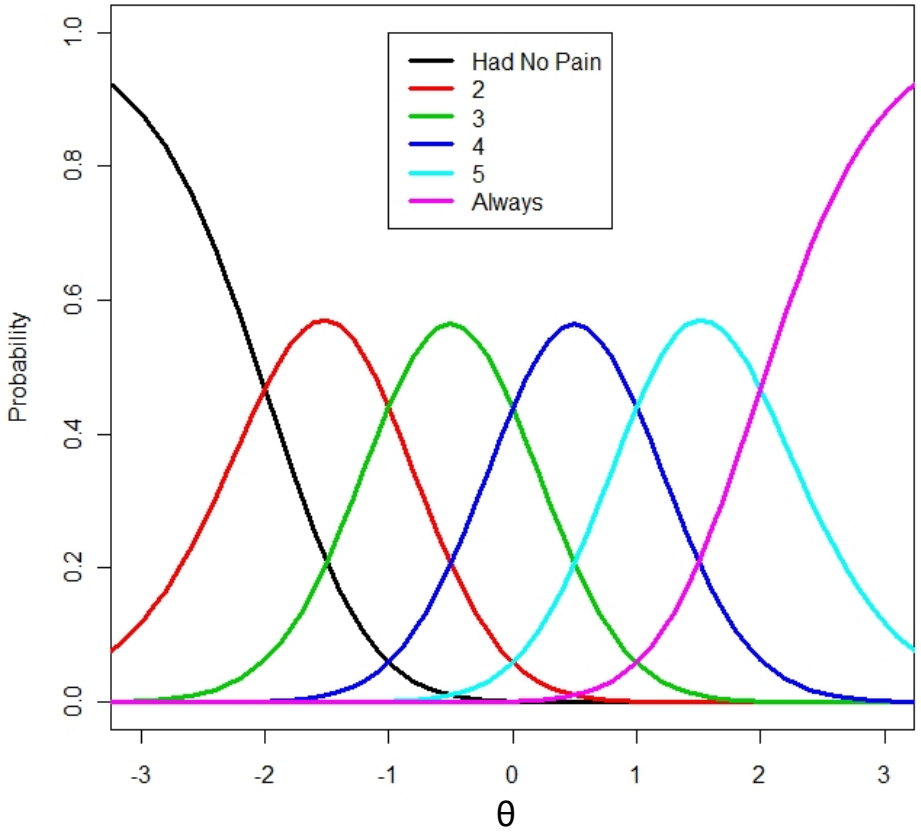
Kathleen Preston, Ph.D.
Professor of Psychology
California State University, Fullerton

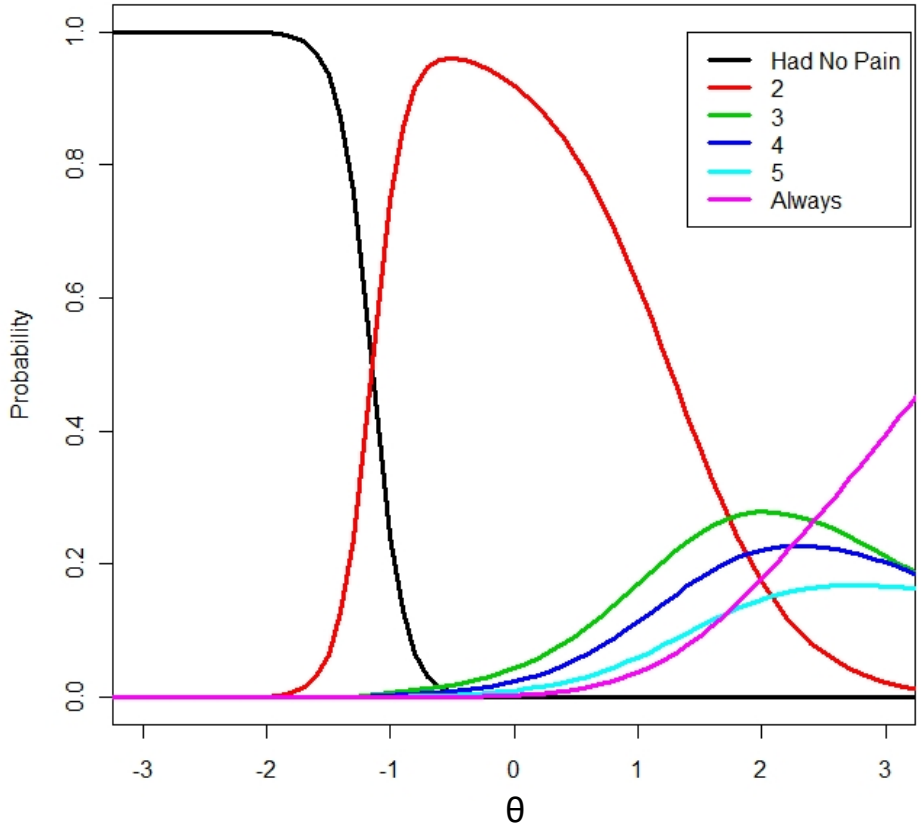
Outline

- Polytomous Item Response Theory
  - The nominal response model
- Example: Cosmetic Surgery Acceptance Scale
- Introduction to flexMIRT
- Brief R and RStudio Tutorial
- Category Response Curves
  - Evaluating scale items at the category level
- Wald test
  - Scale Revisions
- Functioning of Final Scale
- Applications and Recommendations

How do multi-point items function?

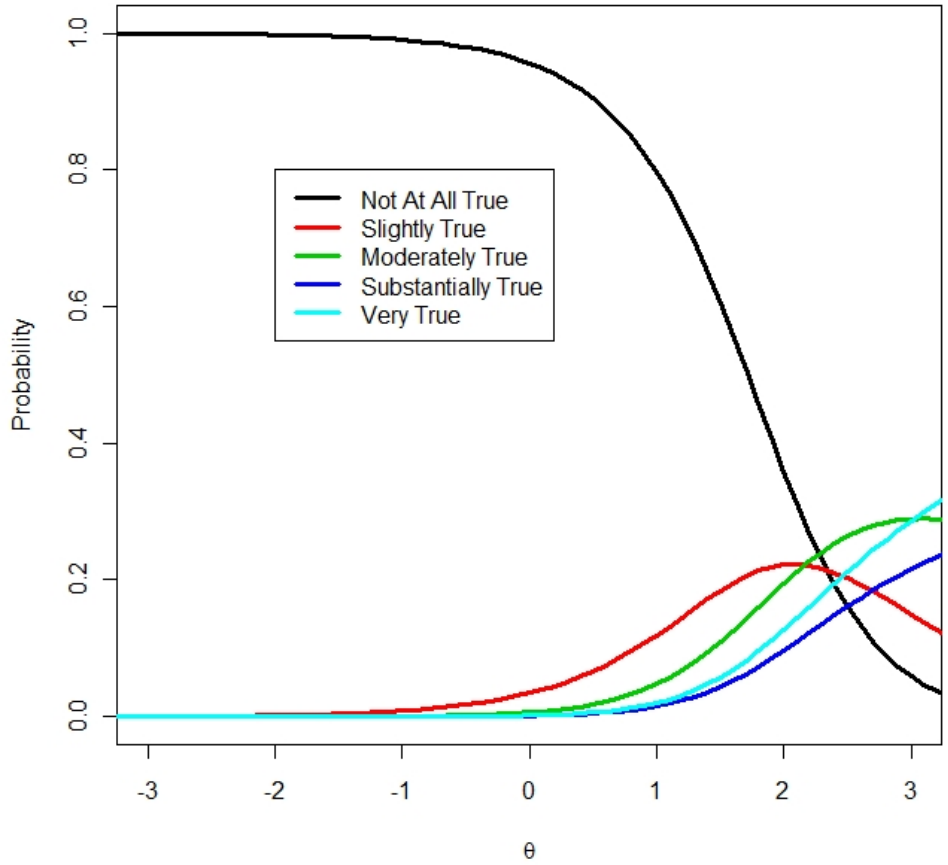
- PROMIS Pain Inventory *"When I was in pain I tried to get relief by changing my posture."*





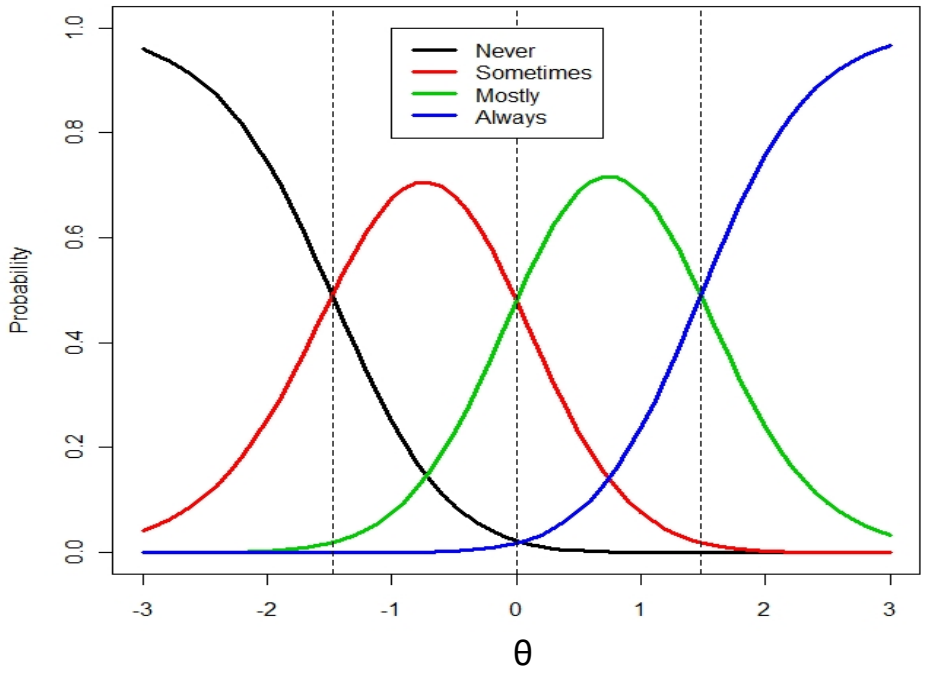
How do multi-point items function?

- SAI *"Manipulating God seems to be the best way to get what I want."*

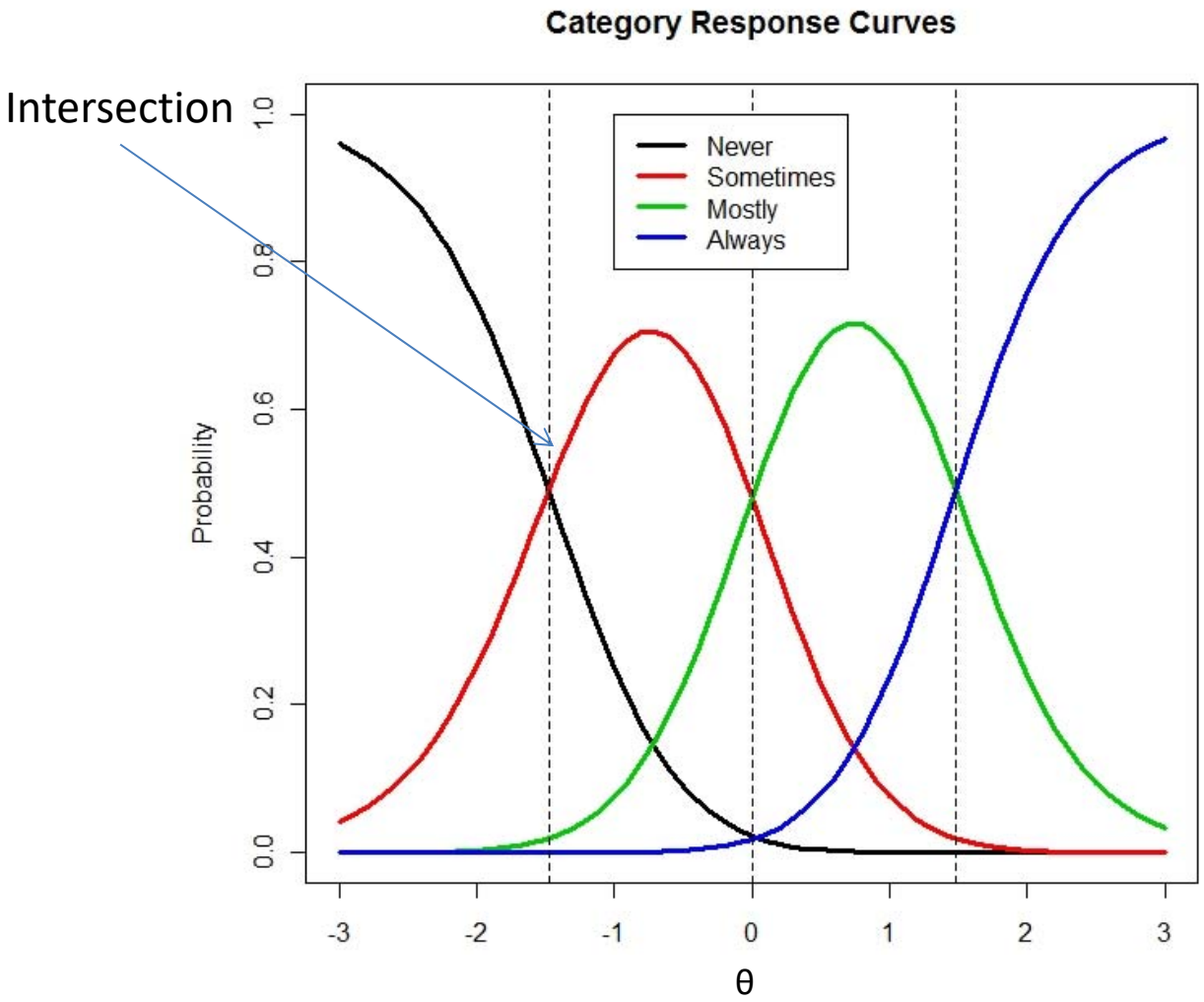


Polytomous IRT

- Are multi-point items really more efficient?
- Do multi-point items provide more measurement precision?

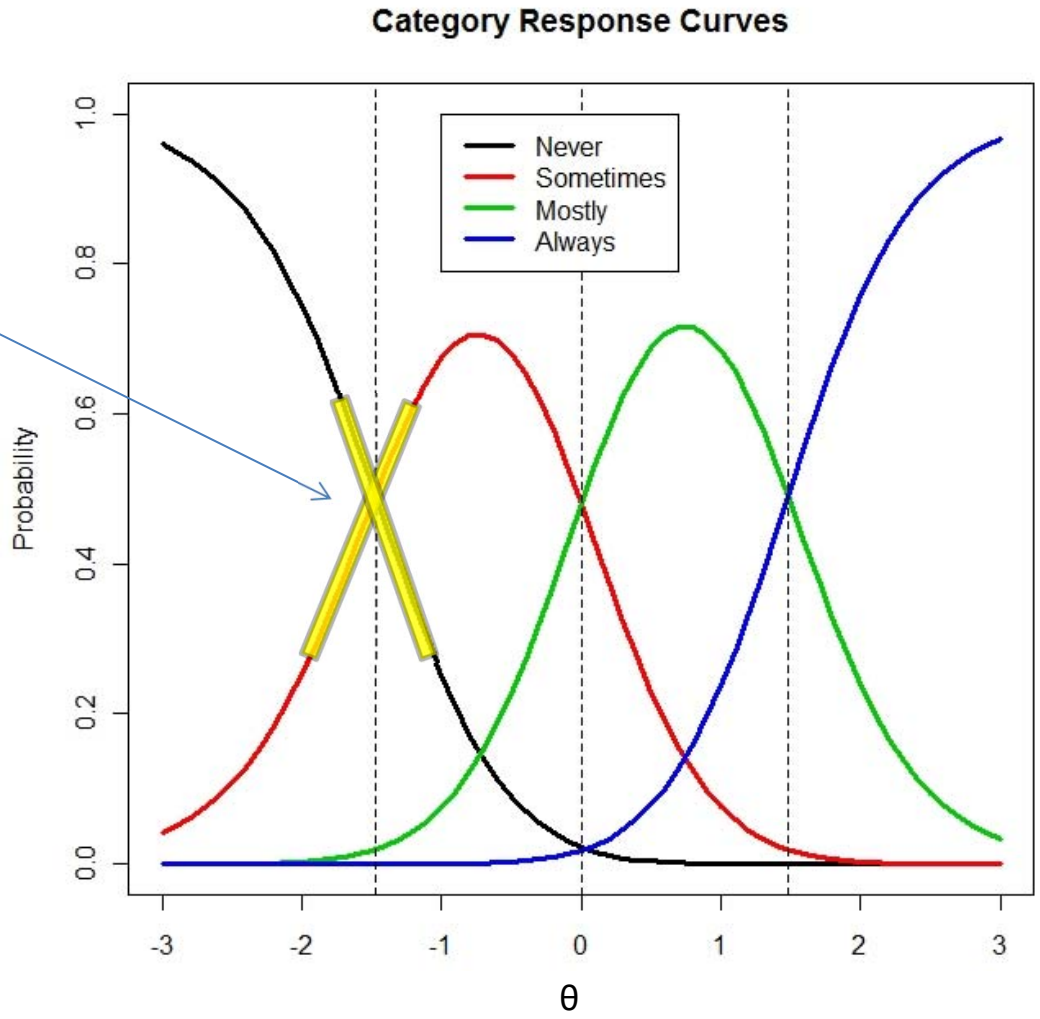


Polytomous IRT



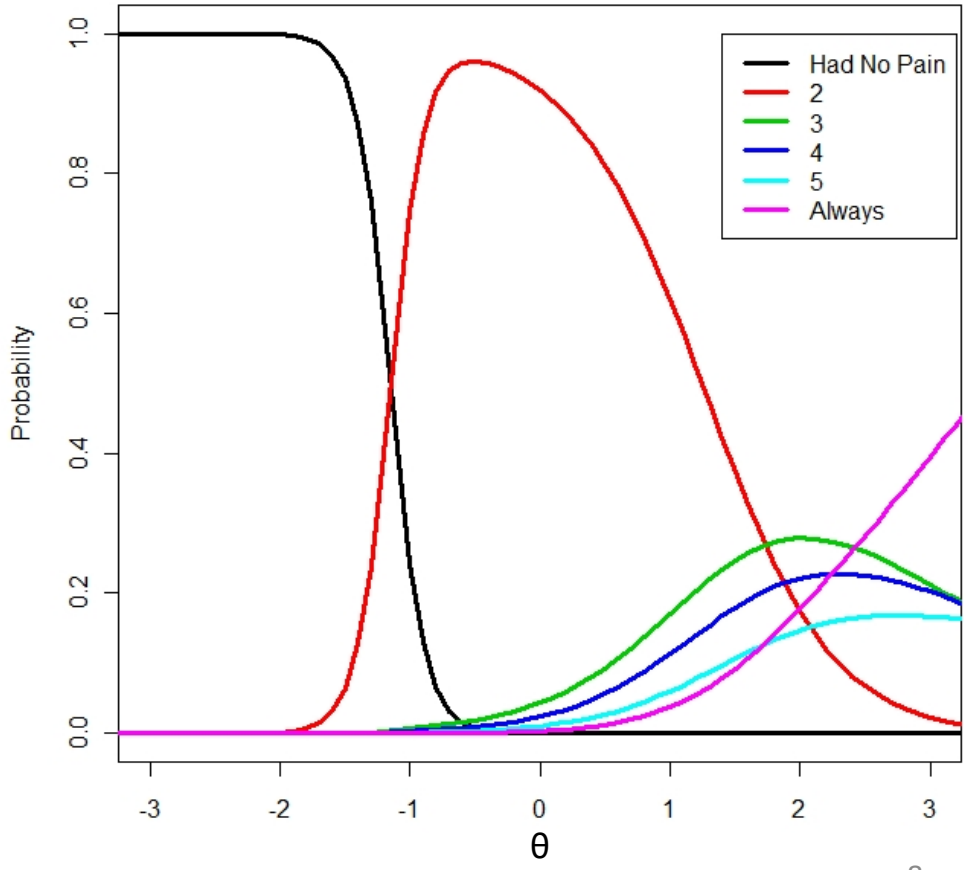
Polytomous IRT

Category Boundary Discrimination



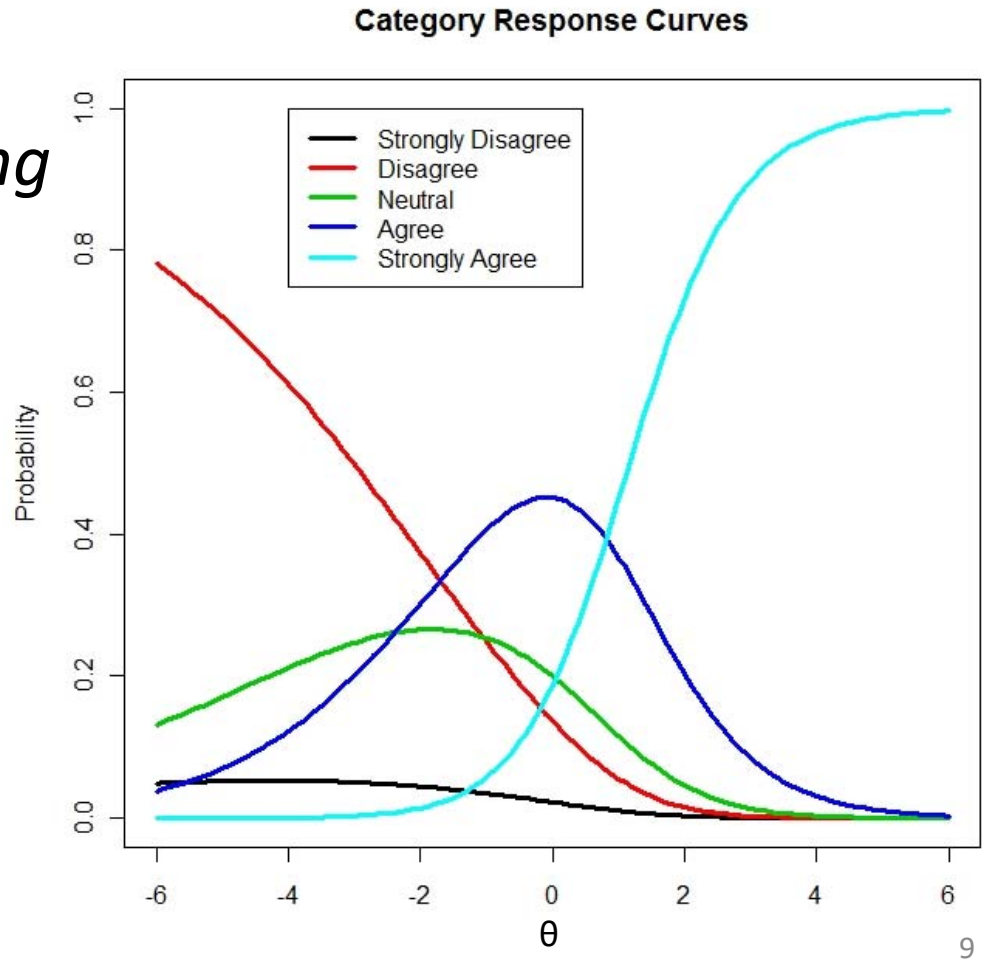
Differentially Functioning Categories

- PROMIS Pain Inventory
  "When I was in pain I tried to get relief by changing my posture."
- CBD = 7.59,
  1.76,
  0.18,
  0.22,
  0.67



Differentially Functioning Categories

- NEO-PI-R "*Without strong emotions, life would be uninteresting to me*"
- CBD = 0.04,
  0.07,
  1.09,
  1.30



Nominal Response Model
Bock (1972)

$$P_{ix}(\theta) = \frac{\exp(a_{ix}\theta + c_{ix})}{\sum_{x=1}^{m} \exp(a_{ix}\theta + c_{ix})}$$

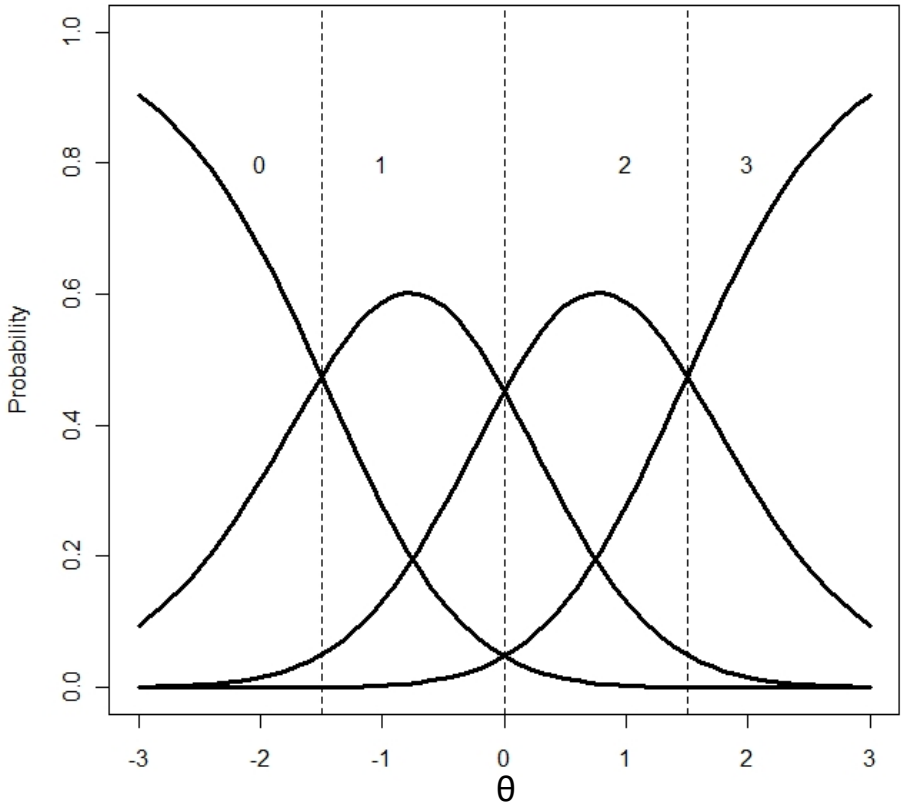
where, for identification, $a_{i1} = c_{i1} = 0$

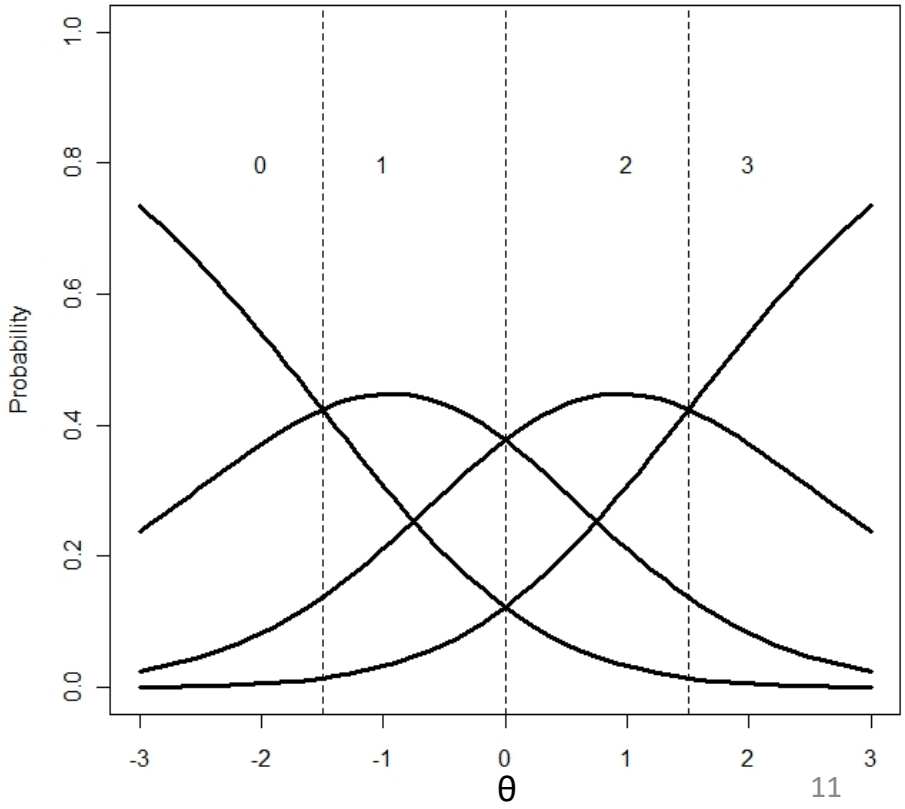
$$CBD_j = a^*_j = a_x - a_{(x\text{-}1)}$$

$$c^*_j = \frac{c_{(x-1)} - c_x}{a_x - a_{(x-1)}}$$

Category Boundary Discriminations (CBDs)

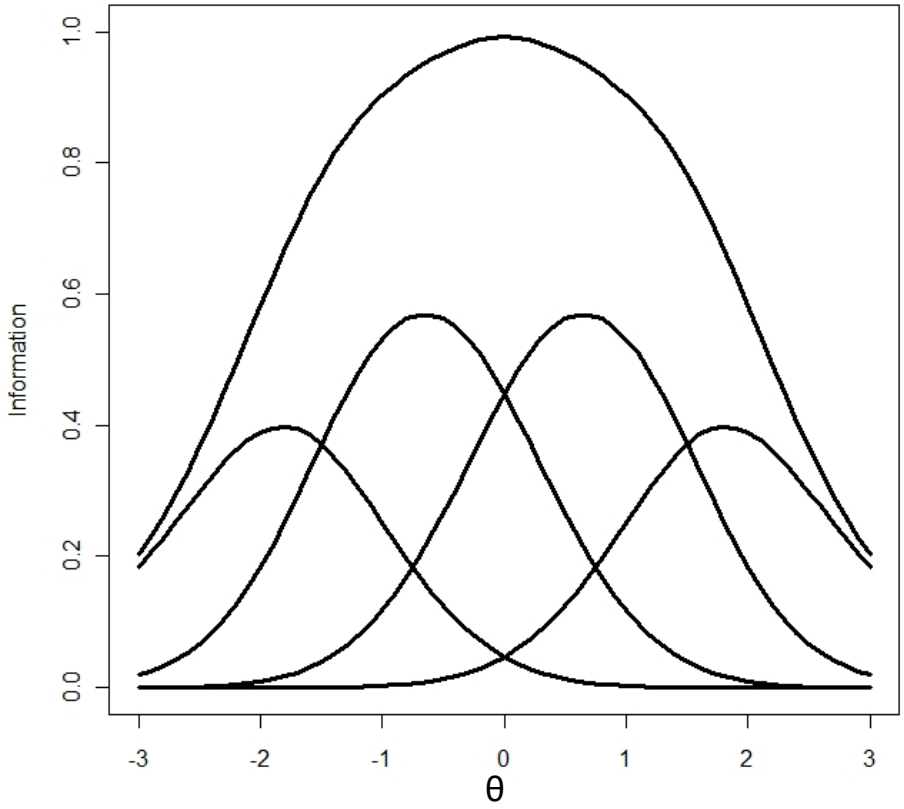
- Categories differentially contribute to the information an item provides

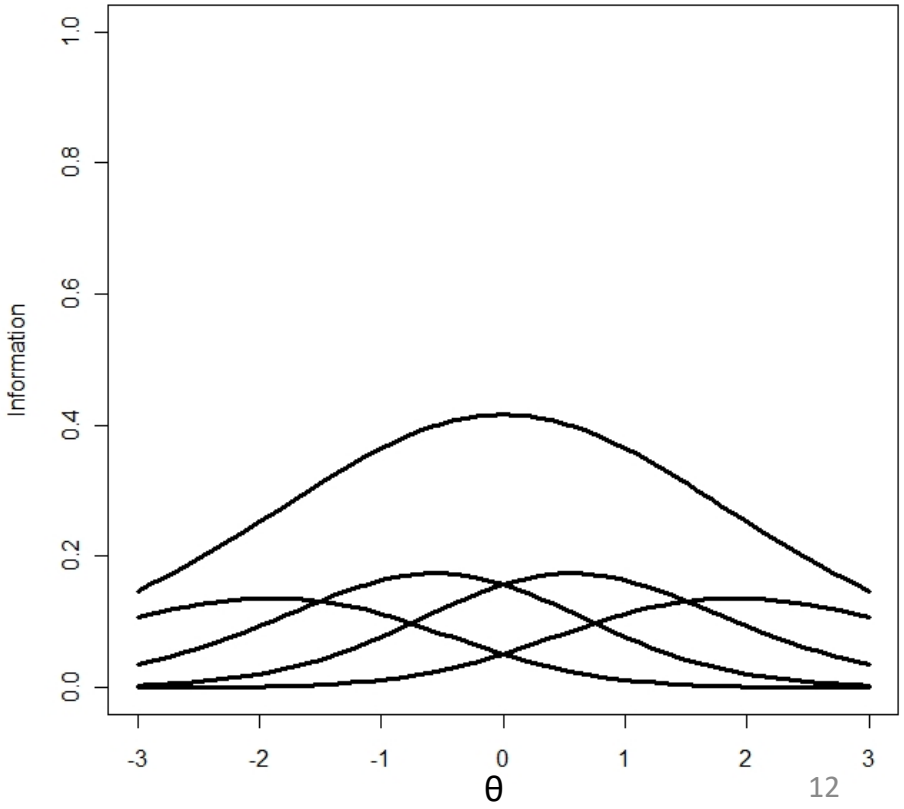




Information

- Defined as the amount of psychometric information an item/category contains at all points across the latent trait continuum





Rating Scale Model Andrich (1978)

a^* c^*

- Polytomous generalization of the dichotomous Rasch model Developed for Likert scales, rating scales, and educational assessment items for which successively higher integer scores are intended to indicate increasing levels of competence or attainment
- All items share the same rating scale structure
- Items can only vary in difficulty/threshold across the items

Rating Scale Model

Partial Credit Model Masters (1982)

$$a^* \quad c^*_i$$

- Each item has a unique rating scale structure
- Distances between the intersection parameters can vary for between, but not within items
- Developed for awarding partial credit in educational assessments

Partial Credit Model

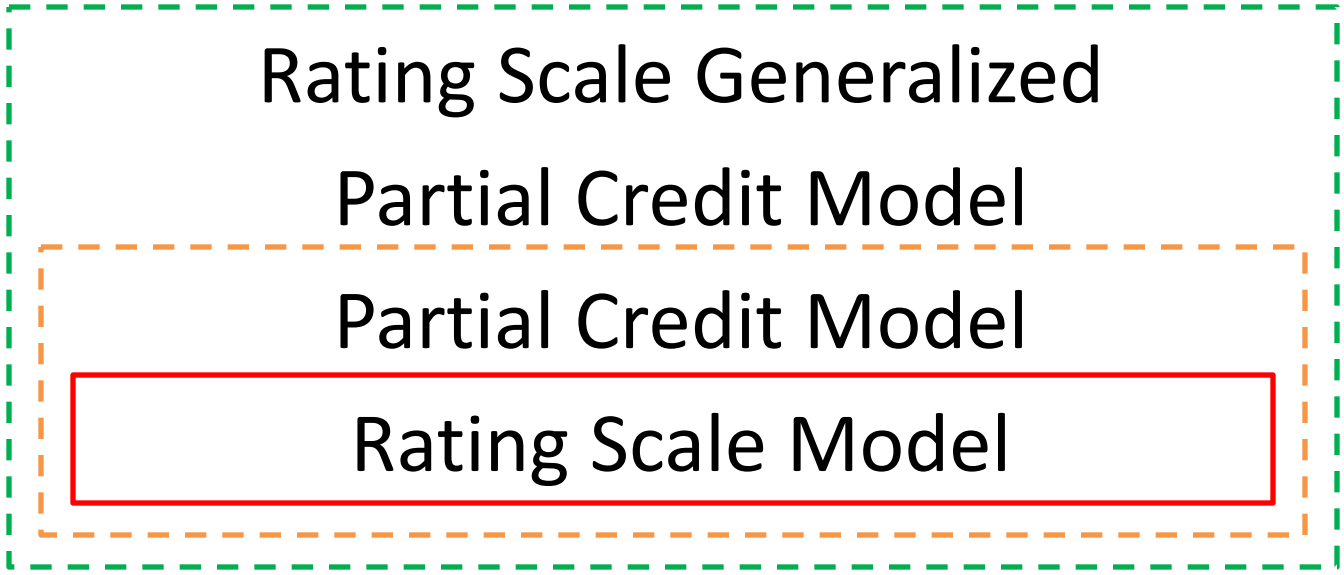
Rating Scale Model

Rating Scale Generalized Partial Credit

Muraki (1990)

$a^*_i \quad c^*$

- Developed for analysis of Likert-scaled data

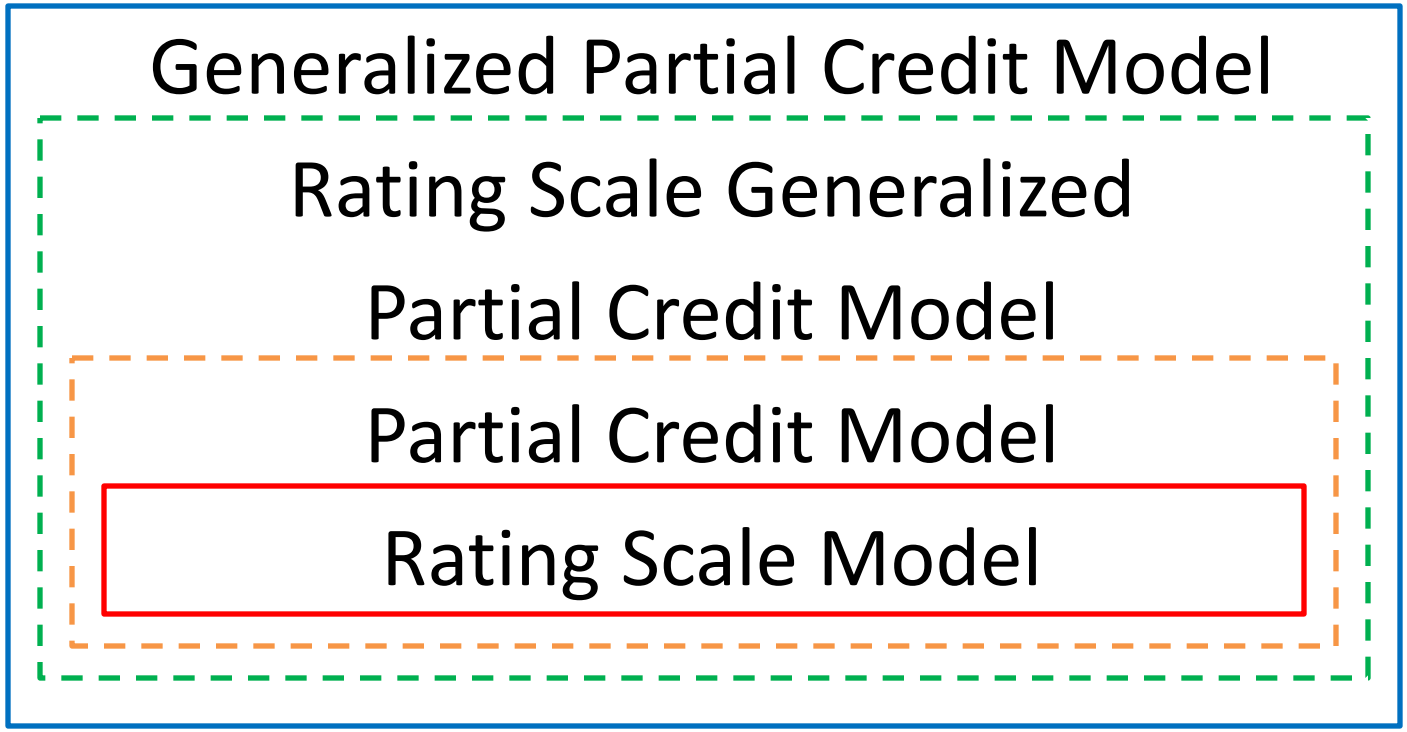


Generalized Partial Credit Model

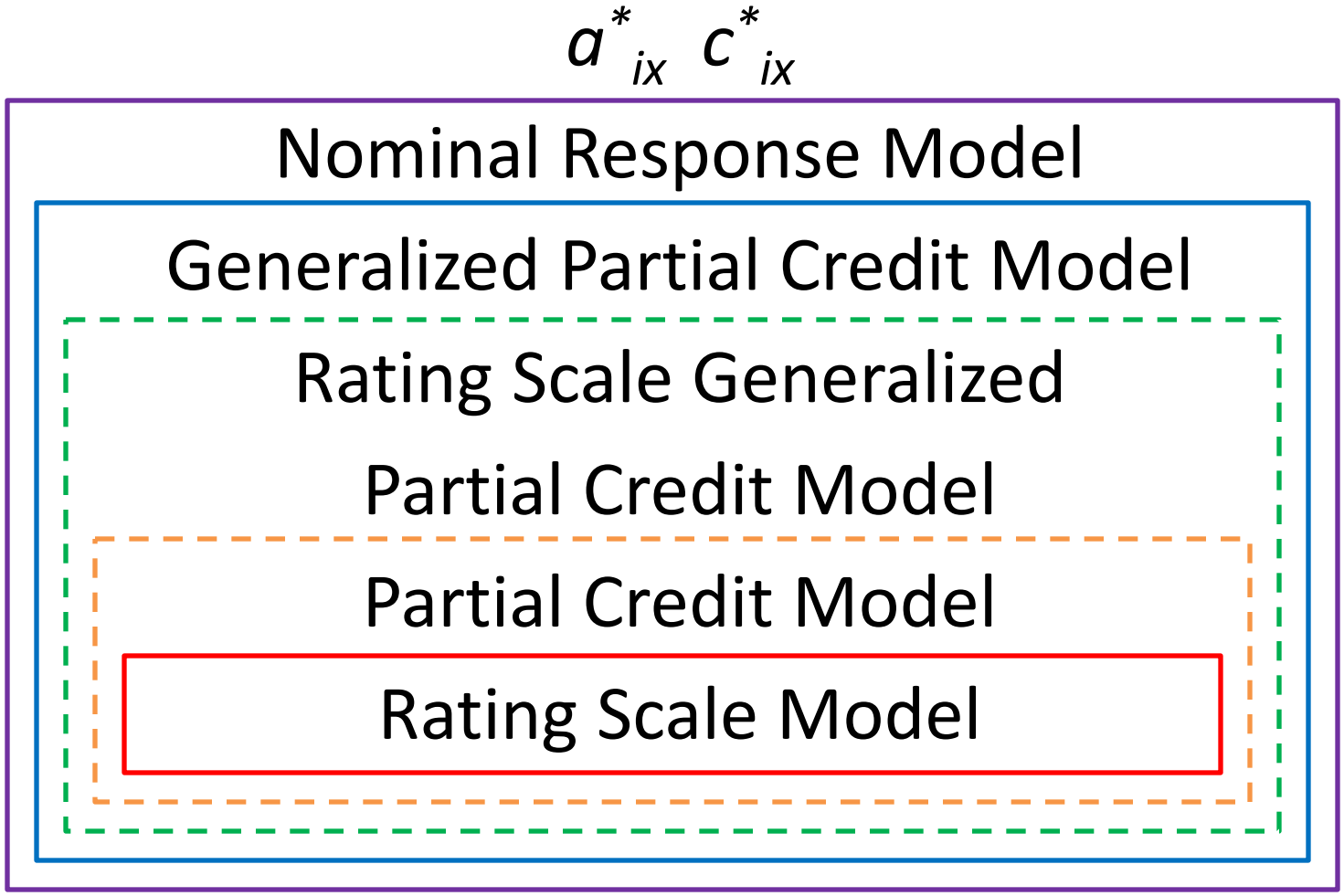
Muraki (1992)

$$a^*_i \quad c^*_{ix}$$

- Developed for partial credit data where not all "steps" are equally spaced

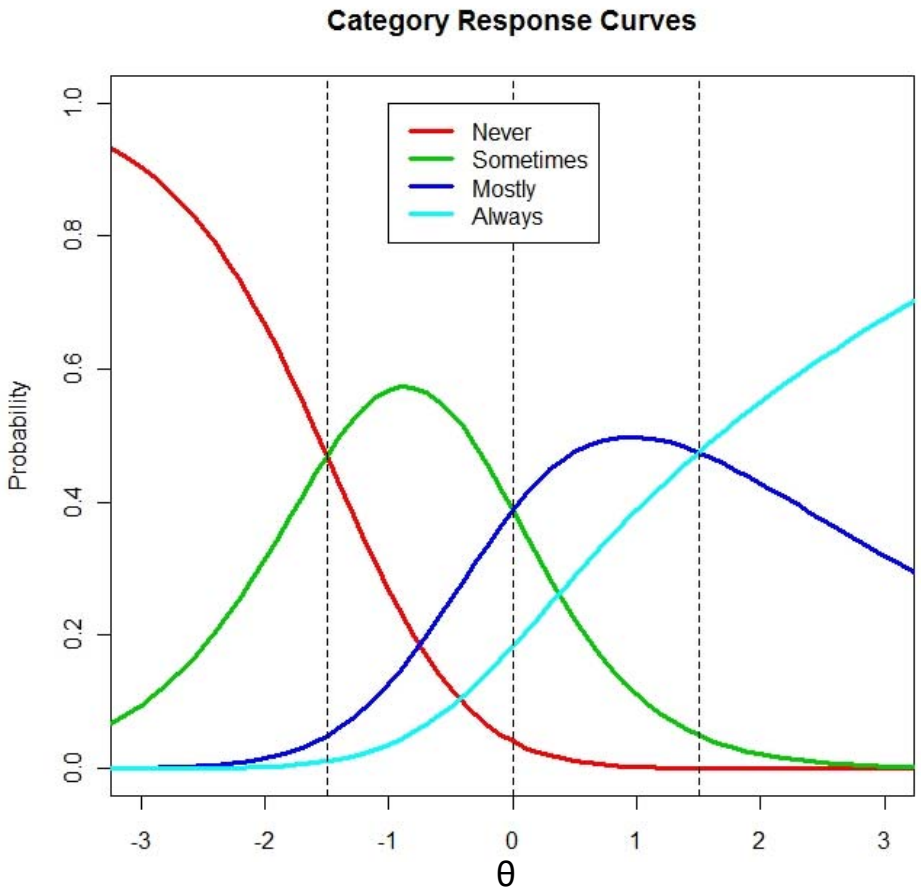


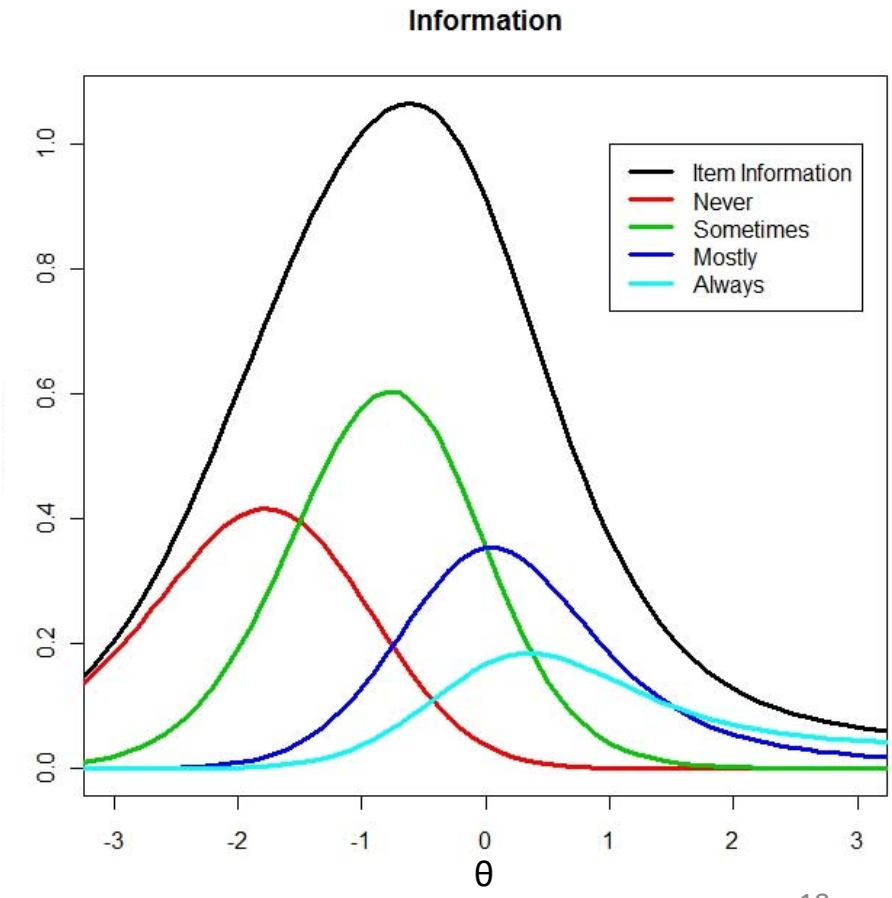
Nesting of Polytomous IRT models



Varying CBDs

CBD = 1.5, 1.5, 0.5

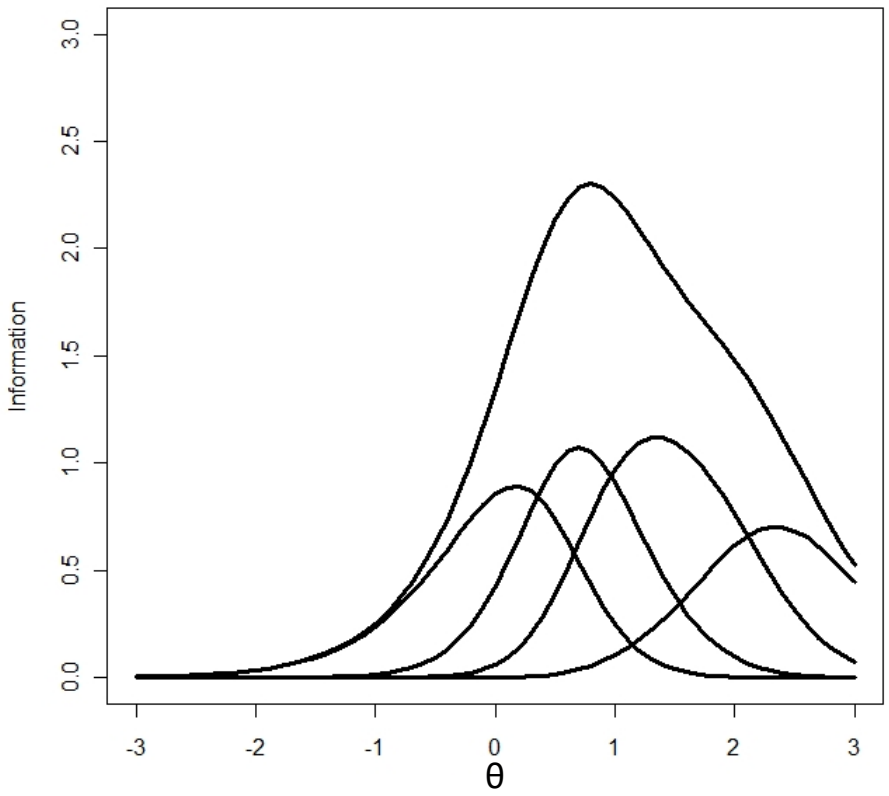




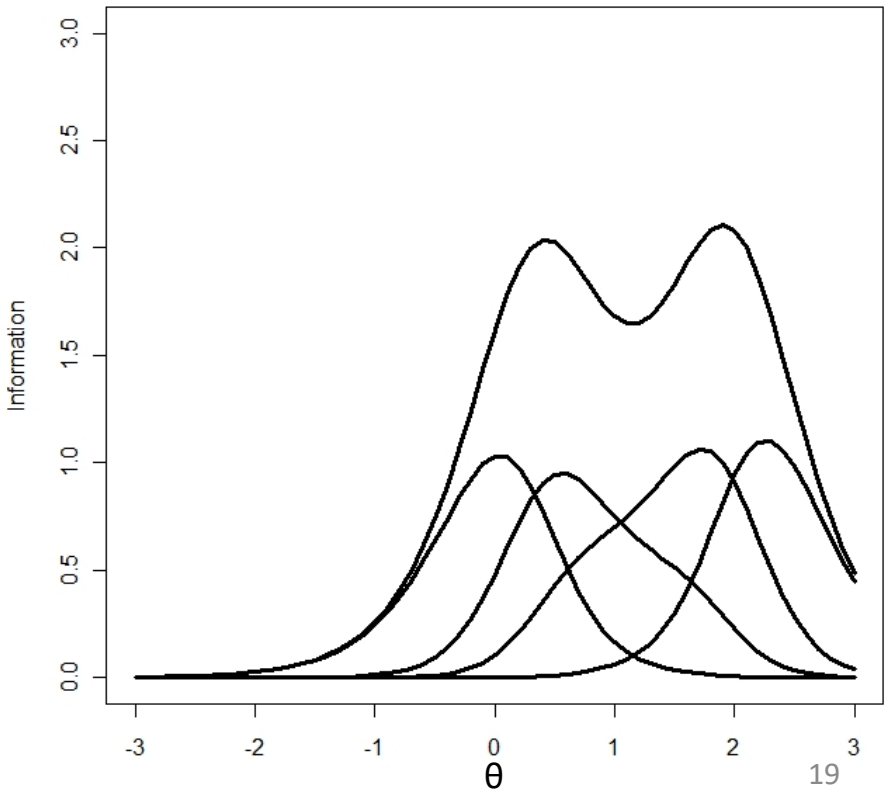
Unequal CBDs

- PROMIS Depression Inventory "*I felt that nothing was interesting*"

Restricting CBDs

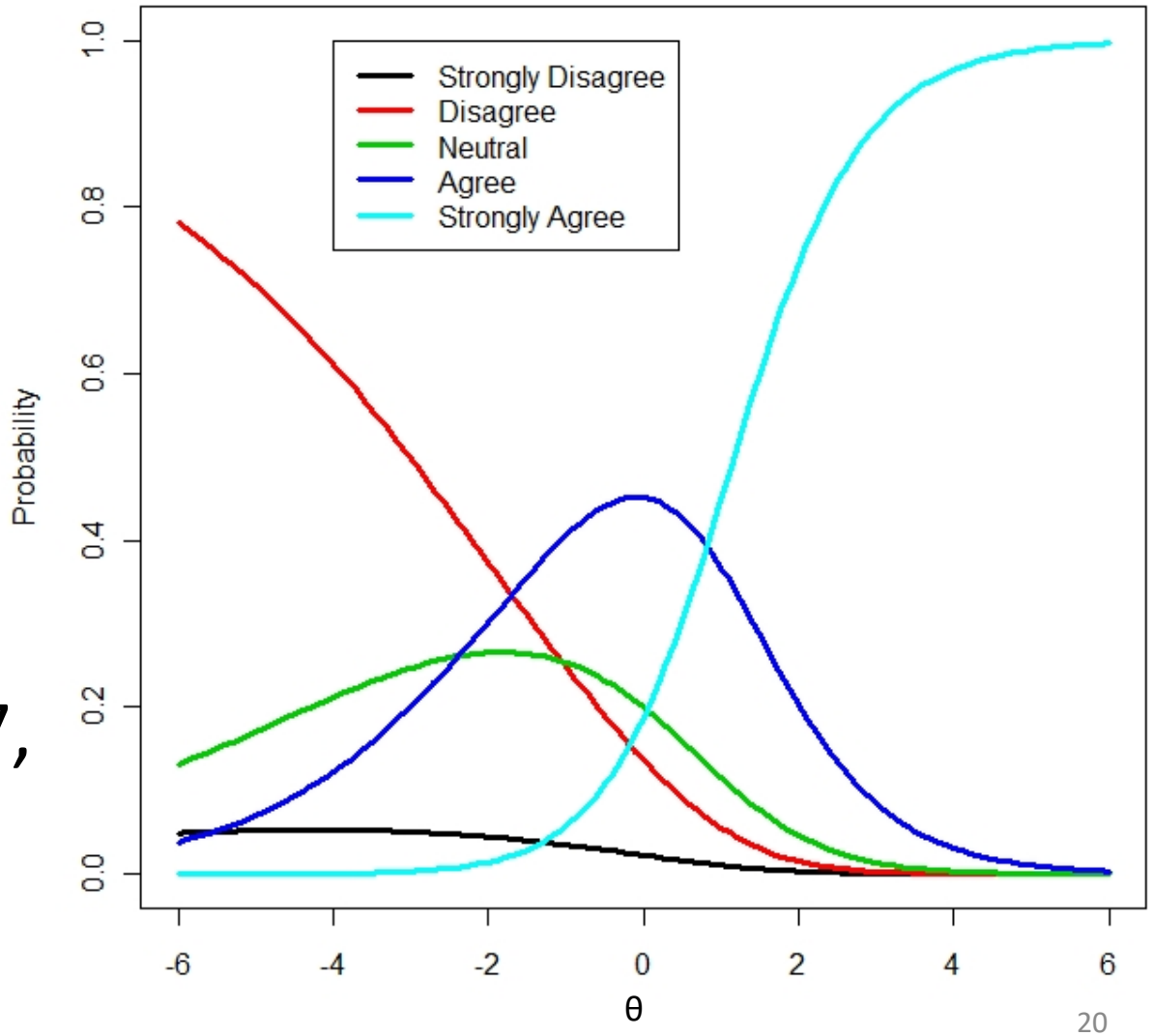


Allowing CBD Variation



Too Many Categories

- NEO-PI-R *"Without strong emotions, life would be uninteresting to me"*
- CBD = .04, .07, 1.09, 1.30



Cosmetic Surgery Acceptance Scale

Henderson-King & Henderson-King (2005)

1 (Strongly Disagree) to 7 (Strongly Agree)

1. It makes sense to have minor cosmetic surgery rather than spending years feeling bad about the way you look.
2. Cosmetic surgery is a good thing because it can help people feel better about themselves.
3. In the future, I could end up having some kind of cosmetic surgery.
4. People who are very unhappy with their physical appearance should consider cosmetic surgery as one option.
5. If cosmetic surgery can make someone happier with the way they look, then they should try it.
6. If I could have a surgical procedure done for free I would consider trying cosmetic surgery.
7. If I knew there would be no negative side effects or pain, I would like to try cosmetic surgery.

Cosmetic Surgery Acceptance Scale

Henderson-King & Henderson-King (2005)

8. I have sometimes thought about having cosmetic surgery.
9. I would seriously consider having cosmetic surgery if my partner thought it was a good idea.
10. I would never have any kind of plastic surgery. (R)
11. I would think about having cosmetic surgery in order to keep looking young.
12. If it would benefit my career, I would think about having plastic surgery.
13. I would seriously consider having cosmetic surgery if I thought my partner would find me more attractive.
14. Cosmetic surgery can be a big benefit to people's self-image.
15. If a simple cosmetic surgery procedure would make me more attractive to others, I would think about trying it.

Introduction to flexMIRT

flexMIRT® Item Response Theory Software

Vector Psychometric Group, LLC is pleased to offer their IRT software flexMIRT®, a multilevel, multidimensional, and multiple group item response theory (IRT) software package for item analysis and test scoring. flexMIRT® fits a variety of unidimensional and multidimensional item response theory models (also known as item factor analysis models) to single-level and multilevel data in any number of groups.

flexMIRT® is easy to use

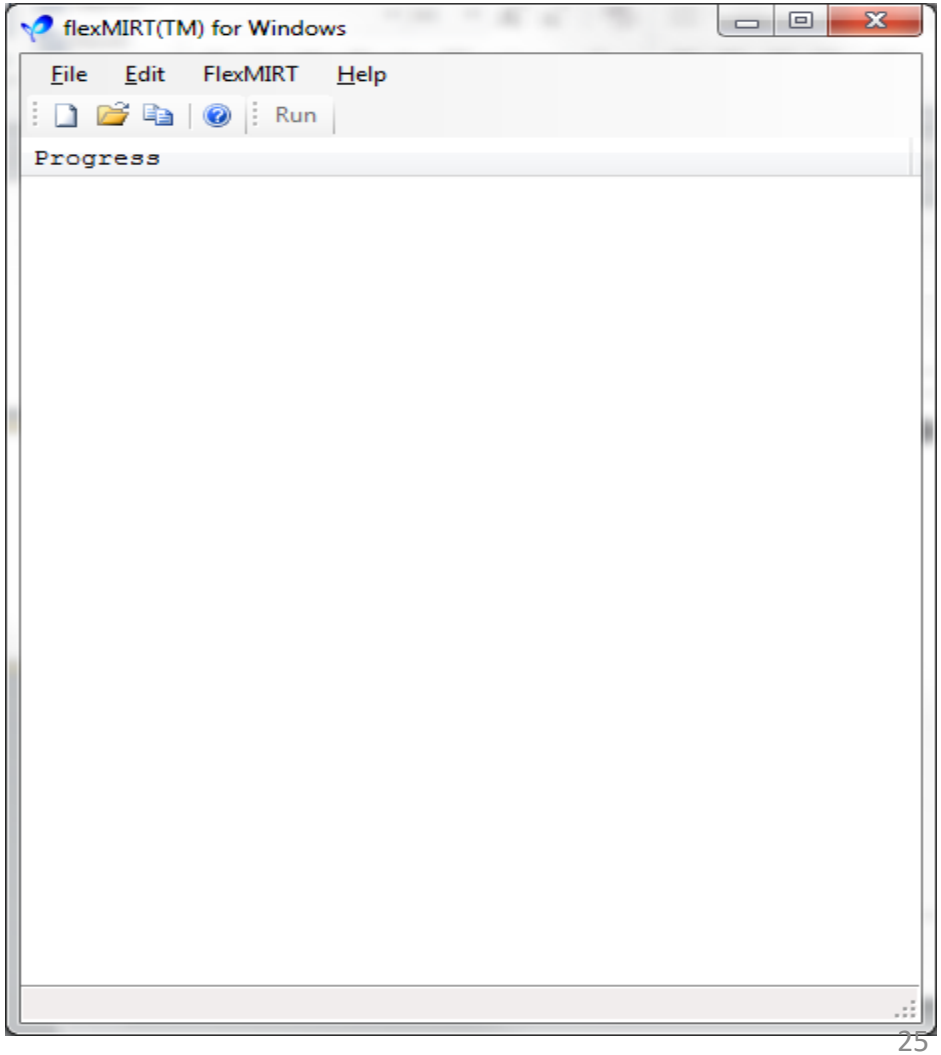
Windows-based flexMIRT® has a graphical user interface (GUI) and is available in both 32-bit and 64-bit versions. It has an intuitive syntax and can be run seamlessly in a command line mode for high volume production. The user's manual demonstrates a variety of analyses with annotated input and output.

flexMIRT® is flexible

Our IRT software can fit a wide variety of item-level models including 1PL, 2PL, 3PL, Graded Response Model, and Generalized Partial Credit and Cognitive Diagnostic models. It is able to accommodate multiple dimensions, dependence within the data (i.e., multilevel), and departures from normality in the latent trait(s).

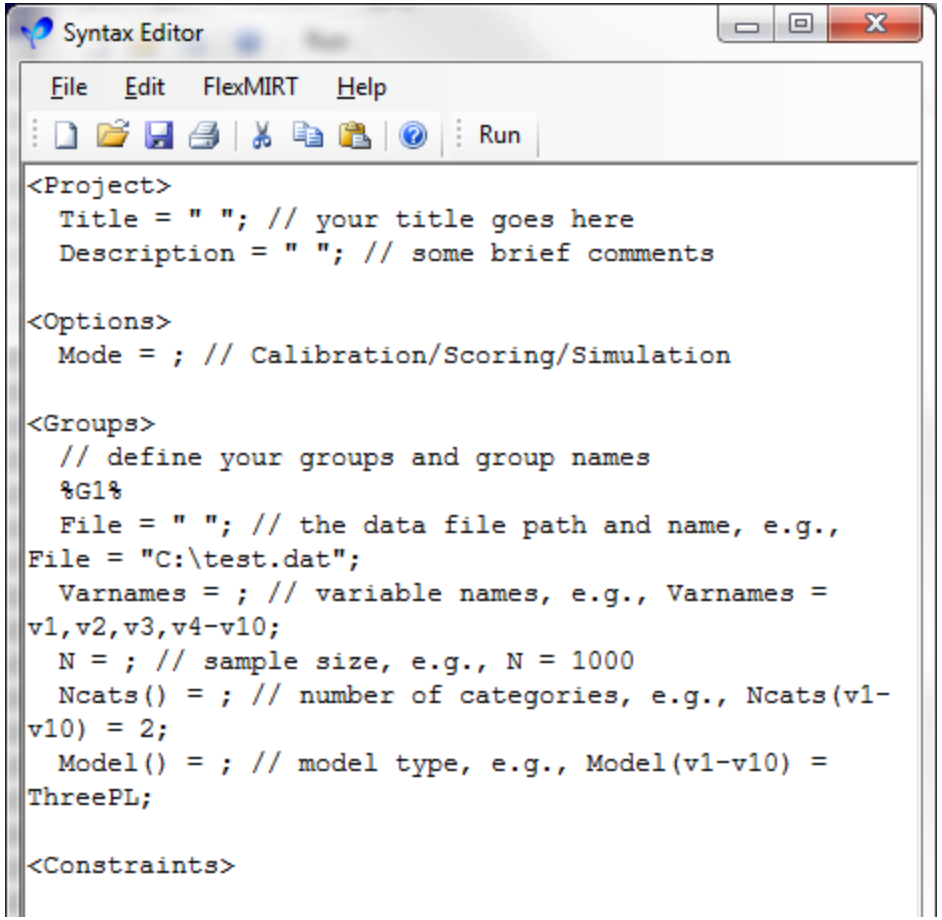
Progress window

- Don’t close this unless you want to shut flexMIRT down entirely
- Options
  - New
  - Open



Syntax Editor

- Provides the basic requirements for developing code
- Code notation basics
  - < > indicates one of the required sections
  - // indicates a comment
  - ; indicates the end of statement
  - Commands are not case sensitive, but file names are



<Project>

- Where you provide a title and a general description of the analysis for record-keeping
- Required commands
  - Title = “ “;
    - Title is enclosed in the double quotation marks
  - Description = “ “;
    - Description contents are enclosed in the double quotation marks

```
<Project>
Title = "Cosmetic Surgery Scale";
Description = "NRM Calibration";
```

<Options>

- Where the type of analysis and options are specified
- Required command
  - Mode = ;
    - Calibration, Scoring, Simulation

```
<Options >
Mode = Calibration;
 SE=SEM;
 smartSEM = Yes;
 SaveSCO = Yes;
 SavePRM = Yes;
 SaveDBG = Yes;
 SaveINF = Yes;
 SaveCOV = Yes;
 FisherInf = 81,4.0;
 Score = EAP;
 GOF = Basic;
 M2 = Full;
 FitNullModel = Yes;
```

<Groups>

- Where the input data and the IRT model are specified
- Required Commands
  - %Groupname%
  - File = “ “;
    - Tab-delimited data file path name with no variable names at the top. ID numbers removed
  - Varnames = ;
    - Variable names – v1, v2, v3,
  - N = ;
    - Number of examinees
  - Ncats( ) = ;
    - Number of response categories in the data for each item
  - Model( ) = ;
    - The model to be fitted to each item

```
<Groups>
%Group1%
File = "Cosmetic Surgery Scale.dat";
Varnames = v1-v15;
Missing = 9;
Code(v1-v9,v11-v15) = (1,2,3,4,5,6,7),(0,1,2,3,4,5,6);
Code(v10) = (1,2,3,4,5,6,7),(6,5,4,3,2,1,0);
N = 441;
Ncats(v1-v15) = 7;
Model(v1-v15) = Nominal(7);
Ta(v1-v15) =
  (0 0 0 0 0 0 0,
   1 0 0 0 0 0 0,
   1 1 0 0 0 0 0,
   1 1 1 0 0 0 0,
   1 1 1 1 0 0 0,
   1 1 1 1 1 0 0,
   1 1 1 1 1 1 0,
   1 1 1 1 1 1 1);
Tc(v1-v15) = Trend;
```

<Constraints>

- Where parameter constraints (such as equality or fixed parameter values) or univariate priors may be specified
- No required commands

NRM flexMIRT syntax

```
<Project>
Title = "Cosmetic Surgery Scale";
Description = "NRM Calibration";
<Options >
Mode = Calibration;
 SE=SEM;
 smartSEM = Yes;
 SaveSCO = Yes;
 SavePRM = Yes;
 SaveDBG = Yes;
 SaveINF = Yes;
 SaveCOV = Yes;
 FisherInf = 81,4.0;
 Score = EAP;
 GOF = Extended;
 M2 = Full;
 FitNullModel = Yes;
<Groups>
%Group1%
File = "Cosmetic Surgery Scale.dat";
Varnames = v1-v15;
Missing = 9;
Code(v1-v9,v11-v15) = (1,2,3,4,5,6,7),(0,1,2,3,4,5,6);
Code(v10) = (1,2,3,4,5,6,7),(6,5,4,3,2,1,0);
N = 441;
Ncats(v1-v15) = 7;
Model(v1-v15) = Nominal(7);
Ta(v1-v15) =
 (0 0 0 0 0 0,
  1 0 0 0 0 0,
  1 1 0 0 0 0,
  1 1 1 0 0 0,
  1 1 1 1 0 0,
  1 1 1 1 1 0,
  1 1 1 1 1 1);
Tc(v1-v15) = Trend;
<Constraints>
```

flexMIRT output

- Prints information from the <Project> section
- Missing data code
- Number of items
- Sample size
- Number of dimensions (default is 1)
- Number of categories for each item and the IRT model estimated

```
Cosmetic Surgery Scale
NRM Calibration

Summary of the Data and Dimensions
   Missing data code          9
     Number of Items         15
     Number of Cases        441
 # Latent Dimensions          1
```

Item	Categories	Model	Ta	Tc
1	7	Nominal	Special	Trend
2	7	Nominal	Special	Trend
3	7	Nominal	Special	Trend
4	7	Nominal	Special	Trend
5	7	Nominal	Special	Trend
6	7	Nominal	Special	Trend
7	7	Nominal	Special	Trend
8	7	Nominal	Special	Trend
9	7	Nominal	Special	Trend
10	7	Nominal	Special	Trend
11	7	Nominal	Special	Trend
12	7	Nominal	Special	Trend
13	7	Nominal	Special	Trend
14	7	Nominal	Special	Trend
15	7	Nominal	Special	Trend

flexMIRT output

- Control values are listed (all default values, but can be altered)
  - Convergence criteria
  - Maximum number of iterations
  - Quadrature points
  - Free parameters
- Processing time
  - Broken down by stages
- Output files
  - Names of the output files generated

```
Bock-Aitkin EM Algorithm Control Values
Maximum number of cycles:   500
Convergence criterion:   1.00e-004
Maximum number of M-step iterations:   100
Convergence criterion for iterative M-steps:   1.00e-007
Number of rectangular quadrature points:    49
Minimum, Maximum quadrature points:   -6.00,    6.00
SEM algorithm tolerance:   1.00e-003
Standard error computation algorithm: Cai-Thissen Modified Supplemented EM

Miscellaneous Control Values
Z tolerance, max. abs. logit value:     50.00
Number of free parameters:   180
Number of cycles completed:   208
Number of processor cores used:    1
Maximum parameter change (P#):  0.000098798 (  176)
```

```
Processing times (in seconds)
E-step computations:      0.35
M-step computations:      2.42
Standard error computations:      7.94
Goodness-of-fit statistics:   2211.53
Total:    2222.24
```

```
Output Files
Text results and control parameters: NRM Cosmetic Surgery-irt.txt
Text parameter estimate file: NRM Cosmetic Surgery-prm.txt
Text parameter error covariance file: NRM Cosmetic Surgery-cov.txt
Information values in a file: NRM Cosmetic Surgery-inf.txt
Technical information in a file: NRM Cosmetic Surgery-dbg.txt
```

flexMIRT output

- Convergence
  - Normal termination
  - Convergence criteria met
  - Solution stability
- Item estimation
  - Bock (1972) formulation

$$CBD_j = a^*_j = a_x - a_{(x\text{-}1)}$$

$$c^*_j = \frac{c_{(x-1)} - c_x}{a_x - a_{(x-1)}}$$

```
Convergence and Numerical Stability
flexMIRT(R) engine status: Normal termination
SEM algorithm status: Normal
SEM cost: 554 forced-EM steps
First-order test: Convergence criteria satisfied
Condition number of information matrix: 71001.5898
Second-order test: Solution is a possible local maximum
```

Original (Bock, 1972) Parameters, Nominal Items for Group 1: Group1

Item	Label	Category:	1	2	3	4	5	6	7
1	v1	a	0.00	1.84	2.85	3.30	4.42	5.34	7.24
		c	0.00	0.76	0.64	1.06	1.09	-0.47	-2.85
2	v2	a	0.00	3.09	4.25	5.20	6.08	7.39	8.57
		c	0.00	2.36	2.44	3.49	3.28	1.42	-0.40
3	v3	a	0.00	2.71	4.03	4.72	7.61	9.10	10.84
		c	0.00	-0.23	-0.67	-0.25	-1.85	-4.38	-7.42
4	v4	a	0.00	3.01	4.29	5.04	6.25	6.99	8.91
		c	0.00	1.60	2.03	2.81	2.22	0.72	-2.28
5	v5	a	0.00	2.69	4.20	5.01	6.17	6.88	7.99
		c	0.00	2.13	2.67	3.97	4.03	2.83	1.26
6	v6	a	0.00	3.45	6.75	7.64	10.68	13.37	15.88
		c	0.00	0.93	1.37	1.54	1.11	-1.40	-4.57
7	v7	a	0.00	2.58	3.81	5.11	6.15	9.20	11.99
		c	0.00	0.22	0.47	0.90	1.10	-1.20	-3.93
8	v8	a	0.00	2.34	3.61	3.65	5.47	7.31	8.71
		c	0.00	-0.28	-0.52	-0.13	-0.31	-2.53	-3.94
9	v9	a	0.00	2.40	3.74	4.62	5.51	6.49	8.23
		c	0.00	-0.37	-0.72	-0.69	-2.14	-3.37	-5.93
10	v10	a	0.00	1.17	2.03	2.26	2.54	2.62	1.77
		c	0.00	-0.42	-0.78	-0.05	-0.43	-0.46	0.09
11	v11	a	0.00	1.65	2.77	3.36	4.66	7.93	11.48
		c	0.00	-0.59	-0.99	-1.30	-2.38	-7.72	-14.28
12	v12	a	0.00	2.25	2.40	3.02	3.70	6.05	9.34
		c	0.00	-0.37	-0.69	-0.66	-1.13	-4.38	-10.18
13	v13	a	0.00	1.59	2.30	3.51	4.64	5.74	8.25
		c	0.00	-0.75	-1.05	-1.42	-2.29	-4.06	-8.76
14	v14	a	0.00	2.55	3.44	3.82	4.56	5.42	7.97
		c	0.00	1.00	1.02	2.25	2.17	1.07	-2.43
15	v15	a	0.00	2.77	3.63	5.09	6.57	9.74	15.55
		c	0.00	-0.10	-0.26	0.04	-1.04	-4.40	-14.00

flexMIRT output

Nominal Model Slopes and Scoring Function Contrasts for Items for Group 1: Group1

Item	Label	P#	a	s.e.	Contrasts	P#	alpha 1	s.e.
1	v1	6	1.84	0.40	Special		1.00	----
2	v2	18	3.09	0.67	Special		1.00	----
3	v3	30	2.71	0.46	Special		1.00	----
4	v4	42	3.01	0.68	Special		1.00	----
5	v5	54	2.69	0.71	Special		1.00	----
6	v6	66	3.45	0.20	Special		1.00	----
7	v7	78	2.58	0.96	Special		1.00	----
8	v8	90	2.34	0.42	Special		1.00	----
9	v9	102	2.40	0.42	Special		1.00	----
10	v10	114	1.17	0.33	Special		1.00	----
11	v11	126	1.65	0.35	Special		1.00	----
12	v12	138	2.25	0.37	Special		1.00	----
13	v13	150	1.59	0.35	Special		1.00	----
14	v14	162	2.55	0.61	Special		1.00	----
15	v15	174	2.77	0.58	Special		1.00	----

P#	alpha 2	s.e.	P#	alpha 3	s.e.	P#	alpha 4	s.e.	P#	alpha 5	s.e.	P#	alpha 6	s.e.
1	0.55	0.25	2	0.25	0.19	3	0.61	0.20	4	0.50	0.23	5	1.03	0.37
13	0.38	0.17	14	0.31	0.13	15	0.28	0.10	16	0.42	0.14	17	0.38	0.16
25	0.49	0.24	26	0.25	0.20	27	1.06	0.26	28	0.55	0.22	29	0.64	0.24
37	0.42	0.18	38	0.25	0.12	39	0.40	0.12	40	0.25	0.13	41	0.64	0.23
49	0.56	0.25	50	0.30	0.16	51	0.43	0.14	52	0.27	0.12	53	0.41	0.16
61	0.96	0.26	62	0.26	0.74	63	0.88	0.36	64	0.78	0.18	65	0.73	0.15
73	0.48	0.35	74	0.51	0.26	75	0.40	0.25	76	1.18	0.61	77	1.08	0.55
85	0.54	0.28	86	0.02	0.22	87	0.77	0.24	88	0.79	0.26	89	0.60	0.24
97	0.56	0.22	98	0.37	0.17	99	0.37	0.20	100	0.41	0.24	101	0.72	0.29
109	0.74	0.40	110	0.20	0.25	111	0.24	0.22	112	0.07	0.21	113	-0.72	0.27
121	0.68	0.28	122	0.36	0.24	123	0.79	0.30	124	1.98	0.76	125	2.15	1.58
133	0.06	0.15	134	0.28	0.15	135	0.30	0.16	136	1.04	0.34	137	1.46	0.75
145	0.45	0.29	146	0.76	0.30	147	0.71	0.30	148	0.69	0.36	149	1.57	0.65
157	0.35	0.21	158	0.15	0.14	159	0.29	0.11	160	0.34	0.14	161	1.00	0.36
169	0.31	0.22	170	0.53	0.20	171	0.54	0.19	172	1.15	0.35	173	2.10	1.42

flexMIRT output

Nominal Model Intercept Contrasts for Items for Group 1: Group1

Item	Label	Contrasts	P#	gamma 1	s.e.	P#	gamma 2	s.e.	P#	gamma 3	s.e.
1	v1	Trend	7	-0.47	0.13	8	2.67	0.44	9	-0.60	0.23
2	v2	Trend	19	-0.07	0.15	20	3.69	0.51	21	-0.09	0.25
3	v3	Trend	31	-1.24	0.18	32	3.04	0.60	33	-0.60	0.29
4	v4	Trend	43	-0.38	0.17	44	3.97	0.59	45	-0.46	0.29
5	v5	Trend	55	0.21	0.13	56	3.30	0.48	57	-0.23	0.23
6	v6	Trend	67	-0.76	0.13	68	4.00	0.49	69	-0.57	0.22
7	v7	Trend	79	-0.66	0.21	80	3.04	0.54	81	-0.91	0.33
8	v8	Trend	91	-0.66	0.12	92	1.70	0.42	93	-0.55	0.21
9	v9	Trend	103	-0.99	0.18	104	2.01	0.60	105	-0.43	0.31
10	v10	Trend	115	0.02	0.04	116	-0.57	0.16	117	-0.06	0.12
11	v11	Trend	127	-2.38	0.97	128	6.09	3.42	129	-1.66	1.45
12	v12	Trend	139	-1.70	0.50	140	4.79	1.81	141	-1.65	0.84
13	v13	Trend	151	-1.46	0.28	152	3.21	0.99	153	-1.21	0.47
14	v14	Trend	163	-0.41	0.21	164	3.53	0.76	165	-1.05	0.35
15	v15	Trend	175	-2.33	1.29	176	7.59	4.59	177	-2.58	1.95

P#	gamma 4	s.e.	P#	gamma 5	s.e.	P#	gamma 6	s.e.
10	0.22	0.16	11	0.21	0.13	12	0.03	0.10
22	0.16	0.17	23	0.47	0.14	24	0.16	0.10
34	-0.21	0.23	35	0.14	0.20	36	0.21	0.15
46	0.22	0.19	47	0.09	0.15	48	0.20	0.10
58	0.12	0.16	59	0.32	0.14	60	0.16	0.10
70	0.09	0.20	71	0.16	0.20	72	-0.08	0.15
82	0.03	0.20	83	0.21	0.16	84	-0.14	0.12
94	-0.24	0.17	95	0.33	0.16	96	-0.10	0.12
106	-0.03	0.22	107	-0.11	0.19	108	0.24	0.16
118	-0.29	0.10	119	0.12	0.11	120	0.18	0.10
130	0.04	0.81	131	0.28	0.51	132	-0.21	0.29
142	0.33	0.50	143	0.05	0.33	144	-0.03	0.19
154	0.33	0.30	155	-0.24	0.23	156	0.08	0.17
166	0.35	0.23	167	0.08	0.15	168	0.28	0.10
178	0.82	1.02	179	-0.33	0.55	180	0.26	0.27

flexMIRT output

- Item and Test information
  - Theta values range from -2.8 to 2.8 increasing in steps of 0.4 (default)
  - Test information is the sum of the Item Information with expected standard error
- Marginal reliability
  - $1 - \frac{var(error)}{var(prior)}$

Item Information Function Values at 15 Values of theta from -2.8 to 2.8 for Group 1: Group1

Item	Theta: Label	-2.8	-2.4	-2.0	-1.6	-1.2	-0.8	-0.4	-0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8
1	v1	0.05	0.11	0.25	0.58	1.22	2.07	2.37	1.95	1.55	1.56	1.86	1.89	1.34	0.70	0.31
2	v2	0.02	0.07	0.27	1.02	3.17	4.71	2.82	1.52	1.20	1.28	1.42	1.34	1.00	0.64	0.38
3	v3	0.00	0.01	0.03	0.10	0.33	1.12	3.11	4.81	4.79	4.13	2.68	2.09	1.71	1.10	0.58
4	v4	0.01	0.04	0.15	0.60	2.20	4.75	3.58	1.74	1.20	1.15	1.37	1.69	1.65	1.12	0.58
5	v5	0.04	0.11	0.37	1.29	3.67	4.78	2.64	1.39	1.00	0.87	0.82	0.77	0.66	0.52	0.37
6	v6	0.00	0.01	0.03	0.12	0.52	2.45	9.30	8.74	5.74	5.01	4.07	2.20	0.91	0.35	0.13
7	v7	0.01	0.02	0.06	0.20	0.71	2.50	5.38	4.41	4.16	6.41	4.05	1.39	0.45	0.15	0.05
8	v8	0.01	0.02	0.05	0.15	0.47	1.39	3.18	4.05	3.51	3.32	2.65	1.50	0.72	0.35	0.18
9	v9	0.01	0.01	0.04	0.11	0.32	0.97	2.53	3.84	2.87	1.99	2.08	2.25	1.74	0.97	0.46
10	v10	0.07	0.14	0.26	0.46	0.74	0.98	1.01	0.81	0.55	0.35	0.22	0.15	0.11	0.09	0.07
11	v11	0.02	0.03	0.07	0.14	0.31	0.68	1.34	2.07	2.23	2.07	3.16	7.62	6.50	1.85	0.44
12	v12	0.01	0.03	0.07	0.19	0.48	1.06	1.76	1.88	1.47	1.48	2.79	5.63	4.50	1.47	0.38
13	v13	0.02	0.03	0.07	0.14	0.29	0.61	1.23	2.17	2.82	2.57	2.21	2.53	2.80	1.87	0.81
14	v14	0.02	0.06	0.22	0.75	2.17	3.51	2.43	1.18	0.86	1.16	2.05	2.62	1.76	0.73	0.25
15	v15	0.00	0.01	0.04	0.12	0.41	1.39	3.63	4.61	3.40	3.88	5.96	11.09	3.97	0.45	0.04
Test Information:		1.28	1.71	2.98	6.97	18.01	33.96	47.32	46.16	38.35	38.23	38.41	45.75	30.82	13.34	6.02
Expected s.e.:		0.88	0.76	0.58	0.38	0.24	0.17	0.15	0.15	0.16	0.16	0.16	0.15	0.18	0.27	0.41

Marginal reliability for response pattern scores: 0.95

flexMIRT output

- Goodness of fit indices
  - 2xLog Likelihood
  - AIC
  - BIC
- Full-information fit indices
  - $Ncat^{Nitem} > N$
  - Pearson χ^2
  - Likelihood ratio (G2) statistic Degrees of freedom
  - Estimated population discrepancy function (F0hat)
  - RMSEA
- Limited-information fit indices
  - M2
  - RMSEA
  - TLI

```
Statistics based on the loglikelihood of the fitted model:
                        -2loglikelihood:    17508.30
      Akaike Information Criterion (AIC):    17868.30
   Bayesian Information Criterion (BIC):    18604.33
```

```
Full-information fit statistics of the fitted model:
                Degrees
          G2  of freedom Probability       F0hat       RMSEA
    12423.03         212      0.0001     28.1701        0.36
  The table is too sparse to compute the Pearson X2 statistic.
  Even though G2 is shown, it should be interpreted with caution.
```

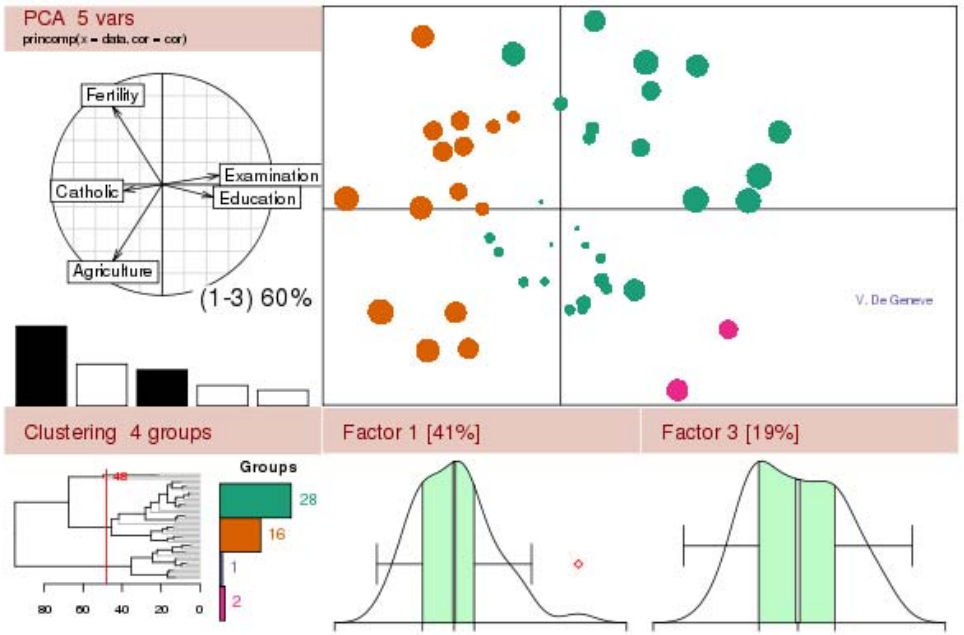
```
Limited-information fit statistics of the fitted model:
                Degrees
          M2  of freedom Probability       F0hat       RMSEA
    18200.44        3690      0.0001     41.2708        0.09
Note: M2 is based on full marginal tables.
Note: Model-based weight matrix is used.

 Tucker-Lewis (non-normed) fit index based on M2 is     0.61
```

Brief R and RStudio Tutorial

Using R to create plots

www.r-project.org

The R Project for Statistical Computing



About R
- What is R?
- Contributors
- Screenshots
- What's new?

Download, Packages
- CRAN

R Project
- Foundation
- Members & Donors
- Mailing Lists
- Bug Tracking
- Developer Page
- Conferences
- Search

Documentation
- Manuals
- FAQs
- The R Journal
- Wiki
- Books
- Certification
- Other

Misc

Getting Started:

- R is a free software environment for statistical computing and graphics. It compiles and runs on a wide variety of UNIX platforms, W
  R, please choose your preferred CRAN mirror.
- If you have questions about R like how to download and install the software, or what the license terms are, please read our answers t
  before you send an email.

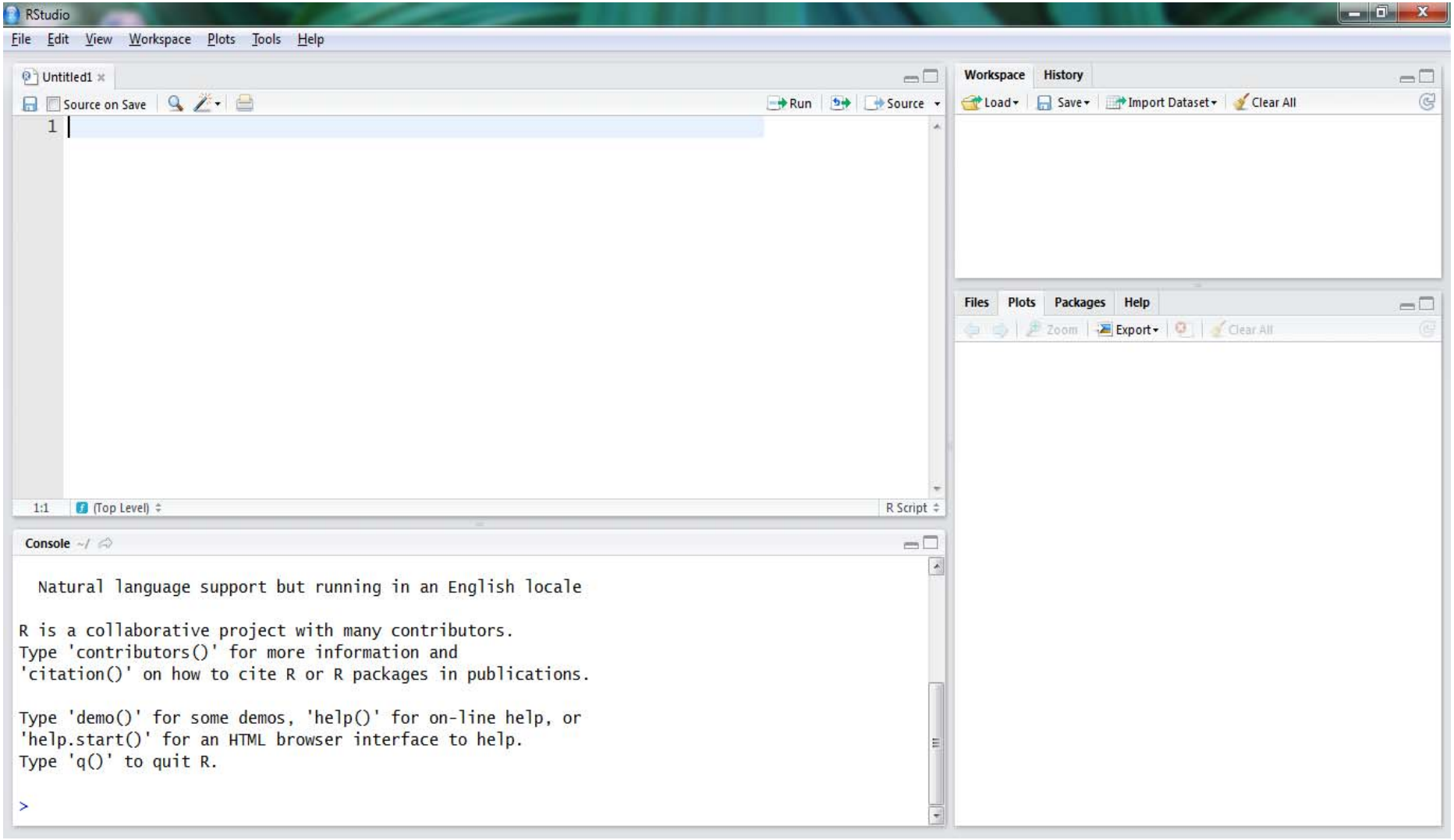
News:

R version 2.13.1 has been released on 2011-07-08. The source code is first available in this directory, and eventually via all of CRA

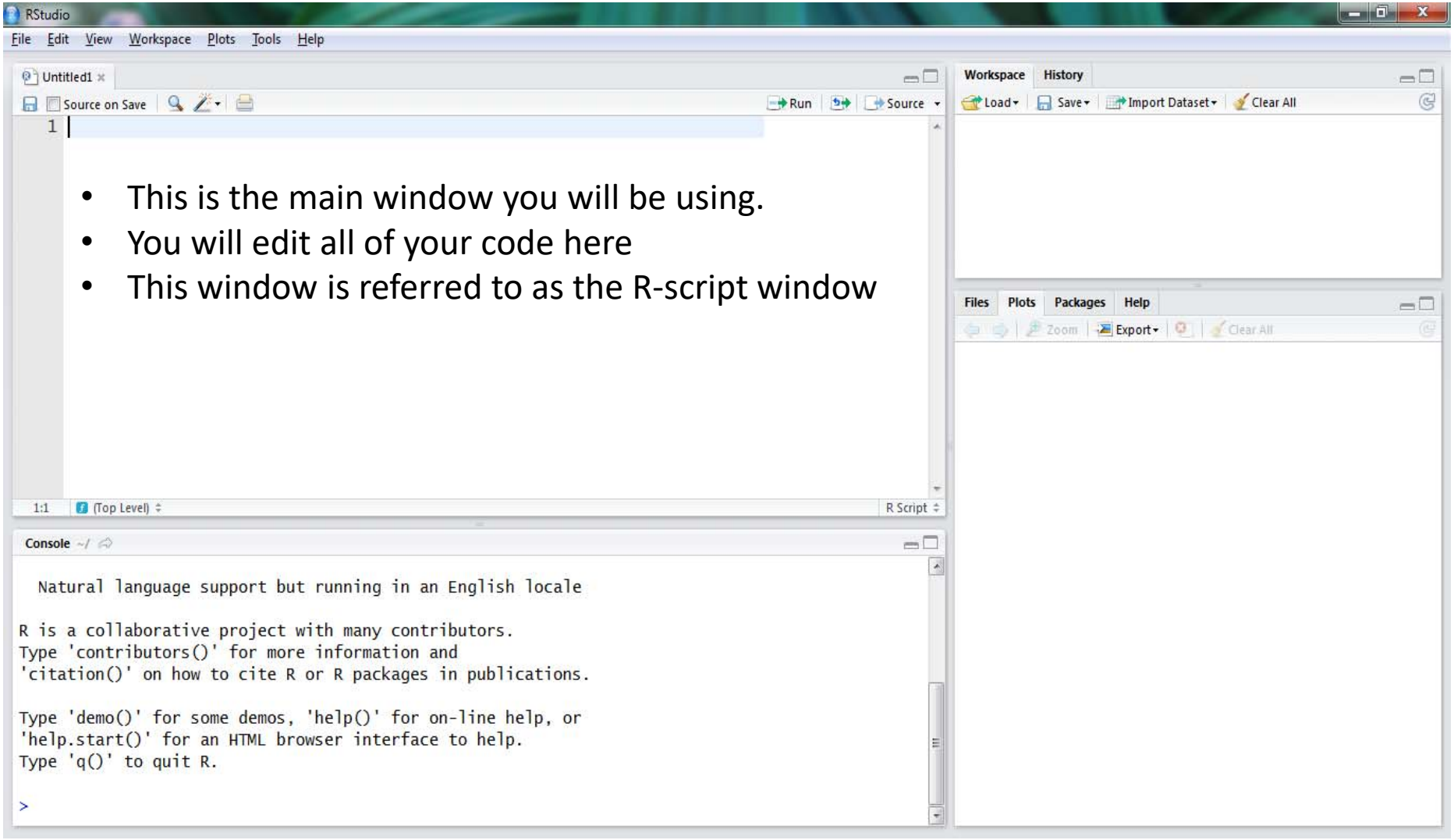
Pretty R Interface

www.rstudio.com

RStudio

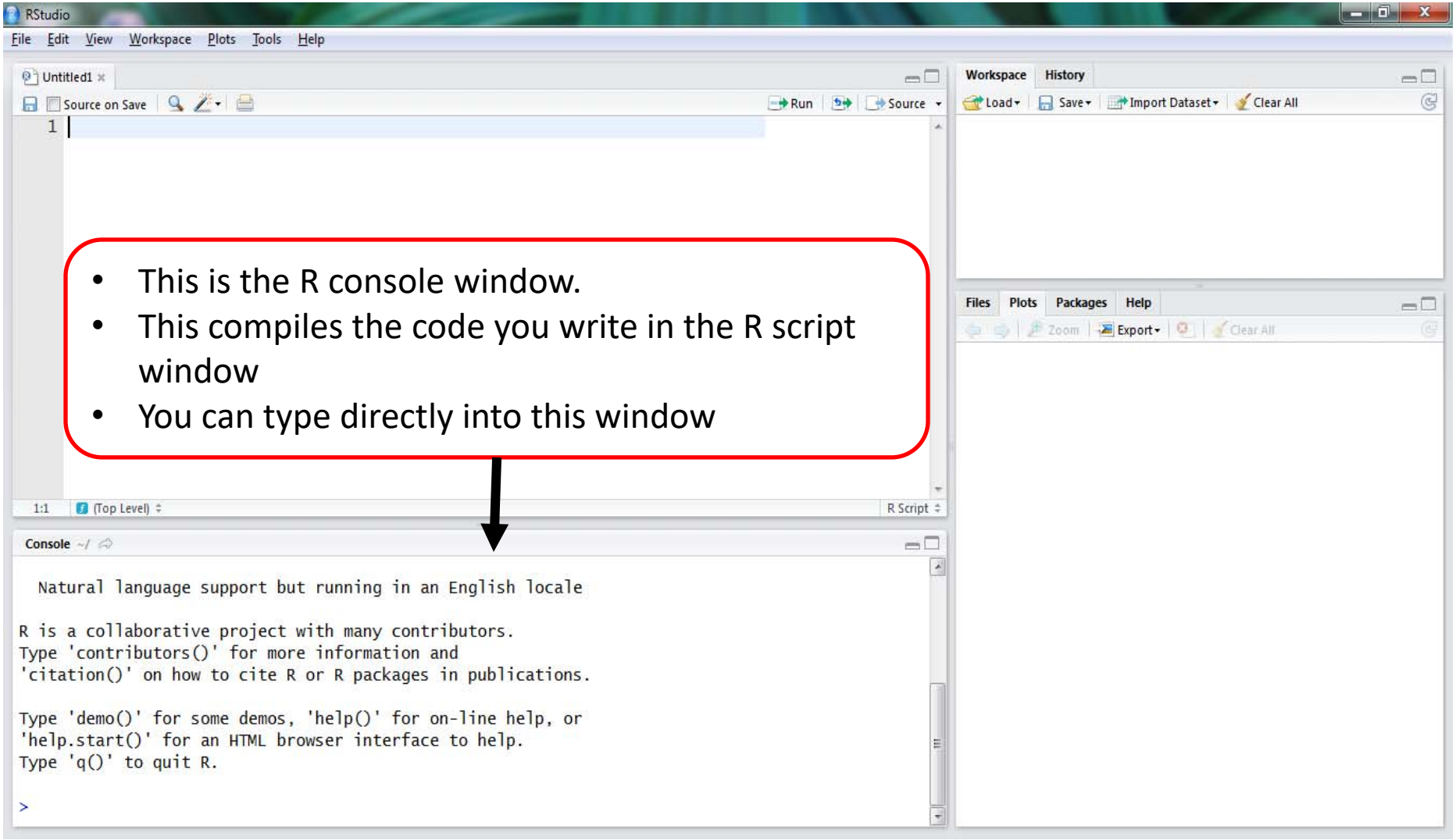

RStudio
File Edit View Workspace Plots Tools Help
Untitled1
Source on Save
Run
Source
1
1:1
(Top Level)
R Script
Workspace
History
Load
Save
Import Dataset
Clear All
Files
Plots
Packages
Help
Zoom
Export
Clear All
Console ~/
Natural language support but running in an English locale
R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.
Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.
>

RStudio: R-script

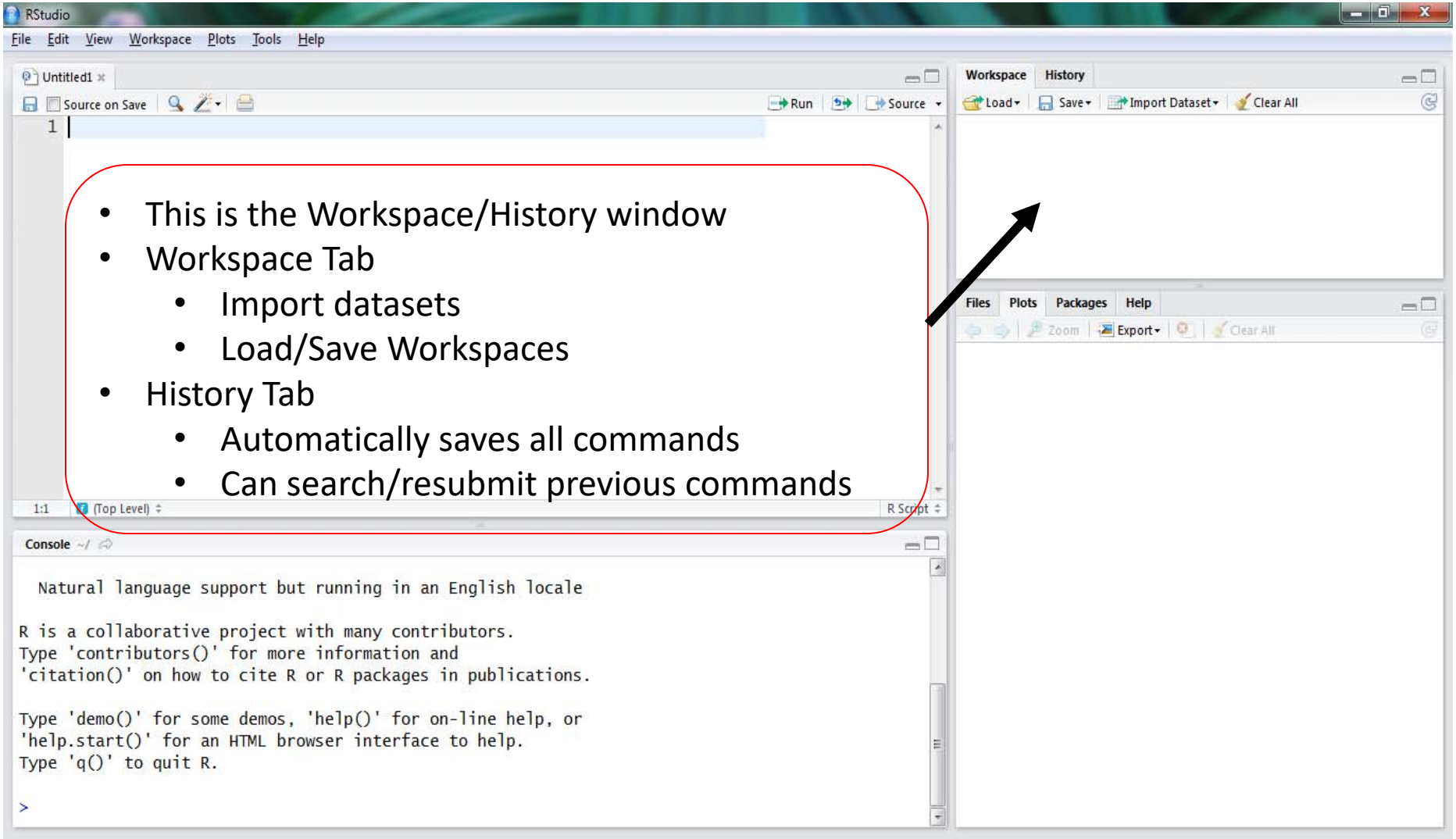


- This is the main window you will be using.
- You will edit all of your code here
- This window is referred to as the R-script window

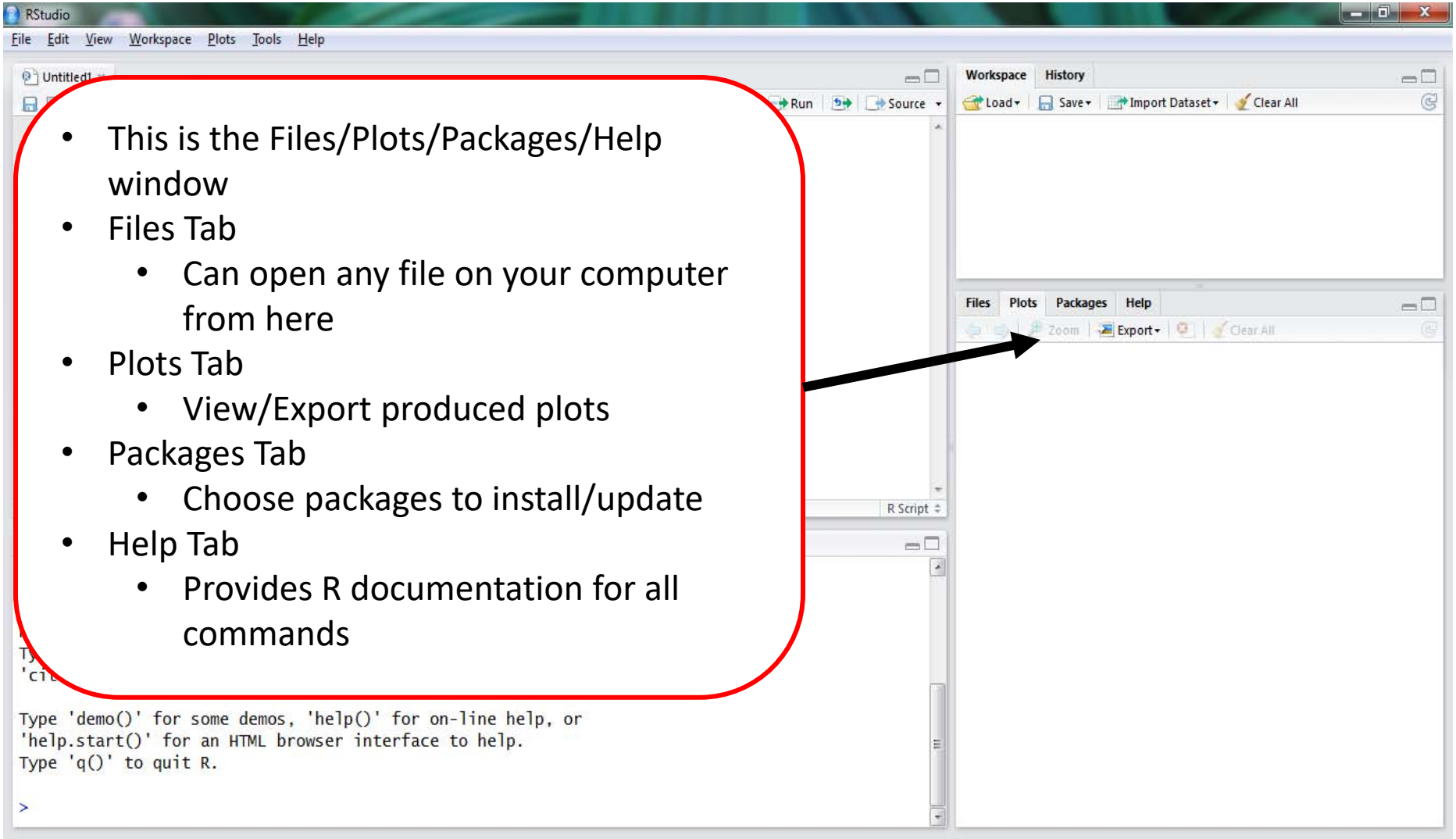
RStudio: R console



RStudio: Workspace/History

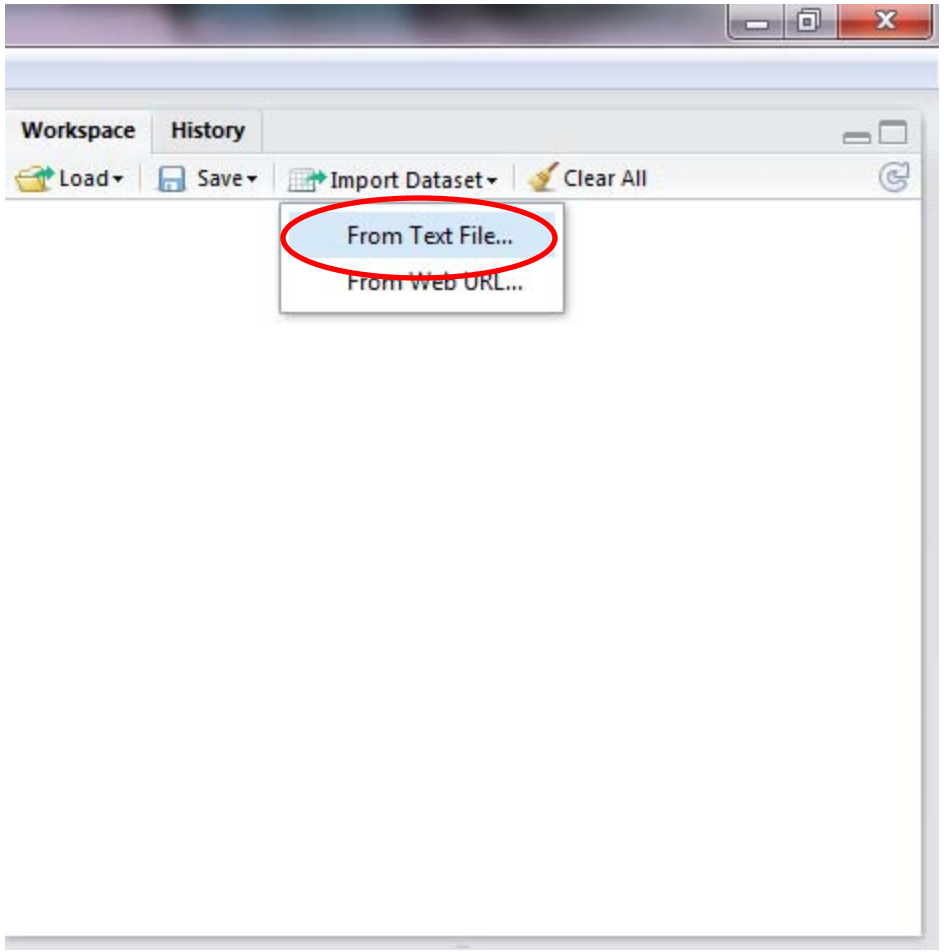


RStudio: Files/Plots/Packages/Help



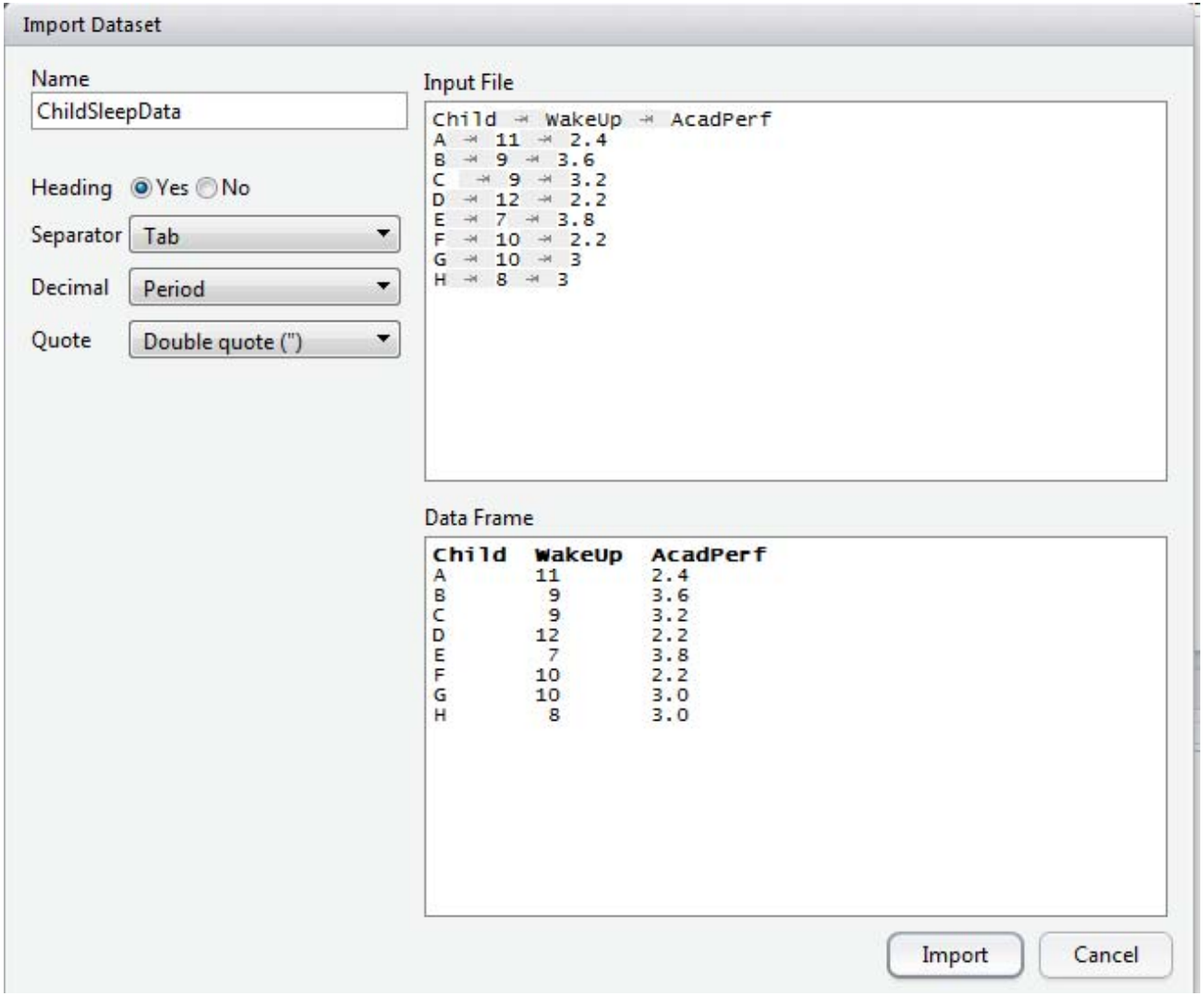
RStudio: Workspace
Importing a Dataset

- Import Dataset
  - From Text File…
    - Dataset must be a .txt file
- Choose .txt file from computer



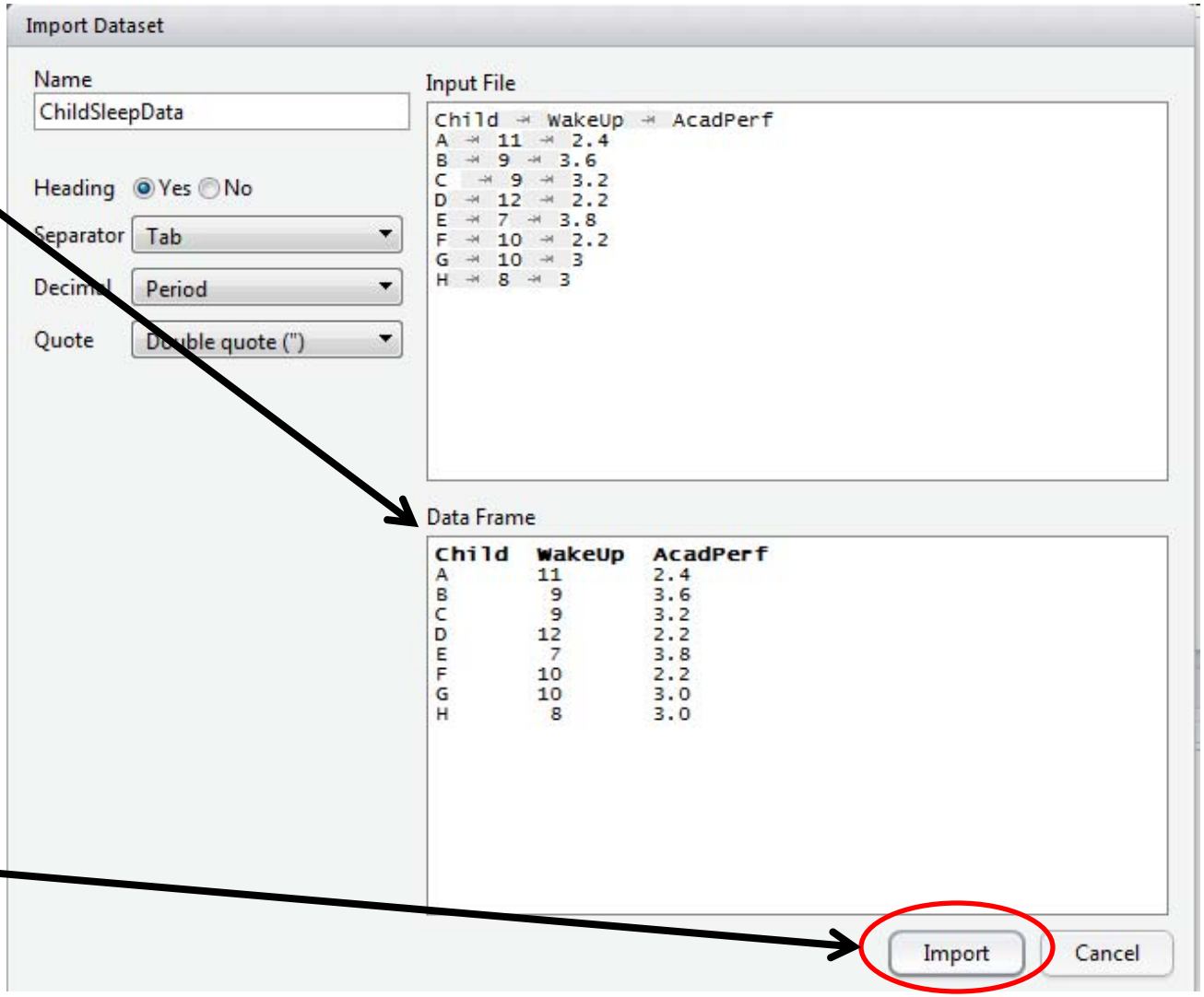
RStudio: Workspace
Importing a Dataset

- Can change the name of your dataset
- Does your dataset have a heading?
- Is your dataset separated by ‘whitespace,’ ‘comma,’ ‘semicolon,’ ‘tab’?
- Do you have quotes or double quotes around your data?



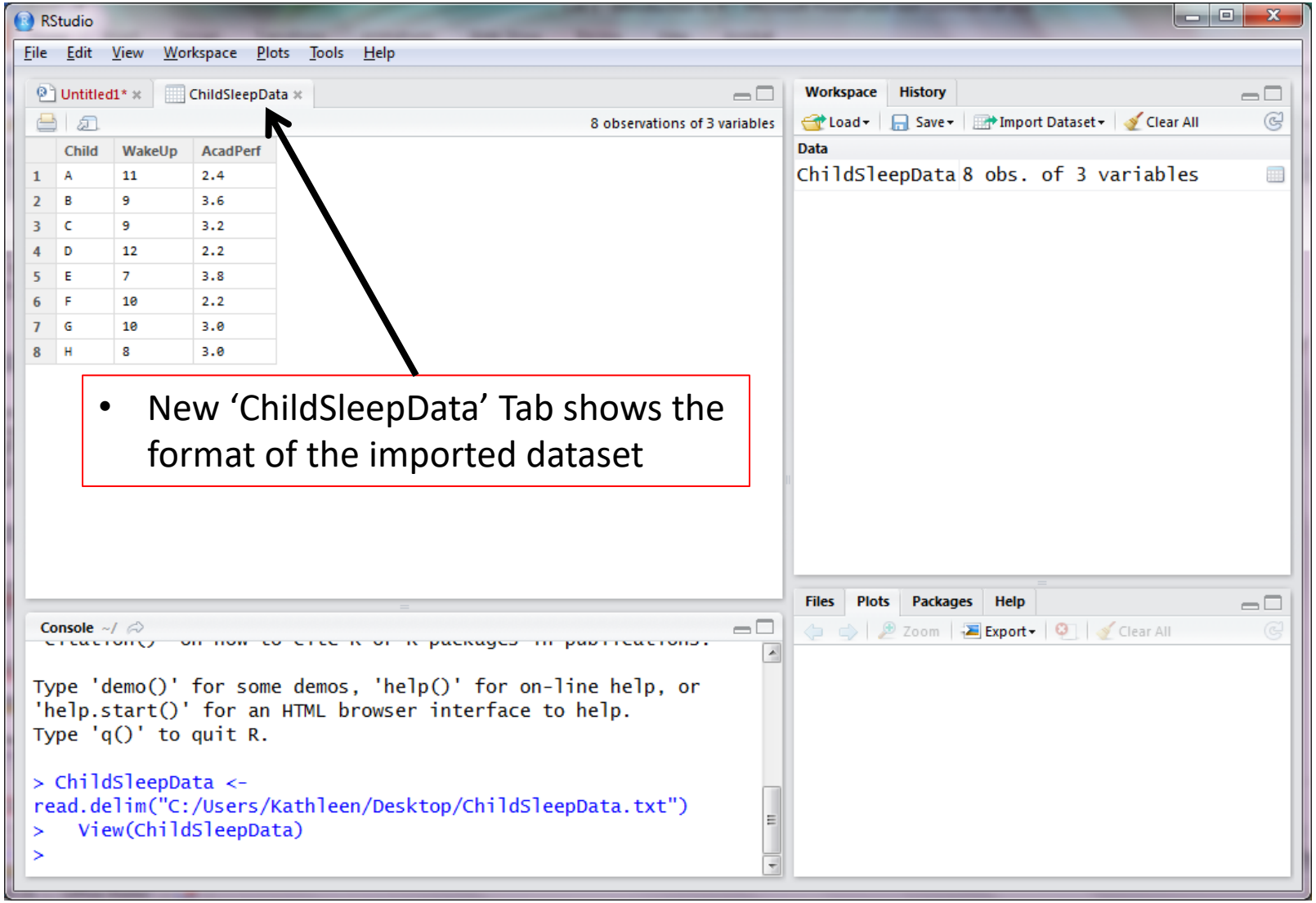
RStudio: Workspace
Importing a Dataset

- If you have chosen the correct options the Data Frame window will be formatted correctly

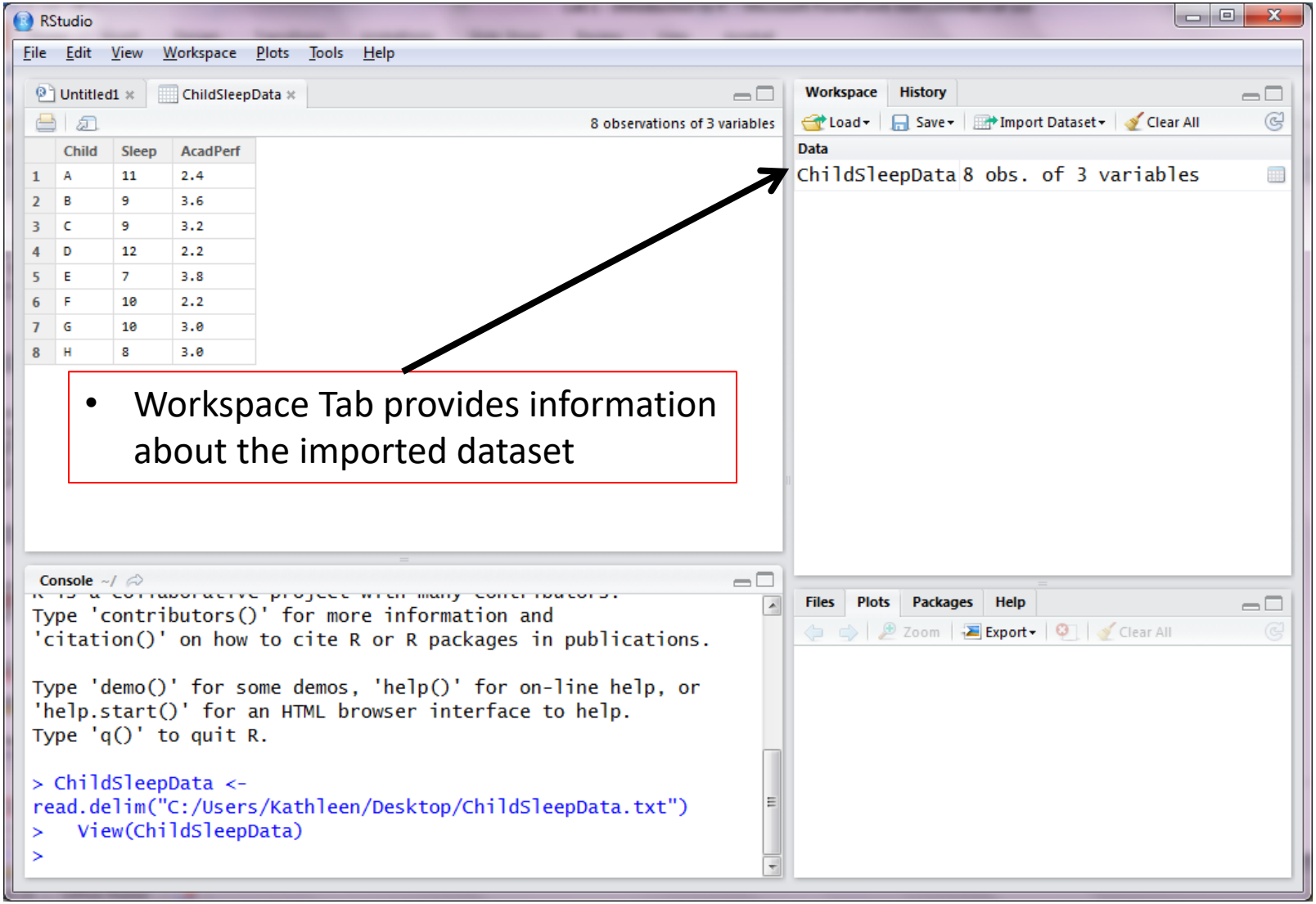


- If everything is correct, click 'Import'

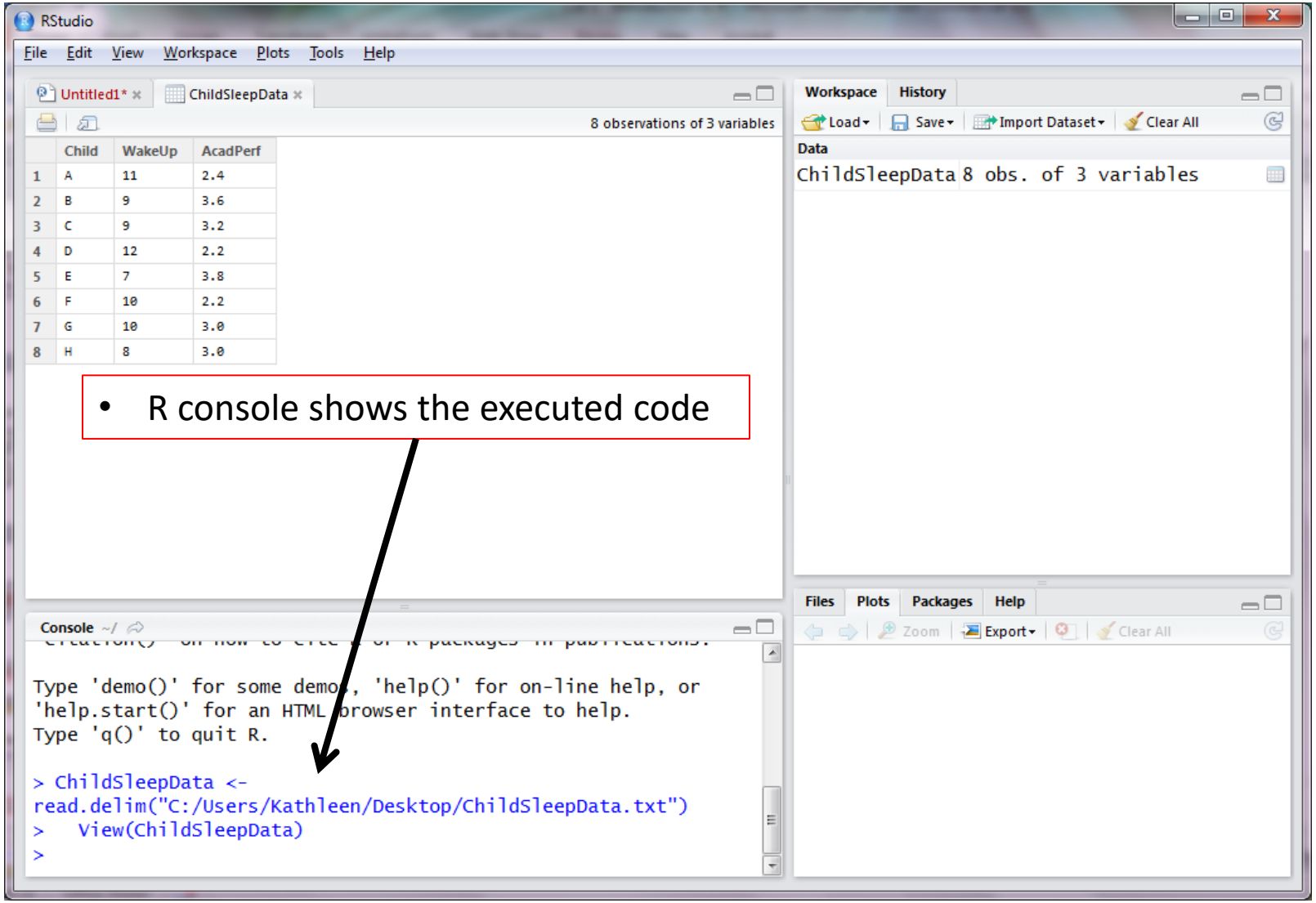
Rstudio:
Dataset Successfully Imported



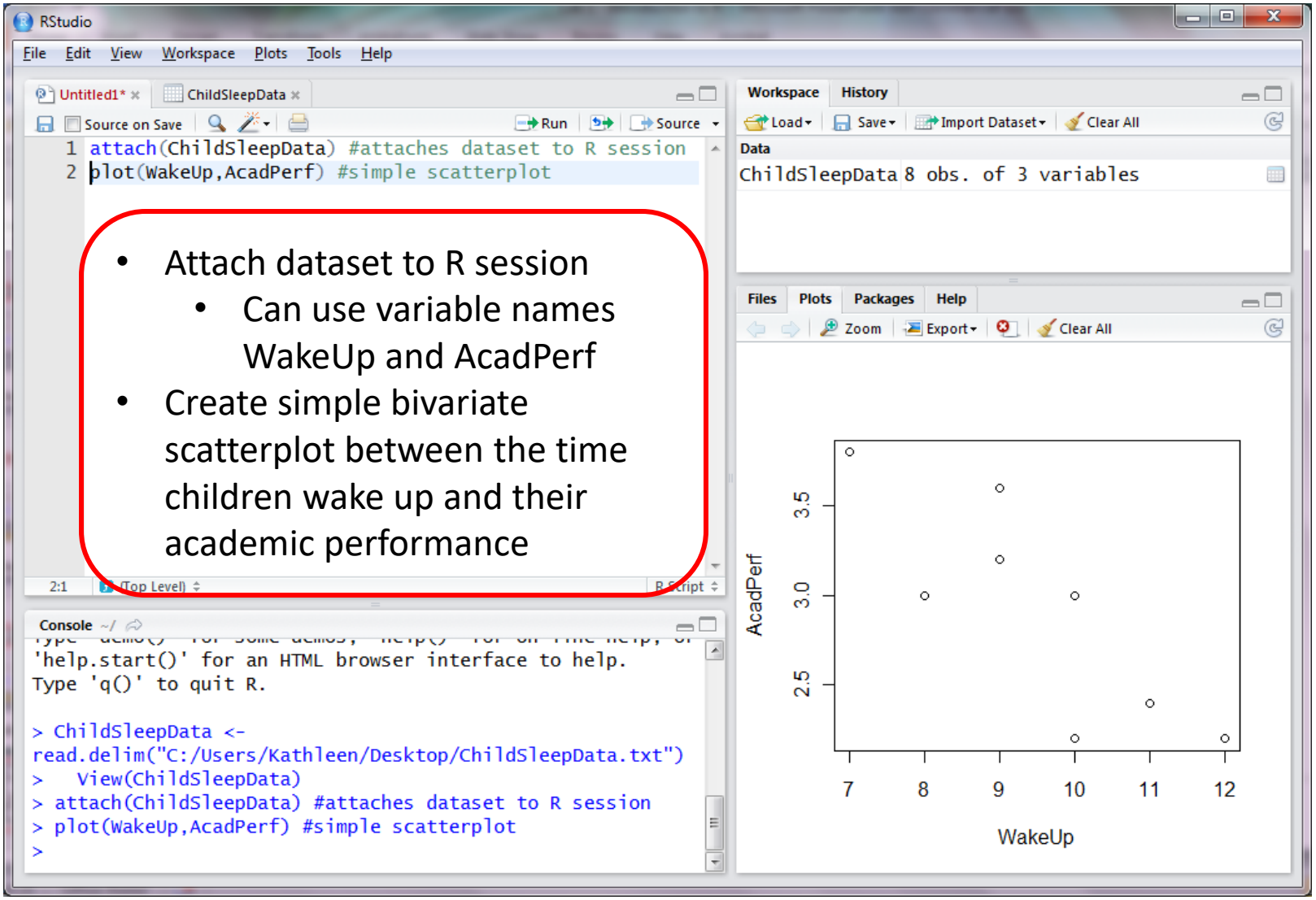
Rstudio:
Dataset Successfully Imported



Rstudio:
Dataset Successfully Imported



Simple plot



- Attach dataset to R session
  - Can use variable names WakeUp and AcadPerf
- Create simple bivariate scatterplot between the time children wake up and their academic performance

Input Data into R

Before Therapy	After Therapy
17	12
19	10
16	14
12	15
17	13
18	12
15	11
16	13

```
bt <- c(17,19,16,12,17,18,15,16)
at <- c(12,10,14,15,13,12,11,13)
ther <- cbind(bt,at)

bt
at
ther
# end of the example
```

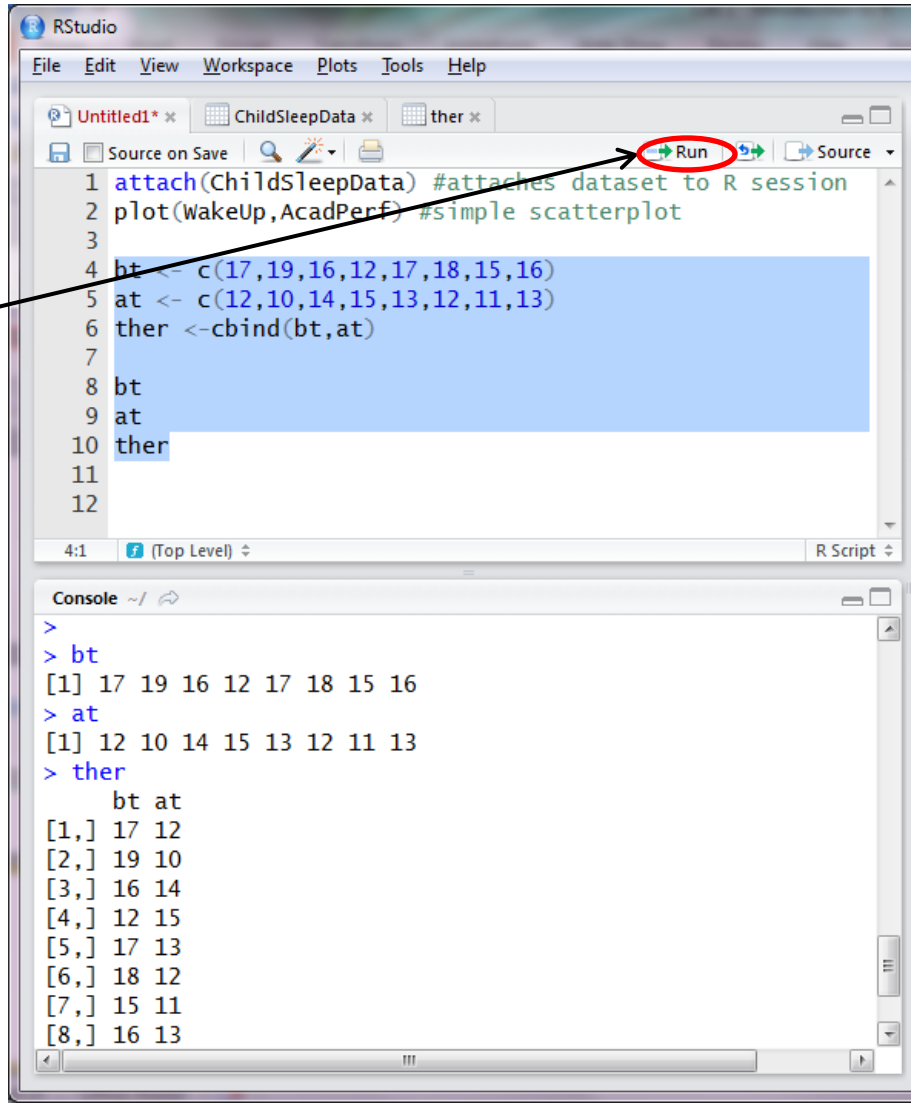
R syntax breakdown

R is case sensitive

<-	assignment
c( )	concatenate (make a list)
cbind( )	column bind
bt	before therapy variable
at	after therapy variable
ther	therapy data
#	commented syntax

R Basics

- Type syntax into R script editor
- Highlight desired section of code
- Click 'Run' or Ctrl+Enter



- See output in the R console

Plotting CRCs and Information with R

```
# Change to reflect the location where your
# flexMIRT output files are saved
wd <- "C:/Users/kathleen/Dropbox/Research
Projects/WPA Stats Talk/CS/"

# Change to reflect the flexMIRT input file
# (.flexmirt) name
flexname <- "NRM Cosmetic Surgery"

# Run code exactly as is
source("https://www.dropbox.com/s/24617l7pvnbjc
8d/Plotting.txt?dl=0 ")
```

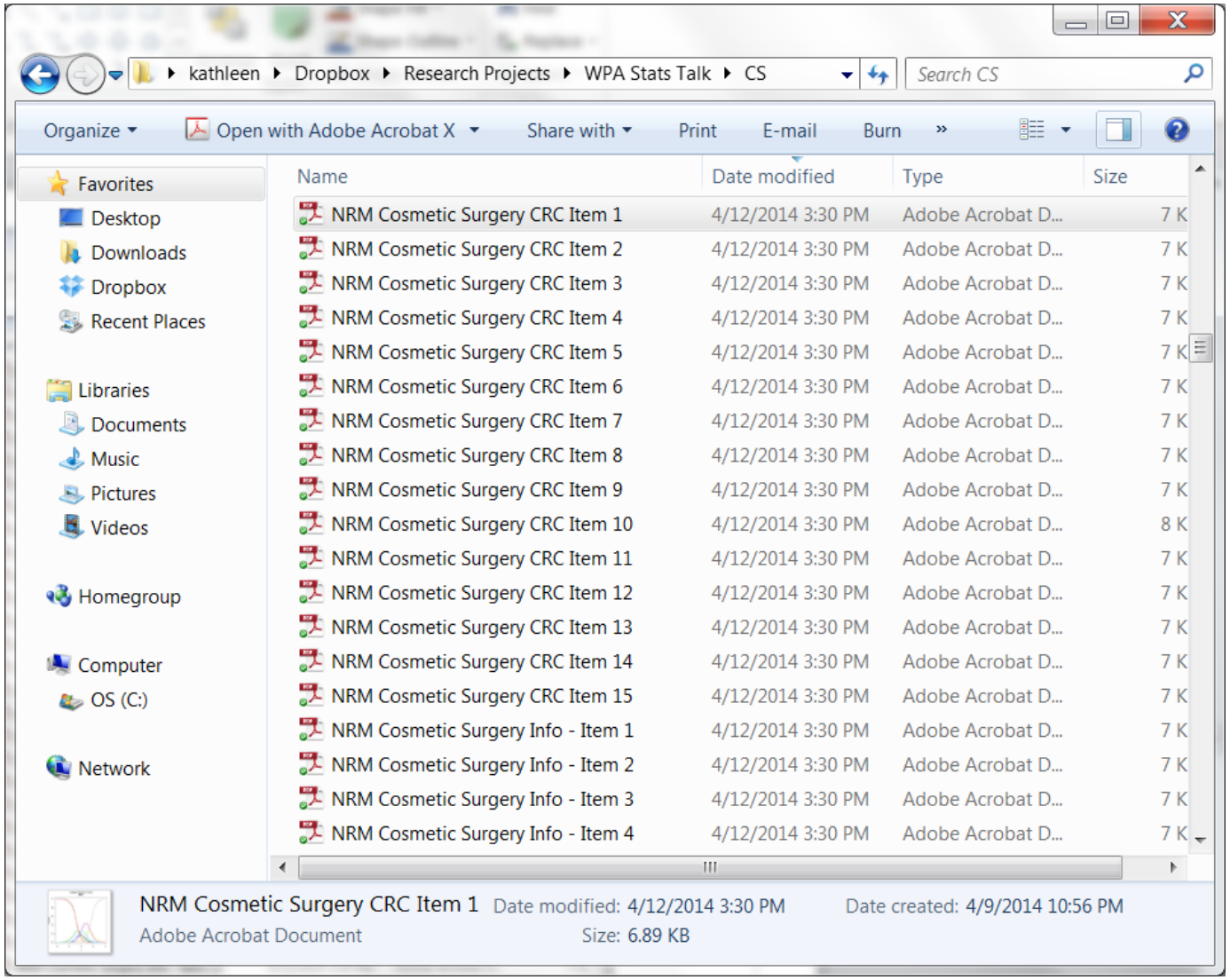
CBDs

	CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
1	1.84	1.01	0.45	1.12	0.92	1.90
2	3.09	1.16	0.95	0.88	1.31	1.18
3	2.71	1.32	0.69	2.89	1.49	1.74
4	3.01	1.28	0.75	1.21	0.74	1.92
5	2.69	1.51	0.81	1.16	0.71	1.11
6	3.45	3.30	0.89	3.04	2.69	2.51
7	2.58	1.23	1.30	1.04	3.05	2.79
8	2.34	1.27	0.04	1.82	1.84	1.40
9	2.40	1.34	0.88	0.89	0.98	1.74
10	1.17	0.86	0.23	0.28	0.08	-0.85
11	1.65	1.12	0.59	1.30	3.27	3.55
12	2.25	0.15	0.62	0.68	2.35	3.29
13	1.59	0.71	1.21	1.13	1.10	2.51
14	2.55	0.89	0.38	0.74	0.86	2.55
15	2.77	0.86	1.46	1.48	3.17	5.81

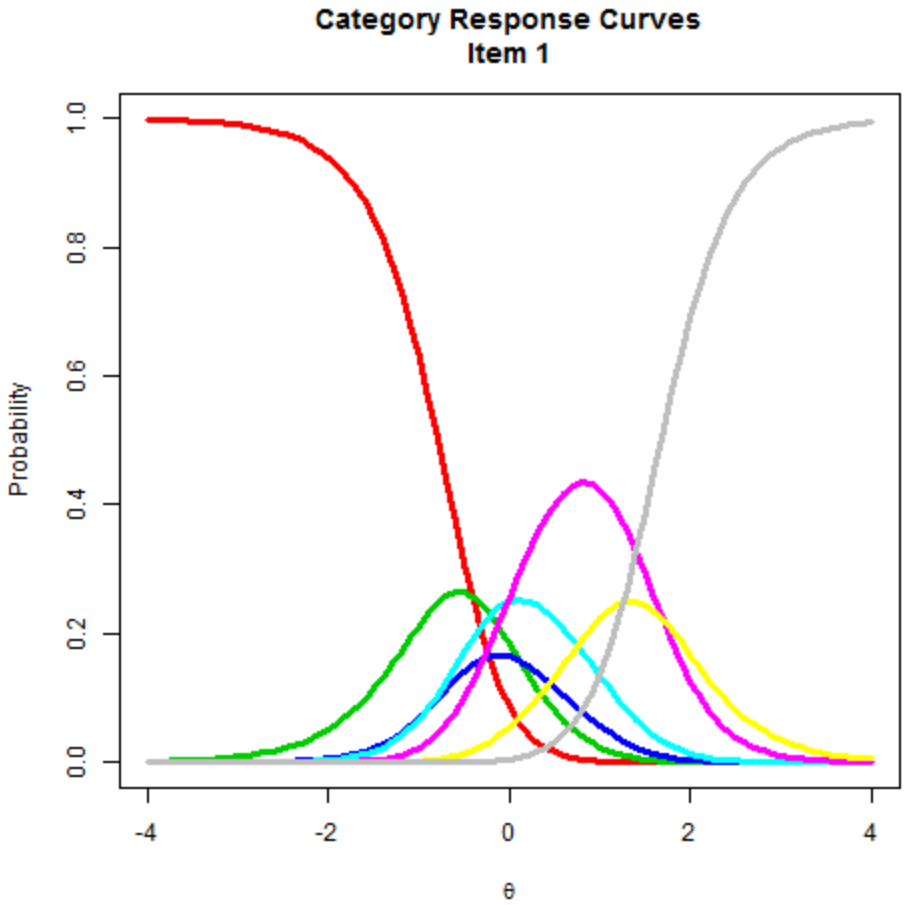
Intersections

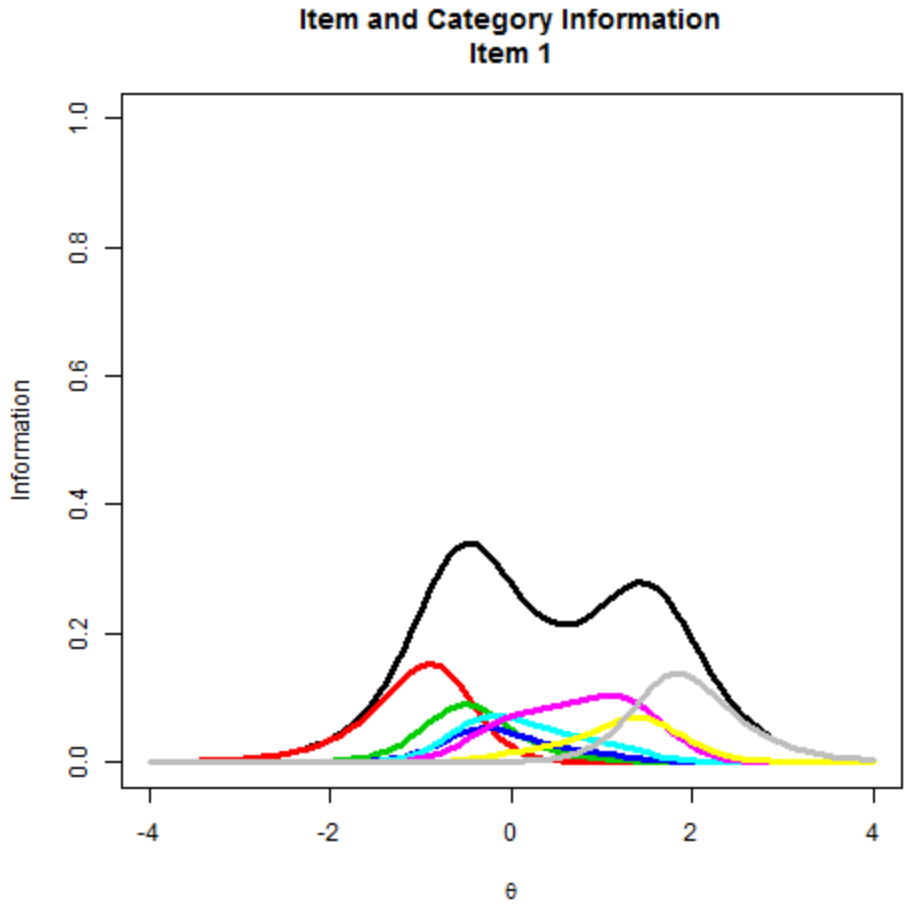
	Int 1	Int 2	Int 3	Int 4	Int 5	Int 6
1	-0.41	0.12	-0.93	-0.03	1.70	1.25
2	-0.76	-0.07	-1.11	0.24	1.42	1.54
3	0.08	0.33	-0.61	0.55	1.70	1.75
4	-0.53	-0.34	-1.04	0.49	2.03	1.56
5	-0.79	-0.36	-1.60	-0.05	1.69	1.41
6	-0.27	-0.13	-0.19	0.14	0.93	1.26
7	-0.09	-0.20	-0.33	-0.19	0.75	0.98
8	0.12	0.19	-9.75	0.10	1.21	1.01
9	0.15	0.26	-0.03	1.63	1.26	1.47
10	0.36	0.42	-3.17	1.36	0.38	0.65
11	0.36	0.36	0.53	0.83	1.63	1.85
12	0.16	2.13	-0.05	0.69	1.38	1.76
13	0.47	0.42	0.31	0.77	1.61	1.87
14	-0.39	-0.02	-3.24	0.11	1.28	1.37
15	0.04	0.19	-0.21	0.73	1.06	1.65

Plots saved as .pdf files



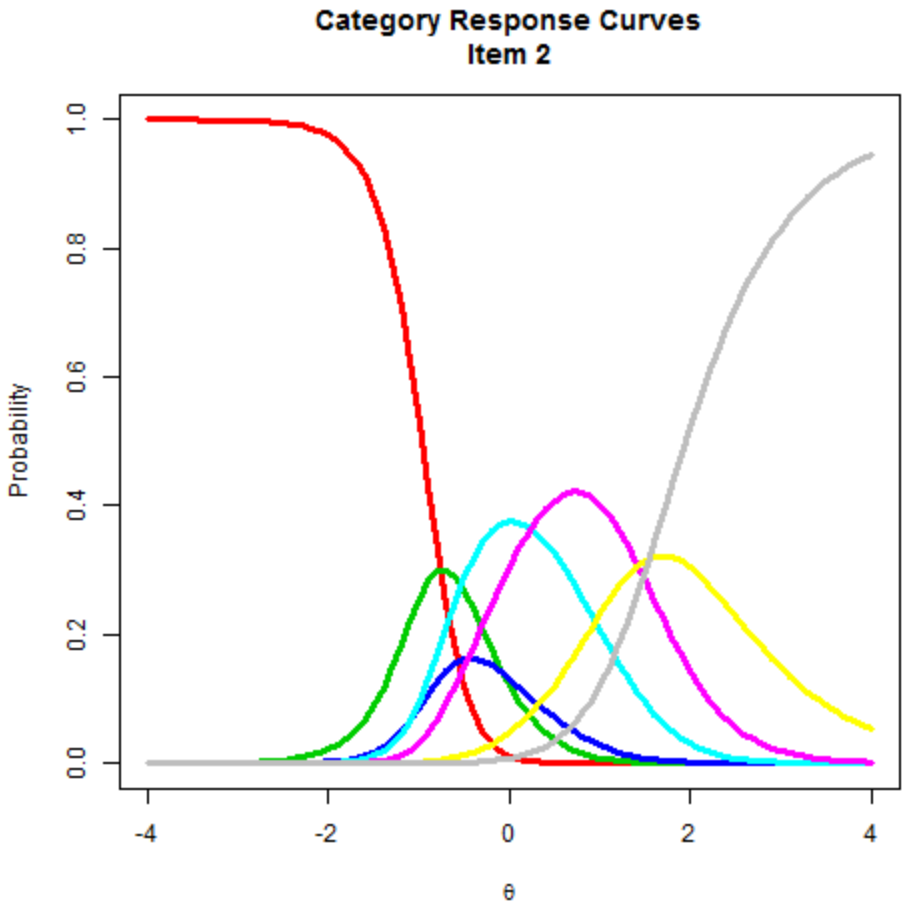
1. It makes sense to have minor cosmetic surgery rather than spending years feeling bad about the way you look.

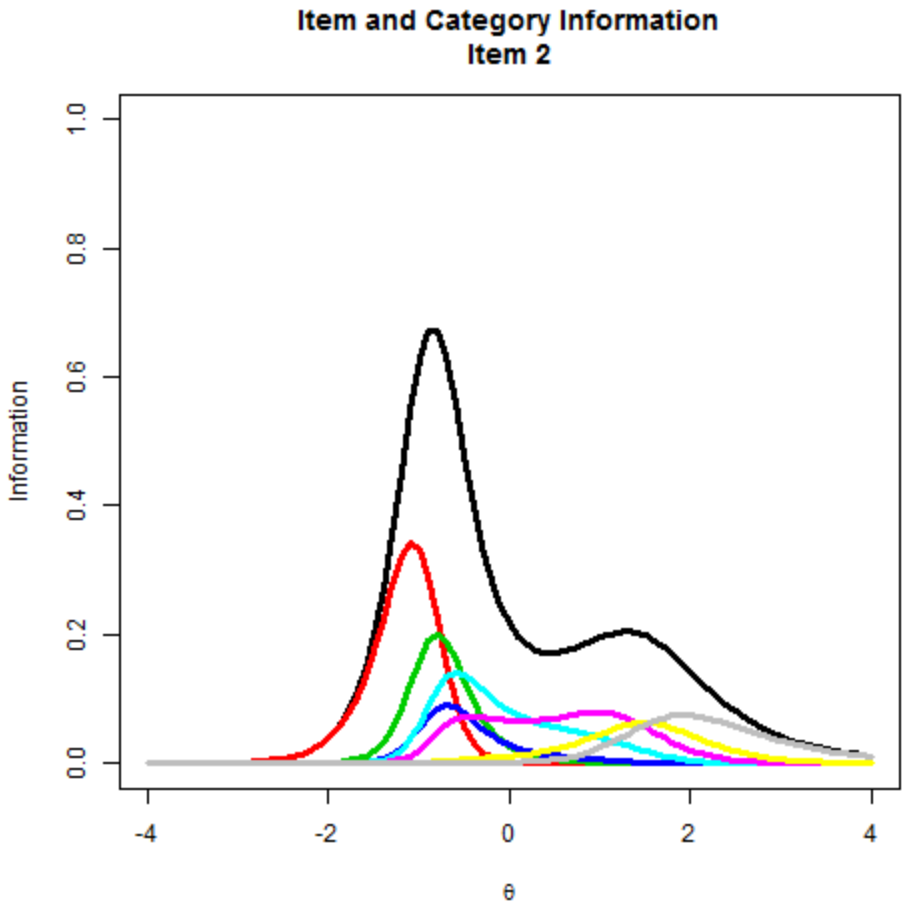




CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
1.84	1.01	0.45	1.12	0.92	1.90

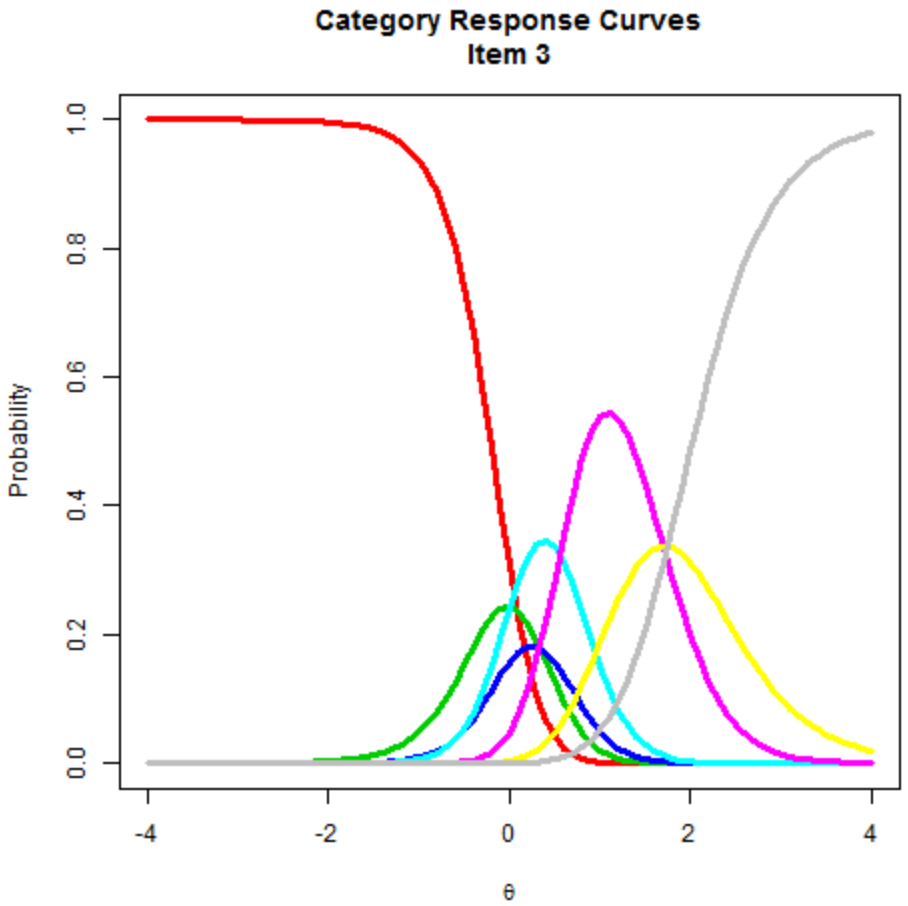
2. Cosmetic surgery is a good thing because it can help people feel better about themselves.

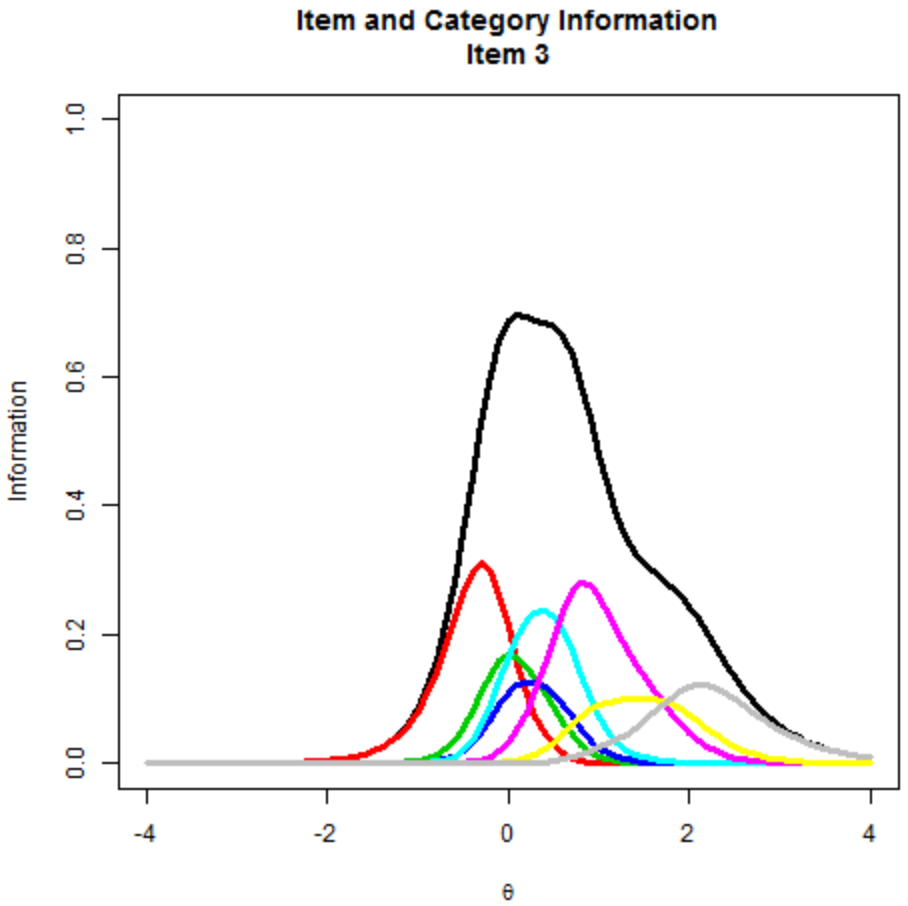




CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
3.09	1.16	0.95	0.88	1.31	1.18

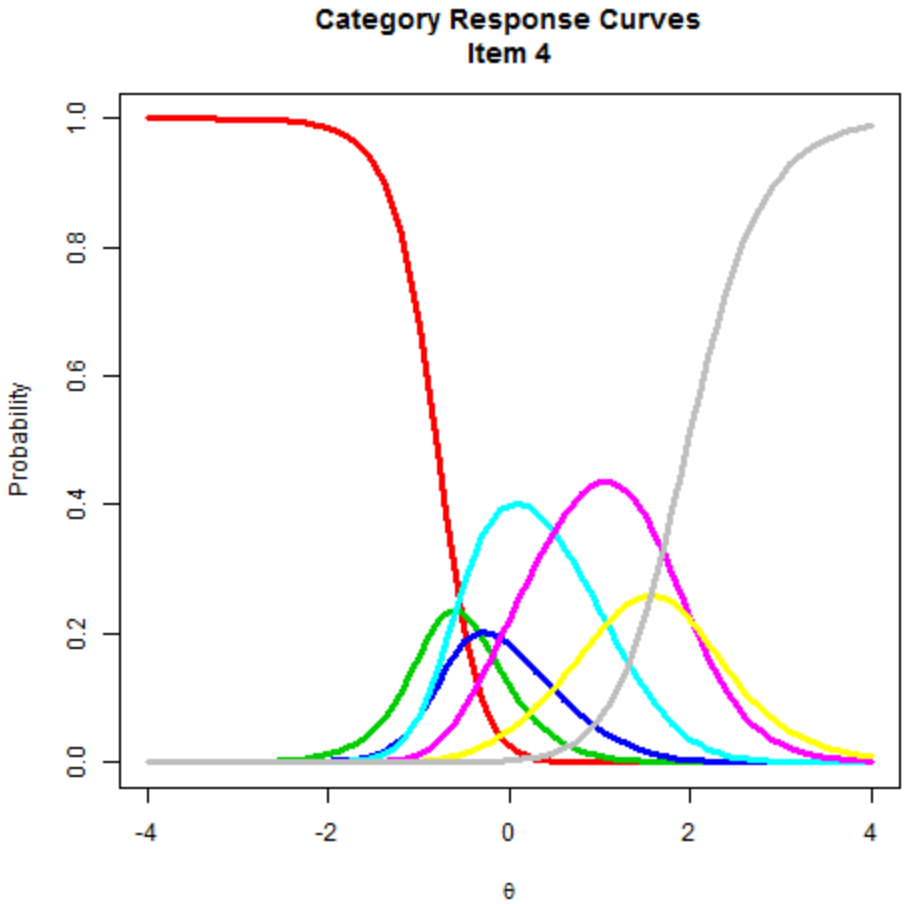
3. In the future, I could end up having some kind of cosmetic surgery.

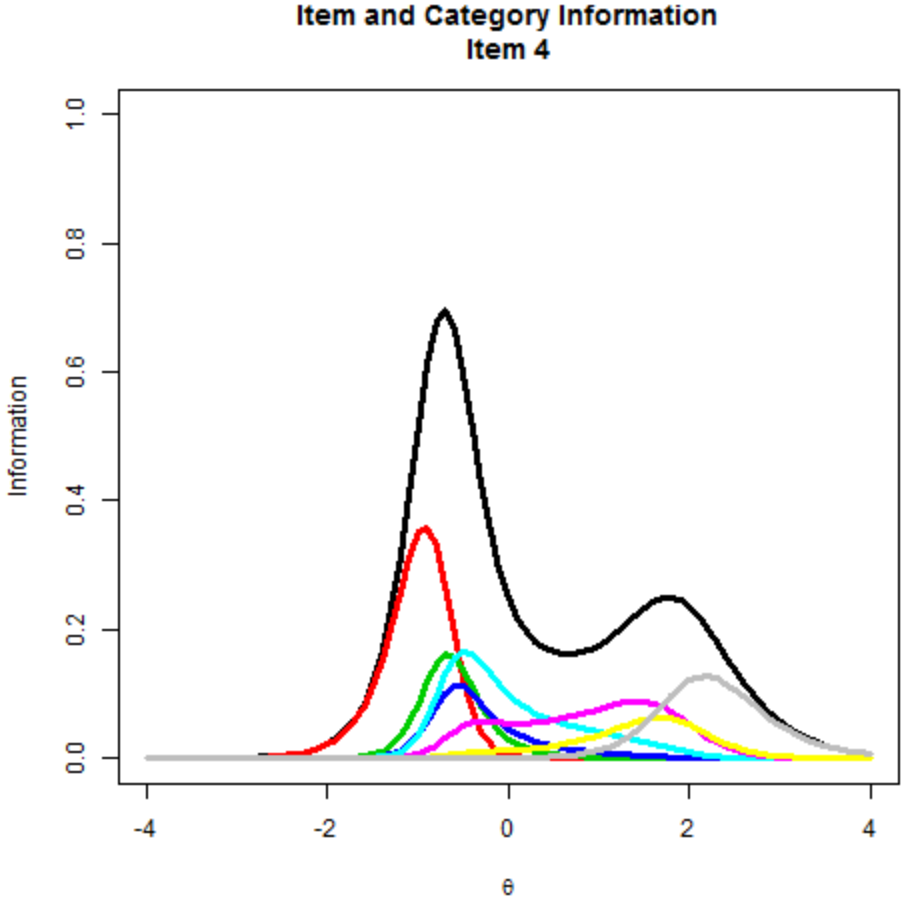




CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
2.71	1.32	0.69	2.89	1.49	1.74

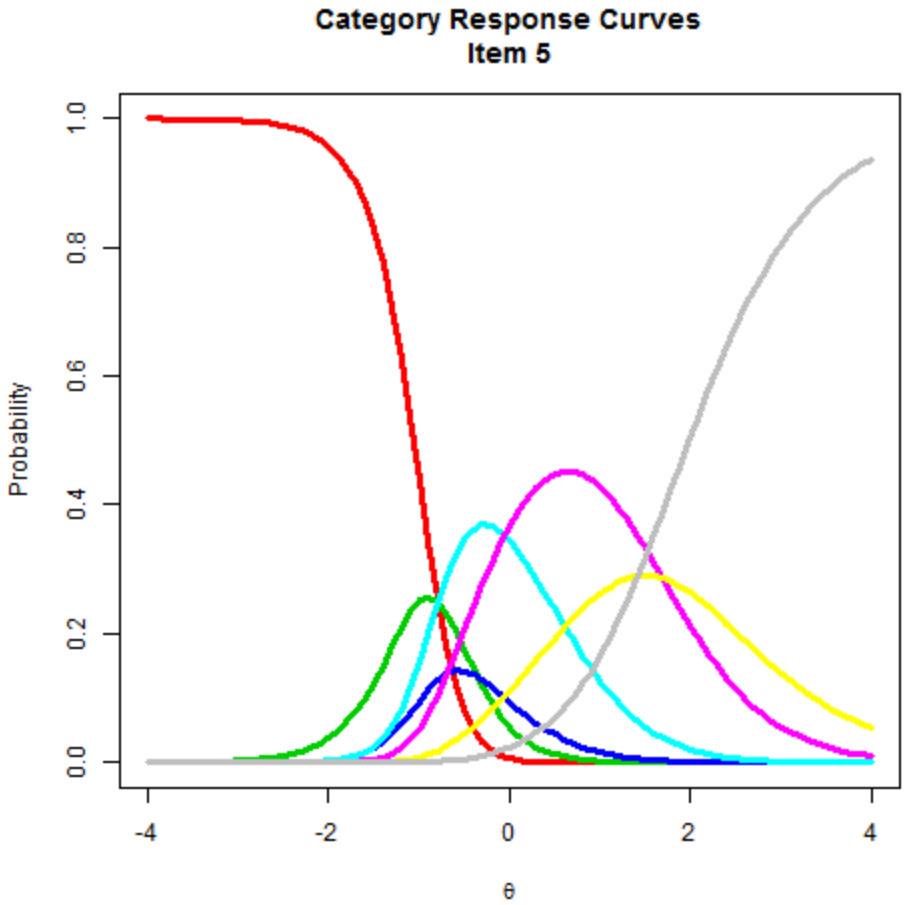
4. People who are very unhappy with their physical appearance should consider cosmetic surgery as one option.

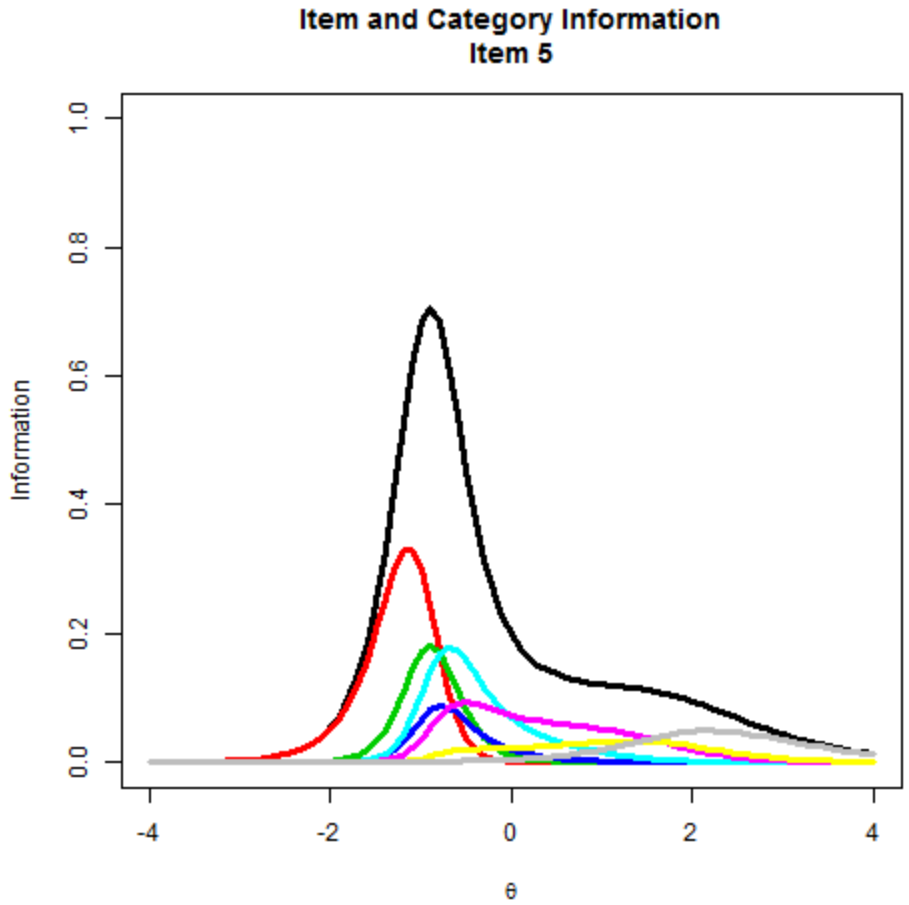




CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
3.01	1.28	0.75	1.21	0.74	1.92

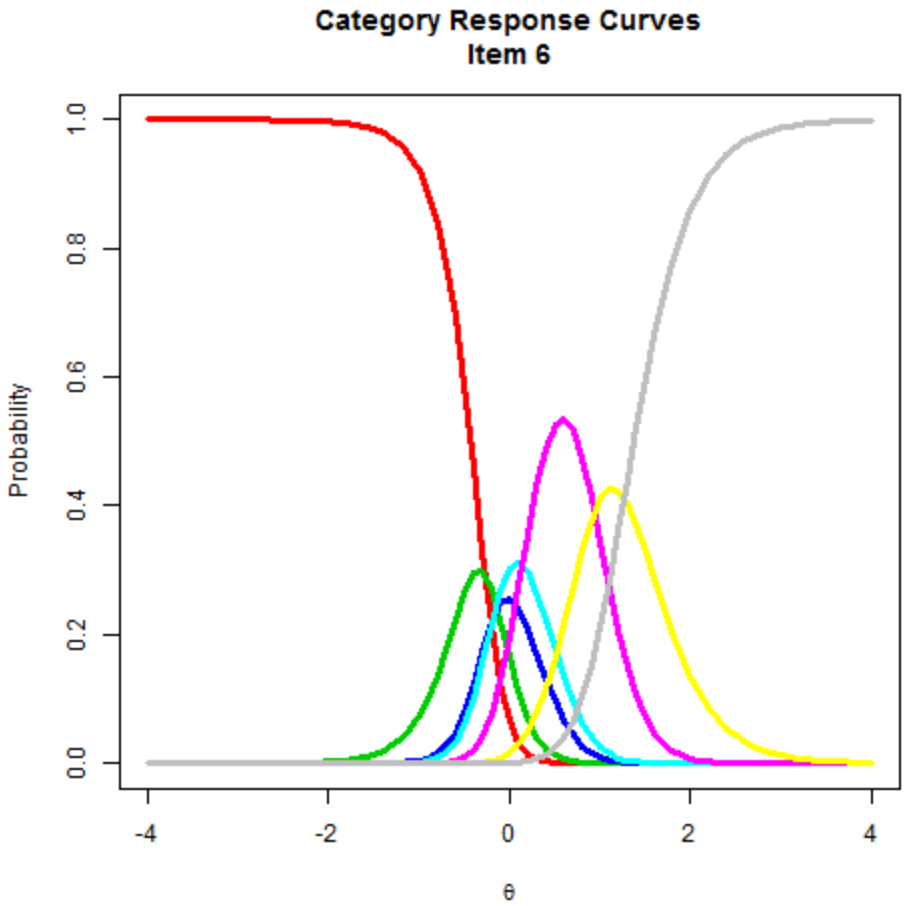
5. If cosmetic surgery can make someone happier with the way they look, then they should try it.

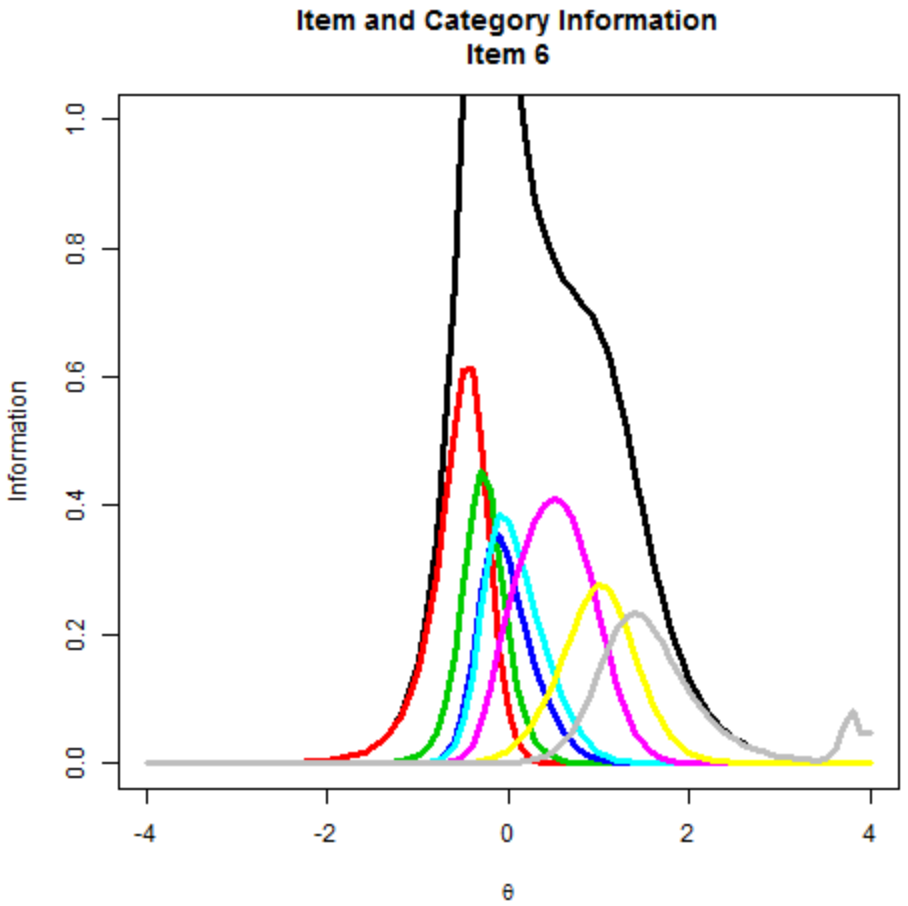




CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
2.69	1.51	0.81	1.16	0.71	1.11

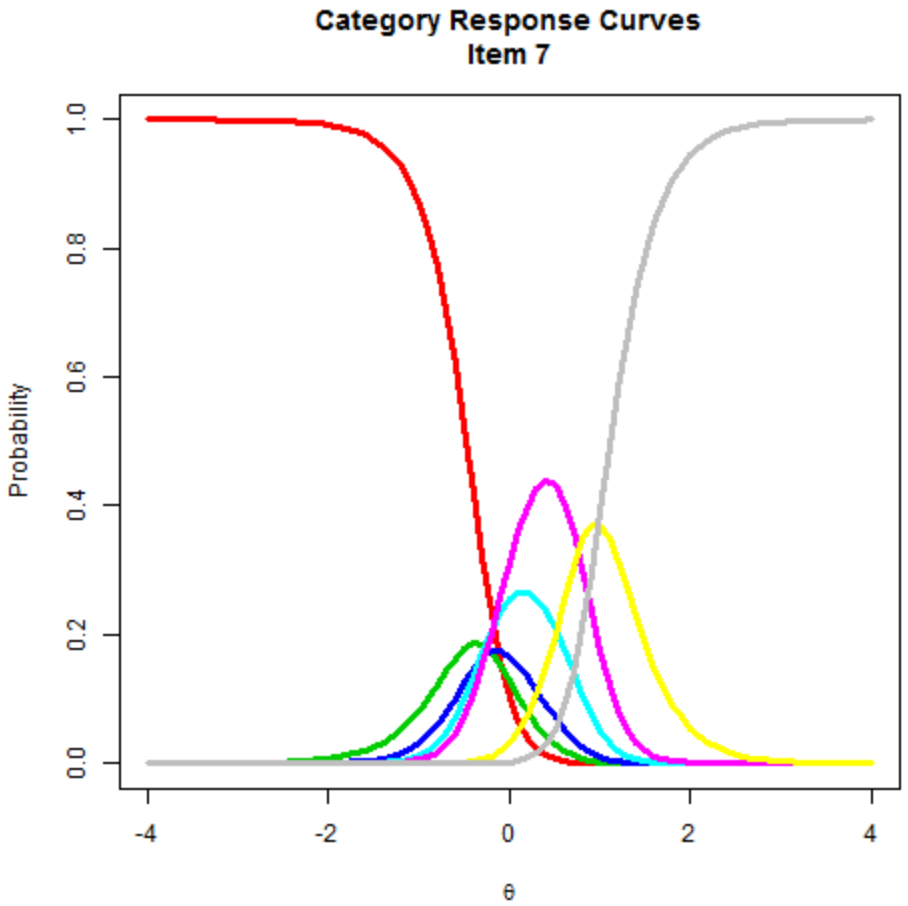
6. If I could have a surgical procedure done for free I would consider trying cosmetic surgery.

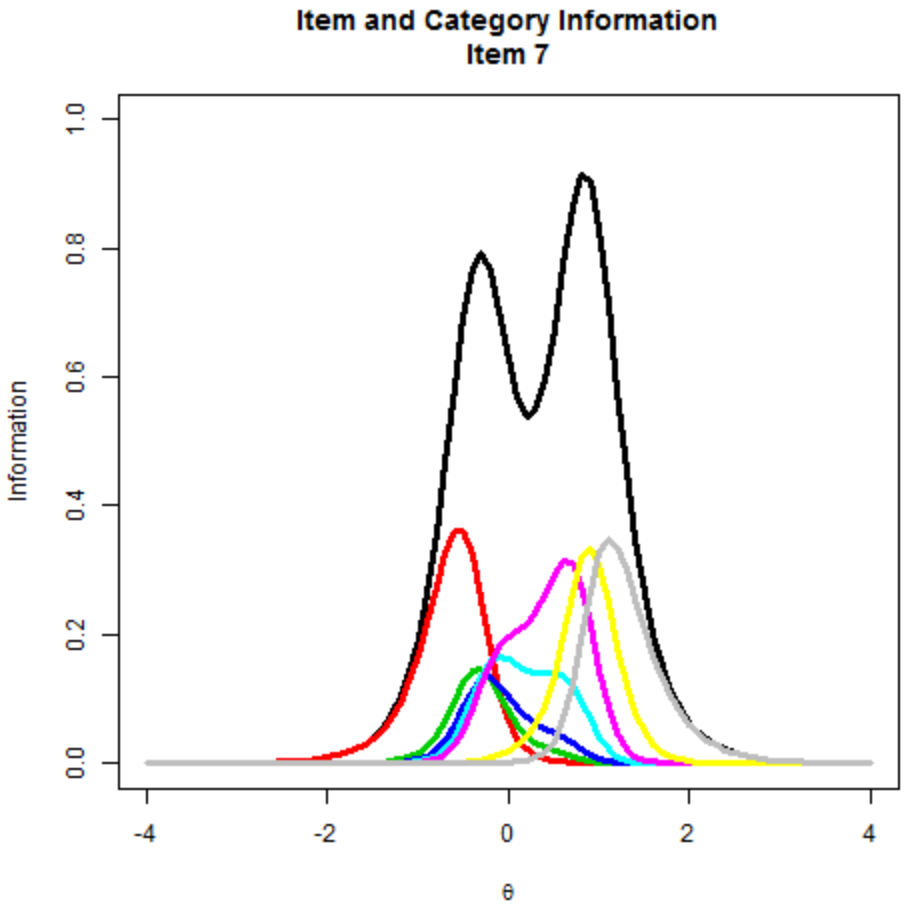




CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
3.45	3.30	0.89	3.04	2.69	2.51

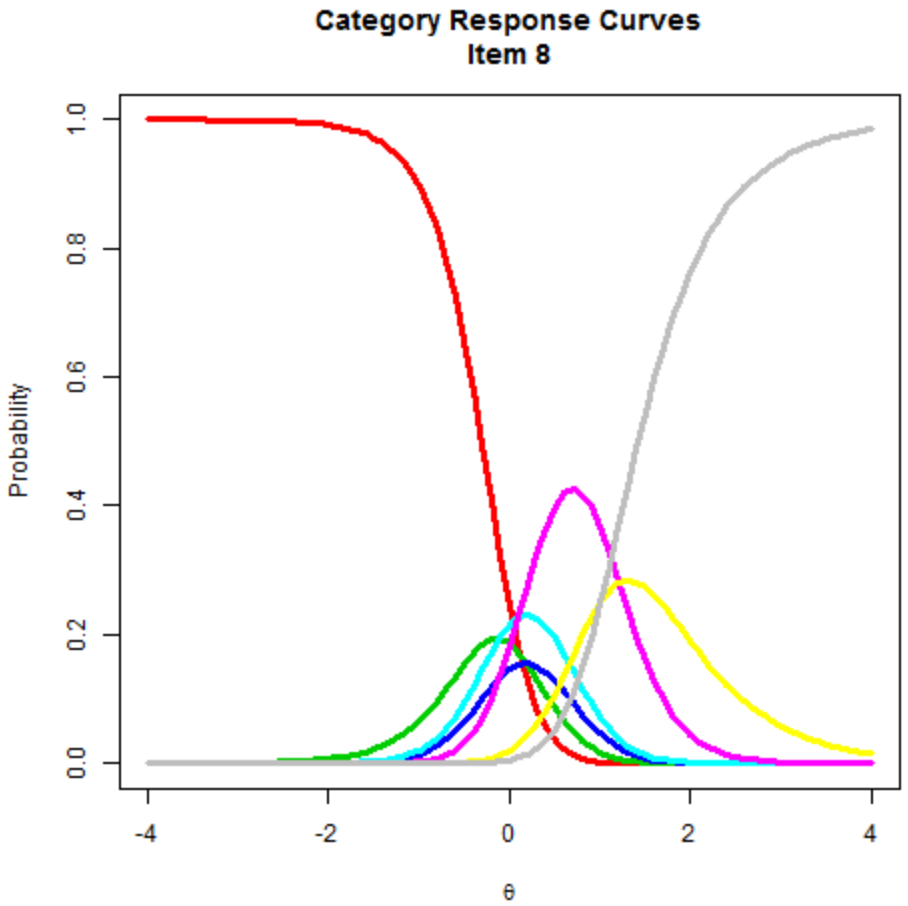
7. If I knew there would be no negative side effects or pain, I would like to try cosmetic surgery.

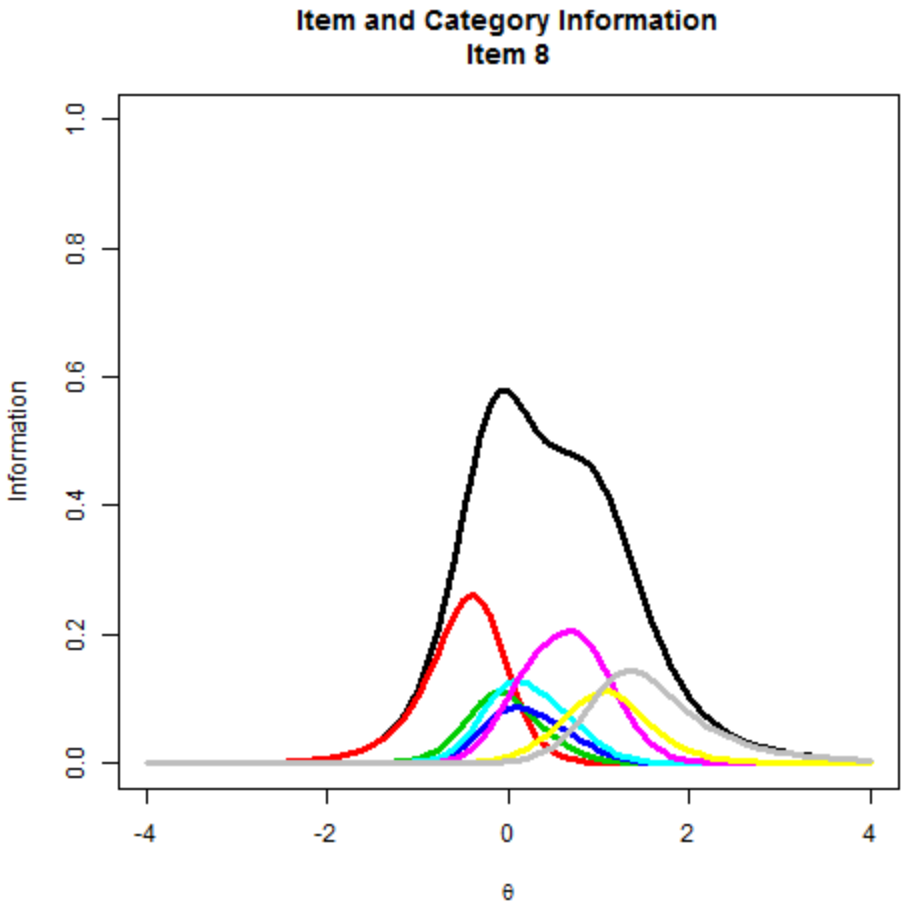




CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
2.58	1.23	1.30	1.04	3.05	2.79

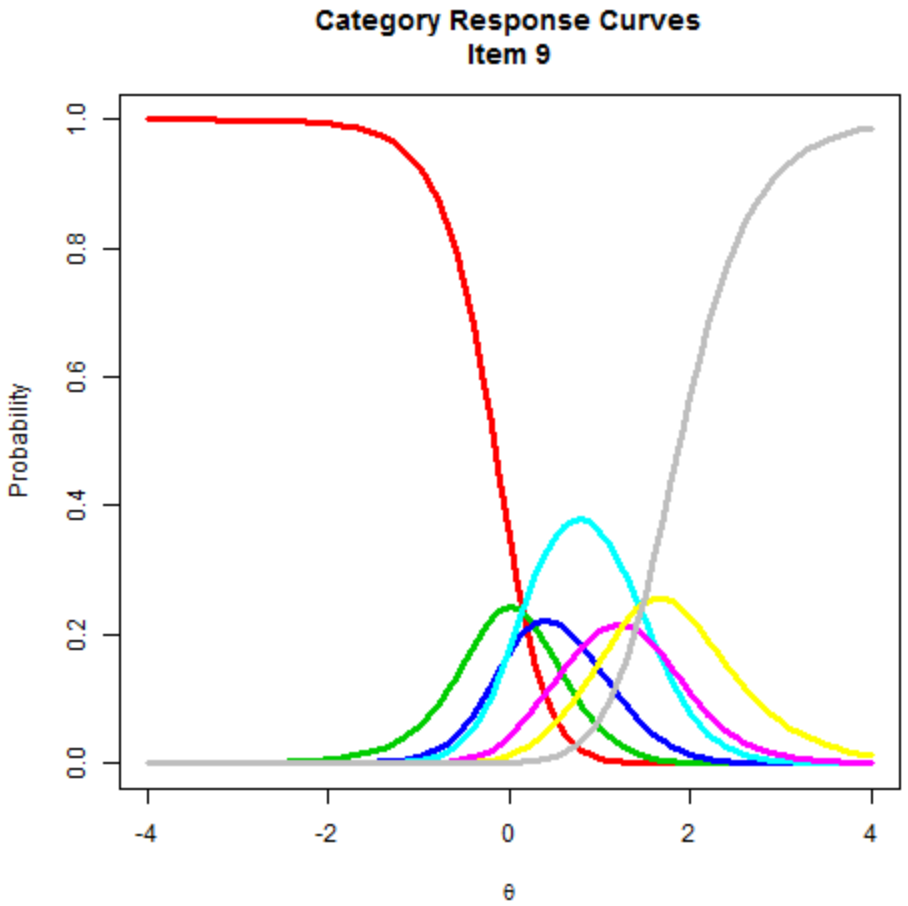
8. I have sometimes thought about having cosmetic surgery.

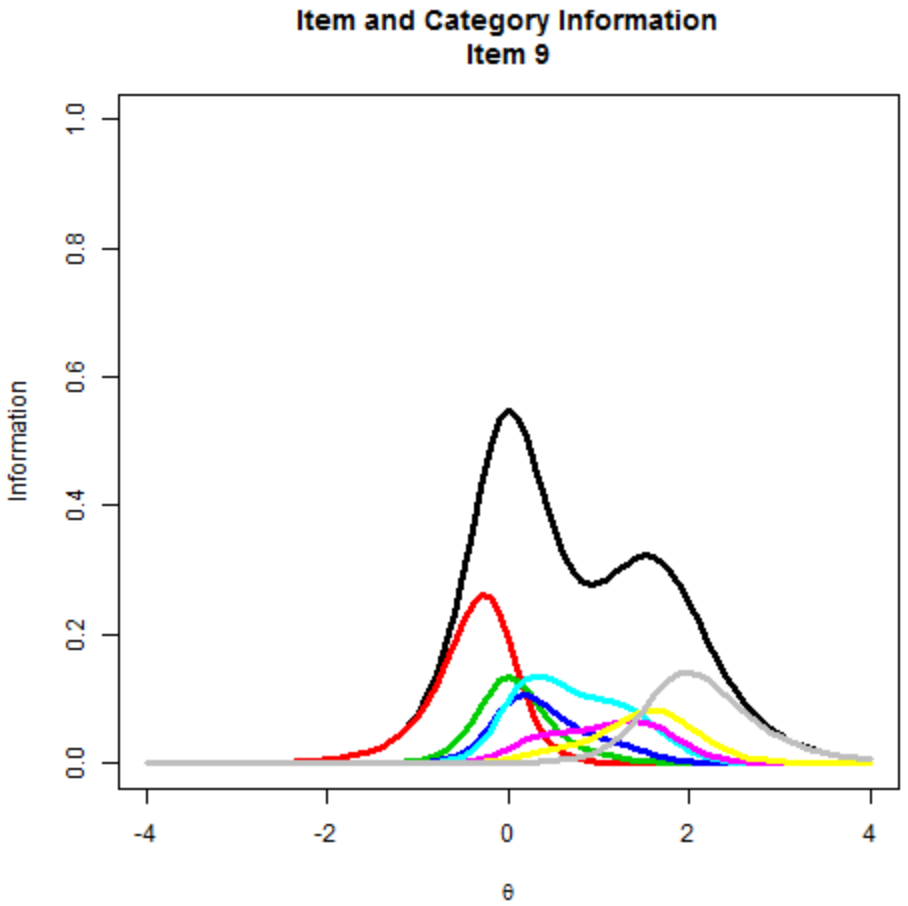




CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
2.34	1.27	0.04	1.82	1.84	1.40

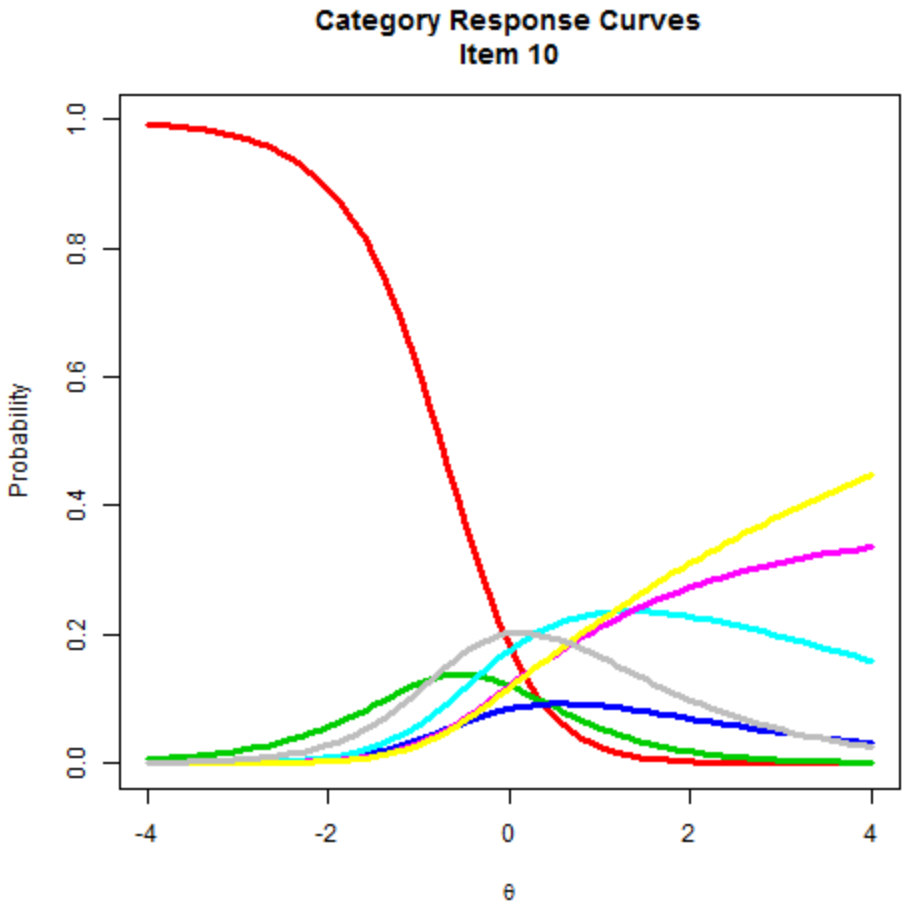
9. I would seriously consider having cosmetic surgery if my partner thought it was a good idea.

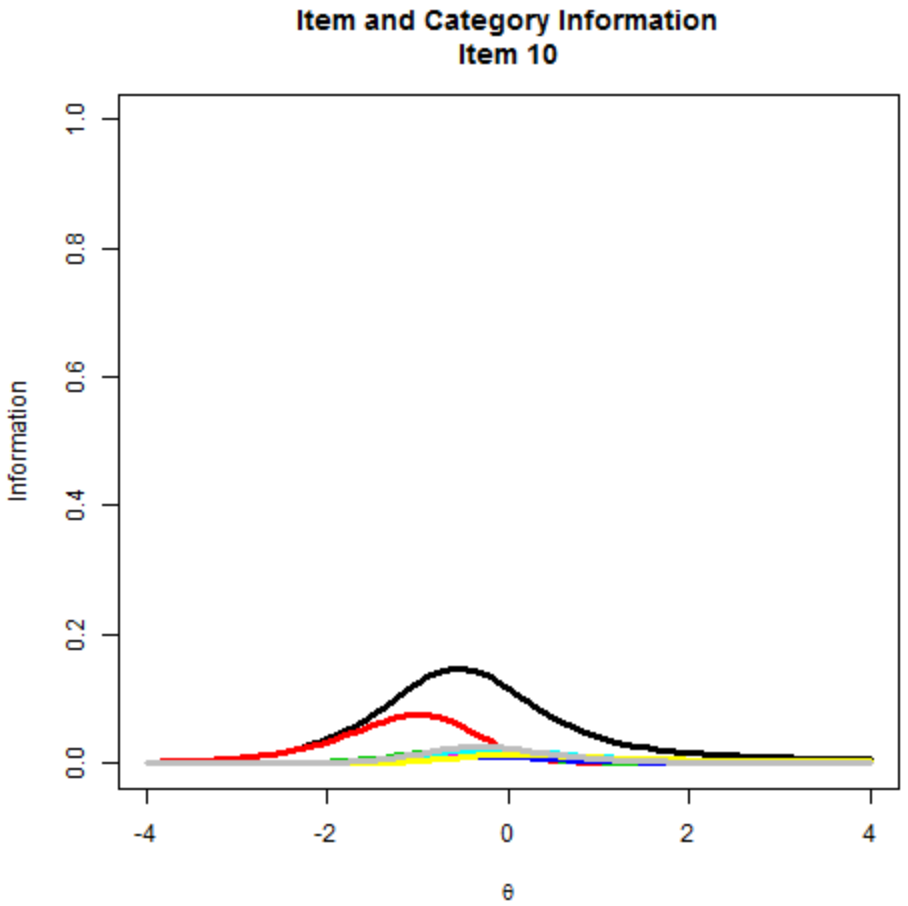




CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
2.40	1.34	0.88	0.89	0.98	1.74

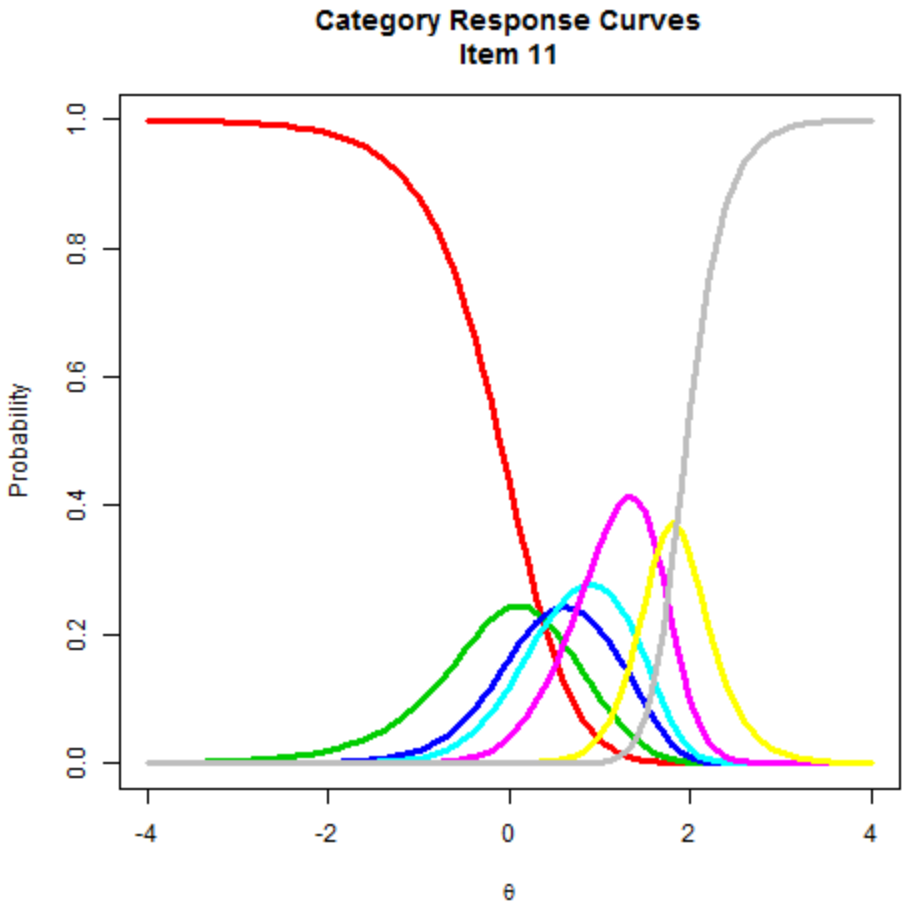
10. I would never have any kind of plastic surgery.

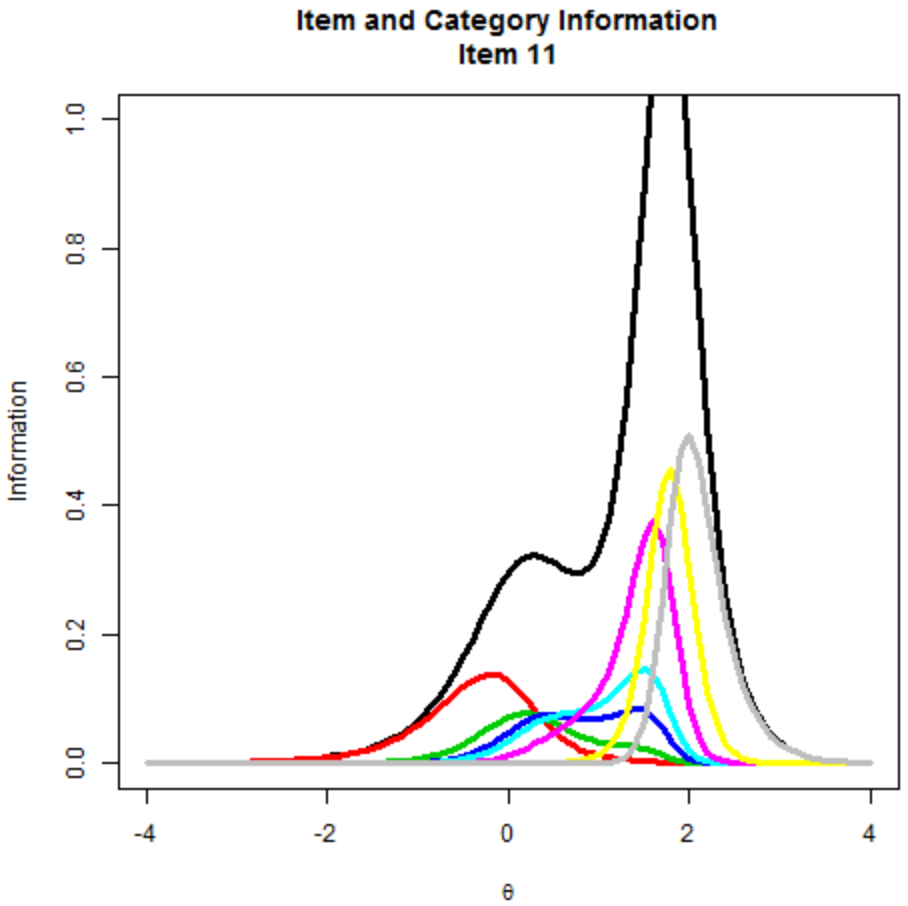




CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
1.17	0.86	0.23	0.28	0.08	-0.85

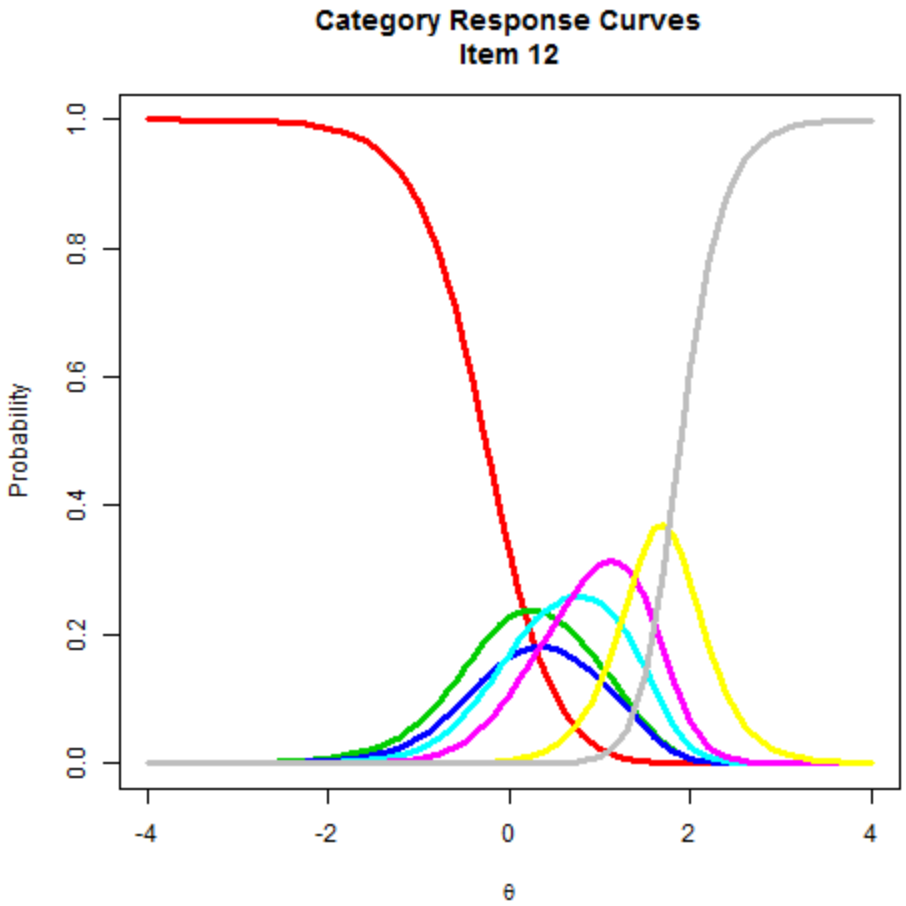
11. I would think about having cosmetic surgery in order to keep looking young.

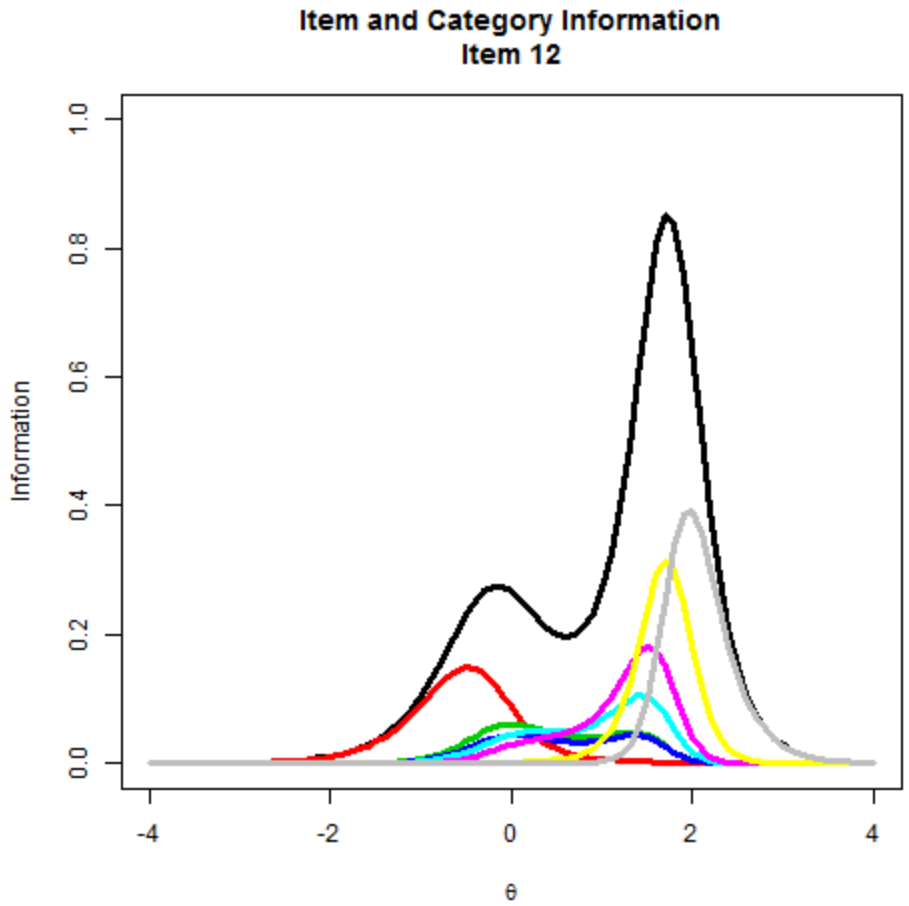




CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
1.65	1.12	0.59	1.30	3.27	3.55

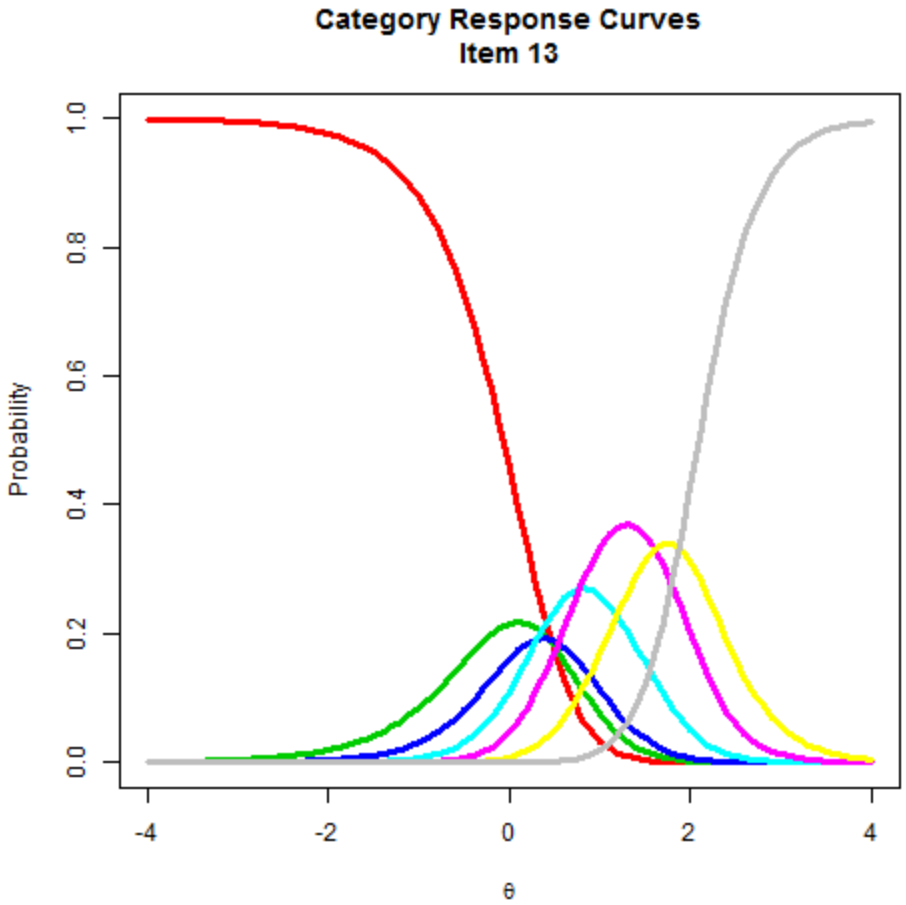
12. If it would benefit my career, I would think about having plastic surgery.

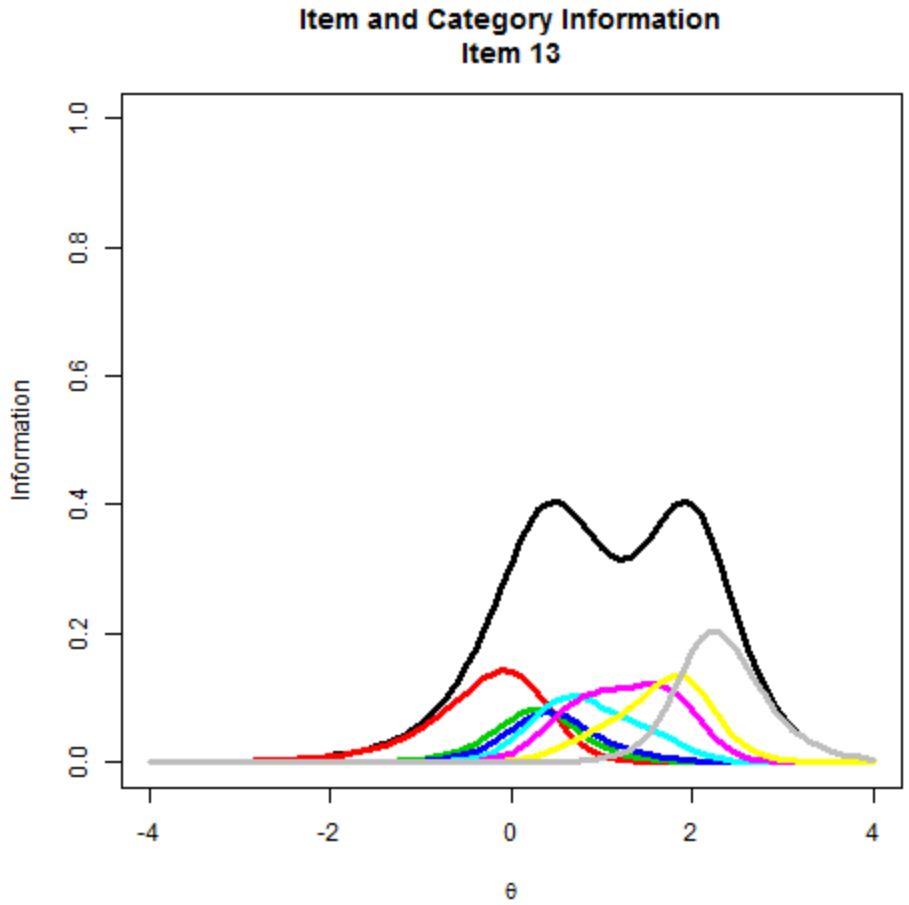




CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
2.25	0.15	0.62	0.68	2.35	3.29

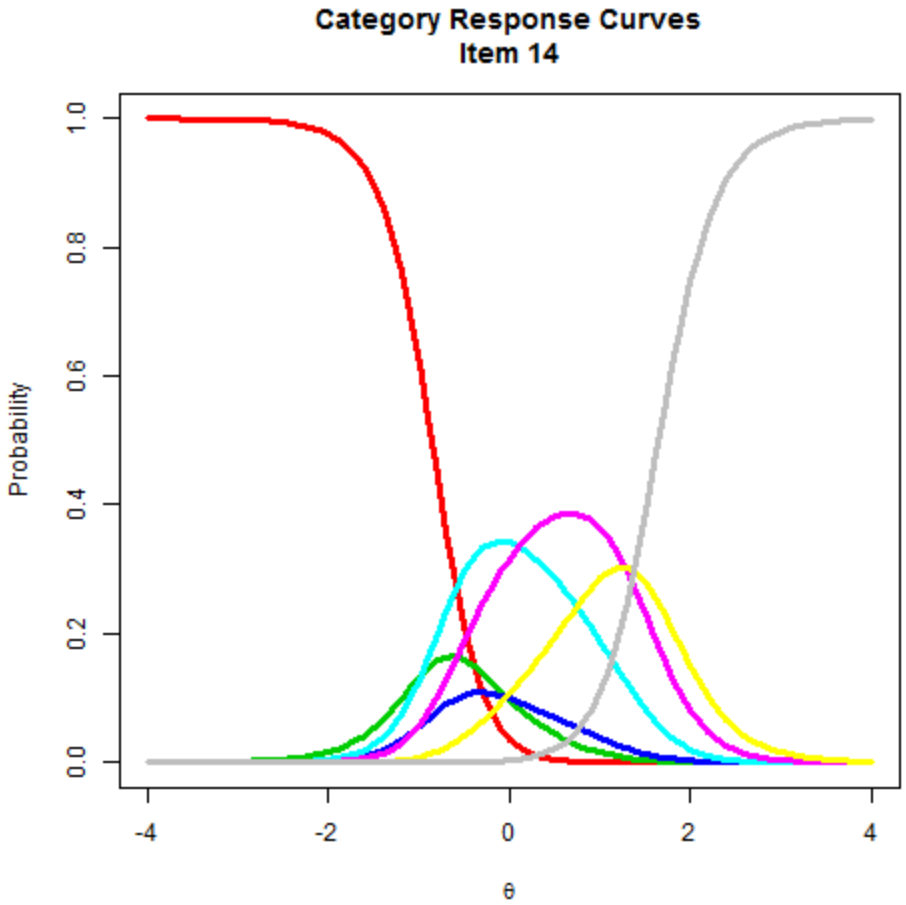
13. I would seriously consider having cosmetic surgery if I thought my partner would find me more attractive.

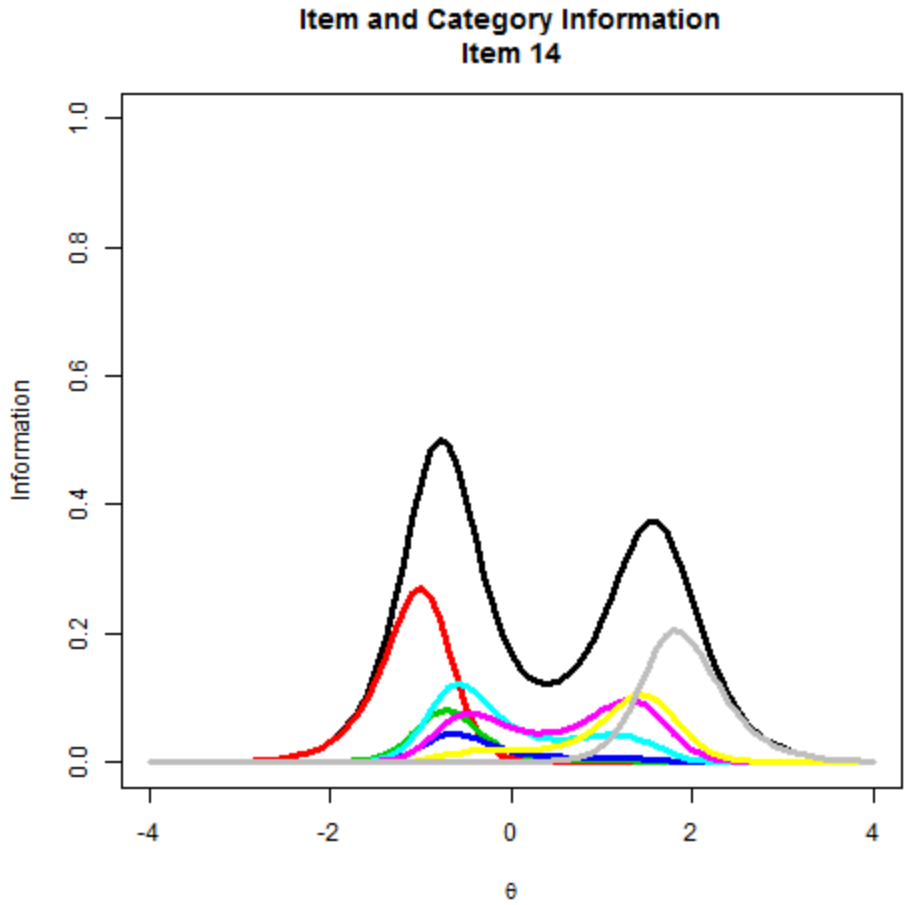




CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
1.59	0.71	1.21	1.13	1.10	2.51

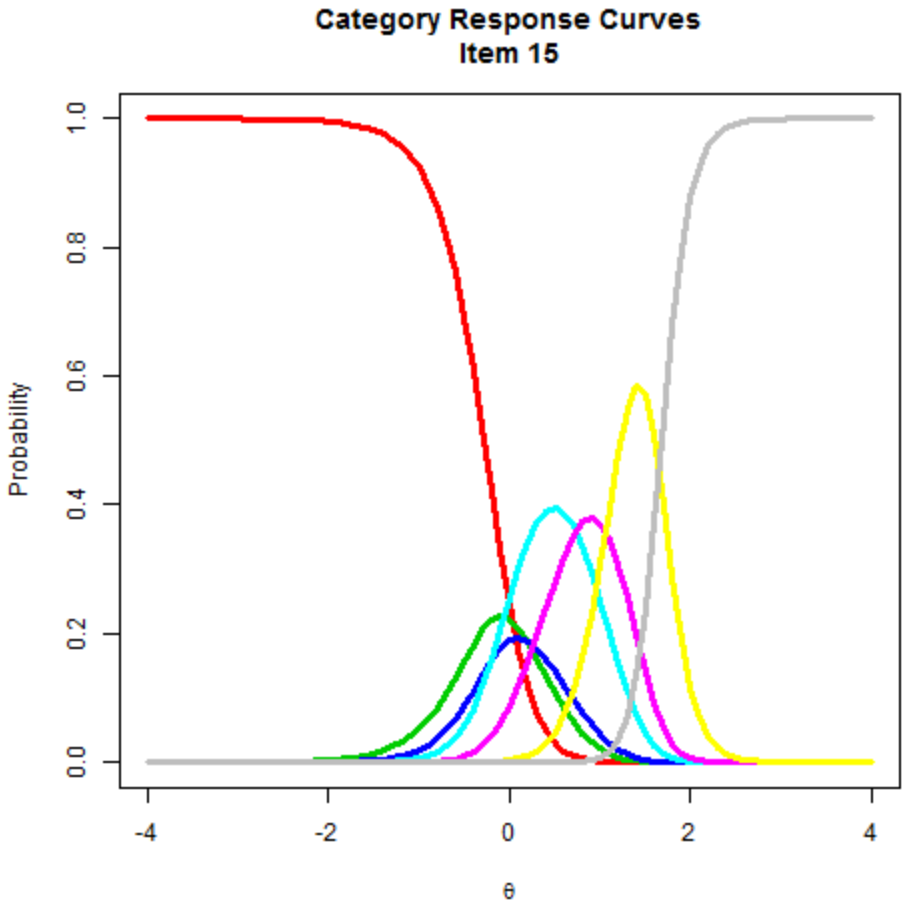
14. Cosmetic surgery can be a big benefit to people's self-image.

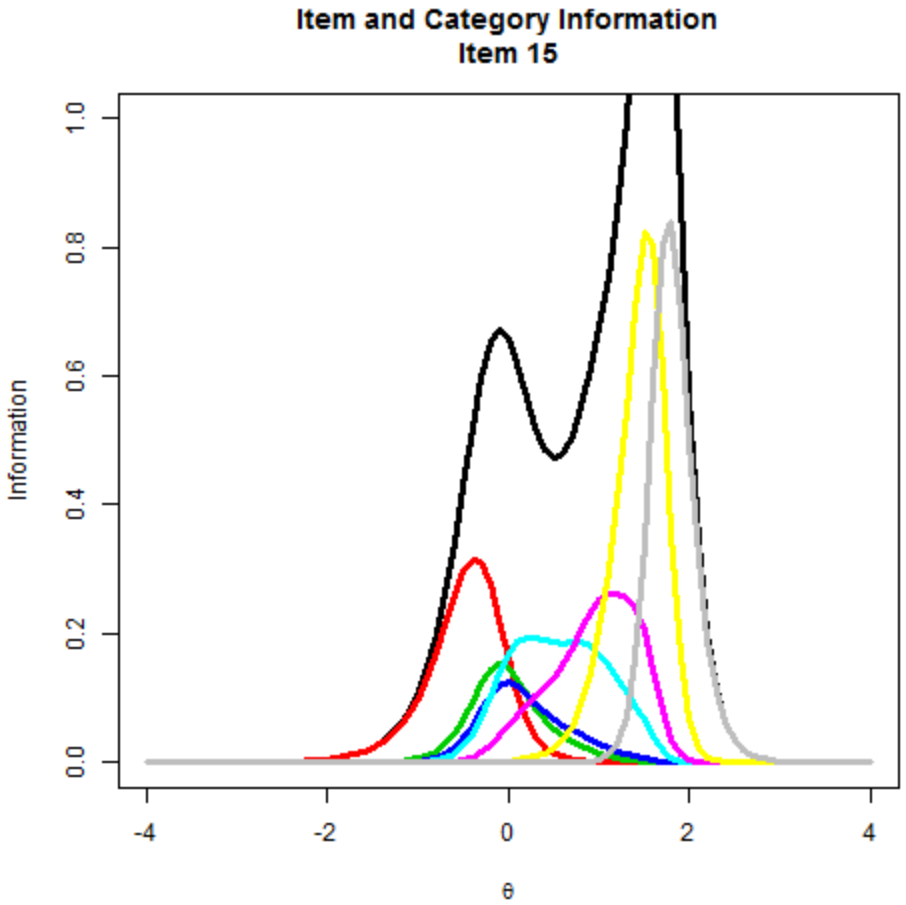




CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
2.55	0.89	0.38	0.74	0.86	2.55

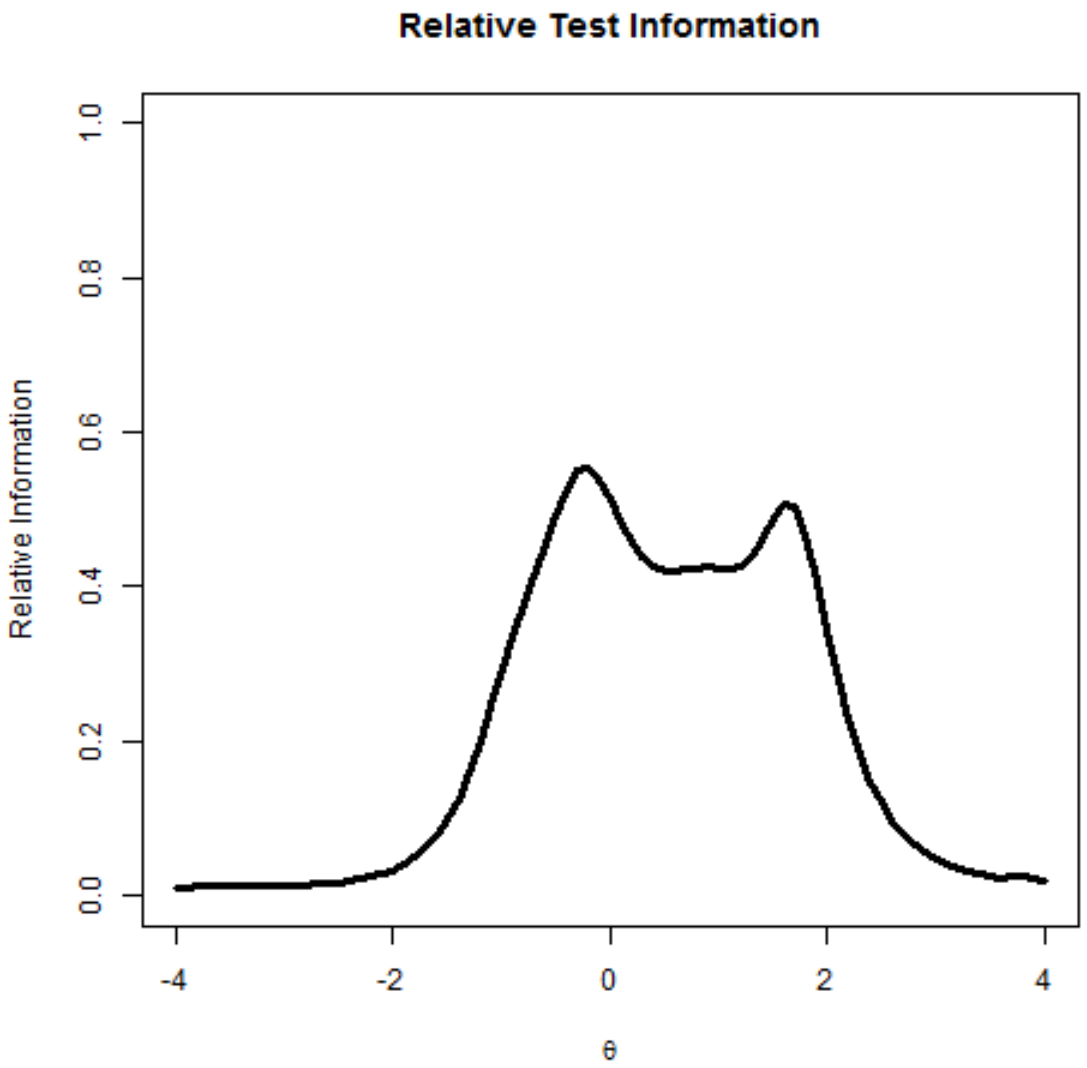
15. If a simple cosmetic surgery procedure would make me more attractive to others, I would think about trying it.





CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
2.77	0.86	1.46	1.48	3.17	5.81

Test Information



Wald Test

- A mechanism for determining whether within-item CBD parameters vary
- Evaluates whether all CBD parameters are necessary, or if one discrimination parameter is sufficient to accurately model the item
- Can also be used to evaluate when an item contains too many categories, or non-functioning categories

Wald Test

- Step 1: Specify NRM model using triangle contrasts
- Step 2: Collect flexMIRT produced NRM parameters (CBD estimates), standard errors, and variance-covariance matrix of parameter estimates
- Step 3: For each item, specify orthogonal linear contrasts to compare all CBD parameters

$$C_{5.6} = \begin{bmatrix} 1 & -1 & 0 & 0 & 0 & 0 \\ 1 & 1 & -2 & 0 & 0 & 0 \\ 1 & 1 & 1 & -3 & 0 & 0 \\ 1 & 1 & 1 & 1 & -4 & 0 \\ 1 & 1 & 1 & 1 & 1 & -5 \end{bmatrix}$$

  - 1st contrast compares CBD_1 to CBD_2
  - 2nd contrast compares average of CBD_1 and CBD_2 with CBD_3
  - 3rd contrast compares average of CBD_1, CBD_2, and CBD_3 with CBD_4
  - Etc…

Wald test

- Step 4: Post-multiply C by a 6x1 matrix of CBD estimates (A)

$$\lambda_{5.1} = C_{5.6} A_{6.1}$$

- Step 5: Derive appropriate standard errors for comparisons by pre- and post-multiplying the var-cov matrix of the item parameters estimates ($\Sigma_{6.6}$) by the contrasts

$$\Omega_{5.5} = C_{5.6} \Sigma_{6.6} C'_{6.5}$$

- Step 6: Compute Wald test statistic

$$W = \lambda'_{1.5} \Omega^{-1}_{5.5} \lambda_{5.1}$$

- Step 7: Evaluate against a chi-square distribution using $N_{CBD} - 1$ degrees of freedom

```
# Run code exactly as is
source("https://www.dropbox.com/s/psfm01m
o8m39q4g/Wald.txt?dl=0 ")
```

Evaluation

	Q	df	p-val
1	39.169	5	0.000
2	221.101	5	0.000
3	80.193	5	0.000
4	216.452	5	0.000
5	124.539	5	0.000
6	65.975	5	0.000
7	63.322	5	0.000
8	83.455	5	0.000
9	73.150	5	0.000
10	19.090	5	0.002
11	48.410	5	0.000
12	147.917	5	0.000
13	14.414	5	0.013
14	190.611	5	0.000
15	113.157	5	0.000

CBDs

	CBD 1	CBD 2	CBD 3	CBD 4	CBD 5	CBD 6
1	1.84	1.01	0.45	1.12	0.92	1.90
2	3.09	1.16	0.95	0.88	1.31	1.18
3	2.71	1.32	0.69	2.89	1.49	1.74
4	3.01	1.28	0.75	1.21	0.74	1.92
5	2.69	1.51	0.81	1.16	0.71	1.11
6	3.45	3.30	0.89	3.04	2.69	2.51
7	2.58	1.23	1.30	1.04	3.05	2.79
8	2.34	1.27	0.04	1.82	1.84	1.40
9	2.40	1.34	0.88	0.89	0.98	1.74
~~10~~	~~1.17~~	~~0.86~~	~~0.23~~	~~0.28~~	~~0.08~~	~~0.85~~
11	1.65	1.12	0.59	1.30	3.27	3.55
12	2.25	0.15	0.62	0.68	2.35	3.29
13	1.59	0.71	1.21	1.13	1.10	2.51
14	2.55	0.89	0.38	0.74	0.86	2.55
15	2.77	0.86	1.46	1.48	3.17	5.81

Scale Revision 1

<Groups>

%Group1%

File = "Cosmetic Surgery Scale.dat";

Varnames = v1-v15;

Select = v1-v9,v11-v15;

Missing = 9;

Code(v12,v13,v15) =
(1,2,3,4,5,6,7),(0,1,1,2,3,4,5);

Code(v1,v3,v6,v8,v9,v11,v14) =
(1,2,3,4,5,6,7),(0,1,2,2,3,4,5);

Code(v2,v7) =
(1,2,3,4,5,6,7),(0,1,2,3,3,4,5);

Code(v4,v5) =
(1,2,3,4,5,6,7),(0,1,2,3,4,4,5);

N = 441;

Ncats(v1-v9,v11-v15) = 6;

Model(v1-v9,v11-v15) = Nominal(6);

Ta(v1-v9,v11-v15) =

(0 0 0 0 0,

1 0 0 0 0,

1 1 0 0 0,

1 1 1 0 0,

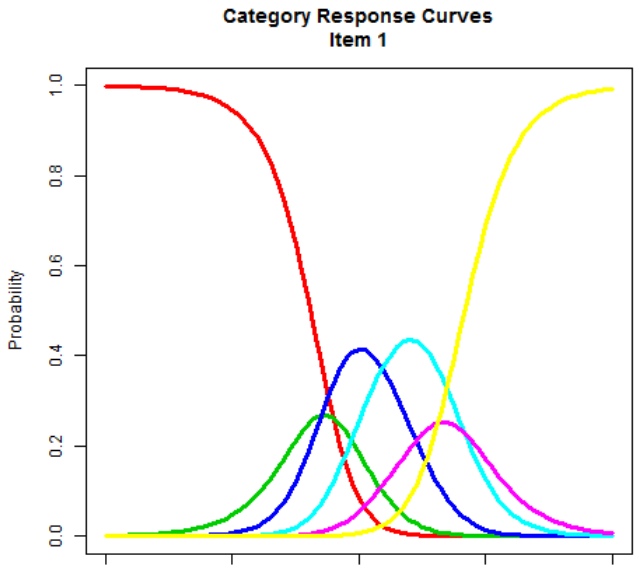
1 1 1 1 0,

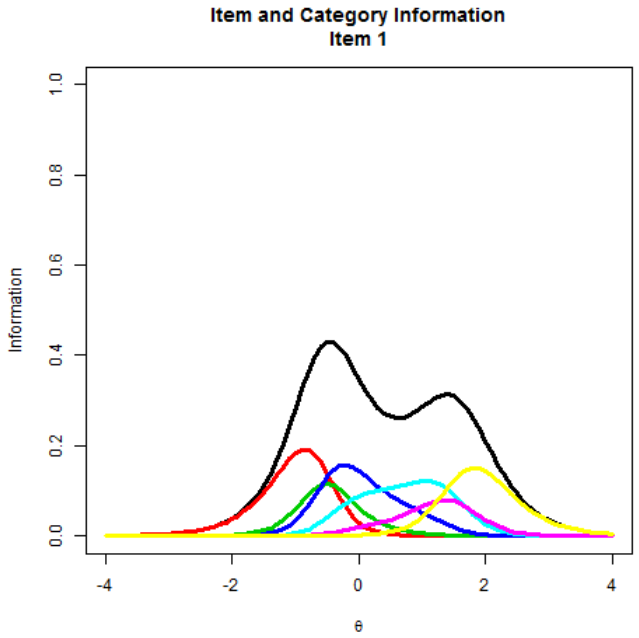
1 1 1 1 1);

Tc(v1-v9,v11-v15) = Trend;

Item 1

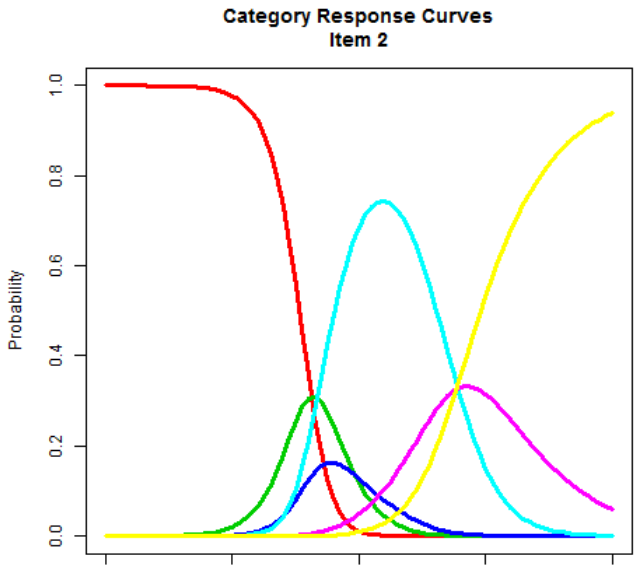
1.89 1.37 1.34 0.93 1.82

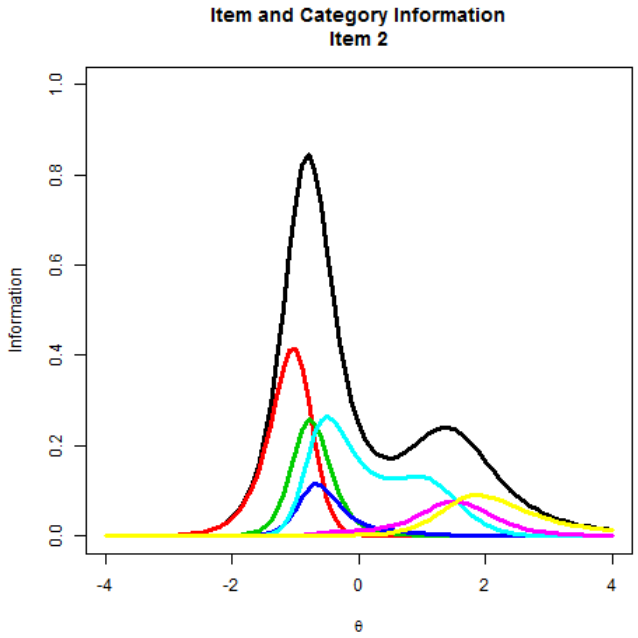




Item 2

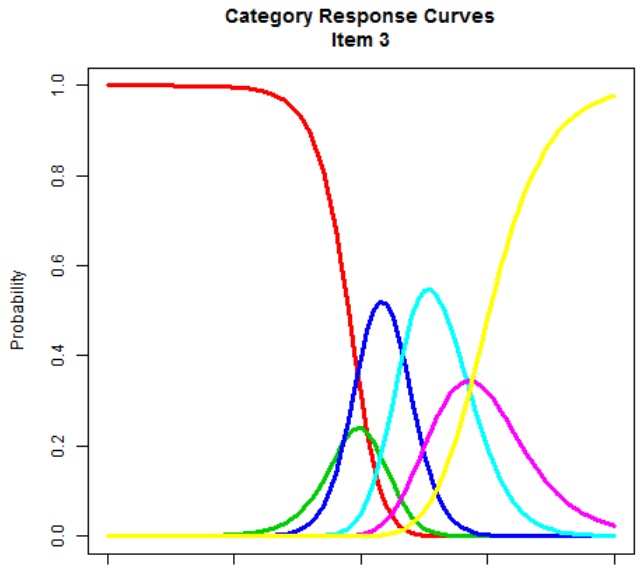
3.11 1.24 1.42 1.69 1.12

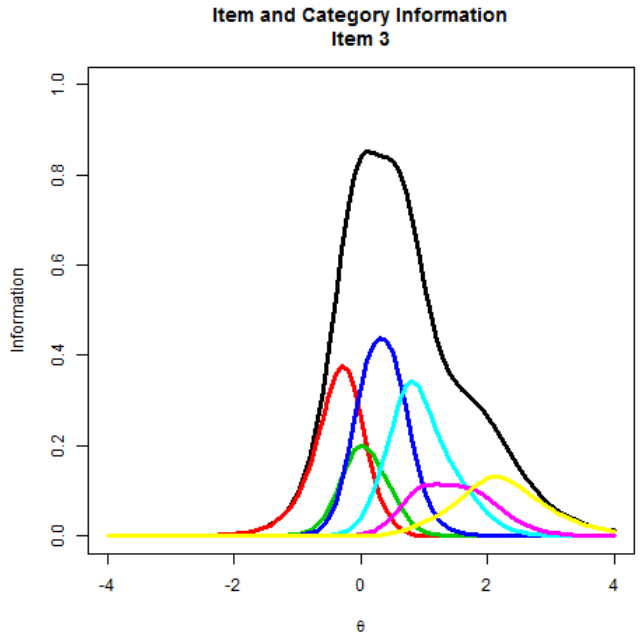




Item 3

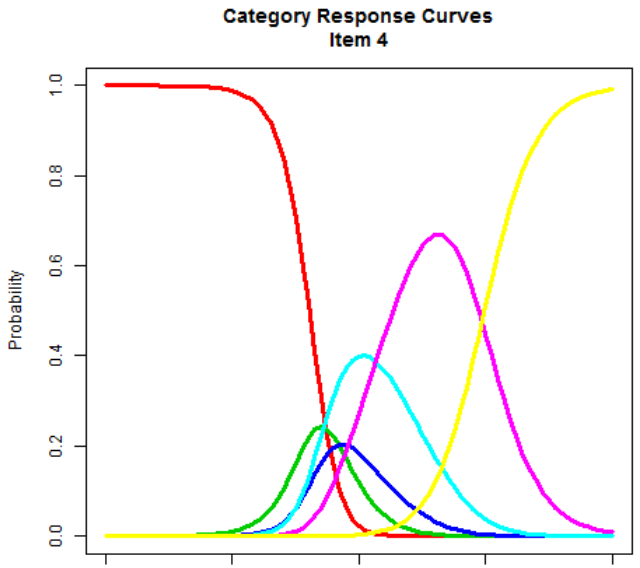
2.71 1.84 3.20 1.49 1.67

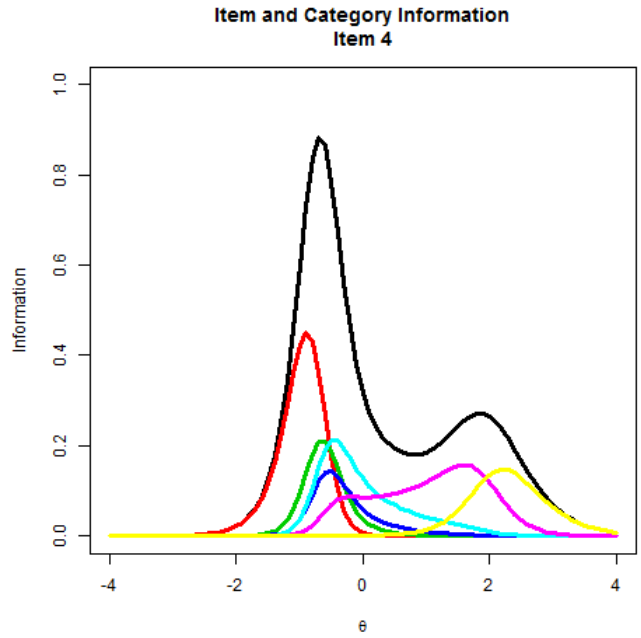




Item 4

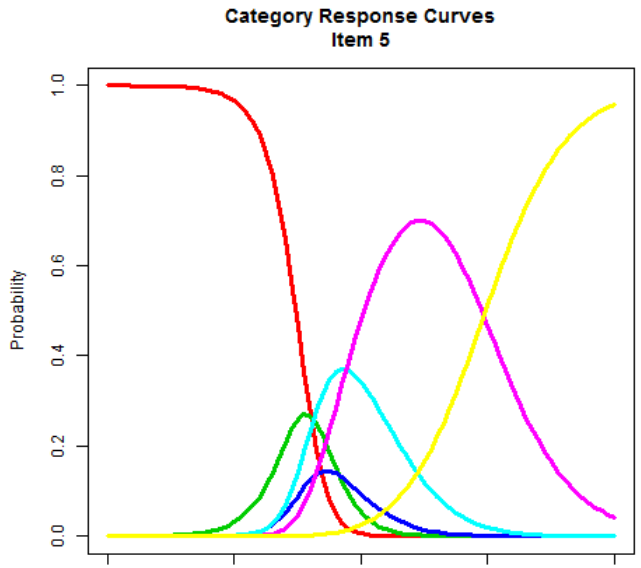
3.10 1.41 0.76 1.44 2.32

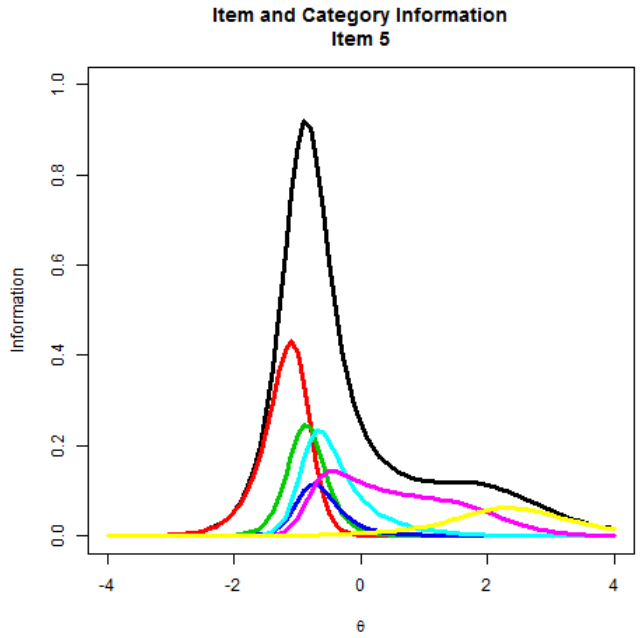




Item 5

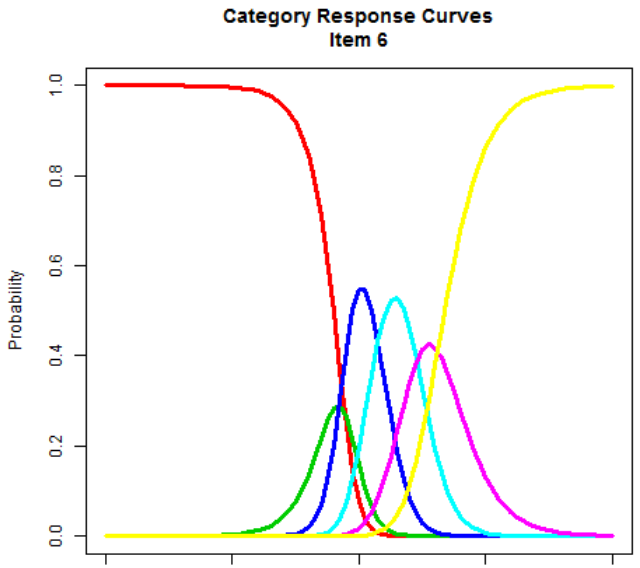
2.87 1.62 0.85 1.44 1.53

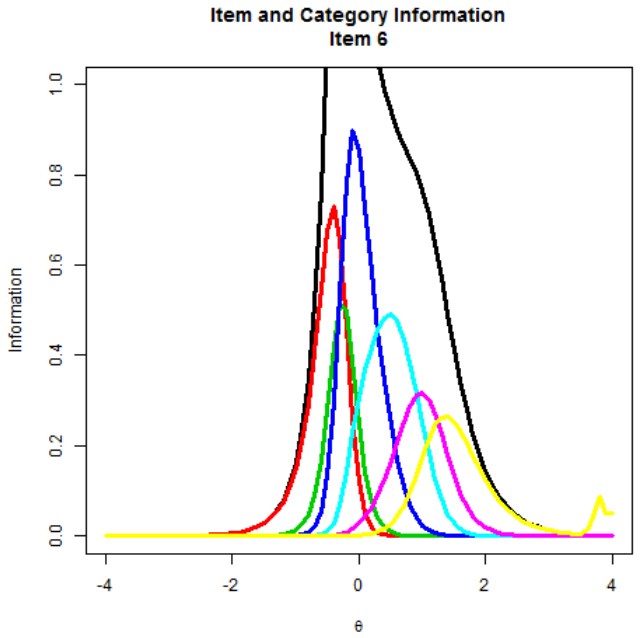




Item 6

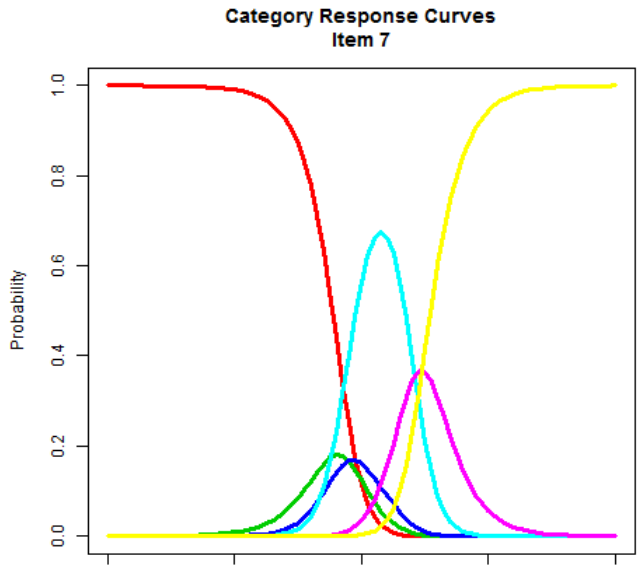
3.18 3.97 3.45 2.65 2.47

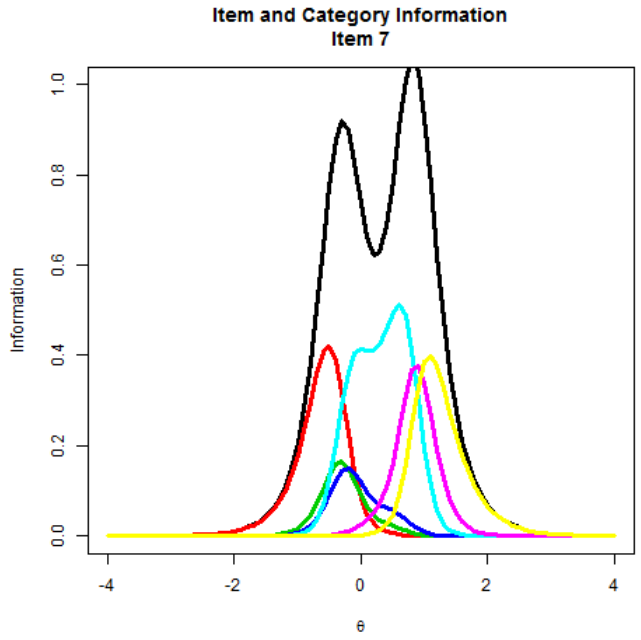




Item 7

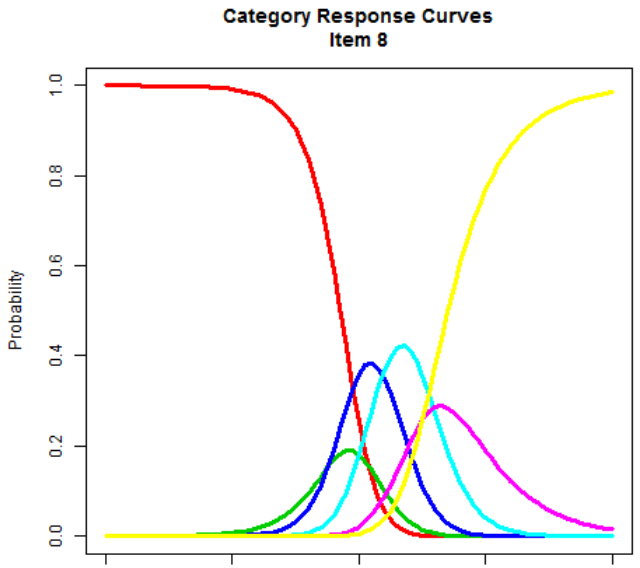
2.41 1.29 1.87 3.36 2.69

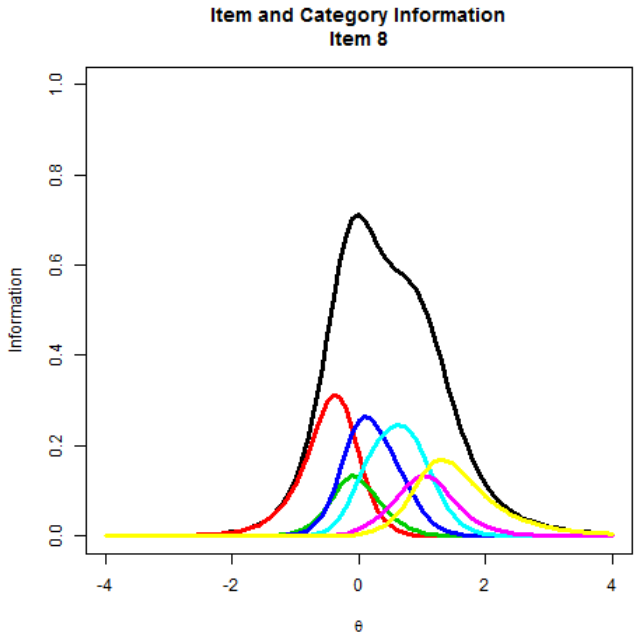




Item 8

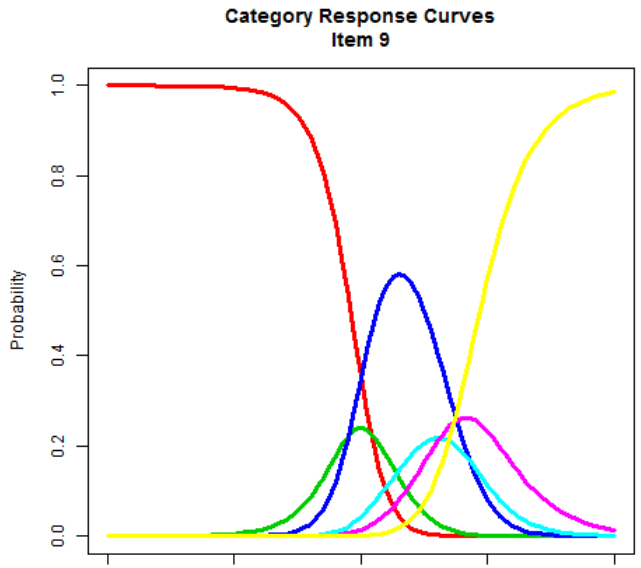
2.29 1.39 1.86 1.85 1.40

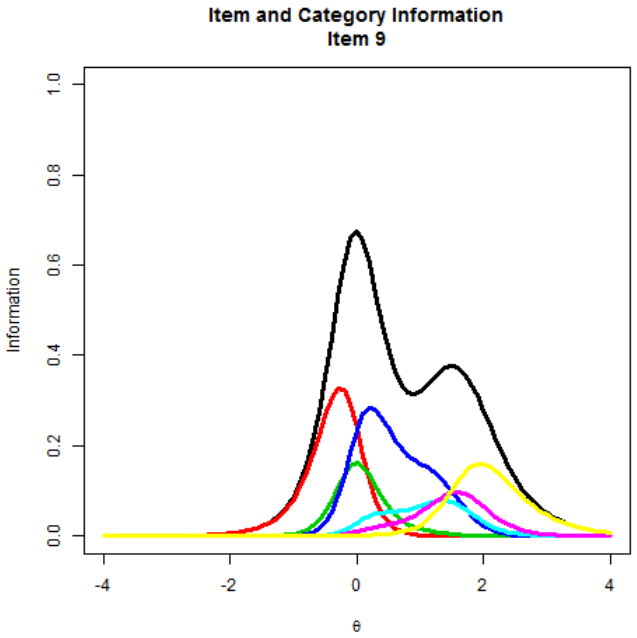




Item 9

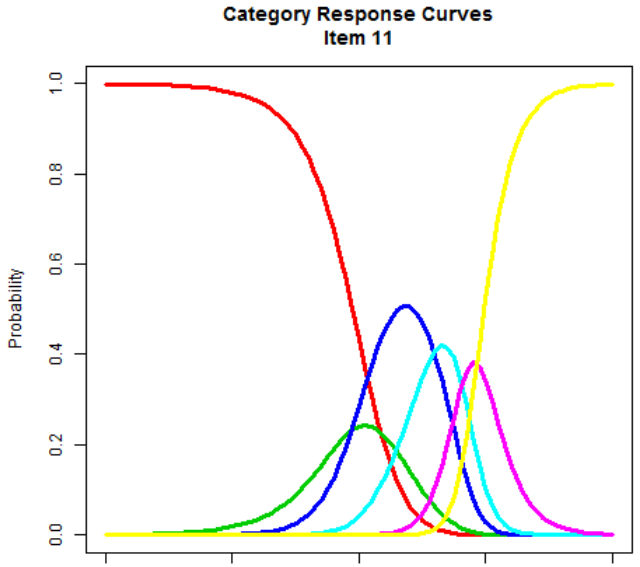
2.43 1.92 1.23 0.95 1.69

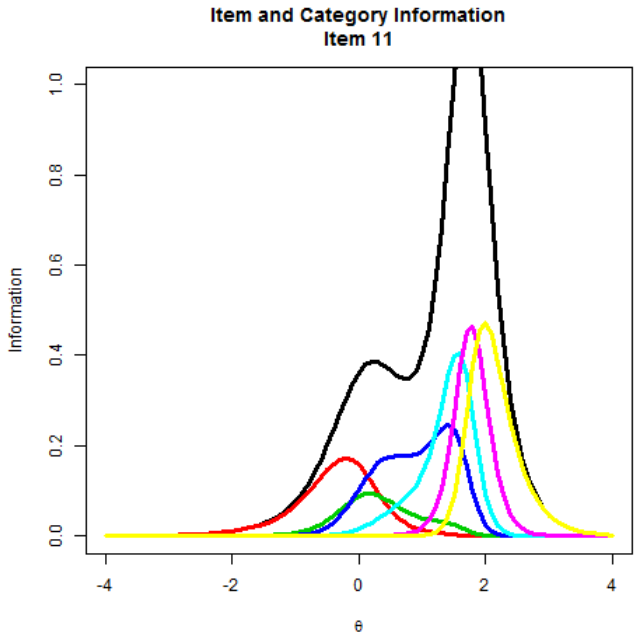




Item 11

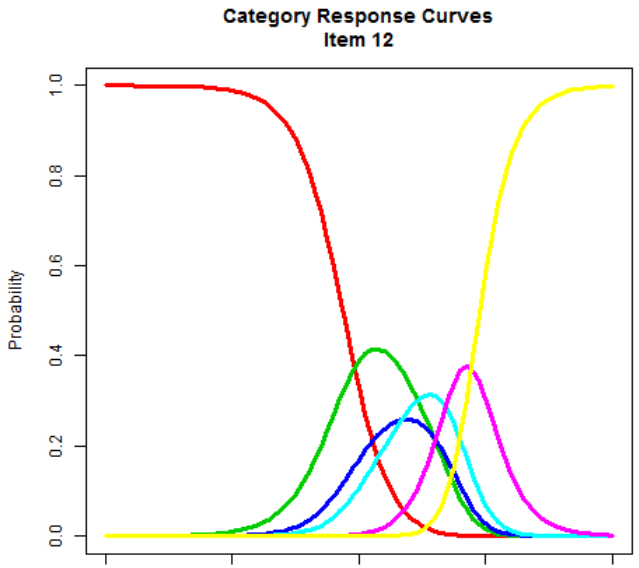
1.71 1.41 1.63 3.17 3.09

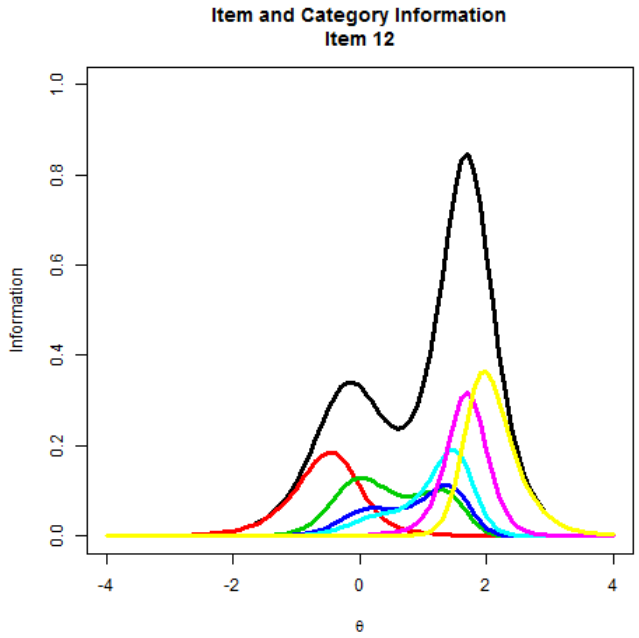




Item 12

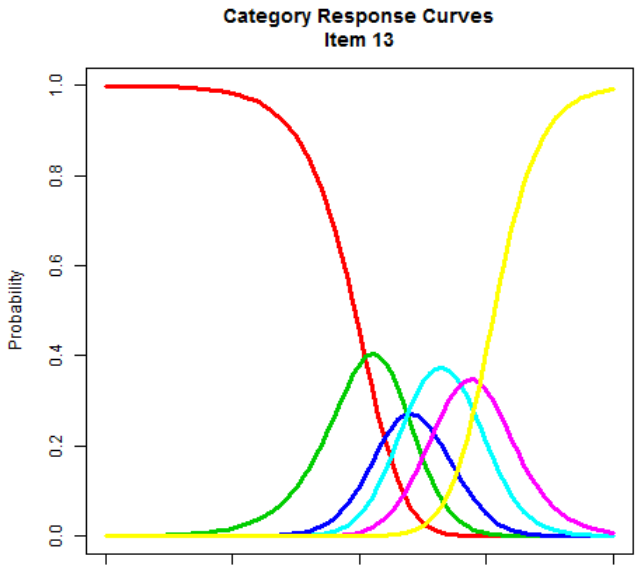
2.39 0.71 0.69 2.34 2.86

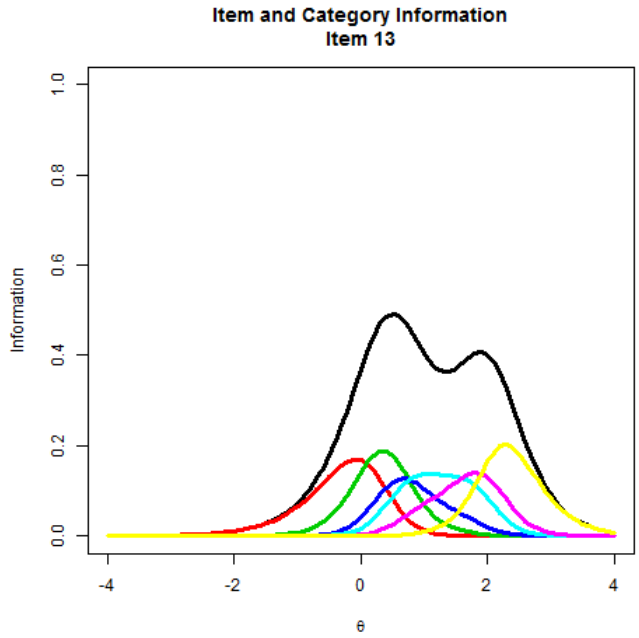




Item 13

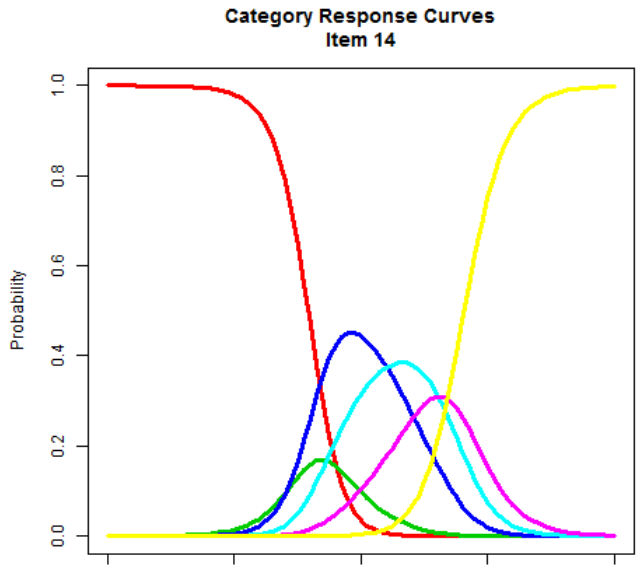
1.93 1.66 1.16 1.09 2.29

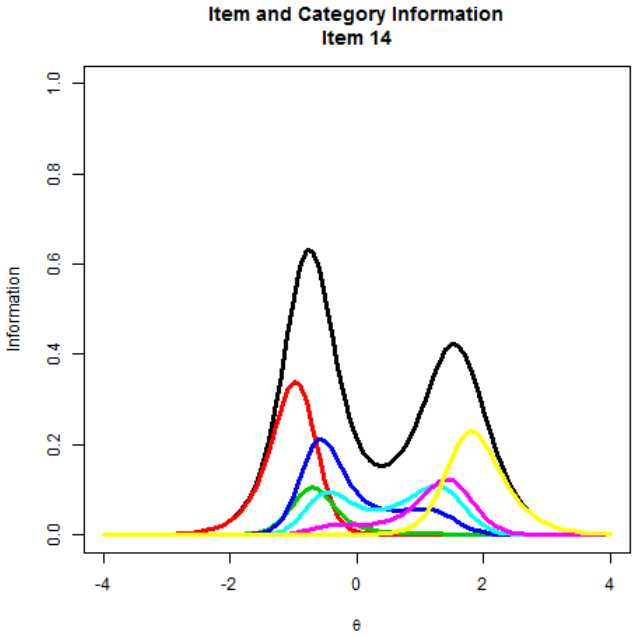




Item 14

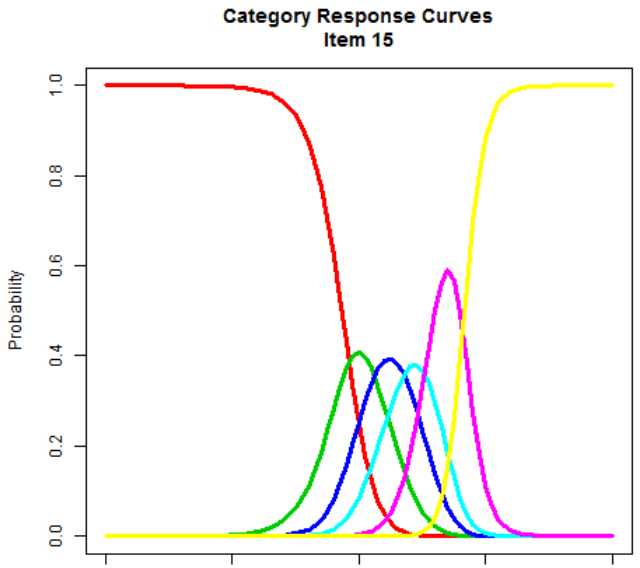
2.63 1.26 0.86 0.91 2.47

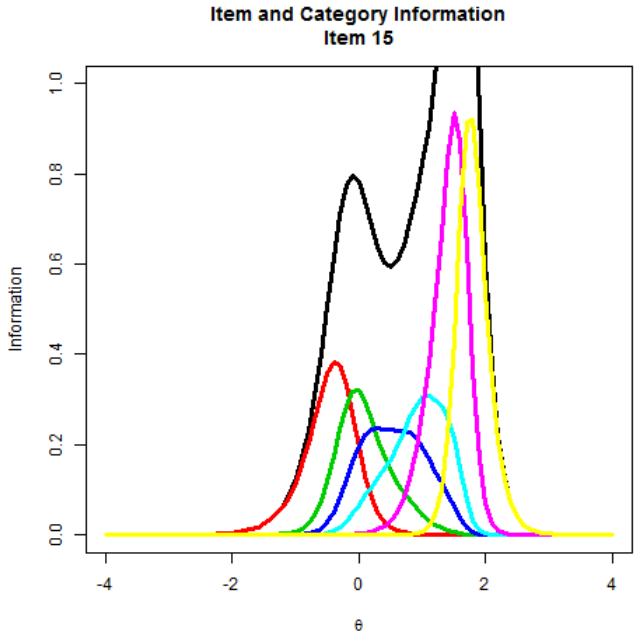




Item 15

3.20 1.95 1.54 3.15 5.67





Scale Revision 1

	Q	df	p-val
1	13.835	4	0.008
2	96.104	4	0.000
3	35.639	4	0.000
4	202.587	4	0.000
5	112.843	4	0.000
6	42.520	4	0.000
7	34.336	4	0.000
8	9.590	4	0.048
9	38.357	4	0.000
11	15.542	4	0.004
12	90.148	4	0.000
13	8.500	4	0.075
14	131.362	4	0.000
15	108.312	4	0.000

	CBD 1	CBD 2	CBD 3	CBD 4	CBD 5
1	1.89	1.37	1.34	0.93	1.82
2	3.11	1.24	1.42	1.69	1.12
3	2.71	1.84	3.20	1.49	1.67
4	3.10	1.41	0.76	1.44	2.32
5	2.87	1.62	0.85	1.44	1.53
6	3.18	3.97	3.45	2.65	2.47
7	2.41	1.29	1.87	3.36	2.69
8	2.29	1.39	1.86	1.85	1.40
9	2.43	1.92	1.23	0.95	1.69
11	1.71	1.41	1.63	3.17	3.09
12	2.39	0.71	0.69	2.34	2.86
13	1.93	1.66	1.16	1.09	2.29
14	2.63	1.26	0.86	0.91	2.47
15	3.20	1.95	1.54	3.15	5.67

Scale Revision 2

Code(v1,v3,v9) = (1,2,3,4,5,6,7),(0,1,2,2,3,3,4);

Code(v2) = (1,2,3,4,5,6,7),(0,1,2,3,3,4,4);

Code(v4,v5) = (1,2,3,4,5,6,7),(0,1,2,3,3,3,4);

Code(v6) = (1,2,3,4,5,6,7),(0,1,2,2,3,4,4);

Code(v7,v12,v15) = (1,2,3,4,5,6,7),(0,1,1,2,2,3,4);

Code(v8,v11,v14) = (1,2,3,4,5,6,7),(0,1,1,1,2,3,4);

Code(v13) = (1,2,3,4,5,6,7),(0,1,1,2,3,4,5);

N = 441;

Ncats(v1-v9,v11-v12,v14-v15) = 5;

Model(v1-v9,v11-v12,v14-v15) = Nominal(5);

Ncats(v13) = 6;

Model(v13) = GPC(6);

Scale Revision 4

	Q	df	p-val
1	5.561	2	0.062
2	4.148	1	0.042
3	8.410	2	0.015
4	194.033	2	0.000
5	7.820	1	0.005
6	302.310	3	0.000
7	0.322	1	0.570
8	6.901	2	0.032
9	45.676	2	0.000
11	5.078	3	0.166
12	19.906	3	0.000
13	6.217	4	0.184
14	8.614	1	0.003
15	34.402	2	0.000

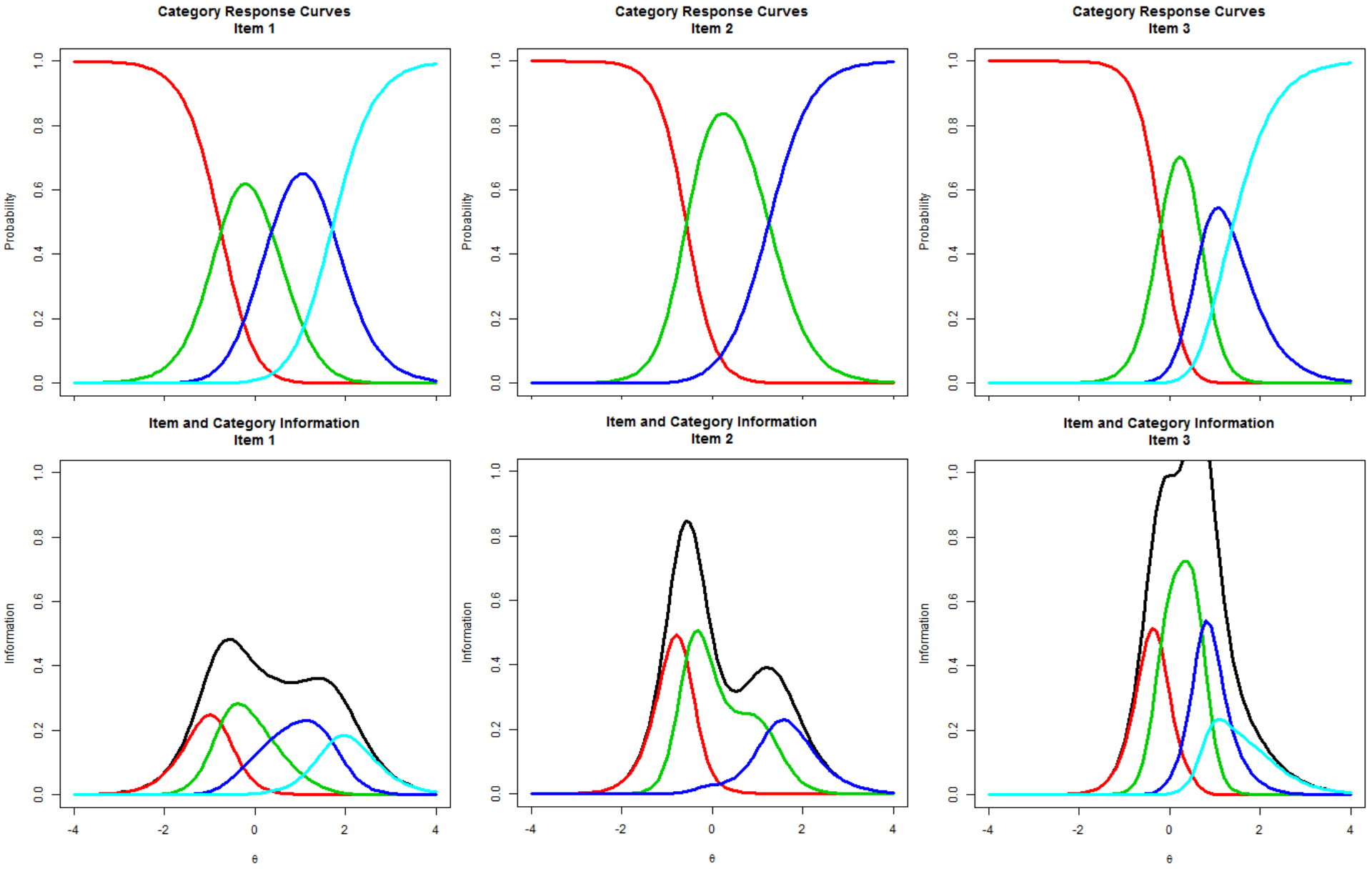
	CBD 1	CBD 2	CBD 3	CBD 4	CBD 5
1	2.40	1.89	2.10	NA	NA
2	3.12	2.15	NA	NA	NA
3	3.61	3.55	1.93	NA	NA
4	3.82	1.84	2.11	NA	NA
5	2.86	1.69	NA	NA	NA
6	5.79	3.88	2.71	1.91	NA
7	3.82	4.20	NA	NA	NA
8	2.96	2.34	2.54	NA	NA
9	3.34	2.06	1.83	NA	NA
11	2.46	1.63	2.96	2.96	NA
12	2.38	1.09	2.90	2.80	NA
13	1.90	1.71	1.26	1.18	1.9
14	3.57	1.93	NA	NA	NA
15	3.23	1.43	3.84	NA	NA

Final Scale flexMIRT

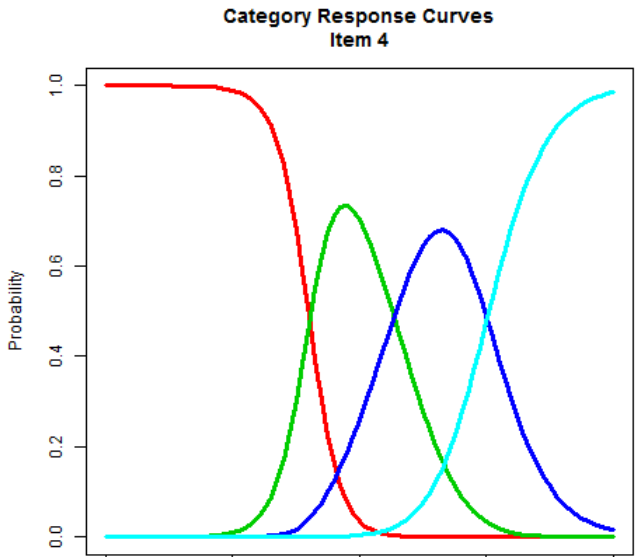
Code(v1) = (1,2,3,4,5,6,7),(0,1,1,1,2,2,3);
Code(v2) = (1,2,3,4,5,6,7),(0,0,1,1,1,2,2);
Code(v3) = (1,2,3,4,5,6,7),(0,1,1,1,2,3,3);
Code(v4) = (1,2,3,4,5,6,7),(0,1,1,1,2,2,3);
Code(v5) = (1,2,3,4,5,6,7),(0,0,0,1,1,1,2);
Code(v6) = (1,2,3,4,5,6,7),(0,0,1,1,2,3,4);
Code(v7) = (1,2,3,4,5,6,7),(0,0,0,1,1,2,2);
Code(v8) = (1,2,3,4,5,6,7),(0,1,1,1,2,3,3);
Code(v9) = (1,2,3,4,5,6,7),(0,1,1,1,2,2,3);
Code(v11) = (1,2,3,4,5,6,7),(0,0,1,1,2,3,4);
Code(v12) = (1,2,3,4,5,6,7),(0,1,1,2,2,3,4);
Code(v13) = (1,2,3,4,5,6,7),(0,1,1,2,3,4,5);
Code(v14) = (1,2,3,4,5,6,7),(0,1,1,1,1,2,2);
Code(v15) = (1,2,3,4,5,6,7),(0,0,0,1,2,3,3);

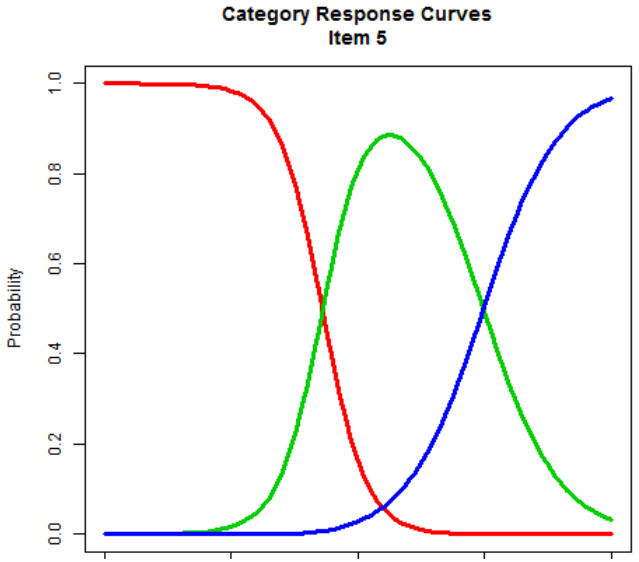
Ncats(v13) = 6;
Ncats(v6,v11,v12) = 5;
Ncats(v1,v3,v4,v8,v9,v15) = 4;
Ncats(v2,v5,v7,v14) = 3;
Model(v6,v12) = Nominal(5);
Model(v3,v4,v8,v9,v15) = Nominal(4);
Model(v2,v5,v14) = Nominal(3);
Model(v13) = GPC(6);
Model(v11) = GPC(5);
Model(v1) = GPC(4);
Model(v7) = GPC(3);

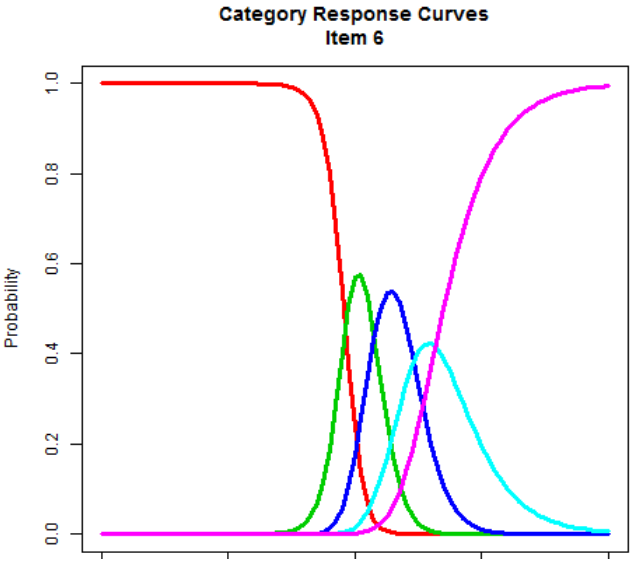
Final Scale (Items 1 – 3)

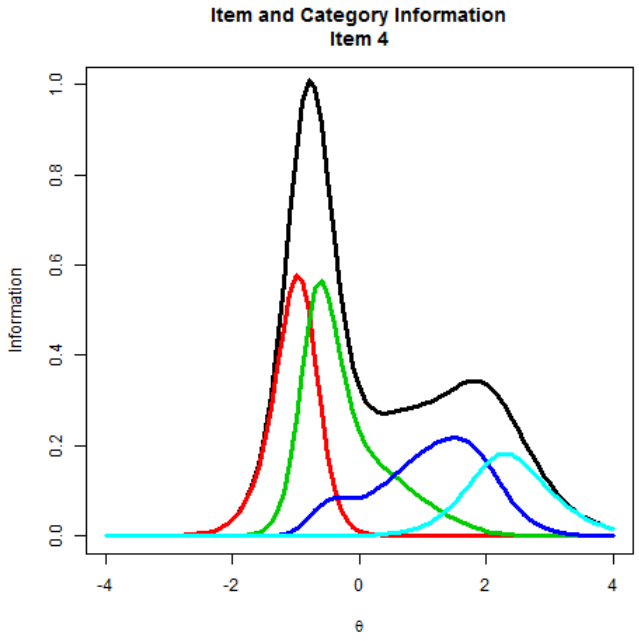


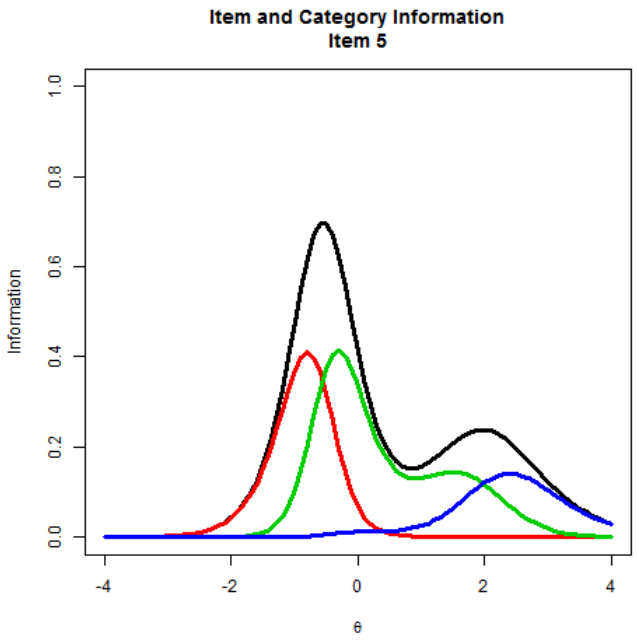
Final Scale (Items 4 – 6)

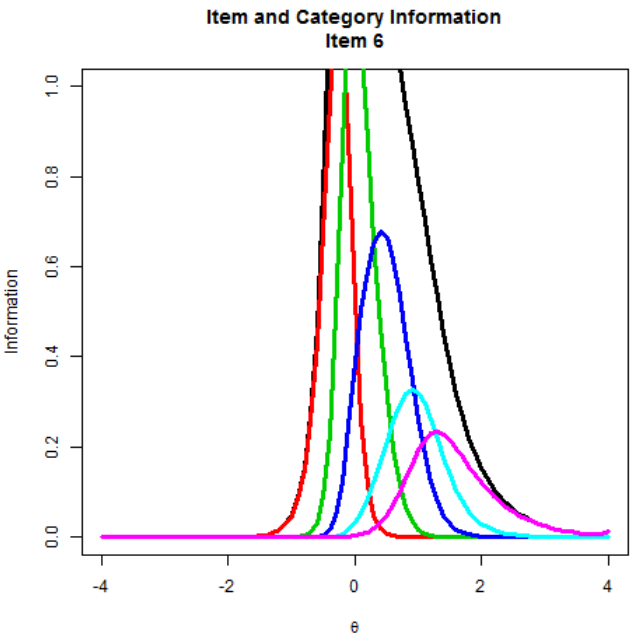




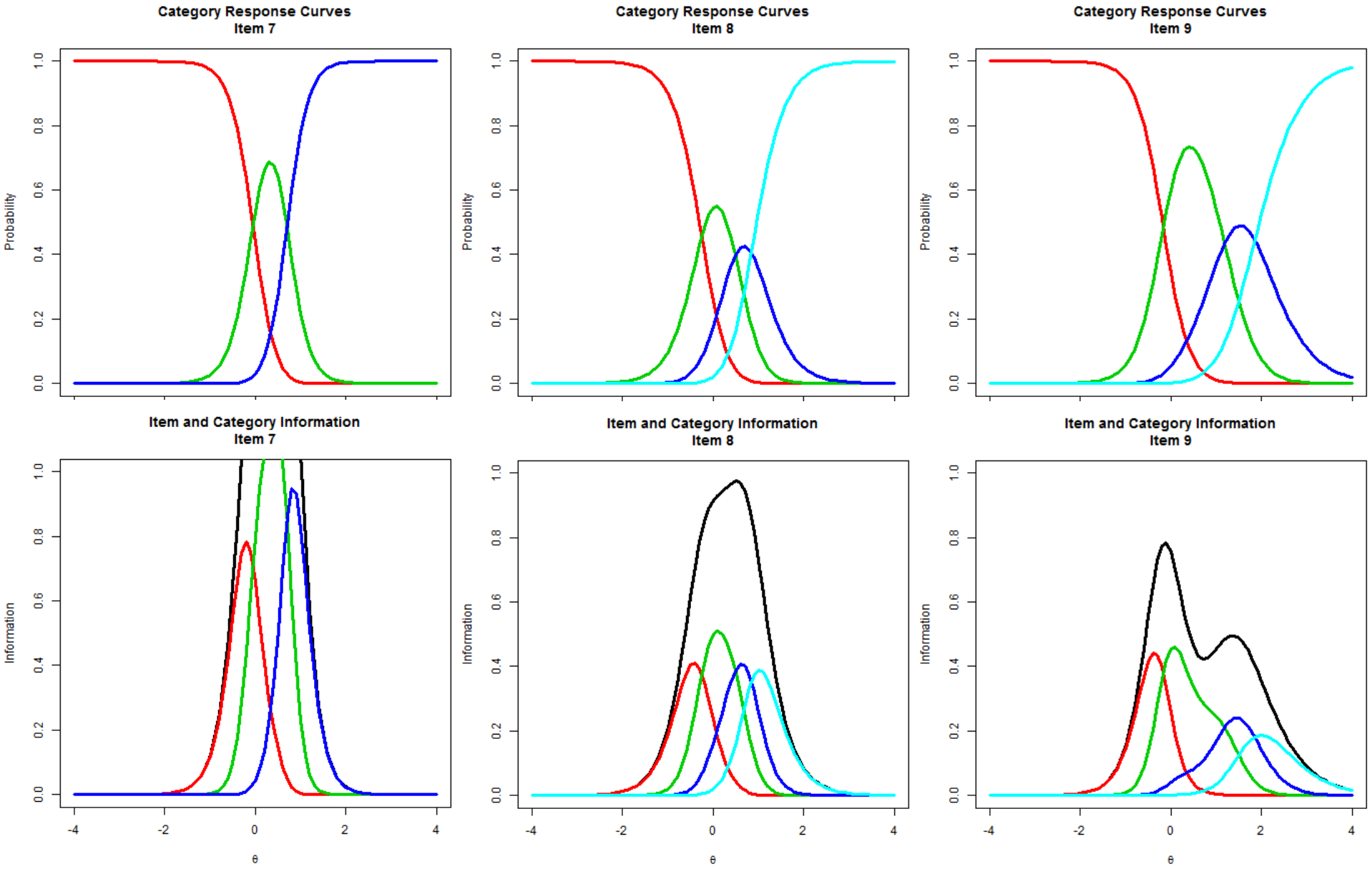




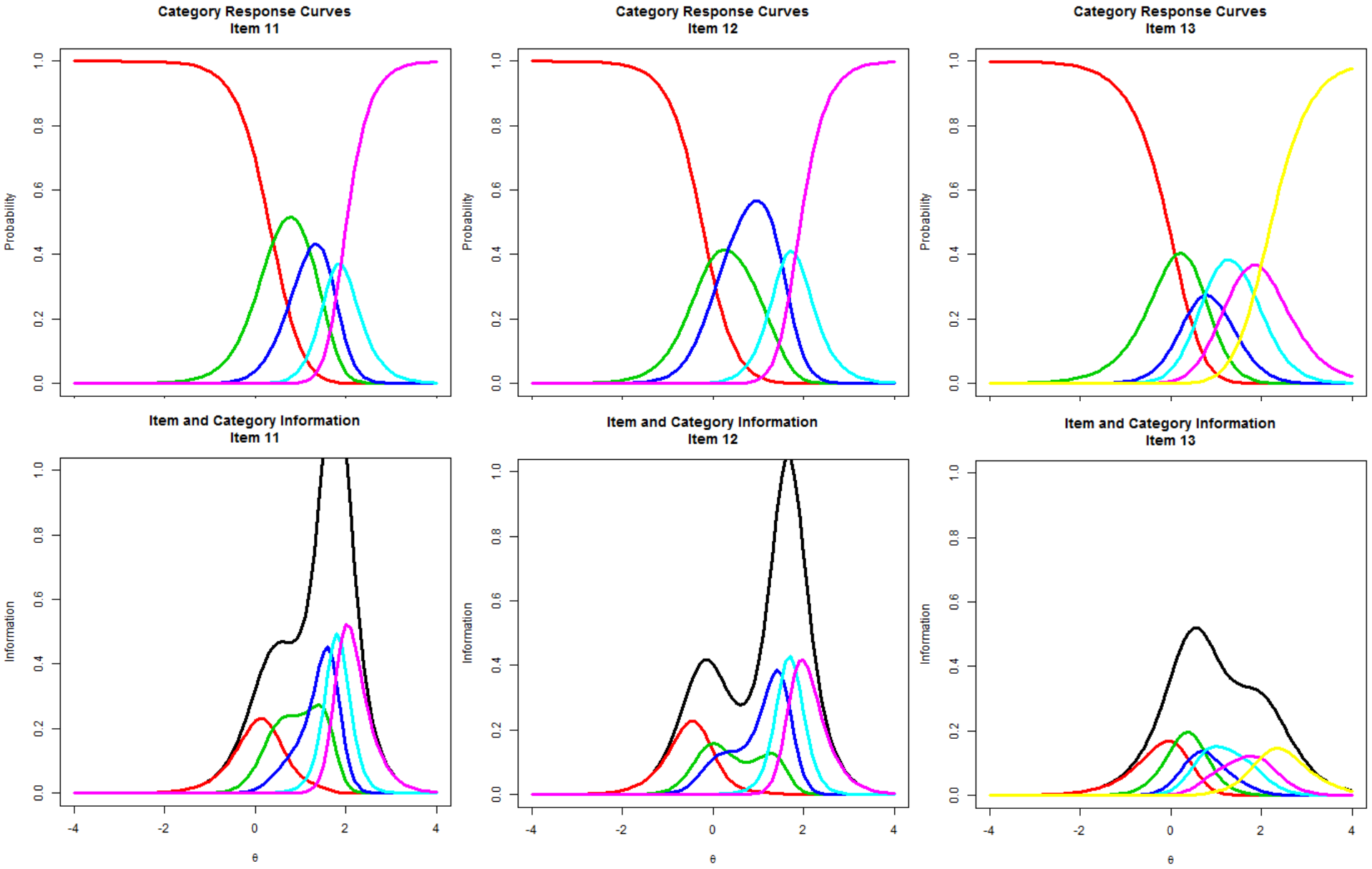




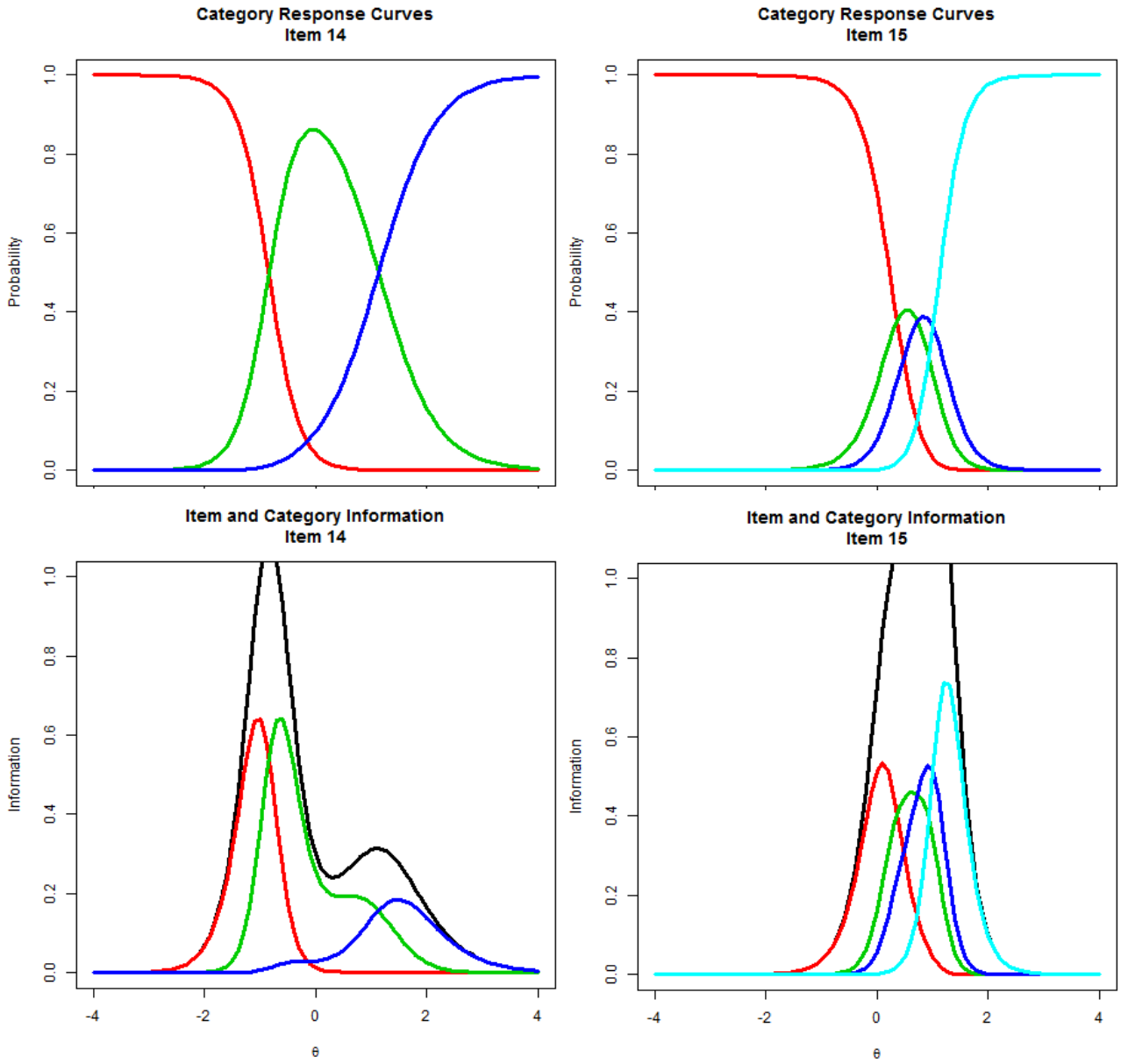
Final Scale (Items 7 – 9)



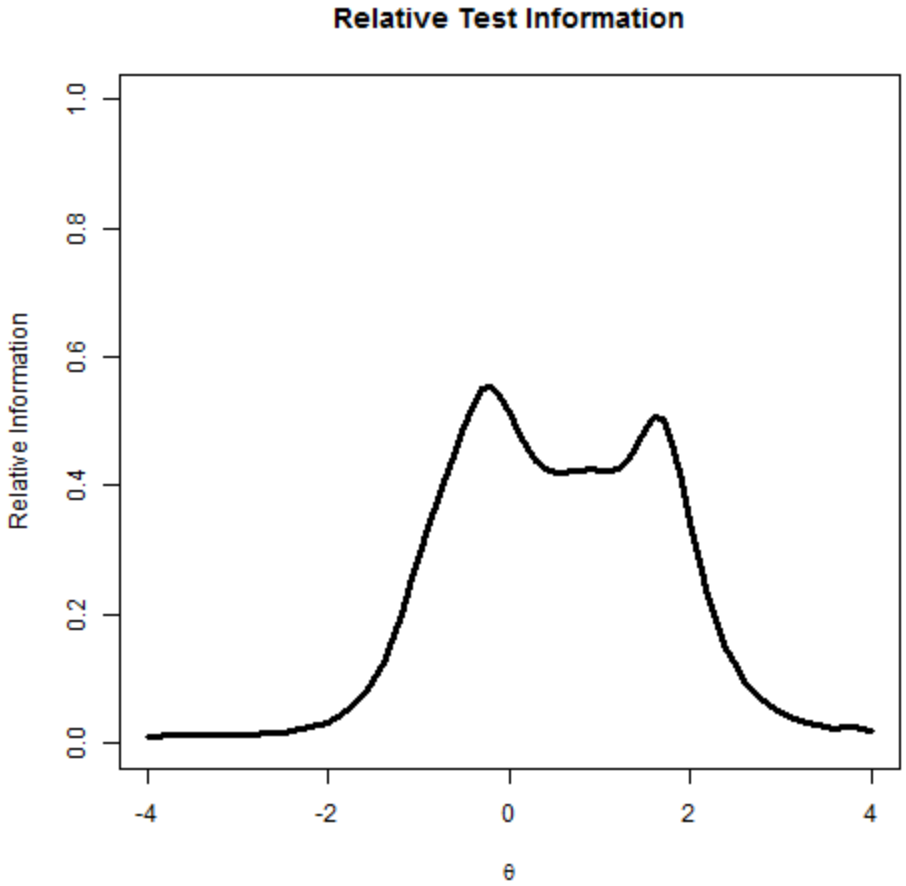
Final Scale (Items 11 – 13)



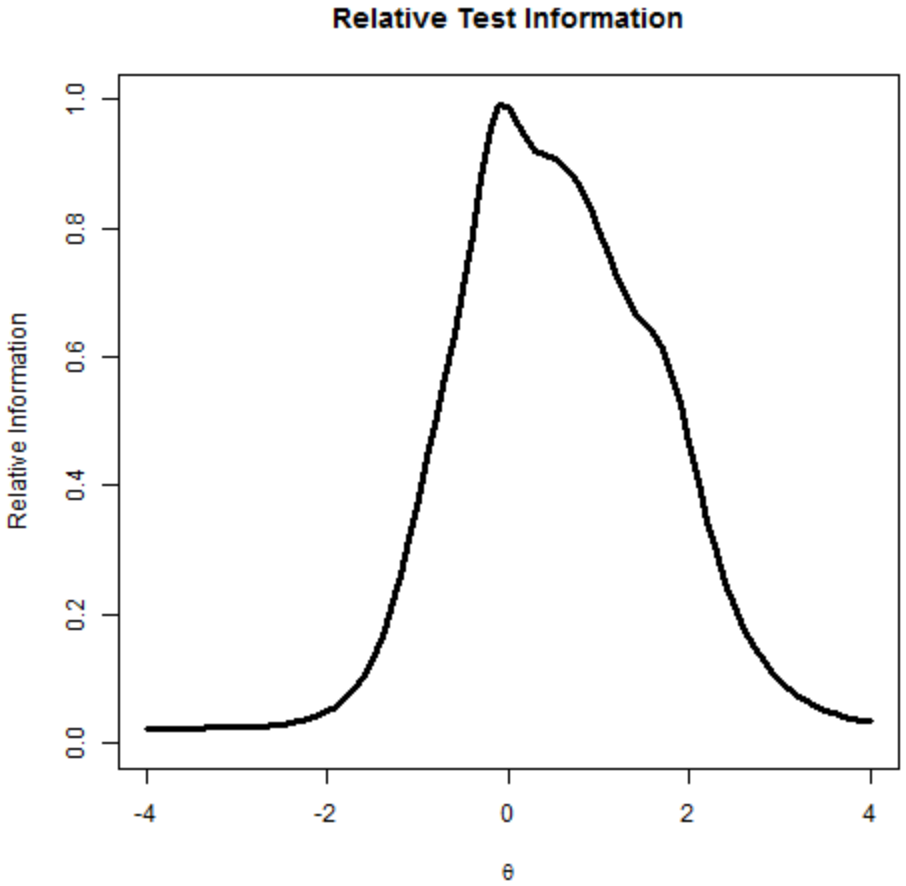
Final Scale (Items 14 – 15)



Test Information Comparison




```
Limited-information fit statistics of the fitted model:
                Degrees
          M2  of freedom Probability       FOhat       RMSEA
    18200.44         3690      0.0001     41.2708        0.09

Tucker-Lewis (non-normed) fit index based on M2 is      0.61
```




```
Limited-information fit statistics of the fitted model:
                Degrees
          M2  of freedom Probability       FOhat       RMSEA
     3589.01         827      0.0001     8.1383        0.09

Tucker-Lewis (non-normed) fit index based on M2 is      0.88
```

Applications & Recommendations

- Detection of a small CBD indicates that:
  - Individuals cannot meaningfully distinguish between response options
  - The item contains too many response options and the researcher should consider rewriting the item
- Model choice is a judgement call of the investigator
  - Why not always apply NRM?
- Cross-validate new response format with a new sample
- NRM is an incredibly useful tool for examining psychometric properties of items

FlexMIRT Extended Trial License

- Please fill out the following form to receive a 3-month trial license for flexMIRT

https://forms.gle/LR4yv6sxje8gsDuAA