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1. Introducing IRTPRO

1.1 IRTPRO features

IRTPRO (Item Response Theory for Patient-Reported Outcomes) is an entirely new application for item calibration and test scoring using IRT.

Item response theory (IRT) models for which item calibration and scoring are implemented in IRTPRO are based on unidimensional and multidimensional [confirmatory factor analysis (CFA) or exploratory factor analysis (EFA)] versions of the following widely used response functions:

- Two-parameter logistic (2PL) (Birnbaum, 1968) [with which equality constraints includes the one-parameter logistic (1PL) (Thissen, 1982)]
- Three-parameter logistic (3PL) (Birnbaum, 1968)
- Graded (Samejima, 1969; 1997)
- o Generalized Partial Credit (Muraki, 1992, 1997)
- Nominal (Bock, 1972, 1997; Thissen, Cai, & Bock, 2010)

These item response models may be mixed in any combination within a test or scale, and any (optional) user-specified equality constraints among parameters, or fixed values for parameters, may be specified.

IRTPRO implements the method of Maximum Likelihood (ML) for item parameter estimation (item calibration), or it computes Maximum *a posteriori* (MAP) estimates if (optional) prior distributions are specified for the item parameters. That being said, alternative computational methods may be used, each of which provides best performance for some combinations of dimensionality and model structure:

- Bock-Aitkin (BAEM) (Bock & Aitkin, 1981)
- o Bifactor EM (Gibbons & Hedeker, 1992; Gibbons *et al.*, 2007; Cai, Yang & Hansen in press)
- Generalized Dimension Reduction EM (Cai, 2010-a)
- Adaptive Quadrature (ADQEM) (Schilling & Bock 2005)
- Metropolis-Hastings Robbins-Monro (MHRM) (Cai, 2010-b, 2010-c)

The computation of IRT scale scores in IRTPRO may be done using any of the following methods:

- Maximum a posteriori (MAP) for response patterns
- Expected a posteriori (EAP) for response patterns (Bock & Mislevy, 1982)
- Expected a posteriori (EAP) for summed scores (Thissen & Orlando, 2001; Thissen, Nelson, Rosa, & McLeod, 2001)

Data structures in IRTPRO may categorize the item respondents into groups, and the population latent variable means and variance-covariance matrices may be estimated for multiple groups (Mislevy, 1984, 1985). [Most often, if there is only one group, the population latent variable mean(s) and variance(s) are fixed (usually at 0 and 1) to specify the scale; for multiple groups, one group is usually denoted the "reference group" with standardized latent values.]

To detect differential item functioning (DIF), IRTPRO uses Wald tests, modeled after a proposal by

Lord (1977), but with accurate item parameter error variance-covariance matrices computed using the Supplemented EM (SEM) algorithm (Cai, 2008).

Depending on the number of items, response categories, and respondents, IRTPRO reports several varieties of goodness of fit and diagnostic statistics after item calibration. The values of -2loglikelihood, Akaike Information Criterion (AIC) (Akaike, 1974) and the Bayesian Information Criterion (BIC) (Schwarz, 1978) are always reported. If the sample size sufficiently exceeds the number of cells in the complete cross-classification of the respondents based on item response patterns, the overall likelihood ratio test against the general multinomial alternative is reported. For some models, the M_2 statistic (Maydeu-Olivares & Joe, 2005, 2006; Cai, Maydeu-Olivares, Coffman, & Thissen, 2006) is also computed. Diagnostic statistics include generalizations for polytomous responses of the local dependence (LD) statistic described by Chen & Thissen (1997) and the $SS-X^2$ item-fit statistic suggested by Orlando & Thissen (2000, 2003).

1.2 Organization of the user's guide

The user's guide has been written to introduce item response theory (IRT) models to researchers new in this field. It also serves as a guide to researchers who are already familiar with the existing IRT programs distributed by Scientific Software International and are upgrading to a program that has an easy to use graphical users interface (GUI) and can handle multidimensional models. In this guide the focus is on the "how to" part of IRT.

Chapter 2 provides a short description of the GUI, since the examples in the remaining chapters further illustrate the features of the user's interface.

IRTPRO uses its own data format, displayed in spreadsheet form. Data may be imported from a long list of statistical software packages and spreadsheet programs. Chapter 3 deals with data import and manipulation and Chapter 4 deals with the calculation of traditional summed-score statistics.

Chapters 5 to 7 deals with the estimation (calibration) of IRT models. Chapter 5 is concerned with the fitting of unidimensional models and Chapter 6 deals with multiple groups and differential item functioning (DIF). In Chapter 7 we describe how IRTPRO handles exploratory and confirmatory factor analysis models. This chapter also contains examples illustrating the fit of bifactor and one and two-tier testlet response theory models.

Unlike classical test theory, IRT does not in general base the estimate of the respondent's ability (or other attribute) on the number-correct (NC) or summed score. To distinguish IRT scores from their classical counterparts, we refer to them as "scale" scores. The computation of IRT scale scores in IRTPRO may be done using one of the three methods discussed in Chapter 8.

Graphics are often a useful data-exploring technique through which the researcher may familiarize her- or him with the data. IRTPRO offers both model-based and data-based graphs. The Model-based graphs discussed in Chapter 9 cover item- and test- characteristic curves; information and total information curves and are available for unidimensional IRT models only.

In the case of the data-based graphs presented in Chapter 10, IRTPRO distinguishes between univariate and bivariate graphs. Univariate graphs are particularly useful to obtain an overview of the characteristics of a variable. However, they do not necessarily offer the tools needed to explore the relationship between a pair of variables.

For most unidimensional and bifactor IRT models parameter estimation can be done effectively selecting the Bock-Aitkin EM algorithm (the default estimation method). In the case of multidimensional models, the method of estimation depends to a large extend on the number of dimensions of the model to be fitted. A general rule is that two-dimensional models can be handled effectively using Bock-Aitkin or adaptive quadrature. For three- to four-dimensional models, the estimation methods of choice are adaptive quadrature and MH-RM. Higher dimensional models are handled most effectively using MH-RM. Chapter 11 provides a short description of the options available for each of these estimation methods.

Each analysis created by the GUI produces a syntax file, essentially being a record of a user's selections from the sequence of dialogs. If a syntax file is opened, IRTPRO automatically fills the relevant GUI dialogs that can be viewed and modified. These aspects are dealt with in Chapter 12.

2. Graphical users interface

2.1 Introduction

In this chapter, the main features of the IRTPRO graphical users interface (GUI) are summarized. The examples in Chapter 3 through to Chapter 10 were all created via the GUI. Use of the available menus and dialogs are discussed in detail in these chapters.

When IRTPRO is launched (typically by clicking on the IRTPRO icon on the computer desktop), a page is opened containing clickable links to recently used files, the **Import Data** menu, online help documentation and to gain access to the SSI website. At his stage, the main menu bar displays the **File**, **View** and **Help** options.



2.2 Opening an IRTPRO data (ssig) file

By clicking the File button, the drop-down menu shown below is activated.

X I	RTPRO	
File	View Help	
	New	Ctrl+N
	Open	Ctrl+O
	Import	
	Print Setup	
	1 Asthma34.ssig 2 Eysenck87-items1_57.2PL-9items-irt.htm 3 Eysenck87-items1_57.ssig 4 SelfMon4.irtpro 5 SelfMon4.ssig	
	Close Exit	

By selecting the **Open** option, a standard **Open** dialog box is displayed.

🔀 Open				X
Look in:	👢 Spelling	•	G 🦻 🖻	? ▼
C.	Name	•		Date modified
Recent Places	Spelling.ssig			5/2/2011 11:45 AM
Desktop				
Libraries				
Computer				
	•	111		4
Network	File name:	Spelling.ssig		▼ Open
	Files of type:	IRTPRO Data File (*.ssig)		Cancel
		IRTPRO Command File (*.irtpro) IRTPRO Data File (*.ssig)		
		Fixed Format Data (*.fixed)		
		IRTPRO HTML Output File (*.htm) IRTPRO Plot Files (*.irtplot)		
		All Files (*.*)		

There are five main file types that IRTPRO can open, these being:

- An IRTPRO command (syntax) file with extension .irtpro (See Chapter 12)
- An IRTPRO data file with extension .ssig (See Chapters 4 to 10)
- Fixed format data with extension .fixed (See Chapter 3)
- An IRTPRO HTML output file with extension .htm (See Chapters 4 to 8)
- An IRTPRO plot file with extension .irtplot (See Chapter 9)

A file with extension .**ssig** refers to an IRTPRO data file and is typically created by importing data from a statistical software package such as SPSS or SAS or a spreadsheet program such as Excel. The import of data into .**ssig** format is dealt with in Chapter 3.

2.3 Spreadsheet main menu bar

IRTPRO data files are displayed in spreadsheet form.

IRTPRO - [Spelling.ssig]								
Eil	e <u>E</u> dit <u>D</u> a	ta <u>M</u> anipul	ate <u>G</u> raphi	cs <u>A</u> nalysis	<u>V</u> iew <u>W</u> in	ndow <u>H</u> elp	_ 8 ×	
🗋 🗅 🚔	🔒 X 🖻	8 4 ?						
	Infidility	Panoramic	Succumb	Girder	Gender		*	
1	0	0	0	0	1		E	
2	0	0	0	0	1			
3	0	0	0	0	1			
4	0	0	0	0	1			
5	0	0	0	0	1			
6	0	0	0	0	1			
7	0	0	0	0	1			
8	0	0	0	0	1			
9	0	0	0	0	1			
10	0	0	0	0	1		.	
•							•	
Ready							A	

Once a file of type .ssig is opened, the main-menu bar displays several options. For example, by clicking the **Analysis** button the drop-down menu shown below is obtained.

🔀 IRTI	PRO - [Spelli	ng.ssig]										_ (X	C
🔳 Fil	e Edit Da	ta Manipul	late Graphi	cs	Ana	alysis	View	Win	dow	Help			-	8	×
🗅 🚅	🔒 X 🖻	6 8 ?				Trad	itional	Sumr	ned-S	Score S	Statist	ics			
	Infidility	Panoramic	Succumb			Unid	imensi	onal I	IRT						
1	0	0	0	0		Mult	idimen	isiona	I IRT.					1	
2	0	0	0	0		тот с	corina							1	
3	0	0	0	0		111.3	coning							-1	
4	0	0	0	0		Adva	anced (Optio	ns					1	
5	0	0	0	0	J	Show	v Progr	ess R	ox					1	
6	0	0	0	0	<u> </u>	Shot	ritogi	000 0	0.	_	_	_	_	_	
7	0	0	0	0		1									
8	0	0	0	0		1									
9	0	0	0	0		1									
10	0	0	0	0		1									-
•	1		1											Þ	

There are four main types of analyses, namely:

- Traditional summed-score statistics (See Chapter 4)
- Unidimensional IRT (See Chapter 5 and 6)
- Multidimensional IRT (See Chapter 7)
- IRT scoring (See Chapter 8)

There are two additional items on the Analysis list, these being Advanced Options... (see Section 2.9) and Show Progress Box. By selecting the Show Progress Box option (the default), various results of the analysis are displayed, enabling the user to visually determine if the analysis is still running and what progress has been made.

The image below is a screen shot of the progress box for an analysis that is partially completed.

IRTPRO	
<pre>IRTPRO: Test 1 Parsing config Record 0 / 586 Beginning IRTPRO computations Initializing integration methodsdone. Initializing segment structuresdone. Initializing intem structuresdone. Initializing data structuresdone. 27 : 21.9162 : 63709.7570</pre>	
Abort	

2.4 Test Tabs

Regardless of the type of analysis specified, several tests (analyses) may be created using the same IRTPRO dataset. To insert a new test, right-click on the right-hand side of a current test to insert a new test tab.

idimensional <i>i</i>	Analysis		-	
Data File: C:\	IRTPRO Examples\By Da	ataset\Spelling\Spelling	g.ssig	Read file
Test1				
	Insert Test			
Descrip	Delete Test	coring		
⊤itle	Rename			
Sp	Manage Test			
_	_			
Comme	ents:			
2PL m	odel. Grouping variable i	is Gender		
Options			ОК	Cancel Run

By right clicking on a test tab, the test may be renamed or deleted. The sequence of steps to rename the first test tab to 2PL is shown below.

Select the Rename option	Enter 2PL
Unidimensional Analysis	Unidimensional Analysis
Data File: C:\IRTPRO Examples\By Dataset\Spelling\Spelling.ssig Teets Insert Test Delete Test dels Scoring Rename Manage Test	Data File: C:\IRTPRO Examples\By Dataset\Spelling\Spelling.ssig 2PL Test2 Description Group Items Models Scoring Title: Spelling test - four items
Comments:	Comments:
2PL model. Grouping variable is Gender	2PL model. Grouping variable is Gender

2.5 The Description, Group and Items tabs

When a traditional statistics, unidimensional, or multidimensional analysis is requested via the **Analysis** option, the first three tabs displayed in the corresponding analysis window are **Description**, **Group** and **Items**. Each of the **Description**, **Group** and **Items** dialogs will be briefly discussed in Sections 2.5.1 to 2.5.3.

2.5.1 The Description tab

Unidimensional Analysis
Data File: C:\IRTPRO Examples\By Dataset\PISA MathBook1\PISAMathBook1USUK.ssig Read file
Traditional IRT Rasch TRT
Description Group Items Models Scoring
<u>T</u> itle:
2-group IRT Analysis (GPC model for polytomous items)
Comments:
Mixture of 2PL and General Partial Credit Models
Options OK Cancel Run

The **Description** tab has two text boxes that are used to enter a title (description) and optional comments for each test tab. Shown below is the **Description** tab for a **Unidimensional Analysis** based on the test named **IRT**.

2.5.2 The Group tab

The **Group tab** allows one to select one or more grouping variable(s) from the **List of Variables:** text box. In the dialog shown below, the variable Country was selected as the grouping variable. By default, the first group is selected as the reference group. However, the **Group** dialog box allows the user to select any other group as the reference. Examples of the use of the **Group tab** are given in Chapters 6 and 7.

Unidimensional Analysis Data File: C:\IRTPRO Examples\By Datas Traditional IRT Rasch TRT Description Group Items Models	set\PISA MathBook1\PISAMathBook1USUK.ssig	<u>R</u> ead file
List of variables: Farms4 Walking1 Walking3 Apples1 Apples2 Apples3 Continent Grow1 Grow3 Grow2 Country	Group: Group: Country Gan and a second s	
Options	ОК Са	ncel Run

2.5.3 The Items tab

The **Items tab** dialog box for a traditional statistics or unidimensional IRT analysis is shown below. Items can be selected for each group from the **List of variables:** column and adding it to the **Items:** column.

In most practical applications, a multiple group analysis is based on the selection of the same set of items for each group. If this situation applies, the user selects the items from the **List of variables**: for the first group and then clicks on the **Apply to all groups** button to make the same selection for all groups. See Chapters 4 to 6 for examples that illustrate, amongst other, the use of the **Items tab**.

Unidimensional Analysis Data File: C:\IRTPRO Examples\By Dataset\PISA MathBook1\PIS	AMathBook1USUK.ssig Read file
Traditional IRT Rasch TRT Description Group Items Models Scoring Country Grouping value: [G1] 1	
List of variables: Cube1 Cube3 Cube4 Farms1 Farms4 Walking1 Walking3 Apples1 Apples2 Cube4	Items:
	OK Cancel Run

The **Items tab** dialog for a multidimensional IRT analysis is shown below.

Multidimensional Analysi	s			X
Data File: C:\IRTPRO E	xamples\By [Dataset\PISA MathBook1\P	ISAMathBook1USUK.ssig	Read file
Traditional IRT Ra	sch TRT Items Mo	dels Scoring		
<u>G</u> rouping value:	Country [G1] 1			-
List of variables:			<u>I</u> tems:	×
Cube1 Cube3 Cube4 Farms1 Farms4		Add >>	Cube1 Cube3 Cube4 Farms1 Farms4	 ↑ ↓
Walking1 Walking3 Apples1 Apples2	-	Number of latent dimensions:	Walking1 Walking3 Apples1	~
	4		Apply to a <u>l</u> l groups	
Options			OK Canc	el Run

The only difference between this dialog and the corresponding one for a traditional statistics or unidimensional IRT analysis is the presence of the text box **Number of latent dimensions:**. Note that

the number of latent dimensions must be specified by the user. Examples that illustrate the **Items** tab dialog for multidimensional IRT analyses are given in Chapter 7.

2.6 The Categories tab

When a traditional summed-score statistics analysis is requested via the **Analysis** option, the fourth (and last) tab displayed in the corresponding analysis window, is the **Categories tab**. The dialog associated with the selection of this tab displays the default item scores associated with each of the selected items. A user may change these scoring values by selecting a cell and then right-clicking on the selected cell to display the **Recode Item Scores**... option as demonstrated in Section 2.7.1.

Traditional Sun	nmed-Score	Statistics	-	_			X	
<u>D</u> ata File: C	:\IRTPRO Exa	mples\By Da	taset\PISA M	athBook1\PIS/	AMathBook1USI	UK.ssig	<u>R</u> ead file	
Traditional	IRT Rasc	h TRT						
Descripti	on Group	items Cate	gories					
	C	ountry						
Groun	ing value:							
Group	ing value.	[G1] 1					•	
	Item List	Categorie	sData Code	sitem Score	H			
	Cube1	2	0, 1	0, 1			=	
	Cube3	2	0, 1	0, 1				
	Cube4	2	0, 1	0, 1				
	Farms1	2	0, 1	0, 1				
	Farms4	2	0, 1	0, 1				
	Walking1	2	0, 1	0, 1				
	Walking3	4	0, 1, 2, 3	0, 1, 2, 3				
	Apples1	2	0, 1	0, 1				
	Apples2	2	0, 1	0, 1				
	Apples3	3	0, 1, 2	0, 1, 2			-	
Rea	Read parameter values							
Options					ОК	Cancel	Run	

2.7 The Models tab

When a unidimensional IRT, or multidimensional IRT analysis is requested via the **Analysis** option, the fourth tab displayed in the corresponding analysis window, is the **Models tab**. The dialog associated with selection of this tab displays the default models associated with the items and allow a user to change the model type and scoring values of the items.

The dialogs for unidimensional and multidimensional IRT differ somewhat in functionality. These differences will be briefly discussed in Sections 2.7.1 and 2.7.2.

2.7.1 The Models tab, Unidimensional IRT Analysis

The **Models** dialog displays, for each group, five columns of information, namely an item list, the number of categories (distinct values) for each item, the data codes (values) extracted from the IRTPRO dataset, the item scores (coded as 0, 1, 2,... where 0 corresponds to the smallest data code value, etc.), and the model selected. For an item with two categories, the default model is the 2PL

model and for an item with more than two categories, the default is the Graded model.

Unidimensional Analysis	T land	-	- waters	-	I am I a	X
Data File: C:\IRTPRO Exa	mples\By Data	aset\PISA Ma	thBook1\PISA	MathBook1US	UK.ssig <u></u> <u>R</u> ead	file
Traditional IRT Rasc	h TRT					
Description Group	items Model	sScoring				
c	Country					
<u>G</u> rouping value:	(G1] 1				▼	
Item List	Categories	Data Codes	Item Scores	Model	A	
Cubel	2	0,1	0,1	2PL		
Cube3	2	0, 1	0, 1	2PL		
Cube4	2	0,1	0, 1	2PL	=	
Farms1	2	0,1	0, 1	2PL		
Farms4	2	0, 1	0, 1	2PL		
Walking1	2	0, 1	0, 1	2PL		
Walking3	4	0, 1, 2, 3	0, 1, 2, 3	GP Credit		
Apples1	2	0, 1	0, 1	2PL		
Apples2	2	0, 1	0, 1	2PL		
Apples3	3	0, 1, 2	0, 1, 2	GP Credit		
<u>C</u> onstraints	<u>D</u> IF				Apply to all groups	
Options				ОК	Cancel	Run

Item scores can be user-recoded. To do so, select a cell listing the scores to be changed. By rightclicking on the selected cell, the **Recode Item Scores**... option is displayed.

	Item List	Categories	Data Codes	Item Scores	Model		
	Cube1	2	0, 1	0, 1	2PL		Ξ
	Cube3	2	0, 1	0, 1	2PL		
	Cube4	2	0, 1	0, 1	2PL		
	Farms1	2	0, 1	0, 1	2PL		
	Farms4	2	0, 1	0, 1	2PL		
	Walking1	2	0, 1	0, 1	2PL		
	Walking3	4	0, 1, 2, 3	0, 1,	Recode Iter	n Scores	1
	Apples1	2	0, 1	0, 1	21 L		9
	Apples2	2	0, 1	0, 1	2PL		
	Apples3	3	0, 1, 2	0, 1, 2	GP Credit		Ŧ
Cons	straints	<u>D</u> IF <u>R</u>	ead paramete	er values		Apply to all group	s

Selection of this option opens, for each of the groups, an **Item's Codes and Scores** dialog. By double-clicking on an **Item Score:** cell, the relevant cell may be edited and a new value entered. The screenshots below show the recoding of the scores for the item Walking3 from (0, 1, 2, 3) to (0, 1, 1, 2).

Double click on row	Edit number and click OK
Item's Codes and Scores	Item's Codes and Scores
Item: Walking3	Item: Walking3
Data Codes Item Scores OK	Data Codes Item Scores
0 0 0	0 0 Cancel
2 2	2 1
3 3	3 2
< Þ	< H

The user may also change the default model type. This is accomplished by selecting cell(s) that display a similar model type that needs to be changed. Right-click on any of the selected cells to display a drop down list of available models and make a selection. See Section 6.2.2 for an example that illustrates this function.

	C	ountry					
<u>G</u> roupi	ing value:	[G1] 1					•
	Item List	Categories	Data Code	sitem Scores	Model		
	Walking1	2	0, 1	0, 1	2PL		
	Walking3	4	0, 1, 2, 3	0, 1, 2, 3	Graded		
	Apples1	2	0, 1	0, 1	2PL		
	Apples2	2	0, 1	0, 1	2PL		
	Apples3	3	0, 1, 2	0, 1, 2	Graded		
	Continent	3	0, 1, 2	0, 1, 2	Grade	2PI	
	Grow1	2	0, 1	0, 1	2PL	201	1
	Grow3	2	0, 1	0, 1	2PL	JPL	- 11
	Grow2	3	0, 1, 2	0, 1, 2	Grade	Graded	H
						CDCradit	- I

At the bottom of the **Models** dialog there are three buttons, labeled **Constraints...**, and **DIF...**, respectively. The latter button gives access to a dialog for entering parameter values or reading them from a file. Typically, these values are used to score a set of items that were previously calibrated, see Chapter 8 for more details.

By clicking on the **Constraints...** button an **Item Parameter Constraints** window is invoked. Use of this window allows the user to fix or free parameters or to set selected parameters equal. Examples to illustrate the use of the **Item Parameter Constraints** window are given in Sections 5.2.2, 5.2.3, 6.1, 6.2.1, 6.2.2, 6.2.3, and 7.3.

Item Parameter (Const	raints										
Group: Country												
Group, Item												
G2, Cube4	а	37	С	38								
G2, Farms1	а	39	С	40								
G2, Farms4	а	41	С	42								
G2, Walking1	а	43	с	44								
G2, Walking3	а	45	c1		c2		c3		c4			
			Trend	•	γ1	46	γ2	47	γ3	48		
G2, Apples1	a	49	с	50								
G2, Apples2	а	51	С	52								
G2, Apples3	а	53	c1		c2		c3					
			Trend	•	γ1	54	γ2	55				
G2, Continent	а	56	c1		c2		c3					
			Trend	•	γ1	57	γ2	58				
G2, Grow1	а	59	С	60								
G2, Grow3	а	61	С	62								
G2, Grow2	а	63	c1		c2		c3					=
			Trend	•	γ1	64	γ2	65				
G1, Means	μ1	0.0										
G1, Cov	σ1 1	1.0										
G2, Means	μ1	66										
G2, Cov	σ11	67										-
Set parameters eq	ual ac	ross gro	oups									
								0	ж		Cano	el
											Carre	

The DIF button (differential item functioning) is enabled when the analysis entails multiple groups. An example that illustrates the use of the **DIF Analysis** dialog is given in Section 6.1.

DIF Analysis	-			X
 Test all items, anchor Test candidate items, Test candidate items, List of variables: 	all i <u>r</u> ano <u>e</u> sti	tems. domized groups: mate group differenc	e with anchor items	×
Cube1 Cube3 Cube4 Farms1 Farms4 Walking1 Walking3	*	<u>A</u> dd >>		
Apples1 Apples2 Apples3 Continent Grow1 Grow3 Group contrasts	-	Add >>	Anchor	×

2.7.2 The Models tab, Multidimensional IRT Analysis

The Models tab for a multidimensional analysis has exactly the same functionality than that described in the previous section for the unidimensional case, except that the buttons below the

Multidimensional Analysis window are labeled Constraints..., EFA..., and Bifactor..., where EFA denotes exploratory factor analysis and Bifactor denotes a bifactor analysis.

Description	Group II C value: [tem List ube1 ube3 ube4	Country G1] 1 Categorie 2 2 2	els Scoring Scoring Scoring 0, 1 0, 1 0, 1	5 (tem Score 0, 1 0, 1	Model 2PL 2PL		•	
<u>G</u> rouping v Cu Cu Fa Wa	C value: [tem List ube1 ube3 ube4 arms1	Country CG1] 1 Categorie 2 2 2 2	es Data Code 0, 1 0, 1	5 [tem Score 0, 1 0, 1	Model 2PL 2PL		•	
Grouping v Cu Cu Fa Fa Ww	value:	G1] 1 Categorie 2 2 2 2	25 Data Code 0, 1 0, 1 0, 1	5. Item Score 0, 1 0, 1	2PL 2PL		•	
Cu Cu Cu Fa Fa	tem List ube1 ube3 ube4	Categorie 2 2 2	Data Code 0, 1 0, 1 0, 1	5 Item Score 0, 1 0, 1	Model 2PL 2PL	_		
Cu Cu Cu Fa Fa	ube1 ube3 ube4	2 2 2 2	0, 1 0, 1 0, 1	0, 1 0, 1	2PL 2PL	-	Â	
Cu Cu Fa Fa	ube3 ube4	2 2	0,1	0, 1	2PL			
Cu Fa Fa	ube4	2	0.1	-/-				
Fa Fa	arms1			0, 1	2PL		-	
Fa		2	0, 1	0, 1	2PL		=	
W	arms4	2	0, 1	0, 1	2PL			
	alking1	2	0, 1	0, 1	2PL			
W	alking3	4	0, 1, 2, 3	0, 1, 2, 3	Graded			
Ap	ples1	2	0, 1	0,1	2PL			
Ap	ples2	2	0, 1	0, 1	2PL			
Ap	oples3	3	0, 1, 2	0, 1, 2	Graded	1	~	
Constra	aints	<u>E</u> FA	Bifactor			Apply to all g	roups	
								-

Clicking the **EFA**... button activates the **Exploratory Factor Analysis** dialog shown below. To verify that the user intends to specify EFA, the **Exploratory item factor analysis** box is checked. Additionally, a selection of one of the four available rotation methods can be made. Section 7.2.1 gives an example of an exploratory factor analysis.

The reader should note that once the **EFA**... option is selected, the **Constraints**... option is no longer available, since IRTPRO automatically sets up the constraints in this case.

Exploratory Factor Analysis
Exploratory item factor analysis
✓ Treat item responses as ordered
Rotation
Oblique CF-Quartimax
Orthogonal <u>C</u> F-Varimax
Orthogonal CE-Quartimax
Oblique CF- <u>V</u> arimax
OK Cancel

The Bifactor... option provides access to the Bifactor Analysis dialog that allows the user to select

items associated with specific factors. An example of a bifactor analysis is given in Section 7.2.2.

Bifactor Analysis	
<u>G</u> rouping value:	Country [[G1] 1
List of variables: Cube1 Cube3 Cube4 Farms1 Farms4 Walking1 Walking3 Apples1 Apples2 Apples3 Continent Grow1 III	Factor 2 Factor 2 Cube1 Cube3 Cube4
	OK Cancel

2.8 The Scoring tab

When a unidimensional IRT, or multidimensional IRT analysis is requested via the **Analysis** option, the last tab displayed in the corresponding analysis window, is the **Scoring tab**. Examples of the use of the **Scoring** dialog is given in Chapter 8.

Unidimensional Analysis	
Data File: C:\IRTPRO Examples\By Dataset\PISA MathBook	1\PISAMathBook1USUK.ssig Read file
Traditional IRT Rasch TRT	
Description Group Items Models Scoring	
Person ID:	Compute response pattern EAP MAP scores
Create summed-score to scale conversion table	Score persons
Scaling	Standard deviation: 1
Minjimum:	Ma <u>x</u> imum:
Scale	
Options	OK Cancel Run

2.9 Advanced options window

The Advanced options window can be accessed using the Analysis, Advanced Options... selection via the main-menu bar, or alternatively, by clicking the Options... button (lower right-hand corner of an Analysis window).

IRTPRO - [PISAMathBook1USUK.ssig]								
File Edit Data Manipulate Graphics Analysis View Window Help								
0 🖻	- X 🖻	6 8 ?			Traditional Summed-Score Statistics			
	Cube1	Cube3	Cube4		Unidimensional IRT			
1	0	0	0	0	Multidimensional IRT			
2	1	1	1	0	IDT Cooring			
3	1	1	0	0	IRT Scoring			
4	1	1	0	1	Advanced Options			
5	1	1	1	1	J Show Progress Box			
6	1	1	0	0				

This window currently has five active tabs, these being Estimation, Starting Values, Priors, Miscellaneous, and Save. The estimation window is shown below and makes provision for three estimation methods that are described in Chapter 11:

	Bock-Aitkin Bock-Aitkin Adaptive Quadrat MH-RM	▼ ure	
Advanced Options			×
Test: IRT Estimation Starting Values	Priors Miscellaneous	Save Simulate	Apply to all tests
Estimation Bock <u>C</u> onverge information Maximum number of <u>c</u> <u>M</u> -Step maximum itera	-Aitkin	Convergence crite	rion: 1e-005
Quadrature details Number of 49		Ma <u>x</u> imum va	alue: 6
Standard S-EM	•	Apply dimens Group G1 G2	Gen Dim
		ОК	Cancel <u>A</u> pply

The **Miscellaneous** dialog is used to control printout of results, and the number of processors to be used.

Advanced Options
Test: IRT Apply to all tests
Estimation Starting Values Priors Miscellaneous Save Simulate
Number of decimal places in tabular
Number of processors: 2
Print table of standardized residuals
Compute Chen-Thissen LD and item fit statistics
Compute limited-information overall model fit statistics
Print each item's goodness of fit frequency table
Minimum expected
Print factor loadings
Print parameter numbers
Print diagnostic information
Print dump file Print full dump file
OK Cancel Apply
d

The **Save** dialog is used to request the print-out of results to specific files. See Chapter 8 for an example that illustrates the use of this dialog.

dvanced	d Options
Test:	IRT Apply to all tests
Estima	ation Starting Values Priors Miscellaneous Save Simulate
	Item parameter estimates (-prm.txt)
	Asymptotic covariance matrix of the parameter estimates (-cov.txt)
	Information values, for unidimensional models only (-inf.txt)
	Inter-item polychoric correlations, for EFA models only (-pol.txt)
•	Factor loadings (-fac.txt)
	Main output in ASCII text format (-irt.txt, -sss.txt, or .ssc.txt)
	Debugging output (-dbg.txt)
	OK Cancel Apply

2.10 The Data menu

The **Data** option (main menu-bar) enables one to insert or delete variables and/or cases from the IRTPRO data file that is currently open. In addition, the drop-down menu makes provision for the renaming of variables (**Variable Properties...** option) and for entering a missing value code.

🔀 IRT	IRTPRO - [PISAMathBook1USUK.ssig]							
File Edit Data Manipulate Graphics Analysis View Window H								
🛛 🗅 🖨	8 X	I	nsert Variables					
	Cube [*]	[Delete Variables		Farms4	Walking1		
1	0	T	nsert Cases		1	0		
2	1		Delete Cores		1	0		
3	1	L	Delete Cases		1	0		
4	1	1	/ariable Properties		1	1		
5	1	N	vissing Value Code		1	0		
6	1		vissing value code		0	0		
7	1	F	Recalculate Item Counts		0	1		

2.10.1 The Variable Properties... Option

The **Properties** dialog displays the distinct values (data codes) for each item together with the frequency counts.

Prope	erties	-	-	-						
<u>N</u> a	me: Cube1		•	<u>R</u> ename						
Iyi	Type: Fixed point Type: Discrete									
De	scription:									
-v	'alues									
	Item	Count	Label							
	0 1	411 836								
						Edit				
						Edic				
	ОК	Cancel								

Variables may be renamed; a description of each item may be entered along with descriptive names for corresponding to the numeric values. For example 0 = Experimental, 1 = Control.

perties <u>N</u> ame: Group		Rename
Type: Fixed po	int	▼ Type: Discrete ▼
Description: De	fines the con	trol and experimental groups
Values		
Item	Count	Label
0	130 870	Control Experimental
		Edit

2.10.2 The Missing Value Code... Option

The **Missing Value Code**... option allows one to assign a missing value code by entering the appropriate value in the **Missing Value** text box. The value entered is accepted if the **OK** button is clicked. In this case, the user must use the **File, Save** option to ensure that this change to the dataset definitions is permanent.

ſ	Missing Value Code		X
	<u>M</u> issing value	9	OK Cancel

2.11 The Data Manipulation window

This window makes provision for the recoding of variables. Suppose, for example, that the variable Group is coded 0, 3 and 4 and that we want to recode these values so that 0 = 1; 3 and 4 = 2. This recoding is accomplished by clicking the **if...else...endif** button. Variable names can be entered by double-clicking on a variable name, or dragging it to the appropriate position in the recode window. The last statement shows the recoding of the variable Score to Score = exp(Score).

Data Manipulation	-		X
Variables: + × Item_1 Item_2 Item_3 Score Group	Functions: Abs() Exp() Ln() Rand() Randomize() Sqrt()	ifend if < <= >= () ^ Z & 9 4 5 6 1 2 3 0 . =	ifelseendif
		ОК	Cancel

3. Data import and manipulation

There are many ways to import data into IRTPRO for analysis. In this chapter, we briefly describe procedures for data-import from three commonly used formats: the **.sav** file format used by SPSS, fixed-format ASCII data, and comma-delimited text files.

In all cases, data are "imported" into IRTPRO (fixed-format input uses the **Open** command, but the effect is the same), and then re-saved as an IRTPRO system data (**.ssig**) file that is subsequently opened for analysis.

3.1 Importing Data from SPSS .sav Files

SPSS .sav files represent one example of many proprietary formats from which IRTPRO can import data.

To begin the data-import process, one starts IRTPRO and selects Import... under the File menu:



This brings up a standard **Open File** dialog; in the lower center is a pop-up menu from which the user may select one of a large number of formats.

		PRO Assess(f mdb)		L
Flexible Profession	al Item Response Theo	ASCII File - Delimited(*.txt;*.csv)	£.	
		dBASE(*.dbf)		
🔀 Open		Excel(*xls)		X
Look in:	📜 Asthma34	Epi Info(*.rec) Gauss(*.dat) Gauss - Unix(*.dat) HTML Table(*.htm*)		
æ	Name	Informix(*.ifx)		dified
	Asthma 34.sav	JMP(*.jmp)		11 11:21 AM
Recent Places		LIMDEP for Windows(^.lpj)	Ξ	
Desktop Libraries		Lotus 1-2-3(".WK",".WF") Matlab Matrix(*.mat) Mineset(*.schema,".sch) Minitab(*.mtw) OSIRIS(*.dct*.dict) Paradox(*.db) Quattro Pro(*.wq?,*.wb?) S-Plus(*.ssc) SAS V6 Data File - Versions 7/8/9(*.sd7,*.sas7bdat) SAS V6 Data File - HP.IBM.SGI & SUN Unix(*.ssd01) SAS V6 Data File - HP.IBM.SGI & SUN Unix(*.ssd01) SAS V6 Data File - Dec Unix(*.ssd04) SAS V6 Data File - Versions 7/8/9(*.sd7,*.sas7bdat) SAS(Alpha) Data File - Versions 7/8/9(*.sd7,*.sas7bdat)		
Computer		SAS Transport File(*.xpt;*.tpt)		
	✓ File name:	SAS Program & Data File(*.sas) SPSS Data File(*.sav) SPSS Data File - HP,IBM, & Sun Unix(*.sav)		Open
Network		SPSS Portable File(*.por)	*	
	Files of type:	SPSS Data File(*.sav)		Cancel
		Open as read-only		

Here we select **SPSS Data File (*.sav)**; then, after navigating to the folder that contains the .**sav** file from which we wish to import data, we **Open** the file:

🔀 Open				X
Look <u>i</u> n:	👢 Asthma34	•	G 🦻 🖻	୭▼
Recent Places Desktop Libraries	Name	,		Date modified 7/21/2011 11:21 AM
Computer	4			
Network	File <u>n</u> ame: Files of <u>type</u> :	Asthma_34.sav SPSS Data File(*.sav)		Open Cancel

The next thing that happens is a standard **Save As** dialog appears, which has as its default to save the data as a .ssig file with the same name as the .sav file (in the case of this example, Asthma_34).

The user may (optionally) change the first part of the name; however, the extension should remain **.ssig**. Click the **Open** button to start the data import process.

Save As				X
Save <u>i</u> n:	👢 Asthma34	•	G 🦻 🖻	۶ 🛄 🗸
æ	Name	*		Date modified
Recent Places	Asthma34.ssig			2/11/2011 9:55 AM
Eibraries				
Computer				
Network	∢ File <u>n</u> ame:	III Asthma_34.ssig		► <u>S</u> ave
_	Save as <u>t</u> ype:	System Data File (*.ssig)		▼ Cancel

After one clicks **Save** the file is saved as a .ssig file, and the user has the opportunity to **Open** it to begin the analysis:

Finish Import	X
Done importing.	Do you want to open Asthma_34.ssig
	Yes <u>N</u> o

If one clicks **Yes**, the file opens.

A very important first thing to do, the first time a new .**ssig** file is opened, is to enter missing the code that represents missing data in the dataset. This code must be numeric; there can only be a single missing data code, common to all of the items; and the missing data code cannot also be a valid item response code for any item. For data coded 0, 1, 2, 3, ..., it is common to use -9 as the missing value code. Note that the default missing value code in IRTPRO is -1.

To set the missing value code, select the Missing Value Code... entry under the Data menu:

🔀 IRTI	IRTPRO - [Asthma_34.ssig]								
📑 Fil	File Edit Data Manipulate Graphics Analysis View Window Help								
0 🖻	8		Insert Varia	ables					
	DISAB		Delete Var	iables			DISAB_5	DISAB_6	DISAB_7
1	2		Insert Cases				1	1	2
2	2		Delete Cases				2	2	4
3	2		Delete Cases				2	1	2
4	0		Variable Properties				0	1	0
5	3		Missing Va	lue Code			2	4	2
6	3		without g vo	nue coue			1	0	-9
7	4		Recalculate Item Counts				4	2	4
8	0	_	0 0 1		1		2	1	2
9	2		2	2	3		4	3	3
10	3		3	1	2		2	2	2
11	0		0	0	2		0	1	0

That brings up a **Missing Value Code** dialog into which the user may enter the code, and click on **OK**.

Missing Value Code		X
Missing value	-9	ОК
		Cancel

After that is done, it is important to **Save** the **.ssig** file:

🔀 IRTPI	🔀 IRTPRO - [Asthma_34.ssig]							
File] Edit Data	a Manipulate	Graphics	Analysis				
D	New		(trl+N				
	Open		C	Ctrl+O				
	Close							
	Save		(Ctrl+S				
4	Save As							

Once the missing value code has been set, and the **.ssig** file has been saved, the missing data code will be stored within the **.ssig** file and IRTPRO will "remember" the code in subsequent uses of the data.

The file is now ready, and the user may proceed with analyses as described in Chapters 4 to 5.

3.2 Opening Fixed-Format Data Files

To bring in data from a fixed-format file, there is a slightly different procedure. It begins with **Open under the File** menu:

File	Edit	Data	Manipulate	Graphics	Analysis
	New			C	Ctrl+N
	Open			C	Ctrl+O
	Close Save Save A	\s		(Ctrl+S
	Print Print P Print S	review etup		(Ctrl+P
	1 Asth 2 Asth 3 AAC 4 PISA 5 PISA	ma_34. ma34.s L3_21It 00Read MathBe	ssig sig ems.ssig MathBook8.s ook1USUK4.ir	ssig tpro	
	Exit				

which brings up a standard **Open File** dialog. In the lower center of this dialog, the user selects **Fixed Format Data (*.fixed)** from the pop-up menu, identifying **Files of type:**

K Open				
Look <u>i</u> n:	👢 Simulated	•	G 🦻 🖻	୭▼
Recent Places Desktop Libraries	Name im simul5.fixed	•		Date modified 7/20/2011 8:04 PM
Computer Network	 ✓ File <u>n</u>ame: Files of<u>type:</u> 	III simul5.fixed Fixed Format Data (*.fixed)		► <u>Open</u> ■ Cancel

Then one opens the file; here we use as an example the file **simul5.fixed** stored in the folder **IRTPRO Examples/By Dataset/Simulated**. The data consists of five multiple category items. The simulated data represents 1000 examinees drawn at random from a population with mean ability score of 0.0 and standard deviation of 1.0.

Note that it is necessary that the fixed-format data file has the extension .fixed.

🔀 Open				X
Look <u>i</u> n:	👢 Simulated	•	G 🤌 🛙	୭▼
Recent Places Desktop Libraries	Name image: simul5.fixed			Date modified 7/20/2011 8:04 PM
Network	 ✓ File <u>n</u>ame: Files of type: 	III simul5.fixed Fixed Format Data (*.fixed)		

After the user clicks **Open**, an image of the file appears on the screen:

IRTPRO	IRTPRO - [simul5.fixed]						
Eile \	Eile View Help						
🗅 🚅 日	X 🖻 f	1 6 ?					
						-	
	12345	1 678901				Ξ	
1	0001	42444					
2	0002	12221					
3	0003	32212					
4	0004	13222					
5	0005	21211					
6	0006	34443					
7	0007	23343					
8	8000	44444					
9	0009	44444					
10	0010	11111					
11	0011	43344					
12	0012	11111					
13	0013	11121					
14	0014	13243					
15	0015	33222				-	
•					Þ		

In the file **simul5.fixed**, there is a **Case Number** variable in columns 1 to 4 (its values are 0001 to 1000), and item responses for five items, each of which is in a one-column field, in columns 7 to 11. To bring those data into IRTPRO as an **.ssig** file, the user must indicate the division of the file into (sets of) columns, or **Fields**, and assign names to the variables.

To indicate that columns 1 to 6 should be separated from columns 7 to 11, the user double-clicks between the small **6** and **7** in the gray column-header; after that is done, a vertical line appears

between columns 1 to 6 and the subsequent columns:

🔀 IRTPRO	- [simul5.fix	ed]				J
Eile <u>F</u> ile	<u>/</u> iew <u>H</u> elp			- 8	×	
🗅 🖼 🖪	X 🖻 💼	a 🔋				
					•	
	123456	1 7890	1		Ш	
1	0001	4244	4			
2	0002	1222	1			
3	0003	3221	2			
4	0004	1322	2			
5	0005	2121	1			
6	0006	3444	3			
7	0007	2334	3			
8	8000	4444	4			
9	0009	4444	4			
10	0010	1111	1			
11	0011	4334	4			
12	0012	1111	1			
13	0013	1112	1			
14	0014	1324	3			
15	0015	3322	2		Ŧ	
•						
					đ	

After that is accomplished, there is a small rectangular box above the column-header numbers 1 to 6. A right-click within that box brings up a menu within which the user selects the entry **Field Property** ... to give a name to this **Field**:

IRTPRC) - [simul5.fix	ed]			X
File	View Help			-	e ×
🗋 🗁 🖬	X 🖻 🖻	8			
FI	eld Property				=
Re Re	emove Field	Label			_
Se	et Subfield				
CI	ear subfield				
4	0004	13222	_		
5	0005	21211			
6	0006	34443			
7	0007	23343			
8	8000	44444			
9	0009	44444			
10	0010	11111			
11	0011	43344			
12	0012	11111			
13	0013	11121			
14	0014	13243			
15	0015	33222			Ŧ
•					Þ

In this case, the Field (columns 1 to 6) contains the data for the Case Number variable, so we give it the label Case Number, and click OK:

Field Property	×
Field label(col 1 to col 6):	ОК
Case Number	Cancel
Type: Integer 🔻	

Then we move to the right, and double-click between the column headers 7 and 8; then 8 and 9 then 9 and 10; and then 10 and 11 to get the vertical separation lines shown below.

🔀 IRTPRO - [simul5.fixed]					
Eile <u>F</u> ile	<u>/</u> iew <u>H</u> elp		_ 8 ×		
🗅 🖻 🖪	X 🖻 💼	8			
	*		·		
	123456	1 78901			
1	0001	42444			
2	0002	12221			
3	0003	32212			
4	0004	13222			
5	0005	21211			
6	0006	34443			
7	0007	23343			
8	8000	4444			
9	0009	4444			
10	0010	11111			
11	0011	43344			
12	0012	11111			
13	0013	11121			
14	0014	13243			
15	0015	33222	T		
•			Þ		

Once this is done, we right-click on the empty gray rectangle above the column heading **7**; that again brings up the **Field Property** dialog. In this case, we enter the label Item1 and click **OK**:

Field Property	X
<u>F</u> ield label(col 7):	ОК
Item1	Cancel
Type: Integer 🗨	

Repeat this procedure by right-clicking, in turn, on the empty gray rectangles above the column headings **8**, **9**, **10** and **11** and enter the item names Item2, Item3, Item4, and Item5 respectively.

IRTPRO - [simul5.fixed]	
File View Help	×
12345678901	
1 0001 4244	
Field Property	
Eield label(col 11): OK Item5 Cancel	
Type: Integer	
12 0012 11111	
13 0013 11121	
14 0014 1324 <mark>3</mark>	
	~
	.4

Once the **OK** button is clicked (see image above) after entering the last item name, each rectangle will be marked by an * symbol, and the **File** menu becomes active. We select **Save as IRTPRO Data File** from the **File** menu:

🔀 IR	IRTPRO - [simul5.fixed]							
F	File View Help							
	New	Ctrl+N						
	Open	Ctrl+O						
	Close							
	Save	Ctrl+S						
	Save as IRTPRO Data File							
	Print Setup							
	1 simul5.fixed							
	2 simul5it.ssig							
	3 simul5items.ssig							
	4 Anger6IT.ssig							
	5 simul5.ssig	5 simul5.ssig						
	Exit							
	11 0011 43344 12 0012 11111							

This brings up the standard **Save As** dialog, and we save the file as **Simul5.ssig** (or whatever name we might prefer, with the extension.**ssig**):

🔀 Save As	C MOND IN		X
Save <u>i</u> n:	👢 Simulated	• G	🏚 📂 🛄 🗸
C.	Name	*	Date modified
Recent Places		No items match your search	ı.
Desktop			
Libraries			
Computer			
	4		
Network	File <u>n</u> ame:	simul5.ssig	<u>S</u> ave
	Save as <u>t</u> ype:	IRTPRO Data File (*.ssig)	▼ Cancel

In this case, unlike **Import**, the new **.ssig** file opens immediately.

🔀 IRTPRO - [simul5.ssig]								
Eile Edit Data Manipulate Graphics Analysis View Window Help								
🗋 🗅 🖻	□ ☞ ■ ↓ ʰ ඬ ⊕ ?							
	Case Number	ltem1	Item2	Item3	Item4	Item5	•	
1	1	4	2	4	4	4	Ξ	
2	2	1	2	2	2	1		
3	3	3	2	2	1	2		
4	4	1	3	2	2	2		
5	5	2	1	2	1	1		
6	6	3	4	4	4	3		
7	7	2	3	3	4	3		
8	8	4	4	4	4	4		
9	9	4	4	4	4	4		
10	10	1	1	1	1	1		
11	11	4	3	3	4	4		
12	12	1	1	1	1	1		
13	13	1	1	1	2	1		
14	14	1	3	2	4	3		
15	15	3	3	2	2	2	-	
•	▲							
Ready	Ready							

It is important to remember to set the **Missing Value Code**, if there are missing values in the data, as described in the previous section:

	🔀 IRTPRO - [simul5.ssig]						
	📑 File	e Edit	Data	a Manipulate	Graphics	Analys	
	0 🖻	₽ %		Insert Variables Delete Variables			
l		Case Nur		Insert Cases			
l	1	1		Delete Cases			
	2	2					
	3	3		Variable Properties			
	4	4	Missing Value Code				
	5	5					
	6	6	Recalculate Item Counts				

Importing space delimited fixed-format files

If there are spaces between the columns in a fixed format file, one can import the file directly if the file is saved with an extension **.txt**. As an illustration, consider the same simulated dataset used above, but in this instance saved with spaces between each variable:

📕 simul5it	.txt	_ 0	X
<u>F</u> ile <u>E</u> dit	F <u>o</u> rmat	<u>V</u> iew	<u>H</u> elp
	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	4 2 2 3 3 4 4 4 4 4 2 2 3 3 4 4 4 3 2 3 3 3 3	
			E.

Use the File, Import option and select files of type (*.txt, (*.csv). Browse for the file simul5it.txt stored in the folder IRTPRO Examples\By Dataset\Simulated and click the Open button:

🔀 Open				X
Look <u>i</u> n:	👢 Simulated		👻 🧿 🥬 👂	۶ 🛄 🕶
Recent Places	Name simul5it.txt	5V		Date modified 7/20/2011 8:46 PM 7/20/2011 8:47 PM
Libraries Computer				
Network	 ✓ File <u>n</u>ame: Files of type: 	III simul5it.txt ASCII File - Delimited(*.tx Open as <u>r</u> ead-only	t*csv)	▼ <u>Open</u> ▼ Cancel

This action will prompt the user to save the IRTPRO data file:

Save As				X
Save <u>i</u> n:	🗼 Simulated	•	G 🤌 🛙	۶ ◄
Recent Places Desktop Libraries Computer	Name simul5.ssig simul5it.ssig			Date modified 7/20/2011 9:48 PM 7/21/2011 11:59 AM
Network	✓	III simul5it ssig		Save
	Save as <u>t</u> ype:	System Data File (*.ssig)		Cancel

A portion of this file is shown below.
🔀 IRTI	PRO - [simul	5it.ssig]									
Eil Eil	Eile Edit Data Manipulate Graphics Analysis View Window Help										
	Col1	Col2	Col3	Col4	Col5	Col6	<u> </u>				
	1	4	2	4	4	4	E				
2	2	1	2	2	2	1					
3	3	3	2	2	1	2					
4	4	1	3	2	2	2					
5	5	2	1	2	1	1					
6	6	3	4	4	4	3					
7	7	2	3	3	4	3					
8	8	4	4	4	4	4					
9	9	4	4	4	4	4					
10	10	1	1	1	1	1					
11	11	4	3	3	4	4					
12	12	1	1	1	1	1					
13	13	1	1	1	2	1					
14	14	1	3	2	4	3					
15	15	3	3	2	2	2	.				
•							Þ				
Ready							NL				

The default column names are Col1, Col2,.... To rename, use the Data, Variable Properties... option.

3.3 Importing Comma-delimited Data

Comma-delimited .csv files represent another commonly used format from which IRTPRO can import data.^{1 2}

To begin the data-import process, one starts IRTPRO and selects Import... under the File menu:

1 While it is possible that IRTPRO may not properly open certain types of Excel ".xls" worksheet files, Excel will also save data as comma-delimited, and that can be used if the data are in an Excel-readable format.

2 While tab- or space-delimited data are also commonly used, IRTPRO cannot currently open those files. However, one can use a text editor to change tabs to commas, and then one has a comma-delimited file that IRTPRO can open.

🔀 II	RTPRO									
File	View Help									
	New	Ctrl+N								
	Open	Ctrl+O								
	Import									
	Print Setup									
	1 Efficacy_cfa.irtpro									
	2 Asthma34.ssig									
	3 Asthma34.irtpro									
	4 Anxiety14itemsV7.irtpro									
	5 Isat6-3plPriors.irtpro									
	Close									
	Exit									

This brings up a standard **Open File** dialog; in the lower center is a pop-up menu from which the user may select one of a large number of formats:

IR		ASCII File - Delimited(*.txt* csv)	•	
Flexible Professional Ite	em Response Theory N	ASCII File - Fixed Format (S/TSchema)(".sts) ASCII File - Fixed Format (All Schemas)(*.fix) dBASE(*.dbf)		X
Look in:	🗼 CFA	Excel(*.xls) Epi Info(*.rec) Gauss(*.dat)	F	
C.	Name	Gauss - Unix(*.cat) HTML Table(*.htm*) Informix(*.ifx)	×	dified
Recent Places		JMP(*.jmp) LIMDEP for Windows(*.lpj)	≡	
		Matlab Matrix(*.mat) Mineset(*.schema,*.sch)		
Desktop		Minitab(*.mtw) OSIRIS(*.dct*.dict)		
		Paradox(*.db) Quattro Pro(*.wq?;*.wb?) S-Plus(*.scc.)		
Libraries		SAS Data File - Versions 7/8/9(*.sd7;*.sas7bdat) SAS V6 Data File - HP.IBM.SGI & SUN Unix(*.ssd01)		
		SAS V6 Data File - Windows/OS2(*.sd2) SAS V6 Data File - Dec Unix(*.ssd04)		
Computer		SAS(Sun) Data File - Versions 7/8/9(*.sd7;*.sas7bdat) SAS(Alpha) Data File - Versions 7/8/9(*.sd7;*.sas7bdat)		
	•	SAS Transport File(*.xpt;*.tpt) SAS Program & Data File(*.sas)		· · ·
Network	File name:	SPSS Data File(*.sav) SPSS Data File - HP,IBM, & Sun Unix(*.sav)	Ŧ	Open
	Files of type:	ASCII File - Delimited(*.txt*.csv)		Cancel
		Open as read-only		

Here, we select **ASCII File – Delimited (*.txt,*.csv)**.

Then we navigate to the folder that contains the **.csv** file we wish to import, and **Open** it:

🔀 Open					X
Look <u>i</u> n:	👢 Anger	•	G 🤌 🖻	۶ 🛄 🔻	
Recent Places	Name	·		Date modified 6/6/2011 4:19 P	M
Desktop					
Libraries					
Computer					
	•	111			•
Network	File <u>n</u> ame:	Anger6IT.csv		-	Open
	Files of type:	ASCII File - Delimited(*.txt;*.csv)		▼ C	ancel
		Open as <u>r</u> ead-only			

In this case, as an example, we are using the file **Anger6IT.csv** which contains the same data as the **Anger6IT.fixed** file used in the previous section, except that the data in **Anger6IT.csv** are commadelimited, one line per observation, instead of in fixed columns. When we **Open** the file, a standard **Save As** dialog appears

Save As					X
Save in:	👢 Anger	•			
e.	Name	*		Date modified	
Recent Places		No items match your s	earch.		
Desktop					
Libraries					
Computer					
Network	•				4
	File <u>n</u> ame:	Anger6IT.ssig		-	<u>S</u> ave
	Save as <u>t</u> ype:	System Data File (*.ssig)		▼ C	ancel

and we **Save** the file as **Anger6IT.ssig**. After one clicks **Save** the file is saved as a **.ssig** file, and the user has the opportunity to **Open** it to begin the analysis:



If one clicks **Yes**, the file opens.

It is again important to remember to set the Missing Value Code as described in Section 3.1.

🔀 IRTF	PRO - [Ar	nger6	iT.ssig]				_		
🗉 Fil	e Edit	Data	a Manipul	ate Graphi	cs Analys	is	View Wi	ndow Help	
🗅 🖻	8		Insert Varia	ables					
	IRTPRO - [Anger6IT.ssig] File Edit Data Manipulate Graphics An Image: Second sec						Anger4	Anger5	Anger6
1	1		Insert Case	ic i			2	2	3
2	2 1 Delete Cases						1	2	3
3	3 1 Delete Cases						1	2	3
4	1		/ariable Properties				2	2	3
5	1		Missing Va	lue Code			1	2	2
6	1		without a start of the start of	nue coue			2	2	3
7	7 1 Recalculate Item Counts				ts		1	2	1
8	1		3	2	2		3	3	3
9	1	2	2	1	1		1	1	1
10	1	3	}	2	3		2	3	3

There are many other ways to "get data into" IRTPRO, but they are variations on the procedures described in this document. If you encounter difficulties opening a file of some particular format, please let us know. However, in the interim, a good work-around would be to re-write the file in one of the formats that IRTPRO *does* successfully read, and proceed from there.

3.4 Data Manipulation: Data menu

3.4.1 Introduction

To demonstrate the data manipulation options available in IRTPRO, we use the dataset **AnxietyItems.ssig.** To see the data, use the **Open** file dialog under the **File** menu, navigate to the **C:\IRTPRO Examples\By Dataset\Anxiety14** folder, select **Files of type: IRTPRO Data File (*.ssig)** in the **Open File** dialog, and open the file **AnxietyItems.ssig**. There are eight variables and the first ten cases are shown below.

IRTI	PRO - [Anxie	tyItems.ssig]						_ 0	x
Eil Eil	e <u>E</u> dit <u>D</u> a	ita <u>M</u> anipu	late <u>G</u> raphi	cs <u>A</u> nalysis	<u>V</u> iew <u>W</u> i	ndow <u>H</u> elp)	-	e x
	Item1	ltem2	ltem3	Item4	ltem5	ltem6	V13	V14	
1	3	2	2	3	3	2	2	3	
2	3	5	5	3	4	3	4	2	
3	3	3	3	3	1	4	1	2	
4	3	2	2	3	2	3	2	3	
5	2	2	4	3	4	4	4	4	
6	1	1	1	1	1	2	1	1	
7	3	1	1	2	1	1	2	2	
8	1	2	1	1	1	1	1	1	
9	3	3	1	3	2	1	1	4	
10	3	2	1	2	2	1	2	2	Ψ.
•	1								Þ
Ready								NUM	

If the spreadsheet is the current window, the main menu-bar displays the **Data**, **Manipulate**, **Graphics** and **Analysis** options. The list of available options from the **Data** drop-down menu is next.

X IRTPRO - [AnxietyItems.ssig]										
🔳 File	e Edit	Data] Manipulate G	iraphics	Analys	is				
🗋 🗅 🚔	🔒 X	1	nsert Variables							
	ltem1	1	Delete Variables							
1	3	1	Insert Cases							
2	3		Delete Cases							
3	3		Jelete Cases			1				
4	3	١	/ariable Propertie	es		2				
5	2		Missing Value Code							
6	1		wissing value code							
7	3	I	Recalculate Item Counts							

3.4.2 Delete variables or cases

Selection of the **Data**, **Delete Variables**... option provides the user with access to the **Delete Variables** dialog. In the following demonstration, the variables V13 to V14 are deleted by selecting the **Delete from:** drop-down list and then the **Delete to:** drop-down list.



By clicking the **OK** button, the revised spreadsheet is displayed. These changes have not been made to the original data yet and therefore an asterisk (*) sign is appended to the file name, as shown in the top pane of the IRTPRO window. Use the **File, Save** option to make the changes permanent.

🔀 IRTF	IRTPRO - [AnxietyItems.ssig *]											
Eile	📧 File Edit Data Manipulate Graphics Analysis View Window Help 🛛 - 🖉 🗙											
0 🖻												
	ltem1	Item2	ltem3	Item4	ltem5	ltem6	×					
1	3	2	2	3	3	2	E					
2	3	5	5	3	4	3						
3	3	3	3	3	1	4						
4	3	2	2	3	2	3						
5	2	2	4	3	4	4	.					
•							•					
							NUM					

To delete cases from the data, select the **Data**, **Delete Cases**... option and make the required selections using the **Delete Cases** dialog.

Delete Cases	5 1-	X
Delete	cases, starting from <u>c</u> ase	1
O Delete from case: 1	▲ to case: 1	×
🔘 Delete <u>a</u> ll cases		
	ОК	Cancel

3.4.3 Renaming Variables

Next, we would like to rename the variable names Item1 to Item6. These names are to be replaced by Calm, Tense, Regretful, AtEase, Anxious, and Nervous. Select the **Variable Properties**... option from the **Data** menu to activate the **Properties** dialog.

ſ	🔀 IRTE	IRTPRO - [AnxietyItems.ssig]										
	🔳 Fil	e Edit	Data	Manipulate G	Graphics A	Analys	is	View Wi	ndow Help			
l	🗋 🗅 🚅	🗅 🗃 🖬 🐰 Insert Variables										
l		ltem1	0			ltem5	ltem6					
	1	3	Б	nsert Cases				3	2			
	2	3		Notato Conco				4	3			
	3	3	L	Jelete Cases			ľ	1	4			
	4	3	V	ariable Properti	es			2	3			
	5	5 2 Missing Value Code						4	4			
		<										
	-		F	Recalculate Item Counts								

Starting with Item1 in the Name: drop-down list, click the Rename... button and change the name to Calm (see the two dialogs below).

Prope	erties					-			
<u>N</u> a	me: Item1		•	Rename	·				
Тy	pe: Fixed point		•	<u>T</u> ype:	Discrete		•		
<u>D</u> e	scription:								
-V	/alues								
	Item	Count	Label						
	1	114							
	2	204							
	3	143							
	5	4/				_			
	5	9							
						<u>E</u> dit			
							_		
	ок	Cancel							
						V			
IR	RTPRO								
	Variable name	9							
	Calm								
	ОК	Cano	cel						

Click the \mathbf{OK} button to return to the **Properties** dialog. Repeat the above procedure for Item2 to Item6.

Prope	erties				-	-	
<u>N</u> an Iyi De:	me: Anxious Calm Tense Regretful AtEase Anxious scrip		-	<u>R</u> ename <u>Т</u> уре:	 Discrete		•
-v	Item 1 2 3 4 5	Count 153 196 111 54 3	Label				
	ОК	Cancel				Edit]

Once the last variable has been renamed by using the **Variable name** text box, click the **OK** button to return to the **Properties** dialog.

See income	×
	10 Mar.

When the **Properties** dialog is displayed, use the **OK** button to display the revised spreadsheet and then use the **File**, **Save** option to make the changes to **AnxietyItems.ssig** permanent.

🔀 IRTF	🔀 IRTPRO - [AnxietyItems.ssig *]										
Eil	File Edit Data Manipulate Graphics Analysis View Window Help - 🕫										
0 🖻											
	Calm	Tense	Regretful	AtEase	Anxious	Nervous	•				
1	3	2	2	3	3	2	E				
2	3	5	5	3	4	3					
3	3	3	3	3	1	4					
4	3	2	2	3	2	3					
5	2	2	4	3	4	4	-				
•											
Ready							NU .d				

3.4.4 Missing value code

To set the missing value code, select the Missing Value Code... entry under the Data menu:



That brings up a **Missing Value Code** dialog into which the user may enter the code (-1 is the default, but is also the code for this data) and click on **OK**.

Missing Value Code		X
Missing value	1	OK Cancel

After that is done, it is important to **Save** the **.ssig** file by using the **File**, **Save** option. Once the missing value code has been set, and the **.ssig** file has been saved, the missing data code will be stored within the **.ssig** file and IRTPRO will "remember" the code in subsequent uses of the data.

3.4.5 Insert variables or cases

Suppose that we want to insert two new variables into **AnxietyItems.ssig** before the item Calm and then rename the new variables to SumScore and CalmRecoded. To proceed, select the **Data**, **Insert Variables**... option.

🔀 IRTPRO - [AnxietyItems.ssig]										
Eİ Fi	le Edit	Data	Manipulate	Graphics	Analys	sis	View Wi	ndow Help	- 8	
Insert Variables										×
🗋 🗅 🚅	: 🖪 🐰		Delete Variable	S						
	Calm		Insert Cases				Anxious	Nervous		
1	3		Delete Cases				3	2		Ξ
2	3					4	3			
3	3		Variable Prope	rties		1		4		
4	3		Missing Value (Code			2	3		
5	2		windowing value code				4	4		Ŧ
•	1		Recalculate Iter	m Counts				1	F.	
									NL	.4

Selection of this option activates the Insert Variable(s) dialog. Make the selections shown below

and click **OK**.

Insert Variable(s	;)	-		X
	2	variables	● <u>b</u> efore ○ after	Calm 🔹
				OK Cancel

The revised spreadsheet is displayed with default variable names VAR0 and VAR1 and with all the corresponding data cells filled with the missing value code. Use the **File**, **Save** option to make the changes to **AnxietyItems.ssig** permanent.

🔀 IRT	K IRTPRO - [AnxietyItems.ssig *]											
Eil Eil	Eile Edit Data Manipulate Graphics Analysis View Window Help - 🖻											
	VARO	VAR1	Calm	Tense	Regretful	AtEase	Anxious					
1	-1	-1	3	2	2	3	3					
2	-1	-1	3	5	5	3	4					
3	-1	-1	3	3	3	3	1					
4	-1	-1	3	2	2	3	2					
5	-1	-1	2	2	4	3	4	Ŧ				
•												

Rename VAR0 to SumScore and VAR1 to CalmRecoded as explained in Section 3.4.3.

3.5 Data Manipulation: Manipulate menu

Currently, the only option available from the **Manipulate** menu, is the **Recode**... option as shown. This option is selected in what follows.

🔀 IR	式 IRTPRO - [AnxietyItems.ssig]										
	File Edit	Data	Manipula	ate Graphi	cs Analysis	View Wi	ndow Help	- 8			
			Reco	ode		×					
🗋 🗅 🚅 🔛 🗼 🛍 🛱			1 🗟 🦹 🛛								
	SumSo	core Ca	ImRecoded	Calm	Tense	Regretful	AtEase	Anxious			
1	-1	-1	:	3	2	2	3	3	Ξ		
2	-1	-1	:	3	5	5	3	4			
3	-1	-1	:	3	3	3	3	1			
4	-1	-1	:	3	2	2	3	2			
5	-1	-1	:	2	2	4	3	4	-		
•											
								NU			

3.5.1 Recoding item scores

Suppose, for example, that we want to define a new variable called CalmRecoded by combining the fourth and fifth categories of the item Calm. In Section 3.4.3 the **Properties** dialog showed that the

five distinct values of Calm are 1, 2, 3, 4, and 5. Therefore, we want to recode these values so that, for the new variable CalmRecoded 5 = 4 and all the remaining data values remain unchanged. This recoding is accomplished by, selection of the **Manipulate**, **Recode**... option to invoke the **Data Manipulation** window.

When using the if () statement, follow the next rules:

- 1. Click with mouse pointer within the () brackets, then double click on Calm or drag Calm to within the () brackets.
- 2. Click on the appropriate operator from the following list:
 - \circ < (Less than)
 - \circ <= (Less than or equal to)
 - \circ >= (Greater than or equal to)
 - \circ > (Greater than)
 - != (Not equal to)
 - == (Equal to; must be to = symbols)

Data Manipulation	the local data	X
Variables: + × SumScore CalmRecoded Calm Tense Regretful AtEase Anxious Nervous	Functions: Abs() Exp() Ln() Rand() Randomize() Sqrt() if (Calm == 5) then CalmRecoded = 4 else CalmRecoded = Calm endif	ifend ififelseendif $< <= > = > != =$ () ^ %Backspace 2 8 2 /Delete 4 5 6 * 1 2 3 - 0 . = +
		OK Cancel

Click **OK**, then save the data file and select **Data**, **Properties**... from the main menu-bar to verify that CalmRecoded has four categories.

Properties <u>N</u> ame: CalmRecod	led	•	<u>R</u> ename	2	-				
Type: Fixed point Type: Discrete									
Description: Values									
Item	Count	Label							
1	114								
2	204								
3 4	143 56								
					Edit				
ОК	Cancel								

3.5.2 Calculating the sum of two or more variables

Suppose that the new variable SumScore equals the sum of the six items, CalmRecoded and Tense to Nervous. In the illustration below we used three statements. After the first statement is entered, use the **Enter** button to advance to the next line. Variables are entered onto the compute window by either double-clicking or dragging.

Data Manipulation		X
Variables: + × SumScore CalmRecoded Calm Tense Regretful AtEase Anxious Nervous	Functions: Abs() Exp() Ln() Rand() Randomize() Sqrt() \$umScore = CalmRecode SumScore = SumScore + SumScore = SumScore +	ifend ififelseendif $< <= > = > != ==$ () ^ %Backspace 2 2 4 5 6 1 2 0 $= +$
		OK Cancel

Click the **OK** button and use the **File,Save** option to make the changes to the file **AnxietyItems.ssig** permanent. The distribution of the SumScore values (see Section 10.2 of Chapter 10 to learn how to obtain this univariate bar chart) is shown below.



4. Traditional statistics

IRTPRO can compute a set of traditional summed-score-based statistics that are useful in checking data before an IRT analysis, and interpreting IRT results. We illustrate this feature with traditional summed-score-based statistics for the State-Trait Anxiety Inventory (STAI). This example examines item responses obtained from 517 undergraduate students at the University of Houston and the University of Arkansas who completed a 20-item anxiety questionnaire derived from the State-Trait Anxiety Inventory (STAI, Spielberger, 1983).³

For illustration purposes, six items are selected:

- o I feel calm.
- o I am tense.
- I am regretful.
- o I feel at ease.
- I feel anxious.
- o I feel nervous.

In these data, the responses were on a five-point unipolar Likert-type response scale: 1 = not at all, 2 = very little, 3 = somewhat, 4 = moderately, and 5 = very much.

To see the data, use the **Open** file dialog under the **File** menu of IRTPRO, navigate to the **C:\IRTPRO Examples\Traditional** folder, select **Files of type: IRTPRO Data File (*.ssig)** in the **Open** file dialog, and open the file **Anxiety14.ssig**.

While this file contains responses to fourteen items, only the six items listed above have meaningful variable names (Calm, Tense, and so on). The other variables are named V2, V6, V7, etc., and will not be used here. A portion of the spreadsheet is shown below.

3 Thanks to Lynne Steinberg for these data, which are described more completely by Thissen & Steinberg (2009).

🔀 IRT	IRTPRO - [Anxiety14.ssig]												
Eile Edit Data Manipulate Graphics Analysis View Window Help												- 8	×
	Calm	V2	Tense	Regretful	AtEase	V6	V7	V8	Anxious	V10	V11	Nervous	
2	3	3	5	5	3	3	3	4	4	3	3	3	
3	3	3	3	3	3	1	4	4	1	2	3	4	
4	3	3	2	2	3	2	4	2	2	1	2	3	
5	2	3	2	4	3	2	1	3	4	5	2	4	
6	1	1	1	1	1	1	3	2	1	1	1	2	
7	3	2	1	1	2	1	5	1	1	1	3	1	Ĭ
8	1	1	2	1	1	1	2	2	1	1	1	1	Ĭ
9	3	3	3	1	3	2	4	1	2	2	3	1	Ť
10	3	2	2	1	2	2	3	2	2	2	2	1	-
•											•		
												NUM	

To view the statistics for these data, select **Traditional Summed-Score Statistics** ... from the **Analysis** menu.

ſ	IRTPRO - [Anxiety14.ssig]									
l	📑 File	e Edit [Data Manipu	late Grapł	nics	Analysis View Window Help				
l	🗋 🗅 🚔	📙 X 🖻	b 🖪 🕭 🤋			Traditional Summed-Score Statistics				
L		Calm	V2	Tense		Unidimensional IRT				
l	2	3	3	5	5	Multidimensional IRT				
	3	3	3	3	3	IDT Cooving				
I	4	3	3	2	2	IRT Scoring				
	5	2	3	2	4	Advanced Options				
I	6	1	1	1	1	Show Progress Box				
	7	3	2	1	1					

The **Traditional Statistics** dialog appears, and the user enters the title and any desired comments in the **Description** tab as shown below.

Traditional S	ummed-Score Statistics	X	
Data File:	C:\IRTPRO Examples\Traditional\Anxiety14.ssig	id file	
Traditional Summed-Score Statistics Data File: C:\IRTPRO Examples\Traditional\Anxiety14.ssig Test1 Description Group Items Categories Itel: Six anxiety items selected from the file Anxiety14.ssig Comments: To illustrate the computation of traditional statistics			
Test1			
Descri	iption Group Categories		
<u>T</u> it	le:		
Si	ix anxiety items selected from the file Anxiety14.ssig		
Cor	mments:		
	o illustrate the computation of traditional statistics		
Options	OK Cancel	Run	

Since there is only one group, we proceed to the **Items** tab and select the six items in question:

Traditional Summed-Scor	e Statistics						
Data File: C:\IRTPRO Examples\Traditional\Anxiety14.ssig Read file Test1							
Description Group Items Categories Single Group Analysis							
<u>G</u> rouping value: List of variables:	No Group Variable	Items: X					
Calm V2 Tense Regretful AtEase V6 V7 V8 Anxious	E Add >>	Calm Tense Regretful AtEase Anxious Nervous Apply to all groups					
Options		OK Cancel Run					

IRTPRO computes the number of categories and associated values for each item. By clicking the **Categories** tab, these values are displayed as shown next.

Traditional Summed-Score	Statistics				X
Data File: C:\IRTPRO Exa	mples\Traditional\Anxie	ty14.ssig			<u>R</u> ead file
Test1					1
Description Group I	tems Categories				
<u>G</u> rouping value:	No Group Variable				—
					-
Item List	Categories Data Coc	5 0 1 2 2	B1		- 11
	5 1, 2, 3, 4	50123	4		
Regretful	5 1, 2, 3, 4	5 0, 1, 2, 3,	4		
AtEase	5 1, 2, 3, 4	5 0, 1, 2, 3,	4		
Anxious	5 1, 2, 3, 4	5 0, 1, 2, 3,	4		
Nervous	5 1, 2, 3, 4	5 0, 1, 2, 3,	4		
				Apply to all group	
Read parameter v	alues			Abbia to all dion	ps
Ontions			ОК	Cancel	Run
			JK	Canter	

When Run is clicked, the output appears, excerpts of which are on the following page.

Table of Contents

Item and (Weighted) Summed-Score Statistics for Group 1 Summary of the Data and Control Parameters

Item and (Weighted) Summed-Score Statistics for Group 1 (Back to TOC)

Coefficient alpha: 0.8425 Complete data N: 515

Coefficient Alpha, calculated using listwise deletion (if there are missing values in the data) is 0.8425 and in this case, is based on a sample size of 515 complete cases. The table below is a summary of the Coefficient Alpha, if each item in turn is deleted. For example, if item 2 is deleted, the reliability coefficient based on the remaining 5 items equals 0.8059.

The following Statistics are Computed only for the Listwise-Complete Data:

			With Item Deleted			
	Respons	е	Item-Total	Coefficient		
Item	Average	Std. Dev.	Correlation	α		
1	1.287	0.966	0.6340	0.8148		
2	1.443	1.067	0.6746	0.8059		
3	1.212	1.114	0.5325	0.8354		
4	1.452	0.960	0.6580	0.8105		
5	1.146	0.980	0.6199	0.8172		
6	1.357	1.147	0.6261	0.8165		

The tables for Item 1 to Item 6 below give the frequency count for each category of an item as well as the number of missing values for the item in question. Note that Item 4 and Item 6 have one missing value each and that this is reflected in, for example, the differences between the frequency distribution for Item 1 and the corresponding frequency distribution for listwise complete data for Item 1.

Item	Calm						(Back)
1	Category:	0	1	2	3	4	Missing
Frequen	cies:	114	204	143	47	9	0
For listw	vise-complete data:						
Frequen	cies:	114	203	143	46	9	
Average	e (wtd) Score:	3.30	6.85	10.26	14.83	16.78	
Std. Dev	/. (wtd) Score:	2.61	2.99	3.35	3.33	5.12	

Each of the tables also contains a set of average scores and standard deviations. Those are the average and standard deviations for the summed score (totaled over all items) for the subsets of persons that selected each response for the item reported in a table. "Good" graded items should have higher average summed scores associated with higher-numbered responses.

Item	Tense						(Back)
2	Category:	0	1	2	3	4	Missing
Frequencie	S:	104	188	131	77	17	0
For listwise							
Frequencie	s:	104	188	130	77	16	
Frequencies: Average (wtd) Score:		2.87	6.41	9.82	13.18	17.00	
Std. Dev. (v	wtd) Score:	2.44	2.50	3.38	3.29	3.27	
ltem	Regretful						(Back)
3	Category:	0	1	2	3	4	Missing
Frequencie	S:	162	178	99	60	18	0
For listwise	-complete data:						
Frequencie	S:	162	178	97	60	18	
Average (w	rtd) Score:	4.20	7.66	9.70	13.15	16.22	
Std. Dev. (wtd) Score:		3.08	3.19	3.98	3.41	3.86	
Item	AtEase						(Back)
4	Category:	0	1	2	3	4	Missing
Frequencies:		84	195	163	66	8	1
For listwise	-complete data:						
Frequencie	s:	84	195	163	65	8	
Average (w	rtd) Score:	2.49	6.24	9.83	13.85	17.25	
Std. Dev. (v	wtd) Score:	2.23	2.72	3.29	3.54	5.70	
Item	Anxious						(Back)
5	Category:	0	1	2	3	4	Missing
Frequencie	s:	153	196	111	54	3	0
For listwise	-complete data:						
Frequencie	s:	152	196	110	54	3	
Average (w	rtd) Score:	3.64	7.64	10.92	14.06	19.00	
Std. Dev. (v	wtd) Score:	2.82	2.93	3.52	3.89	2.65	
Item	Nervous						(Back)
6	Category:	0	1	2	3	4	Missing
Frequencies:		140	169	112	73	22	1
For listwise-complete data:							
Frequencie	s:	140	168	112	73	22	
Average (w	rtd) Score:	3.46	6.97	10.10	12.77	15.86	
Std. Dev. (v	wtd) Score:	2.47	2.79	3.54	3.25	4.14	

The summary of data below shows that the sample size (before list wise deletion) equals 517 and that the traditional statistics analysis is based on six items.

Summary of the Data and Control Parameters (Back to TOC)

Sample Size517Number of Items6

5. Unidimensional analysis

5.1 Unidimensional analysis of four "self monitoring" items

Thissen & Steinberg (2009) describe IRT model fitting for the responses of 393 undergraduate students to four items of the Self-Monitoring Scale (SMS; Snyder, 1974; modified by Snyder and Gangestad, 1986). The data used is from the 1988 "Self-Monitoring Scale (CAPS-SELFMON, SELF_MONIT and SELF_MONIT_PAPER module)", hdl:1902.29/CAPS-SELFMON Odum Institute Dataverse. They consider a subset of the data for the following four items:

- SelfMon8: I have considered being an entertainer. (T)
- SelfMon13: I have never been good at games like charades or improvisational acting. (F)
- SelfMon18: I would probably make a good actor. (T)
- SelfMon20: In different situations and with different people, I often act like a very different person. (T)

The high self-monitoring response to each of the items above (T or F in parentheses after each item) is coded 1 and the other response is coded 0.

To begin, we use the **Open** file dialog under the **File** menu of IRTPRO and navigate to the **C:\IRTPRO Examples\By Dataset\SelfMonitoring** folder. However, here we change the **Files of type:** selection from its default **IRTPRO Command File (*.irtpro)** to **IRTPRO Data File (*.ssig)** in the open file dialog, and open the file **SelfMon4.ssig**.

🔀 Open				X
Look <u>i</u> n:	👢 SelfMonitoring	•	G 🤌 🖡	۶ ◄
Recent Places	Name SelfMon4.ssig			Date modified 2/11/2011 9:55 AM
Computer Network	 ✓ File name: Files oftype: 	III SelfMon4.ssig IRTPRO Data File (*.ssig) Open as read-only		Open Cancel

The first 15 cases of this data are shown below.

🔀 IRTE	🔀 IRTPRO - [SelfMon4.ssig]									
Eile Edit Data Manipulate Graphics Analysis										
<u>V</u> iew	View Window Help – 🖻 🗙									
D 🚅 🖬 X 🖻 🛍 🍜 💡										
	SelfMon8	SelfMon13	SelfMon18	SelfMon20 🔺						
1	0	1	0	1 🗉						
2	0	0	1	1						
3	1	1	1	1						
4	1	1	1	1						
5	0	0	0	1						
6	1	0	0	0						
7	0	1	0	1						
8	0	0	0	0						
9	0	0	0	1						
10	0	1	1	1						
11	1	1	0	1						
12	0	1	0	0						
13	0	1	0	1						
14	1	0	0	1						
15	0	0	0	1 -						
•		111		4						
Ready										

To set up the analyses, select the **Unidimensional IRT**... option from the **Analysis** menu to invoke the unidimensional analysis widow.

Ana	Analysis View Window Help						
	Traditional Summed-Score Statistics						
	Unidimensional IRT						
	Multidimensional IRT IRT Scoring						
✓	Advanced Options Advanced Show Progress Box						

This window has five tabs called **Description**, **Group**, **Items**, **Models** and **Scoring**. Start with the default tab **Description** and provide a title and comments in the appropriate text boxes as shown below. Note that the default name for the current analysis is Test1. As will be shown later, more tests based on the same dataset may be inserted and each of these can be renamed to something that may be more suitable. In the present case, right-click on the Test1 tab and rename it to 2PL.

Unidimensional Analysis	x
Data File: C:\IRTPRO 2 Examples\By Dataset\SelfMonotoring\SelfMon4.ssig	
2PL	
Description Group Items Models Scoring	
<u>T</u> itle:	
Four Self Monitoring Items	
<u>C</u> omments:	
2PL fited to each item, moderate BAEM controls	
Options OK Cancel Run	

Since this data contains no grouping variable, the **Group** tab is skipped and we proceed to the **Items** tab, where all four items from the **List of variables** are selected. Then use the **Add** button to list these items under **Items**.

Unidimension	nal Analysis				X
Data File:	C:\IRTPRO 2 I	Examples\B) Items Mo Single Grou	r Dataset\SelfMonotoring\S dels Scoring p Analysis	SelfMon4.ssig	Read file
<u>G</u> ro	uping value:	No Group \	/ariable	Thomas	▼
List Se Se Se	elfMon8 elfMon13 elfMon18 elfMon20		Add >>	SelfMon8 SelfMon13 SelfMon18 SelfMon20	▲ ↓ ups
Options				ОК Са	ancel

Because the **2PL** model is the default for dichotomous items, the entry of information for the analysis is now complete, and clicking on the **Run** button in the lower right of the **Unidimensional Analysis** dialog will produce the results. However, to see more details of how the data will be modeled, selection of the **Models** tab shows the list of items, their data codes, the translation of those codes into response categories, and the model selected:

Unidimensio	nal Analysis						X
<u>D</u> ata File:	C:\IRTPRO 2 E	kamples\By D	ataset\SelfM	onotoring\Self	Mon4.ssig	R	ead file
2PL							
Descri	ption Group I	tems Mode	Is Scoring				
Gro	uning value:	la Casua Mar	is la la				
<u></u>		vo Group var	IdDie				
	Item List	Categories	Data Code	Item Score	Model		
	SelfMon8	2	0, 1	0, 1	2PL		
	SelfMon13	2	0, 1	0, 1	2PL		
	SelfMon18	2	0, 1	0, 1	2PL		
	SelfMon20	2	0, 1	0, 1	2PL		
2	Constraints	<u>D</u> IF				Apply to all group	5
Options				(ОК	Cancel	Run

Click the **Run** button to run the 2PL analysis. Portions of the output file **SelfMon4.2PL-irt.htm** are shown below. We find that the slope parameter for item 2 is estimated to be much lower than those for the other three items:

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

Item	Label	а		s.e.	С		s.e.	b	s.e.
1	SelfMon8	2	4.12	1.37	1	-0.09	0.28	0.02	0.07
2	SelfMon13	4	0.12	0.13	3	0.49	0.10	-4.23	4.67
3	SelfMon18	6	2.41	0.46	5	-0.91	0.22	0.38	0.08
4	SelfMon20	8	2.02	0.34	7	0.89	0.19	-0.44	0.09

Note that the values in the table above are not exactly the same as those reported by Thissen & Steinberg (2009) for two reasons: (1) Thissen & Steinberg (2009) tabulate the slopes divided by 1.7, or in the so-called "normal metric", to compare to normal ogive slopes, and (2) even if that is corrected, there are slight numerical differences between the results, due to different numerical quadrature used for the Newton-Raphson estimation in R that Thissen & Steinberg (2009) used vs. the EM estimation used here in IRTPRO.

If we click on the entry Likelihood-based Values and Goodness of Fit Statistics in the table of

contents for this 2PL fit to these items, we find that the model appears to fit very well:

Statistics based on the full item x item x classification						
G ²	Degrees of freedom	Probability	RMSEA			
5.03	7	0.6570	0.00			
Statist	ics based on one	- and two-way margin	al tables			
M_2	Degrees of freedom	Probability	RMSEA			
3.17	2	0.2063	0.04			
Note: M_2 is based on full marginal tables.						
Note:	Note: Model-based weight matrix is used.					

The statistics based on the full item classification can rarely be computed in applications IRT, because they require that the sample is sufficiently large to "fill" all of the cells of crossclassification created by listing all response patterns. For four dichotomous items, that is a manageable 16 cells, and so IRTPRO tabulates the observed and expected frequencies (and some other values) for each response pattern as follows:

Response Pattern Observed a	nd Expected Frequencies,	, Standardized Residuals	, EAPs and SDs for
Group 1 (Back to TOC)			

Item	า:			Frequ	iencies	Standard		
1	2	3	4	Obse	rved Expecte	d Residual	EAP[θ u]	SD[θ u]
0	0	0	0	44	44.72	-0.11	-1.07	0.65
0	0	0	1	25	25.07	-0.01	-0.44	0.49
0	0	1	0	4	3.55	0.24	-0.35	0.47
0	0	1	1	4	6.35	-0.94	0.04	0.43
0	1	0	0	65	64.87	0.02	-1.02	0.63
0	1	0	1	40	39.11	0.15	-0.41	0.48
0	1	1	0	6	5.60	0.17	-0.33	0.46
0	1	1	1	12	10.48	0.48	0.06	0.43
1	0	0	0	7	5.90	0.45	-0.02	0.43
1	0	0	1	25	20.10	1.12	0.36	0.46
1	0	1	0	2	3.88	-0.96	0.44	0.47
1	0	1	1	38	39.42	-0.24	1.02	0.62
1	1	0	0	9	9.67	-0.22	0.00	0.43
1	1	0	1	29	34.44	-0.97	0.39	0.46
1	1	1	0	8	6.72	0.50	0.47	0.48
1	1	1	1	75	73.10	0.25	1.07	0.63

The G^2 value (5.03, on 7 d.f.) reported above is obtained by using the likelihood-ratio chi-square to compare the observed and expected frequencies in that table. In this case, those values do not differ by more than is expected by sampling error.

For scales that involve more items, or more response categories, the complete cross-classification is often too large to "fill"; for example, for 6 five-alternative items the full cross-classification

would have $5^6 = 15,625$ cells, which can only be sparsely populated by a few hundred respondents. So in that case, as well as this one, an updated version of the M_2 statistic proposed by Maydeu-Olivares & Joe (2005, 2006) may be used as a proxy for G^2 . The M_2 statistic is based on the oneand two-way marginal tables of the complete cross-classification; those subtables are easier to "fill" with reasonable sample sizes.

IRTPRO can also compute a trace line diagnostic statistic for each item, which is a generalization for polytomous responses of the $S \cdot X^2$ item-fit statistic suggested by Orlando & Thissen (2000, 2003). For the 2PL fit to these four items, these statistics are tabulated as shown in the following table.

S-X2 Item Level Diagnostic Statistics

Item	Label	X ²	d.f.	Probability
1	SelfMon8	0.51	2	0.7748
2	SelfMon13	0.23	2	0.8909
3	SelfMon18	1.86	2	0.3950
4	SelfMon20	0.23	2	0.8902

The summary table (above) indicates that for all four of these items, the trace lines have been fitted sufficiently well that the model-expected proportions responding 0 and 1 match the observed data well.

For each item, the complete tables printed below have one row for each summed score for the "other items" (for each of these four items, the summed score on the "other items" ranges (0 - 3), and within those scores the observed and expected frequencies are tabulated. The entries are printed in blue if the observed frequency exceeds the expected frequency, and in red if too few responses are observed.

Item 1 S-X2(2) = 0.5 , p = 0.7748 (Back)

	Category 0	Ca	ategory 1	
Score	Observed Ex	kpected Ob	oserved B	Expected
0	44	45.1	7	5.9
1	94	95.6	36	34.4
2	50	48.5	75	76.5
3	12	10.9	75	76.1

Item 2 S-X2(2) = 0.2 , p = 0.8909 (Back)

	Category 0)	Category	1
Score	Observed	Expected	Observed	Expected
0	44	44.5	65	64.5
1	36	35.3	55	55.7
2	31	29.6	49	50.4
3	38	39.6	75	73.4

Item 3 S-X2(2) = 1.9 , p = 0.3950 (Back)

	Category 0	Ca	ategory 1	
Score	Observed Ex	kpected Ob	oserved I	Expected
0	44	44.5	4	3.5
1	97	93.5	12	15.5
2	74	72.4	58	59.6
3	29	33.3	75	70.7

Item 4 S-X2(2) = 0.2 , p = 0.8902 (Back)

	Category 0	Ca	Category 1		
Score	Observed Ex	xpected OI	oserved I	Expected	
0	44	44.2	25	24.8	
1	76	77.0	69	68.0	
2	17	17.8	79	78.2	
3	8	7.0	75	76.0	

The tables shown above illustrate good fit. In cases in which the model fits poorly, deviations between observed and expected may be large, and there may be long "runs" of red (or blue) in columns, as the trace line is "over" or "under" due to some model misspecification. (The latter can really only be observed in longer tests.)

Because the "full tables" for $S-X^2$ can be very large, printing them is optional. Printing of optional results is control by clicking the **Options** button (bottom left-hand corner of the **Unidimensional Analysis** window) and then selecting the **Advanced Options**, **Miscellaneous** dialog:

Advanced Options
Test: 2PL Apply to all tests
Estimation Starting Values Priors Miscellaneous Save Simulate
Number of decimal places in tabular
Number of processors: 4
Print table of standardized residuals
Compute Chen-Thissen LD and item fit statistics
Compute limited-information overall model fit statistics
✓ Print each item's goodness of fit frequency table
Minimum <u>e</u> xpected 1
Print factor loadings
Print parameter numbers
Print diagnostic information
Print dump file
OK Cancel <u>Apply</u>

5.2 Hybrid model fitted to Eysenck Extraversion Scale data

To illustrate the way the 1PL and 2PL models fit data, and their use in item analysis, we consider the responses to a subset of items from the Eysenck Personality Inventory Form A Extraversion scale (Eysenck and Eysenck, 1969). Responses of 189 undergraduate students to nine items are used to illustrate models in this section. The Extraversion scale has been divided into two subscales by Revelle, Humphreys, Simon, and Gilliland (1980). The items under consideration comprise the "impulsivity" subscale and are shown below. The response (yes or no) is keyed in the direction of impulsivity.

Item		
#	Question	Key
10	Would you do almost anything for a dare?	Y
5	Do you stop and think things over before doing anything?	Ν
8	Do you generally do and say things quickly without stopping to think?	Y
22	When people shout at you, do you shout back?	Y
9	Do you like doing things in which you have to act quickly?	Y
13	Do you often do things on the spur of the moment?	Y
3	Are you usually carefree?	Y
1	Do you often long for excitement?	Y
41	Are you slow and unhurried in the way you move?	Ν

The item response data are from the *Computer Administered Panel Survey* (CAPS), a survey sponsored by the Odum Institute for Research in Social Science at the University of North Carolina at Chapel Hill. Approximately 100 undergraduates participated in the study, which involved responding to a large number of questionnaires via computer terminals. Data are available for each academic year between 1983-84 and 1987-88.

The Eysenck Personality Inventory was among the scales administered in 1987 and 1988. The data (for all of the questionnaires) remain publicly available at the Odum Institute's website. In this section, we use the data for the two academic years 1987 and 1988⁴ to illustrate the models of interest here.

Below is an IRTPRO spreadsheet presentation of the data showing the first 15 cases for the items eys1 to eys10.

🔀 IRT	IRTPRO - [Eysenck87-items1_57.ssig]										
📑 <u>E</u> il	『 <u>F</u> ile <u>E</u> dit <u>D</u> ata <u>M</u> anipulate <u>G</u> raphics <u>A</u> nalysis <u>V</u> iew <u>W</u> indow <u>H</u> elp _ <i>■</i> ×										
0 🖻											
	eys1	eys2	eys3	eys4	eys5	eys6	eys7	eys8	eys9	eys10	
1	1	1	2	1	1	1	1	2	2	2	Ξ
2	1	1	1	1	2	1	1	1	1	2	
3	1	1	1	1	1	2	1	2	2	2	
4	1	2	1	2	1	1	2	2	2	2	
5	1	1	1	2	2	1	1	2	2	2	
6	1	1	1	2	1	1	1	1	1	1	
7	1	1	1	1	1	1	1	1	1	1	
8	2	1	1	2	1	1	1	1	2	1	
9	1	2	1	2	1	1	2	2	2	2	
10	1	1	1	2	1	1	1	2	1	2	
11	1	1	1	2	1	1	2	2	1	2	
12	1	1	1	1	2	2	1	1	1	2	
13	1	1	1	2	1	2	1	2	1	2	
14	1	1	1	2	1	1	1	1	1	1	
15	2	1	1	1	2	2	2	1	2	2	~
•	111									•	
										NUM	

4 Data from the 1988 "Eysenck Personality Inventory Form A (CAPS-EYSENCK module)", http://hdl.handle.net/1902.29/CAPS-EYSENCK Odum Institute [Distributor] V1 [Version].

5.2.1 The 2PL Model

IRT item analysis for these data begins with fitting the 2PL model. In this example, use is made of the IRTPRO data file stored as **Eysenck87-items1_57.ssig** in the folder **IRTPRO Examples\By Dataset\Impulsivity**.

From the main menu bar, we select the **Analysis**, **Unidimensional IRT**... option. Click on the righthand side of the **Test1** tab and insert a second test. Next right-click on the **Test1** tab and rename it to **2PL-9Items**. Likewise, rename the **Test2** tab to **1PL-9Items**. Starting with the **2PL-9Items** tab, fill in a title and optional comments on the **Description** window, then select the **Items** tab and select the items Eys1, Eys3, Eys8, Eys10, Eys13, Eys22, Eys39, Eys5 and Eys41.

Data File: C:\IRTPRO 2 Examples\By Dataset\Impulsivity\Eys 2PL-9items 1PL-9items IPL-9items Hybrid Description Group Items Models Single Group Analysis Grouping value: No Group Variable List of variables: eys1 eys2 eys4	enck87-items1_57.ssig Items: eys1 eys1 eys8 eys0	Read file
eys5 eys6 eys7 eys8 eys9 € €	eys13 eys22 eys39 eys5 eys41 Apply to all groups	Run

By clicking on the **Models** tab of the **Unidimensional Analysis** window, the list of items selected and model type is displayed. In the IRTPRO data, 1 = Yes and 2 = No. Therefore, (see Section 5.2) all of the items except Eys5 and Eys41 need to be reverse keyed on the Models dialog. The recoding is accomplished by selecting the first seven cells in the **Item Score** column. Right-click on any of the selected cells and then click the **Recode Item Scores...** option.

Unidimensiona	l Analysis		1			×			
Data File: C	Data File: C:\IRTPRO 2 Examples\By Dataset\Impulsivity\Eysenck87-items1_57.ssig Read file								
2PL-9items	1PL-9items	Hybrid							
E E									
Descriptio	on 🛛 Group 🗍 I	tems Model	s Scoring						
Group	ing value: 📊	lo Croup Var	iablo						
					, .	•			
	Item List	Categories	Data Codes	item Score	Model				
	eys1	2	1, 2	0,1	2PL				
	eys3	2	1, 2	0, 1	2PL				
	eys8	2	1, 2	0, 1	2PL				
	eys10	2	1, 2	0, 1	2PL				
	eys13	2	1, 2	0, 1	Recode Item	n Scores			
	eys22	2	1, 2	0, 1	21 6				
	eys39	2	1, 2	0, 1	2PL				
	eys5	2	1, 2	0, 1	2PL				
	eys41	2	1, 2	0, 1	2PL				
Con	nstraints	DIF				Apply to all groups			
Options					ОК	Cancel Run			

Selection of the **Recode Item Scores** ... option results in the display of the **Item's Codes and Scores** dialog where the **Item Scores** are changed in accordance with the answer key.

Iter	Item's Codes and Scores								
	Item: eys1								
	Data Codes	Item Scores	ОК						
	1	1	Cancal						
	2	0	Calicer						
	•	4							

When done, click **OK** to obtain the revised **Models** dialog shown next.

Unidimensiona	al Analysis	-	1.1		-		x		
Data File: C:\IRTPRO 2 Examples\By Dataset\Impulsivity\Eysenck87-items1_57.ssig									
2PL-9items 1PL-9items Hybrid									
Descript	ion 🛛 Group 🗍 I	items Mode	sScoring						
<u>G</u> rou	ping value:	No Group Var	iable			•			
	Item List	Categories	Data Codes	Item Score	Model				
	eys1	2	1, 2	1, 0	2PL				
	eys3	2	1, 2	1, 0	2PL				
	eys8	2	1, 2	1, 0	2PL				
	eys10	2	1, 2	1, 0	2PL				
	eys13	2	1, 2	1, 0	2PL				
	eys22	2	1, 2	1, 0	2PL				
	eys39	2	1, 2	1, 0	2PL				
	eys5	2	1, 2	0, 1	2PL				
	eys41	2	1, 2	0, 1	2PL				
Constraints DIF Apply to all groups									
Options]			(ОК	Cancel Rur	1		

In this example, as in Section 5.1, we use the implementation of the Bock-Aitkin (1981) EM algorithm to compute the maximum likelihood (ML) estimates of the parameters. By clicking the **Options** button (see left bottom above), the **Advanced Options** window is displayed. The default display is the estimation settings, shown below. One can use this dialog to set convergence criteria to values deemed suitable for a given analysis.

st: 2PL-9items		 Apply to all tests
stimation Starting	J Values Priors Miscellane	Dus Save Simulate
Estimation	Bock-Aitkin	T
<u>C</u> onverge inform	ation	
Maximum nur	nber of <u>cy</u> cles 500	Convergence criterion: 1e-005
<u>M</u> -Step maxin	num iterations 50	Convergence criterion: 1e-006
<u>Q</u> uadrature deta	ils	
Number of	49	Ma <u>x</u> imum value: 6
<u>S</u> tandard	S-EM 🔻	Apply dimension reduction
		Group Gen Dim
Default		Single Group 1

Click **OK** to close the **Advanced Options** window, and then click the **Run** button to start the estimation procedure.

A selection of parts of the output is listed below. The first part shown lists the item parameter estimates for the 2PL model. The a (slope, or discrimination) parameter estimates vary from 0.13 up to 3.7. However, we note that the corresponding standard errors vary from 0.19 up to 7.13; such large values are attributable to the small sample size (for IRT), less than 200 respondents.

Item	Label	а	s.e.	c s.e.	b	s.e.
1	eys1	2 1.18	0.37	1 1.99 0.34	-1.68	0.39
2	eys3	4 0.75	0.41	3 1.24 0.21	-1.65	0.81
3	eys8	6 1.07	0.36	5 -0.43 0.21	0.40	0.19
4	eys10	8 0.83	0.42	7 -1.68 0.32	2.03	0.79
5	eys13	10 3.70	7.13	9 2.11 3.81	-0.57	0.13
6	eys22	12 0.52	0.24	11 0.19 0.18	-0.37	0.42
7	eys39	14 0.76	0.27	13 0.60 0.21	-0.79	0.41
8	eys5	16 0.82	0.39	15 -1.60 0.37	1.95	0.66
9	eys41	18 0.13	0.19	17 0.56 0.16	-4.16	6.04

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

Summed-Score Based Item Diagnostic Tables and X^2 s for Group 1 (Back to TOC)

S-X2 Item Level Diagnostic Statistics

Item	Label	X^2	d.f.	Probability
1	eys1	7.66	5	0.1757
2	eys3	10.66	5	0.0584
3	eys8	11.29	5	0.0458
4	eys10	3.59	5	0.6111
5	eys13	6.63	3	0.0844
6	eys22	9.74	6	0.1359
7	eys39	14.92	5	0.0107
8	eys5	12.15	5	0.0327
9	eys41	13.29	5	0.0208

The value of the M_2 goodness-of-fit statistic (Maydeu-Olivares & Joe, 2005, 2006; Cai, Maydeu-Olivares, Coffman, & Thissen, 2006) reported in the printout below indicates some lack of fit (M_2 =47.45, 27 *d.f.*, p = 0.009); however the associated RMSEA value (0.06) suggests this may be due to a limited amount of "model error"; there must be some error in any strong parametric model.

Likelihood-based Values and Goodness of Fit Statistics (Back to TOC)

Statistics based on the loglikelihood	
-2loglikelihood:	1918.13
Akaike Information Criterion (AIC):	1954.13
Bayesian Information Criterion (BIC):	2012.48

Statistics based on the full item x item x ... classification The table is too sparse to compute the general multinomial goodness of fit statistics.

Statistics based on one- and two-way marginal tables							
M_2	Degrees of freedom	Probability	RMSEA				
47.45	27	0.0088	0.06				
Note: N	Note: M_2 is based on full marginal tables.						
Note: Model-based weight matrix is used.							

Before interpreting the variability among the slopes as indicative of reliable differences among the items' association with the latent variable being measured (impulsivity), we fit the 1PL model to the data to use the difference between the goodness of fit of the two models to compute a test of significance of the variation among the 2PL slopes.

5.2.2 The 1PL Model

By closing the output file with extension .htm we return to the Analysis option on the main menu bar and click on the 1PL-9items tab. Start with the Description tab and enter a title and comments.

Unidimensional Analysis
Data File: C:\IRTPRO 2 Examples\By Dataset\Impulsivity\Eysenck87-items1_57.ssig
2PL-9items 1PL-9items
Description Group IItems Models Scoring
<u>T</u> itle:
1PL-9items
<u>C</u> omments:
1PL model fitted to each of the nine items. This is accomplished by constraining all the slope parameters to be equal.
Qptions OK Cancel Run

Select the same nine items that were chosen for the 2PL model and then click the **Models** tab and recode the first seven items as discussed in the previous section:

Unidin	nensional	Analysis	_					X		
<u>D</u> ata	a File: C	(IRTPRO 2 E	kamples\By D	ataset\Impuls	ivity\Eysenck8	87-items1_57.	.ssig <u>R</u> ead fil	e		
2PI	2PL-9items 1PL-9items Hybrid									
	Descriptio	on Group I	tems Mode	Scoring						
	<u>G</u> roup	ing value:	No Group Var	iable			•			
		Item List	Categories	Data Codes	item Score	Model				
		eys1	2	1, 2	1, 0	2PL				
		eys3	2	1, 2	1, 0	2PL				
		eys8	2	1, 2	1, 0	2PL				
		eys10	2	1, 2	1, 0	2PL				
		eys13	2	1, 2	1, 0	2PL				
		eys22	2	1, 2	1, 0	2PL				
		eys39	2	1, 2	1, 0	2PL				
		eys5	2	1, 2	0, 1	2PL				
		eys41	2	1, 2	0, 1	2PL				
	Con	straints	<u>D</u> IF				Apply to a <u>l</u> l groups			
<u>O</u> p	otions				(ОК	Cancel	un		

In the **Models** window, click the **Constraints...** button to obtain the **Item Parameter Constraints** window shown below. Next, select all nine items by clicking on them while holding down the **Shift** or **Control** key and right-clicking from any of the selected cells.

m a 1 c 2 s1 a 1 c 2 s3 a 3 c 4 s8 a 5 c 6 10 a 7 c 8 13 a 9 c 10 22 a 11 c 12 39 a 13 c 14 5 a 15 c 16 Fix Value	p: Single Group Item a 1 c 2 eys1 a 1 c 2 eys3 a 3 c 4 eys8 a 5 c 6 eys10 a 7 c 8 eys13 a 9 c 10 eys2 a 11 c 12 eys39 a 13 c 14 eys4 Set Parameters Equal Mea Fix Value ovaria Set Parameters Free	Item Param	eter Cons	traints	
m a c s1 a 1 c s3 a 3 c s8 a 5 c 10 a 7 c 13 a 9 c 10 a 7 c 13 a 9 c 10 a 7 c 13 a 9 c 22 a 11 c 39 a 13 c 4 5 a 15 5 a 15 c 4 Set Parameters Equal	Item a 1 eys1 a 1 c eys3 a 3 c 4 eys8 a 5 c 6 eys10 a 7 c 8 eys13 a 9 c 10 eys22 a 11 c 12 eys3 a 15 c 16 eys4 Set Parameters Equal Mean Fix Value ovaria Set Parameters Free	oup: Sinale	Group		
m o s1 a 1 c 2 s3 a 3 c 4 s8 a 5 c 6 10 a 7 c 8 13 a 9 c 10 22 a 11 c 12 39 a 13 c 14 5 a 15 c 16 Fix Value	Item a 1 c 2 eys1 a 1 c 2 eys3 a 3 c 4 eys8 a 5 c 6 eys10 a 7 c 8 eys13 a 9 c 10 eys22 a 11 c 12 eys39 a 13 c 14 eys4 Set Parameters Equal 10 Mean Fix Value Set Parameters Free	,			
a1 c 2 s3 a 3 c 4 s8 a 5 c 6 10 a 7 c 8 13 a 9 c 10 22 a 11 c 12 39 a 13 c 14 s5 a 15 c 16 Fix Value	eys1 a 1 c 2 eys3 a 3 c 4 eys8 a 5 c 6 eys10 a 7 c 8 eys13 a 9 c 10 eys22 a 11 c 12 eys39 a 15 c 16 eys4 Set Parameters Equal Fix Value Set Parameters Free parameters equal across groups parameters equal across groups Fix Value	Item			
a3 a 3 c 4 s8 a 5 c 6 10 a 7 c 8 13 a 9 c 10 22 a 11 c 12 39 a 13 c 14 5 a 15 c 16 4 Set Parameters Equal 16 16 9 Fix Value 16 16	eys3 a 3 c 4 eys8 a 5 c 6 eys10 a 7 c 8 eys13 a 9 c 10 eys22 a 11 c 12 eys39 a 13 c 14 eys5 a 15 c 16 eys4 Set Parameters Equal Mean Fix Value Set Parameters Free parameters set Parameters Free set Parameters Free set Parameters Free	eys1	a	1 c	2
88 a 5 c 6 10 a 7 c 8 13 a 9 c 10 22 a 11 c 12 39 a 13 c 14 5 a 15 c 16 Fix Value	eys8 a 5 c 6 eys10 a 7 c 8 eys13 a 9 c 10 eys22 a 11 c 12 eys39 a 13 c 14 eys4 Set Parameters Equal Mea Fix Value ovaria Set Parameters Free Set Parameters Free	eys3	a	3 c	4
10 a 7 c 8 13 a 9 c 10 22 a 11 c 12 39 a 13 c 14 5 a 15 c 16 Fix Value	eys10 a 7 c 8 eys13 a 9 c 10 eys22 a 11 c 12 eys39 a 13 c 14 eys5 a 15 c 16 eys4 Set Parameters Equal Meaa Fix Value varia	eys8	а	5 c	6
13 a 9 c 10 22 a 11 c 12 39 a 13 c 14 5 a 15 c 16 Fix Value	eys13 a 9 c 10 eys22 a 11 c 12 eys39 a 13 c 14 eys5 a 15 c 16 eys4 Set Parameters Equal Mea Set Parameters Free	eys10	а	7 c	8
22 a 11 c 12 39 a 13 c 14 5 a 15 c 16 4 Set Parameters Equal Fix Value	eys22 a 11 c 12 eys39 a 13 c 14 eys5 a 15 c 16 eys4 Set Parameters Equal Mea Fix Value ovaria Set Parameters Free	eys13	а	9 c	10
39 a 13 c 14 55 a 15 c 16 4 Set Parameters Equal Fix Value	eys39 a 13 c 14 eys5 a 15 c 16 eys4 Set Parameters Equal Mea Fix Value ovaria Set Parameters Free	eys22	а	11 c	12
Set Parameters Equal	eyss a 15 c 16 eyss Set Parameters Equal Mear Fix Value ovaria Set Parameters Free	eys39	а	13 c	14
Set Parameters Equal Fix Value	eyse Set Parameters Equal Mear Fix Value ovaria Set Parameters Free parameters equal across groups	eys5	а	15 c	16
Fix Value	Mea Fix Value varia Set Parameters Free parameters equal across groups	eys4	Set Pa	ramete	rs Equal
	varia Set Parameters Free	Mear	Fix Va	lue	
Set Parameters Free	arameters equal across groups	/aria	Set Pa	ramete	s Free
beer arameters nee	parameters equal across groups	_	Jetru	i anne tei	onee
	parameters equal across groups				
	<u></u>	Set paramete	ers equal a	cross are	oups
meters equal across groups				gr	
meters equal across groups					

From the drop-down menu, select **Set Parameters Equal** to obtain the required constraints on the nine slope parameters.

Group: Single Gro	up				
Item					
eys1	а	13	с	2	
eys3	а	13	с	4	
eys8	а	13	с	6	
eys10	a	13	с	8	
eys13	a	13	с	10	
eys22	a	13	с	12	
eys39	a	13	с	14	
eys5	а	13	с	16	
eys41	а	13	с	18	
Means	μ1	0.0			
Covariances	σ1 1	1.0			
				_	
Set parameters e	equal a	cross	group	s	

As shown below, the ML estimate of the (single, common, equal) a parameter for all nine items is 0.83, with a standard error of 0.10; the standard error has become much smaller than the slope standard errors for the 2PL model because the data from all nine items is used to estimate the single common slope.

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

Item	Label	а	s.e.	С	s.e.	b	s.e.
1	eys1	9 0.83	0.10	1 1.80	0.22	-2.16	0.34
2	eys3	9 0.83	0.10	2 1.26	0.19	-1.52	0.27
3	eys8	9 0.83	0.10	3 -0.40	0.17	0.49	0.21
4	eys10	9 0.83	0.10	4 -1.68	3 0.20	2.02	0.32
5	eys13	9 0.83	0.10	5 0.93	0.18	-1.12	0.24
6	eys22	9 0.83	0.10	6 0.21	0.16	-0.25	0.20
7	eys39	9 0.83	0.10	7 0.61	0.17	-0.73	0.21
8	eys5	9 0.83	0.10	8 -1.60	0.20	1.93	0.31
9	eys41	9 0.83	0.10	10 0.64	0.17	-0.77	0.21

Summed-Score Based Item Diagnostic	Tables and X2s for Group 1	(Back to TOC)
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S-X2 Item Level Diagnostic Statistics

Item	Label	X^2	d.f.	Probability
1	eys1	5.93	5	0.3144
2	eys3	10.53	5	0.0614
3	eys8	12.54	6	0.0509
4	eys10	3.83	5	0.5747
5	eys13	16.27	5	0.0061
6	eys22	11.41	5	0.0437
7	eys39	14.94	5	0.0106
8	eys5	11.70	5	0.0390
9	eys41	25.41	5	0.0001

The primary purpose of fitting the 1PL model is to obtain the value of -2loglikelihood to use with the corresponding value from the 2PL fit to test the significance of the variation among the a parameters in the 2PL model.

Likelihood-based Values and Goodness of Fit Statistics (Back to TOC)

Statistics based on the loglikelihood	
-2loglikelihood:	1943.71
Akaike Information Criterion (AIC):	1963.71
Bayesian Information Criterion (BIC):	1996.13

For these data, the likelihood ratio test of the significance of variation among the slope parameters is computed as the difference between -2loglikelihood for the 1PL and 2PL models, 1943.71 - 1918.13 = 25.58, which is distributed as χ^2 on 8 d.f., p = 0.0012. The significance of that test statistic leads to the conclusion that there is some reliable difference in discrimination for these nine items; further data analysis can be used to identify that variation.

Under the hypothesis of perfect model fit, the $S-X^2$ statistics are approximately distributed as χ^2 values with the tabulated degrees of freedom; significant values indicate lack of fit. Because a very strong model such as the 2PL rarely fits perfectly, one expects some (slightly) significant values, because the model is not perfect. The statistics tabulated for the 2PL fit illustrate this point: Four of the nine values are significant at the p = 0.05 level; however, none have p < 0.01. For the 1PL model, however, the value of the S-X² for item 41 is very large: 25.41 on 5 d.f., p < 0.0001. That value suggests that closer inspection of the underlying frequency table is warranted.

We notice that the reason for the large value of the $S-X^2$ diagnostic statistic for this item is that for low summed scores on the other items (0-4), we observe more "no" responses than expected, while for higher summed scores on the other items (5-8) we observe more "yes" responses than expected. This pattern suggests that the 1PL fitted value of the slope (a) parameter for item 41 is too high, producing expected values that are too high for low scores, and too low for high scores. Having noted this large S-X² diagnostic statistic for this item, with the pattern of observed and expected values, and also that item 41 has (by far) the lowest estimated a parameter for the 2PL fit, we re-fit the data with a special model that is a hybrid between the 1PL and 2PL models.

5.2.3 A Special Model with Equality Constraints

The special hybrid model imposes the constraint that the *a* parameters are equal for all of the items except eys41; however, it permits eys41 to have its own slope estimate, which is lower.

Select the **Analysis**, **Unidimensional IRT**... option and right-click next to the **1PL-9items** tab to insert a **Test3** tab. Right-click on this tab and rename it to **Hybrid**. Select the same nine items that were used in Sections 5.2.1 and 5.2.2.
Unidimensional Analysis Data File: C:\JRTPRO 2 2PL-9items 1PL-9items Description Grouping value:	Examples\By Data Hybrid Items Models Single Group Ana No Group Variabl	set\Impulsivity\Eysen Scoring	ck87-items1_57.ssig	Read file
List of variables: eys37 eys38 eys39 eys40 eys41 eys42 eys43 eys44 eys45 		<u>A</u> dd >>	Items: eys1 eys3 eys8 eys10 eys13 eys22 eys39 eys5 eys41 Apply to all group	× +
Options			OK Car	icel Run

Proceed to the **Models** tab and recode the item scores of the first seven items from (0,1) to (1,0). See Section 5.2.1 where the steps to do the recoding is discussed. Click the **Constraints...** button to obtain the following display.

Inidimensior	nal Analysis								X	
Data File:	C:\IRTPRO 2 E	kamples∖I	By Dataset\Imp	oulsivity\Eys	enck87-item	s1_57.ssig	Rea	d file		
2PL-9items	1PL-9items	Hybrid								
Descrip	otion Group]	items M	odels Scorin	al						L
	1, · 1,			- 1		Item Parameter	Const	raint	s	
Gro	uping value:	No Group	Variable			Group: Single Grou	μ			
	Item List	Catego	riesData Co	desitem So	ore: M	Itom				
	eys1	2	1, 2	1, 0	2PL	evel	a	1	c	2
	eys3	2	1, 2	1,0	2PL	eysi	a	3	с с	4
	eys8	2	1, 2	1,0	2PL	eyss	a	5	c	- 6
	eys10	2	1, 2	1, 0	2PL	eys0	a	7	c c	8
	eys13	2	1, 2	1, 0	2PL	evs13	a	ý	c	10
	eys22	2	1, 2	1, 0	2PL	evs22	a	11	c	1
	eys39	2	1, 2	1, 0	2PL	evs30	a	13	c	14
	eys5	2	1, 2	0, 1	2PL	evs5	a	15	c	1
	eys41	2	1, 2	0, 1	2PL	evs41	a	17	c	18
_			n			Means	μ1 (0.0	-	
C	onstraints	DIF				Covariances	σ1 1	1.0		
						Set parameters e	equal ac	ross	groups	

In the special model, we want to constrain the slope parameters of the first eight items to be equal, but freely estimate the slope parameter of eys41. To achieve this, select the slope cells of the first eight items, then right-click to obtain the **Set Parameters Equal**, **Fix value**..., or **Set Parameters Free** options.

Itom e	Set Par	ametei	rs Equ	al				
e	Fix Valu	ıe						
e	Set Par	ametei	rs Free	;				
eys13	a	9	c	10				
eys22	a	11	с	12				
eys39	а	13	с	14				
eys5	a	15	с	16				
eys41	a	17	С	18				
Covarian	ces σ1	1.0						

By selecting the **Set Parameters Equal** option, the constraints screen changes to reflect that the first eight items have equal slope and that the slope of the ninth item is estimated freely, as shown below.

Group: Single Grou	qu			
Item				
eys1	a	13	с	2
eys3	а	13	С	4
eys8	а	13	С	6
eys10	а	13	С	8
eys13	а	13	С	10
eys22	a	13	С	12
eys39	a	13	С	14
eys5	а	13	С	16
eys41	a	17	С	18
Means	μ1	0.0		
Covariances	σ1 1	1.0		

The item parameter estimates, standard errors, and goodness of fit statistics for this model are as follows.

Item	Label	а	s.e.	С	s.e.	b	s.e.
1	eys1	⁹ 0.98	0.12	¹ 1.87	7 0.22	-1.92	0.29
2	eys3	⁹ 0.98	0.12	² 1.32	2 0.19	-1.35	0.23
3	eys8	⁹ 0.98	0.12	³ -0.4	2 0.17	0.43	0.18
4	eys10	⁹ 0.98	0.12	⁴ -1.7	5 0.22	1.79	0.27
5	eys13	⁹ 0.98	0.12	⁵ 0.97	7 0.18	-1.00	0.21
6	eys22	⁹ 0.98	0.12	⁶ 0.22	2 0.17	-0.22	0.17
7	eys39	⁹ 0.98	0.12	⁷ 0.64	4 0.18	-0.65	0.19
8	eys5	⁹ 0.98	0.12	⁸ -1.6	67 0.21	1.71	0.27
9	eys41	¹¹ 0.11	0.20	¹⁰ 0.5	5 0.15	-5.26	10.03

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

Summed-Score Based Item Diagnostic Tables and X2s for Group	1 (Back to	TOC	3
buillinea beble basea item blagnostio rabies ana Azsion broup	• •	Buok to	100	1

S-X2 Item Level Diagnostic Statistics

Item	Label	X²	d.f.	Probability
1	eys1	6.23	5	0.2860
2	eys3	10.67	5	0.0582
3	eys8	11.34	5	0.0450
4	eys10	3.43	5	0.6348
5	eys13	13.97	5	0.0157
6	eys22	13.11	5	0.0223
7	eys39	14.94	5	0.0106
8	eys5	12.85	5	0.0247
9	eys41	13.23	5	0.0213

From the S-X² item level diagnostic statistics given above it follows that six of the nine values are significant at the p = 0.05 level. However, none is significant at the p = 0.01 level, suggesting these statistics may indicate real, but negligible, misfit.

Likelihood-based Values and Goodness of Fit Statistics (Back to TOC)

Statistics based on the loglikelihood	
-2loglikelihood:	1931.41
Akaike Information Criterion (AIC):	1953.41
Bayesian Information Criterion (BIC):	1989.07

Likelihood ratio tests indicate that this model fits significantly better than the 1PL model ($\chi^2 = 1943.71 - 1931.41 = 12.3$, 1 d.f., p = 0.0005), but it does not fit significantly worse than the 2PL model ($\chi^2 = 1931.41 - 1918.13 = 12.3$, 7 d.f., p = 0.066). The values of the M₂ overall goodness of fit statistic and its associated RMSEA are approximately the same for this hybrid model as they were for the 2PL model, although the special model estimates seven fewer parameters (2 a's and 9 c's, as opposed to 9 a's and 9 c's). Therefore, the combined considerations of goodness of fit and parsimony suggest the use and interpretation of the special hybrid model.

Inspection of the underlying summed-score by item response tabulations for these statistics

confirms that. The printout below shows the underlying summed-score by item response tabulation for the S-X² item level diagnostic statistics for the special hybrid model fit to eys1 and eys39. The table for item 1 (eys1) shows perfectly good fit, with a non-significant value of S-X². The summedscore by item response table for item 7 (eys39), has a "significant" S-X² value of 14.9 on 5 d.f. (p = 0.0106). We note that even in the table for eys39, the worst-fitting of the nine items, there is no particular tendency for higher observed than expected values to occur in blocks or "runs" that might indicate bad fit of the trace line, as we previously observed with eys41 fitted with the 1PL model.

	Categ	ory (0		Categ	ory 1	
Score	Obser	ved	Exp	ected	Obser	ved Exp	ected
0		l		1.3	2		1.7
1	2	2		2.9	6		5.1
2	9)		8.7	2	2	22.3
3	(3		5.1	1	8	18.9
4	(3		7.7	4	4	42.3
5	7	7		3.6	2	5	28.4
6	1 1		2.1	2.8	2	6	24.9
7	0		0.6		1	1	10.4
8	0		0.1		3		2.9

Item 1 S-X2(5) = 6.2 , p = 0.2860 (Back)

Item 7 S-X2(5) = 14.9 , p = 0.0106 (Back)

	Ca	tegory	0		Category 1				
Score	Ob	served	d Exp	ected	Ob	servec	l Exp	ected	
0	1		0.7		0		0.3		
1	4	5	6.5	7.2	6	6	3.5	3.8	
2		9		8.5		6		6.5	
3		22		17.0		14		19.0	
4		10		16.8		34		27.2	
5		17		11.1		20		25.9	
6		6		7.0		25		24.0	
7	1	1	2.0	2.3		11		10.0	
8	0		0.3			3		2.7	

Chen & Thissen (1997) proposed the LD X^2 statistic, computed by comparing the observed and expected frequencies in each of the two-way cross tabulations between responses to each item and each of the other items. These diagnostic statistics are (approximately) standardized χ^2 values (that is, they are approximately z-scores) that become large if a pair of items indicates local dependence, that is, if data for that item pair indicates a violation of the local independence assumption that is the essence of the item response model. The printout below shows the pairwise values of the standardized LD X^2 statistics for this impulsivity subscale fitted with the special model intermediate between the 1PL and 2PL models; italic entries indicate positive LD, while roman entries indicate negative LD. All of the values are relatively small⁵, indicating no evidence of LD, and suggesting that the model fits satisfactorily.

⁵ Because the standardized LD X2 statistic is only approximately standardized, and is known to be based on a statistics with a longtailed (\Box 2) distribution, we do not consider values larger than 2 or 3 to be large. Rather, we consider values larger than 10 large, indicating likely LD; values in the range 5-10 lie in a gray area, and may either indicate LD or they may be a result of sparseness in the underlying table of frequencies. In practice data analysts use inspection of the item content, as well as these statistics, to evaluate the presence of LD when it is indicated.

		Margina	al							
Item	Label	X ²	1	2	3	4	5	6	7	8
1	eys1	0.0								
2	eys3	0.0	-0.6							
3	eys8	0.0	-0.7	-0.4						
4	eys10	0.0	-0.2	1.2	-0.5					
5	eys13	0.0	4.6	-0.7	2.6	-0.6				
6	eys22	0.0	-0.5	2.7	-0.1	-0.2	-0.7			
7	eys39	0.0	-0.1	-0.7	0.6	-0.4	-0.1	-0.2		
8	eys5	0.0	6.6	-0.6	0.5	0.1	-0.0	2.2	-0.6	
9	eys41	0.0	-0.6	-0.6	1.3	-0.2	-0.4	0.0	-0.5	-0.6

Marginal fit (X2) and Standardized LD X2 Statistics for Group 1 (Back to TOC)

5.2.4 Trace Lines and information curves for the 2PL model

To obtain graphical representations of the trace lines and information curves for the nine impulsivity subscale items, open the output file containing the results of the 2PL analysis (Eysenck87–items1_57.2PL–9items.htm) and select Analysis, Graphs as shown below.



This action opens the **Graphics** window and as default, a display of the trace lines. The trace lines shown plot the probability of the "impulsive" responses for each item as a function of the underlying latent variable. The curves show that the nine items are spread to cover the range of the impulsivity continuum. For item 41, with its very low slope value (0.11), the probability of a "no" response changes very little across levels of impulsivity from lowest to highest.



To obtain the information curves, click on the Information option.



Below we show the information curves for each item. If we were constructing an "**impulsivity**" scale based on the IRT analyses, we would omit item 41 since it provides negligible information.



5.3 Analysis of the State-Trait Anxiety Inventory (STAI) data

This example examines item responses obtained from 517 undergraduate students at the University of Houston and the University of Arkansas who completed a 20-item anxiety questionnaire derived

from the State-Trait Anxiety Inventory (STAI, Spielberger, 1983).⁶

For illustration of fitting the graded, partial credit, and nominal response models, six items are selected:

- I feel calm.
- I am tense.
- I am regretful.
- I feel at ease.
- o I feel anxious.
- o I feel nervous.

In these data, the responses were on a five-point unipolar Likert-type response scale: 1 = not at all, 2 = very little, 3 = somewhat, 4 = moderately, and 5 = very much.

5.3.1 Graded model

To see the data, use the **Open** file dialog under the **File** menu of IRTPRO, navigate to the **C:\IRTPRO Examples\By Dataset\Anxiety14** folder, select **Files of type: IRTPRO Data File (*.ssig)** in the **Open File** dialog, and open the file **Anxiety14.ssig**.

While this file contains responses to fourteen items, only the six items listed above have meaningful variable names (Calm, Tense, and so on). The other variables are named V2, V6, V7, etc., and will not be used here.

6 6 Thanks to Lynne Steinberg for these data, which are described more completely by Thissen & Steinberg (2009).

🔀 IRT	PRO - [Anxie	ety14.ssig]	_		-	_			_ 0 _>	K
Ei 🗐	le <u>E</u> dit <u>D</u> a	ata <u>M</u> anipu	late <u>G</u> raph	nics <u>A</u> nalysi	s <u>V</u> iew <u>M</u>	<u>(</u> indow <u>H</u> e	lp		- 8	×
0 🖬	: 🖬 X 🖻	8 8 ?								
	Calm	V2	Tense	Regretful	AtEase	V6	V7	V8	Anxious	
1	3	2	2	2	3	2	3	4	3	=
2	3	3	5	5	3	3	3	4	4	
3	3	3	3	3	3	1	4	4	1	
4	3	3	2	2	3	2	4	2	2	
5	2	3	2	4	3	2	1	3	4	
6	1	1	1	1	1	1	3	2	1	
7	3	2	1	1	2	1	5	1	1	
8	1	1	2	1	1	1	2	2	1	
9	3	3	3	1	3	2	4	1	2	
10	3	2	2	1	2	2	3	2	2	
11	1	1	1	1	1	1	1	1	1	
12	3	3	2	1	3	2	3	1	2	
13	3	3	1	2	3	2	4	1	1	
14	2	2	1	1	2	1	2	1	2	
15	2	2	2	2	2	2	4	2	2	
•			111						4	
Ready									NUM SCRI	

To initiate the unidimensional IRT analysis, select **Unidimensional IRT** ... under the **Analysis** menu.

After adding a title and (optional) comments, click the **Items** tab and select the six items as shown next.

Unidimensional Analys	S Examples\By Data	set\Anxiety14\Anxiety	14.ssig	Read file
Description Grouping value	Items Models Single Group Ar No Group Variation	I Scoring		•
List of variable: Regretful AtEase V6 V7 V8 Anxious V10 V11 Nervous	S:	Add >>	Items: Calm Tense Regretful AtEase Anxious Nervous Apply to all groups	< * +
Options			OK Cancel	Run

Selection of the **Models** tab in that dialog shows that each item has five response categories, the data codes 1, 2, 3, 4, 5 have been automatically given item scores (model category values) 0, 1, 2, 3, 4, and Samejima's (1969, 1997) graded model has been selected:

Unidimensio	nal Analysis						X				
Data File:	ta File: C:\IRTPRO Examples\By Dataset\Anxiety14\Anxiety14.ssig Read										
Graded											
Descri	iption Group 1	tems Mode	scoring								
Gro	ouping value:	No Group Va	riable				-				
	Item List	Categorie	sData Codes	Item Scores	Model						
	Tense	5	1, 2, 3, 4, 5	0, 1, 2, 3, 4	Graded						
	Regretful	5	1, 2, 3, 4, 5	0, 1, 2, 3, 4	Graded						
	AtEase	5	1, 2, 3, 4, 5	0, 1, 2, 3, 4	Graded						
	Anxious	5	1, 2, 3, 4, 5	0, 1, 2, 3, 4	Graded						
	Nervous	5	1, 2, 3, 4, 5	0, 1, 2, 3, 4	Graded						
	Constraints	<u>D</u> IF <u>F</u>	Read paramete	er values		Apply to all group	s				
							-				
	_										
Options					ОК	Cancel	Run				

If we click the **Run** button in the lower right hand corner of the dialog, we see the output. The first table of **Graded Model Item Parameter Estimates** lists the slopes (a) and intercepts (c); the second table lists the slopes (a) and thresholds (b).

Note that there are slight numerical differences (larger in the standard errors than in the parameter estimates) between the results obtained with IRTPRO and the Multilog (du Toit, 2003) estimates reported for these items by Thissen & Steinberg (2009). These differences are due to differences in numerical quadrature, and the facts that IRTPRO usually converges to more decimal places, and computes much more accurate standard errors, than did Multilog.

Graded Model Item Parameter Estimates, logit: $a\theta + c$

Item	Label	а		s.e.	c1		s.e.	<i>c</i> 2		s.e.	с3		s.e.	<i>c</i> 4		s.e.
1	Calm	5	2.29	0.21	1	2.17	0.20	2	-0.80	0.16	3	-3.57	0.28	4	-6.31	0.51
2	Tense	10	2.26	0.19	6	2.34	0.20	7	-0.46	0.16	8	-2.60	0.22	9	-5.37	0.39
3	Regretful	15	1.33	0.13	11	1.03	0.13	12	-0.85	0.12	13	-2.22	0.16	14	-4.08	0.28
4	AtEase	20	2.42	0.22	16	2.89	0.24	17	-0.32	0.16	18	-3.19	0.26	19	-6.63	0.55
5	Anxious	25	1.80	0.16	21	1.31	0.15	22	-1.13	0.15	23	-3.07	0.22	24	-6.60	0.62
6	Nervous	30	1.71	0.15	26	1.46	0.15	27	-0.61	0.13	28	-2.20	0.18	29	-4.28	0.29

Graded Model Item Parameter Estimates for Group 1, logit: $a(\theta - b)$ (Back to TOC)

Item	Label	а		s.e.	<i>b</i> 1	s.e.	b2	s.e.	b3	s.e.	b4	s.e.
1	Calm	5	2.29	0.21	-0.95	0.09	0.35	0.07	1.56	0.11	2.76	0.22
2	Tense	10	2.26	0.19	-1.04	0.09	0.20	0.07	1.15	0.09	2.38	0.17
3	Regretful	15	1.33	0.13	-0.77	0.11	0.64	0.10	1.67	0.16	3.08	0.29
4	AtEase	20	2.42	0.22	-1.20	0.09	0.13	0.07	1.32	0.10	2.75	0.21
5	Anxious	25	1.80	0.16	-0.73	0.09	0.63	0.08	1.70	0.13	3.67	0.39
6	Nervous	30	1.71	0.15	-0.85	0.10	0.36	0.08	1.28	0.11	2.50	0.20

Likelihood-based Values and Goodness of Fit Statistics (Back to TOC)

Statistics based on the loglikelihood	
-2loglikelihood:	7522.70
Akaike Information Criterion (AIC):	7582.70
Bayesian Information Criterion (BIC):	7710.14

To see the graded model trace lines graphically, when the output file **Anxiety14.Test1-irt.htm** is in the IRTPRO viewer window, we may select **Graphs** under the **Analysis** menu, and a separate program **IRTPROGraphs** starts and shows various graphics that may be selected using a left side navigation bar:



When finished looking at the graphics, the **IRTPROGraphs** program may be closed using the X in the upper right hand corner of the window, and we return to the main IRTPRO window that has remained running behind the graphics application.

We leave it to the user as an exercise to page through the rest of the output, which shows reasonably good fit of the graded IRT model to these six items.

5.3.2 Muraki's generalized partial credit model fitted to the State Trait Anxiety Inventory (STAI) data

Continuing with the example from the previous section, we add an additional test in order to fit the generalized partial credit model. By right-clicking to the right of the **Test1** tab, a pop-up menu is obtained that enable the user to enter a new test, delete a test or rename an existing test, the default test names being Test1, Test2, ...

Insert Test	
Delete Test	dels
Rename	
Manage Test	[data

Right-click on each of the test tabs to invoke the **Insert Test**..., **Delete Test**, etc. drop-down menu. Click the **Rename** button and replace Test1 with Graded and Test2 with GPCredit, the latter being more descriptive of the type of model to be fitted to the item response data.

Unidimensional Analysis	×
Data File: C:\IRTPRO Examples\By Dataset\Anxiety14\Anxiety14.ssig	<u>R</u> ead file
Graded GPCredit	
Description Group Items Models Scoring	
<u>T</u> itle:	
Six items selected from the STAI data	
<u>C</u> omments:	
Muraki's generalized general model	
	Cancel Run
	Kull

Use the **Items** tab in the **GPCredit** tab in the **Unidimensional Analysis** dialog to select the six items to be analyzed:

V0 V7 V8 Anxious V10 V11 Nervous V13 ▼ ✓ Ⅲ ► Add >> Add >>	Data File: C:\IRTPRO ED	amples\By Dataset\Anxi Items Models Scorir Single Group Analysis No Group Variable	ety14\Anxiety14.s	ssig Items: Calm	Read file
	V6 V7 V8 Anxious V10 V11 Nervous V13 		<< bb,	Arense Regretful AtEase Anxious Nervous	groups

Selection of the **Models** tab in that dialog shows that each item has five response categories, the data codes 1, 2, 3, 4, 5 have been automatically given item scores (model category values) 0, 1, 2, 3, 4, and Samejima's (1969, 1997) graded model has been selected as default. To change the default model to the general partial credit model, select **Graded** for each item under the **Model** column and right click to obtain a pop-up menu showing a list of models appropriate for the selected items.

Unidimensional Analysis					X
Data File: C:\IRTPRO Ex	amples\By	Dataset\Anxiety14\Anxiety14.ss	sig		<u>R</u> ead file
Graded GPCredit					
					1
Description Group	Items M	odels Scoring			
Grouping value:	No. Comm	Menielele			
<u>o</u> rouping value:	No Group	variable			<u> </u>
Item List	Catego	riesData CodesItem Score:	Model		
Calm	5	1, 2, 3, 4, 5 0, 1, 2, 3, 4	Graded		
Tense	5	1, 2, 3, 4, 5 0, 1, 2, 3, 4	Graded		
Regretful	5	1, 2, 3, 4, 5 0, 1, 2, 3, 4	Graded		
AtEase	5	1, 2, 3, 4, 5 0, 1, 2, 3, 4	Grade	2PL	1 11
Anxious	5	1, 2, 3, 4, 5 0, 1, 2, 3, 4	Grade	3DI	
Nervous	5	1, 2, 3, 4, 5 0, 1, 2, 3, 4	Grade	Gradied	
				Graded	
				GPCredit	
				Nominal	
Construists	DIE	Band normation values	_	Apply to all and	
<u>C</u> onsu anus	<u>D</u> IF	<u>Reau parameter values</u>		Apply to a <u>i</u> l glo	ups
				_	
Options			ОК	Cancel	Run

Select **GPCredit** from this list to obtain the new set of models shown below.

Item List	Categories	Data Codes	Item Scores	Model
Calm	5	1, 2, 3, 4, 5	0, 1, 2, 3, 4	GP Credit
Tense	5	1, 2, 3, 4, 5	0, 1, 2, 3, 4	GP Credit
Regretful	5	1, 2, 3, 4, 5	0, 1, 2, 3, 4	GP Credit
AtEase	5	1, 2, 3, 4, 5	0, 1, 2, 3, 4	GP Credit
Anxious	5	1, 2, 3, 4, 5	0, 1, 2, 3, 4	GP Credit
Nervous	5	1, 2, 3, 4, 5	0, 1, 2, 3, 4	GP Credit

If one clicks the **Run** button in the lower right hand corner of the dialog, the output appears.

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Nominal Model Slopes and Scoring Function Contrasts for Group 1, logit: (a $s_k\theta + c_k$); s = To
Nominal Model Scoring Function Values for Group 1, logit: (a s _k θ + c _k); s = Tα
<u>Nominal Model Intercept Contrasts for Group 1, logit: (a s_kθ + c_k); c = Tγ</u>
Original (Bock, 1972) Parameters, Nominal Items for Group 1, logit: $(a_k\theta + c_k)$
Summed-Score Based Item Diagnostic Tables and X ² s for Group 1
Group Parameter Estimates
Marginal fit (X^2) and Standardized LD X^2 Statistics for Group 1
Item Information Function Values for Group 1 at 15 Values of θ from -2.8 to 2.8
Likelihood-based Values and Goodness of Fit Statistics
Summary of the Data and Control Parameters

The first table of Partial Credit Model Item Parameter Estimates lists the slopes (a) and intercepts (c); the second table lists the slopes (a) and thresholds (b):

Item	Label	a	s.e.	b	s.e.	d_1	d_2	s.e.	$d_{\scriptscriptstyle 3}$	s.e.	$d_{\scriptscriptstyle 4}$	s.e.	d_{5}	s.e.
1	Calm	1 1.69	0.19	0.90	0.11	0.00	1.82	0.12	0.50	0.09	-0.65	0.12	-1.67	0.20
2	Tense	6 1.63	0.18	0.66	0.10	0.00	1.66	0.11	0.36	0.09	-0.38	0.10	-1.64	0.16
3	Regretful	11 0.76	0.09	1.11	0.14	0.00	1.59	0.17	0.18	0.19	-0.19	0.23	-1.58	0.31
4	AtEase	16 1.87	0.22	0.74	0.11	0.00	1.92	0.12	0.58	0.09	-0.54	0.11	-1.96	0.21
5	Anxious	21 1.22	0.14	1.37	0.22	0.00	1.98	0.20	0.64	0.20	-0.10	0.22	-2.52	0.53
6	Nervous	26 1.05	0.12	0.80	0.10	0.00	1.46	0.13	0.30	0.13	-0.24	0.16	-1.52	0.22

GPC Model Item Parameter Estimates, logit: $a[k(\theta - b) + \Sigma d_k]$

This part of the printout is followed by a portion of the printout that provides slopes, scoring function contrasts, and intercept contrasts for the Nominal model. These values were used to obtain the GPC parameter estimates listed above. The relationship between this printout and the GPC item parameter estimates is described by Thissen, Cai, & Bock (2010) and the interested reader is referred to this publication for details.

Nominal Model Slopes and Scoring Function Contrasts for Group 1, logit: (a sk θ + ck); s = T α (Back to TOC)

Item	Label	a	s.e.	Contrasts	α_{1}	s.e.	α_{2}	s.e.	α_{3}	s.e.	α_4	s.e.
1	Calm	1 1.69	0.19	Trend	1.00		0.00		0.00		0.00	
2	Tense	6 1.63	0.18	Trend	1.00		0.00		0.00		0.00	
3	Regretful	11 0.76	0.09	Trend	1.00		0.00		0.00		0.00	
4	AtEase	16 1.87	0.22	Trend	1.00		0.00		0.00		0.00	
5	Anxious	21 1.22	0.14	Trend	1.00		0.00		0.00		0.00	
6	Nervous	26 1.05	0.12	Trend	1.00		0.00		0.00		0.00	

Nominal Model Scoring Function Values for Group 1, logit: (a sk θ + ck); s = T α (Back to TOC)

Item	Category	\boldsymbol{S}_1	S_2	S ₃	S_4	S_5
1	Calm	0.00	1.00	2.00	3.00	4.00
2	Tense	0.00	1.00	2.00	3.00	4.00
3	Regretful	0.00	1.00	2.00	3.00	4.00
4	AtEase	0.00	1.00	2.00	3.00	4.00
5	Anxious	0.00	1.00	2.00	3.00	4.00
6	Nervous	0.00	1.00	2.00	3.00	4.00

Nominal Model Intercept Contrasts for Group 1, logit: (a sk θ + ck); c = Ty (Back to TOC)

Item	Label	Contrasts	γ_1	s.e.	γ_2	s.e.	γ_3	s.e.	γ_4	s.e.
1	Calm	Trend	2 -1.51	0.22	3 4.04	0.44	4 0.13	0.13	5 0.13	0.08
2	Tense	Trend	7 -1.07	0.18	8 3.54	0.36	9 0.02	0.10	10 0.26	0.07
3	Regretful	Trend	12 -0.85	0.11	13 1.53	0.22	14 0.00	0.10	15 0.18	0.08
4	AtEase	Trend	17 -1.37	0.27	18 4.90	0.57	19 -0.03	0.14	20 0.23	0.08
5	Anxious	Trend	22 -1.67	0.32	23 3.54	0.63	24 -0.33	0.23	25 0.34	0.12
6	Nervous	Trend	27 -0.84	0.14	28 2.03	0.26	29 -0.03	0.10	30 0.18	0.08

The next part the printout lists summed-scored based item diagnostics, marginal fit (χ^2) and standardized LD χ^2 statistics. See Section 5.2.3 for an interpretation of these results.

Summed-Score Based Item Diagnostic Tables and X2s for Group 1 (Back to TOC)

S-X2 Item Level Diagnostic Statistics

Item	Label	X ²	d.f.	Probability
1	Calm	36.37	36	0.4527
2	Tense	59.84	39	0.0175
3	Regretful	54.60	49	0.2695
4	AtEase	35.83	35	0.4309
5	Anxious	51.47	39	0.0870
6	Nervous	56.92	47	0.1520

	Margi	Marginal								
Item	X^2	1	2	3	4	5				
1	0.1									
2	0.1	3.1								
3	0.0	0.3	1.3							
4	0.1	12.2	3.1	1.0						
5	0.0	1.3	3.0	2.9	0.9					
6	0.0	0.5	-1.4	4.1	1.1	7.3				

Marginal fit (X2) and Standardized LD X2 Statistics for Group 1 (Back to TOC)

The last part of the printout shown here are likelihood-based statistics.

Likelihood-based Values and Goodness of Fit Statistics (Back to TOC)

Statistics based on the loglikelihood	
-2loglikelihood:	7554.61
Akaike Information Criterion (AIC):	7614.61
Bayesian Information Criterion (BIC):	7742.05

To see the partial credit model trace lines graphically, when the output file Anxiety14.GPCreditirt.htm is in the IRTPRO viewer window, select Graphs under the Analysis menu, and a separate program IRTPROGraphs starts and shows various graphics that may be selected using a left side navigation bar:



When finished with the graphics, the **IRTPROGraphs** program may be closed using the X in the upper right hand corner of the window; control returns to the main IRTPRO window that has remained running behind the graphics application.

5.3.3 Nominal model example

In this section, we fit Bock's nominal model to these data. To compute and view the output for this model, use the **Window** menu to return to the **Anxiety14.ssig** spreadsheet window, and then the **Analysis** menu to select **Unidimensional IRT**

Insert **Test3** by right-clicking next to the **GPCredit** tab, then right-click on this tab to rename **Test3** to **Nominal**. Follow the instructions in Sections 5.3.1 and 5.3.1. Select the same six items. Select all the Graded cells in the **Models** window, then right-click to change Graded to Nominal. Click the **Run** button to run the analysis.

Unidimensional Analysis		X
Data File: C:\IRTPRO 2 E	xamples\By Dataset\Anxiety14\Anxiety14	.ssig Read file
Graded GPCredit Nomin	al	
Description Group	items Models Scoring	
<u>G</u> rouping value:	No Group Variable	
74		
Calm	5 1, 2, 3, 4, 5, 0, 1, 2, 3, 4	Nominal
Tense	5 1, 2, 3, 4, 5 0, 1, 2, 3, 4	Nominal
Regretful	5 1, 2, 3, 4, 5 0, 1, 2, 3, 4	Nominal
AtEase	5 1, 2, 3, 4, 5 0, 1, 2, 3, 4	Nominal
Anxious	5 1, 2, 3, 4, 5 0, 1, 2, 3, 4	Nominal
Nervous	5 1, 2, 3, 4, 5 0, 1, 2, 3, 4	Nominal
<u>C</u> onstraints	<u>D</u> IF	Apply to a <u>l</u> l groups
Options		OK Cancel Run

A portion of the output is shown next.

Nominal Model Slopes and Scoring Function Contrasts for Group 1, logit: (a sk θ + ck); s = T α (Back to TOC)

Item	Label	а	s.e.	Contrasts	α,	s.e. α	2	s.e.	α ₃	s.e. α	4	s.e.
1	Calm	4 1.46	0.23	Trend	1.00	1	0.46	0.39	² -0.21	0.21 ³	0.22	0.13
2	Tense	¹² 1.57	0.23	Trend	1.00	9	0.27	0.34	10 0.06	0.13 ¹¹	0.06	0.09
3	Regretful	²⁰ 0.78	0.12	Trend	1.00	17	0.11	0.36	¹⁸ 0.18	0.17 19	0.18	0.14
4	AtEase	²⁸ 1.70	0.25	Trend	1.00	25	0.42	0.34	²⁶ 0.03	0.14 ²⁷	0.09	0.09
5	Anxious	³⁶ 1.28	0.47	Trend	1.00	33	0.21	0.92	³⁴ 0.29	0.26 35	[°] -0.04	0.15
6	Nervous	⁴⁴ 1.04	0.13	Trend	1.00	41	0.44	0.30	⁴² 0.12	0.13 ⁴³	³ -0.03	0.11

Likelihood-based Values and Goodness of Fit Statistics (Back to TOC)

Statistics based on the loglikelihood	
-2loglikelihood:	7528.45
Akaike Information Criterion (AIC):	7624.45
Bayesian Information Criterion (BIC)	: 7828.35

The table below is a summary of the information criteria for the three models. Since both the AIC and BIC are the smallest for the Graded model, we conclude that this model provides the better fit of the data.

Comparison of Information criteria

Model	AIC	BIC
Graded	7582.70	7710.14
General Partial Credit	7614.61	7742.05
Nominal	7624.45	7828.35

Note that we cannot use the -2loglikelihood statistic to compare these models, since, for example, the Nominal model is not nested within the Graded model.

5.4 Unidimensional analysis of the Affect Adjective Check List (AACL)

The Affect Adjective Check List (AACL) (Zuckerman, 1980) involves 21 adjectives; the first 11 are called the "anxiety-plus" adjectives, and the final 10 words are "anxiety-minus" adjectives. All 21 adjectives are listed in the following table:

Anxiety-plus		Anxiety-minus	
1. Afraid	7. Shaky	12. Calm	17. Loving
2. Desperate	8. Tense	13. Cheerful	18. Pleasant
3. Fearful	9. Terrified	14. Contented	19. Secure
4. Frightened	10. Upset	15. Happy	20. Steady
5. Nervous	11. Worrying	16. Joyful	21. Thoughtful
6. Panicky		-	-

To collect the data⁷ analyzed here, the adjectives were framed with the instructions "Please indicate whether or not the adjective listed describes how you feel today, today beginning with the time you woke up this morning." Anxiety-plus words are scored 1 if checked, and anxiety-minus words are scored 1 if not checked. A unidimensional 2PL model is fitted to the entire 21-item set, and the diagnostic statistics are examined.

The data have already been imported into IRTPRO and saved as the file AACL_21Items.ssig in the C:\IRTPRO Examples\by DataSet\AACL folder installed with the software (see Chapter 3 for an example of importing data from other sources into IRTPRO). When the file AACL_21Items.ssig is opened, the data are displayed as a spreadsheet:

×	IRTE	PRO - [AACL	3_21Items.ss	sig]							X	
	<u>]</u> <u>E</u> il	e <u>E</u> dit <u>D</u> a	ta <u>M</u> anipu	late <u>G</u> raphi	ics <u>A</u> nalysis	<u>V</u> iew <u>W</u> i	ndow <u>H</u> elp)		-	5	×
) 🖻	🔒 🕺 🖻	8 8 8									
		Afraid	Desperate	Fearful	Frightened	Nervous	Panicky	Shaky	Tense	Terrified		
	1	2	1	2	2	1	2	2	1	2	1	
	2	2	2	2	2	2	2	2	2	2	2	
	3	2	2	2	2	2	2	2	2	2	2	
	4	2	2	2	2	2	2	2	2	2	2	
	5	2	2	2	2	2	2	2	2	2	2	
	6	2	1	1	2	1	1	2	1	2	2	
	7	2	2	2	2	1	2	1	2	2	1	
	8	1	2	1	1	1	1	2	1	2	2	
	9	2	2	2	2	2	2	1	2	2	2	
	10	2	2	2	2	2	2	2	2	2	2	
	11	2	2	2	2	2	2	2	2	2	2	
	12	2	2	2	2	2	2	2	2	2	1	
	13	2	2	2	2	2	2	2	2	2	2	
	14	2	2	2	2	2	2	2	2	2	2	
	15	2	1	1	1	1	1	1	1	1	1	-
1			111								•	
Re	ady									NUM		

To initiate the unidimensional IRT analysis, select **Unidimensional IRT** ... under the **Analysis** menu. The Unidimensional window opens with a **Test1** tab. Right-click on this tab and rename it to **UniD_Allitems**. Start by clicking on the **Description** tab in the **Unidimensional Analysis** window. Enter a title and description.

7 Data (N=290) from the 1988 "Affect Adjective Check List (CAPS-ANXIETY module)", hdl:1902.29/CAPS-ANXIETY, Odum Institute Dataverse.

Unidimensional Analysis	
Data File: C:\IRTPRO 2 Examples\By Dataset\AACL\AACL3_21Items.ssig	
UniD_Allitems	
Description Group II Items Models Scoring	
<u>T</u> itle:	
Unidimensional Analysis of AACL data	
<u>C</u> omments:	
2PL models fitted to all 21 items	
	_
Options OK Cancel Run	

The **Group** tab may be skipped, because there is only one group in this analysis. The **Items** tab is used to select all the items in this case.

Unidimensional Analysis				X
Data File: C:\IRTPRO 2	Examples\By Dat	taset\AACL\AACL3_21	Items.ssig	<u>R</u> ead file
UniD_Allitems	There a Madala	1. Conving 1		
Description	Single Group Ar	alysis		
<u>G</u> rouping value:	No Group Varia	ble		~
List of variables: Cheerful Contented Happy Joyful Loving	•	<u>A</u> dd >>	Items: Afraid Desperate Fearful Frightened Nervous	× • • = •
Pleasant Secure Steady Thoughtful			Panicky Shaky Tense	•
Options			OK Cance	I Run

There are several ways to select all of the items: (1) click on any item, and then press <Ctrl>A to select all, and then either (a) drag the set from the List of variables box to the Items box, or (2) double-click each item in turn, or (3) select each item and press the Add >> button.

Because the **2PL** model is the default for dichotomous items, the entry of information for the analysis would have been complete, if the items were properly scored. However, in this case we would like to recode the item scores of the first 11 items (the Anxiety-plus adjectives) from (0,1) to (1,0) so that Anxiety-plus words are also scored 1 if checked, and scored 0 if not checked. In the data file, 1 is equal to checked and 2 is not checked.

To recode the item scores, use the **Shift** key to select the first eleven cells in the **Item Scores** column then right-click to display the **Recode Item Scores** ... option.

– UnD_A	llitems	xampies\c	y Dataset (NA		ms.ssig		<u>R</u> ead file
Des	scription Group	Items M	odels Scorin	g			
<u>(</u>	<u>G</u> rouping value:	No Group	Variable				•
	Item List	Catego	riesData Co	desitem Score	Model		
	Afraid	2	1, 2	0, 1	2PL		
	Desperate	2	1, 2	0, 1	2PL		-
	Fearful	2	1, 2	0, 1	2PL		=
	Frightened	2	1, 2	0, 1	Recode Iter	n Scores	
	Nervous	2	1, 2	0, 1	21 L		-
	Panicky	2	1, 2	0, 1	2PL		
	Shaky	2	1, 2	0, 1	2PL		
	Tense	2	1, 2	0, 1	2PL		
	Terrifed	2	1, 2	0, 1	2PL		
	Upset	2	1, 2	0, 1	2PL		*
	Constraints	<u>D</u> IF				Apply to all grou	ups

Selecting of the **Recode Item Scores**... option invokes the **Item's Codes and Scores** dialog and allows one to change values in the **Item Scores** text boxes.

Ite	item's Codes and Scores								
	Item: Afraid								
	Data Codes	Item Scores	ОК						
	1	1	Cancel						
	2	0	Curren						
	 II 	4							

Click **OK** when the changes have been made. The resulting **Models** window is shown below.

Unidimensional	Analysis						X		
Data File: C:	Data File: C:\IRTPRO 2 Examples\By Dataset\AACL\AACL3_21Items.ssig								
UniD_Allitems	5								
Descriptio	on Group]	items Mode	Scoring						
<u>G</u> roupi	ng value:	No Group Var	iable				•		
	Item List	Categories	Data Codes	item Score	Model		·		
	Afraid	2	1, 2	1, 0	2PL				
	Desperate	2	1, 2	1,0	2PL				
	Fearful	2	1, 2	1,0	2PL				
	Frightened	2	1, 2	1,0	2PL				
	Nervous	2	1, 2	1, 0	2PL				
	Panicky	2	1, 2	1, 0	2PL				
	Shaky	2	1, 2	1, 0	2PL				
	Tense	2	1, 2	1, 0	2PL				
	Terrified	2	1, 2	1, 0	2PL				
	Upset	2	1, 2	1, 0	2PL		▼		
Con	straints	<u>D</u> IF				Apply to all group	s		
	(-		
Options				[ОК	Cancel	Run		

Clicking the **Run** button in the lower left of the **Unidimensional Analysis** dialog produces the results (after a wait of only a few seconds in this case, for this small problem; other problems may require more time). The results are displayed in web-page format. A portion of the output containing the table of contents and the estimated parameters is shown below.

The table of contents lists (blue) hyperlinks that can be used to navigate the output. To return to the table of contents from any part of the output file, click on the **(Back to TOC)** hyperlink that appears at the right of the heading for most output tables.

🔀 IRTPRO - [AAC	_3_21Ite	ms.Uni	DallItems	-irt	.htm]				. 🗆 🗾	x
Eile Edit Vi	ew <u>A</u> n	alysis	<u>W</u> indow	Ŀ	<u>l</u> elp				- 8	×
D 🖻 🖬 X 🖻		8								
IRTPRO Versio	on 2.0		20 aatiu			anina Var	sion 4 Ed	(20 hit)		A
	lieu by	INTER	(O esui	IIa	uon ei	igine ver	51011 4.54	+ (32-bit)		
Project: /	ACL									
Description:	Jni-Dime	nsional 2	PL all item	ıs						
Date:	18 July 20	11								
Time:	12:19 PM									
Table of Conte	ents									
2PL Model Item Para	ameter Es	stimates f	or Group 1	, log	git: aθ + d	c or a(θ – b)				
Factor Loadings for	Group 1									
Summed-Score Bas	ed Item E	Diagnosti	c Tables a	nd >	(² s for G	roup 1				
Group Parameter Es	timates									
Marginal fit (χ^2) and	Standard	ized LD X	² Statistic	s for	Group 1					
Item Information Fur	ction Val	ues for Gi	roup 1 at 1	5 Va	alues of () from -2.8 to	2.8			
Likelihood-based Va	lues and	Goodnes	ss of Fit St	atist	ics					
Summary of the Data	a and Cor	ntrol Para	meters							
2PI Model Item Par	ameter F	stimates	for Group	1 1	nait: aA +	$c or a(\theta - b)$	(Back to T	00)		
Item Label	unieter E	a	s.e.	1, 10	C	S.e.	b	s.e.		
1 Afraid	2	3.17	0.65	1	-3.98	0.73	1.25	0.12		
2 Despera	ate 4	3.81	0.76	3	-4.43	0.80	1.16	0.11		-
•		111								F
									NUM	

The table of parameter estimates is shown on the next page. Note that the table caption indicates that the logit is $a\theta + c$ or $a(\theta - b)$; that means that the 2PL model trace line is expressed as

$$T = \frac{1}{1 + \exp[-(a\theta + c)]} = \frac{1}{1 + \exp[-a(\theta - b)]} ,$$

in which the first form is called "slope-intercept" with parameters a (the slope, or discrimination) and c (the intercept). That is the form in which the model parameters are estimated. The values of the derived parameter b (the threshold) are also printed in the table.

Also, note especially that there is no "1.7" or "D" anywhere in the model. IRTPRO parameter estimates *for all models* are *always* in the "logistic metric" (in BILOG terminology). To be rendered comparable to normal ogive discrimination parameters, the IRTPRO estimates of the a parameters could be divided by 1.7.

Item	Label	а		s.e.	С		s.e.	b	s.e.	
1	Afraid	2	3.17	0.63	1	-3.98	0.69	1.25	0.14	
2	Desperate	4	3.81	0.76	3	-4.43	0.78	1.16	0.13	
3	Fearful	6	5.80	1.46	5	-6.40	1.59	1.10	0.12	
4	Frightened	8	9.36	3.15	7	-11.35	4.14	1.21	0.11	
5	Nervous	10	2.31	0.36	9	-1.41	0.28	0.61	0.11	
6	Panicky	12	2.73	0.48	11	-2.83	0.44	1.03	0.13	
7	Shaky	14	2.62	0.48	13	-3.20	0.48	1.22	0.15	
8	Tense	16	2.06	0.31	15	-0.62	0.22	0.30	0.11	
9	Terrified	18	4.28	1.38	17	-8.07	2.14	1.88	0.21	
10	Upset	20	2.01	0.35	19	-2.29	0.32	1.14	0.15	
11	Worrying	22	2.08	0.32	21	0.05	0.21	-0.02	0.10	
12	Calm	24	1.78	0.28	23	-1.32	0.23	0.74	0.13	
13	Cheerful	26	1.05	0.19	25	-0.75	0.16	0.71	0.17	
14	Contended	28	1.84	0.28	27	-0.97	0.22	0.53	0.12	
15	Нарру	30	1.70	0.27	29	-1.19	0.22	0.70	0.13	
16	Joyful	32	1.20	0.20	31	0.65	0.17	-0.54	0.15	
17	Loving	34	0.69	0.16	33	-0.52	0.14	0.75	0.24	
18	Pleasant	36	1.67	0.31	35	-2.27	0.29	1.36	0.19	
19	Secure	38	1.99	0.30	37	-1.03	0.23	0.52	0.11	
20	Steady	40	2.16	0.35	39	-1.77	0.29	0.82	0.13	
21	Thoughtful	42	1.02	0.22	41	-1.67	0.20	1.63	0.30	

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

When feasible, IRTPRO computes the value of an updated version of the M_2 statistic proposed by Maydeu-Olivares & Joe (2005, 2006). That statistic is based on the one- and two-way marginal tables of the complete cross-classification of the respondents based on their response patterns. In this case, the value of that statistic indicates that the unidimensional model does not fit these data very well:

Statistics based on one- and two-way marginal tables								
M ₂	Degrees of freedom	Probability	RMSEA					
1208.12	189	0.0001	0.14					
Note: M_2 is based on full marginal tables.								
Note: Mode	el-based weight n	natrix is used.						

IRTPRO also computes (approximately) standardized LD χ^2 statistics based on the local dependence statistic proposed by Chen & Thissen (1997). These begin as basically (approximately) χ^2 distributed statistics comparing the observed and expected frequencies in the two-way marginal tables for each item pair. To make the values roughly comparable among items that may have different numbers of response categories, (approximately) *z*-scores are computed by subtracting the degrees of freedom from those (approximately) χ^2 -distributed statistics, and dividing by the square root of twice the degrees of freedom.

In this example, those statistics yield a clear suggestion of multidimensionality: In the table below, note the cluster of values that are printed in red for items 12-20 (the anxiety-minus words). The values are printed in red if the observed covariation between responses to a pair of items exceeds that predicted by the model, and in blue if the observed covariation is less than fitted. Thus, a cluster of red values indicates a cluster of items that may measure an un-modeled dimension. Because these are approximately standardized statistics, values that exceed 10.0 are also very, very

large and unexpected.

	Marginal										
Item	χ^2	1	2	3	4	5	6	7	8	9	10
1	0.0										
2	0.0	1.1									
3	0.0	0.6	0.9								
4	0.3	-0.4	3.0	0.6							
5	0.2	2.3	-0.1	-0.3	0.2						
6	0.0	-0.5	-0.6	2.6	5.3	1.0					
7	0.0	0.5	2.6	1.3	-0.2	-0.4	1.0				
8	0.2	-0.5	0.4	-0.5	0.0	6.0	1.8	-0.5			
9	0.8	0.0	-0.1		-0.1		0.7	1.0			
10	0.0	-0.1	-0.1	0.2	0.2	-0.2	-0.7	-0.2	-0.6	0.2	
11	0.1	-0.2	1.8	-0.5	0.5	2.1	4.1	-0.4	11.0		2.2
12	0.1	2.3	-0.5	1.3	0.6	-0.3	-0.1	-0.4	0.0	0.4	-0.1
13	0.0	6.3	-0.3	6.4	4.4	4.4	0.3	1.6	1.3	1.3	1.1
14	0.1	4.8	0.9	5.4	6.8	4.0	2.6	2.5	0.5	7.4	2.8
15	0.1	5.2	2.0	6.9	4.1	5.2	3.9	3.6	3.9	1.8	1.4
16	0.0	0.9	0.7	1.6	1.9	2.7	1.6	1.0	3.7		-0.3
17	0.0	9.1	1.9	6.4	6.5	5.4	0.7	0.7	4.1	1.4	0.5
18	0.0	11.0	-0.6	3.9	5.1	4.3	-0.3	0.1	0.8	0.5	2.3
19	0.1	4.5	2.9	2.4	2.6	3.2	2.5	0.5	1.7		0.9
20	0.1	1.4	1.1	1.7	1.2	5.7	1.2	-0.1	1.1	0.7	2.0
21	0.0	3.1	1.5	0.5	0.4	3.4	1.0	-0.0	3.9	0.3	2.4
	Marginal										
Item	X ² 0	11	12	13	14	15	16	17	18	19	20
11	0.1										
12	0.1	-0.5									
13	0.0	2.6	-0.6								
14	0.1	0.0	5.3	2.8							
15	0.1	2.0	-0.6	30.3	11.4						
16	0.0	5.6	-0.6	19.9	8.3	16.7					
17	0.0	5.0	-0.6	14.6	2.0	10.4	27.0				
18	0.0	2.0	-0.3	12.3	0.5	1.0	3.9	7.5			
19	0.1	0.1	-0.5	-0.6	3.6	-0.0	-0.2	1.8	0.8		
20	0.1	0.0	-0.4	-0.5	0.0	-0.6	-0.5	-0.6	0.6	9.9	
21	0.0	2.4	0.3	4.3	-0.5	1.2	1.4	12.1	4.1	1.5	2.2

Marginal fit (X2) and Standardized LD X2 Statistics for Group 1 (Back to TOC)

6. Multiple groups analysis and DIF

6.1 Detection of differential item functioning

The trace line model has many uses, but Lord (1977, 1980) observed that the trace line is ideally suited to defining differential item functioning (DIF), or lack thereof.

The value of the trace line at each level of θ is the conditional probability of a correct response given that level of ability of proficiency. If we are considering the possibility that an item may function differently (exhibit DIF) for some focal group relative to some reference group, then in the context of IRT we are considering whether the trace lines differ for the two groups. If the trace lines are the same, there is no DIF. If the trace lines differ, there is DIF. Because the trace line for an item is determined by the item parameters, Lord (1977, 1980) noted that the question of DIF detection could be approached by comparing estimates of the item parameters between groups.

We illustrate DIF with data obtained from 659 undergraduates at the University of Kansas. The data obtained are based on a conventional orally administered spelling test. The reference group for this analysis includes the male students (N = 285) and the focal group is made up of the female students (N = 374). The original test comprised 100 words, but only 4 have been selected for use here. The four words to be spelled are Infidelity, Panoramic, Succumb, and Girder. These four items were selected because preliminary analysis suggested that they have very nearly equal discrimination parameters; this is convenient for purposes of illustration. The data were free-response, so there is no guessing to be considered. The words Infidelity, Panoramic and Succumb were selected to comprise an "anchor" (a set of items believed to involved no DIF) with information over a range of the θ -continuum. The word Girder is the studied item; it was selected because it shows substantial differential difficulty for the two groups in these data. Thissen, Steinberg, and Wainer (1993) describe several DIF analyses of these data.

To see the data, use the **Open** file dialog under the **File** menu of IRTPRO, navigate to the **C:\IRTPRO Examples\By Dataset\Spelling** folder, select **Files of type: IRTPRO Data File (*.ssig)** in the **Open File** dialog, and open the file **Spelling.ssig**. The first 15 cases of the data are as follows:

🔀 IRTPRO - [Spelling.ssig]								
Eile	Eile Edit Data Manipulate Graphics Analysis View							
Window Help								
D 😅 🖬 X 🖻 🛍 🍜 📍								
	Infidelity	Panoramic	Succumb	Girder	Gender	•		
1	0	0	0	0	1			
2	0	0	0	0	1			
3	0	0	0	0	1			
4	0	0	0	0	1			
5	0	0	0	0	1			
6	0	0	0	0	1			
7	0	0	0	0	1			
8	0	0	0	0	1			
9	0	0	0	0	1			
10	0	0	0	0	1			
11	0	0	0	0	1			
12	0	0	0	0	1			
13	0	0	0	0	1			
14	0	0	0	0	1			
15	0	0	0	0	1	Ŧ		
						đ		

To initiate the unidimensional IRT analysis, select **Unidimensional IRT** ... under the **Analysis** menu. We start by adding two additional tests in order to fit a total of three models to the same data. By right-clicking on the right side of the **Test1** tab, a pop-up menu is obtained that enable the user to enter a new test, delete a test or rename an existing test, the default test names being **Test1**, **Test2**, ... Once the **Test2** tab is displayed, the procedure is repeated to obtain **Test1**, **Test2**, and **Test3**.

Unidimensional	Analysis			X
Data File: C:	\IRTPRO Examples\By Di	ataset\Spelling\Spelling.ss	ig	Read file
Test1	Insert Test			1
Descrip	Delete Test	scoring		
Title	Rename			
	Manage Test			
Comme	ents:			
Options			ок	ancel Run

Right-click on each of the test tabs to invoke the **Insert Test...**, **Delete Test**, etc. drop-down menu. Click the **Rename** button and replace Test1 with Sweep, Test2 with Anchored, and Test3 with 1PL,

the latter being more descriptive of the type of models to be fitted to the item response data.

Unidimensional Analysis	X
Data File: C:\IRTPRO Examples\By Dataset\Spelling\Spelling.ssig	ead file
Test1 Test2 Test3	
Description Group II Items Models Scoring	
Title:	-
Comments:	-
Options OK Cancel	Run

Start by clicking the **Sweep** tab to create the first test. Click the **Description** tab (the default tab for a new analysis) to add a title and comments.

Unidimensional Analysis
Data File: C:\IRTPRO Examples\By Dataset\Spelling\Spelling.ssig
Sweep Anchored 1PL
Description Group II Items Models Scoring
<u>T</u> itle:
Spelling DIF
<u>C</u> omments:
"Sweep" : Test all items for DIF given group differences computed with all items equal.
Options OK Cancel Run

Next, click the Groups tab and select Gender as the grouping variable. The default reference group

is the first group as shown below.

Unidimensional Analysis		X
Data File: C:\IRTPRO Examples\By	Dataset\Spelling\Spelling.ssig	<u>R</u> ead file
Sweep Anchored 1PL		1
Description Group Items Me	odels Scoring	
List of variables:	<u>(</u>	<u>G</u> roup:
Infidelity Panoramic Succumb Girder Gender	<u>A</u> dd >>	Gender
	[Ref] Nar	me Gender
	☑ G1	1
	□ G2	2
Options	(OK Cancel Run

Use the **Items** tab in the **Sweep** tab in the **Unidimensional Analysis** dialog to select the four items to be analyzed, and click on the **Apply to all groups** button to select those items for both groups:

Data File: C:\RTPRO Examples\By Dataset\Spelling\Spelling.ssig Read file Sweep Anchored 1PL Description Group Items Models Gender Grouping value: [G1] 1 Image: Comparison List of variables: Items: X Infidelity Panoramic Succumb Girder Girder Girder
Sweep Anchored 1PL Description Group Items Models Scoring Gender Grouping value: [G1]1 List of variables: Infidelity Panoramic Succumb Girder Add >> Girder
Jescription Group Items Models Scoring Gender
List of variables: Infidelity Panoramic Succumb Girder Add >> Add >> Girder
Panoramic Succumb Girder Add >> Girder
Apply to all groups
Qptions OK Cancel Run

Proceeding to the **Models** tab, it is seen that all four items have two categories and that the 2PL model is displayed as the default for each item.

Unidimensio	nal Analysis	-		-			X
<u>D</u> ata File:	C:\IRTPRO Exa	mples\By Data	set\Spelling\	Spelling.ssig			<u>R</u> ead file
1PL A	nchored Rando	m Sweep					1
Descri	ption 🛛 Group 🗍 I	tems Models	Scoring				
	G	ender					
Gro	uping value:	G1] 1					
	Item List	Categories	Data Codes	Item Score:	Model		
	Infidility	2	0, 1	0, 1	2PL		
	Panoramic	2	0, 1	0, 1	2PL		
	Succumb	2	0, 1	0, 1	2PL		
	Girder	2	0, 1	0, 1	2PL		
2	constraints	<u>D</u> IF	ad paramete	er values		Apply to all gro	ups
Qptions				(OK	Cancel	Run

In the **Models** window, click the **DIF**... button:

Unidime	nsiona	l Analysis							Х
<u>D</u> ata F	ile: C	:\IRTPRO Exa	mples\By Da	taset\Spell	ing\Spelling.s	sig		<u>R</u> ead f	ile
Swee	p Anc	hored 1PL	1						
				,					
D	escripti	on Group	Items Mode	els Scorin	9				- I
		0	Gender						
	<u>G</u> roup	ing value:	[G1] 1					-	
									
		Item List Infidelity	2	0, 1	0. 1	2PL			
		Panoramic	2	0, 1	0, 1	2PL			
		Succumb	2	0, 1	0, 1	2PL			
		Girder	2	0, 1	0, 1	2PL			
	Cor	nstraints	<u>D</u> IF				Apply to all gr	oups	
									-
Optio	ns					ОК	Cancel	F	tun

This procedure brings up the DIF dialog shown next.

DIF Analysis Test all items, anchor all i Test candidate items, ranu Test candidate items, esti	tems. domized groups: mate group differenc	e with anchor items:	X
List of variables: Infidelity Panoramic Succumb Girder Gender	<u>A</u> dd >>	Candidate	×
Group contrasts	Add >>	Anchor	incel

In this analysis we accept the default **Test all items, anchor all items**, so we click the **OK** button to return to the **Models** window and click the **Run** button to initiate the analysis. Portions of the output are as follows.

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

Item	Label	a		s.e.	С		s.e.	b	s.e.
1	Infidelity	2	0.88	0.26	1	1.30	0.18	-1.48	0.37
2	Panoramic	4	1.48	0.35	3	0.78	0.19	-0.52	0.14
3	Succumb	6	1.86	0.54	5	-1.19	0.27	0.64	0.13
4	Girder	8	1.44	0.36	7	0.72	0.19	-0.50	0.14

2PL Model Item Parameter Estimates for Group 2, logit: $a\theta + c$ or $a(\theta - b)$ (F	Back to TOC)
--	--------------

Item	Label	a		s.e.	с		s.e.	b	s.e.
1	Infidelity	10	1.62	0.43	9	2.29	0.34	-1.41	0.22
2	Panoramic	12	1.51	0.37	11	0.94	0.19	-0.62	0.11
3	Succumb	14	1.14	0.29	13	-0.78	0.13	0.69	0.21
4	Girder	16	1.64	0.43	15	0.14	0.16	-0.09	0.09

DIF Statistics for Graded Items (Back to TOC)

Item num	bers in:									
Group 1	Group 2	Total X^2	d.f.	р	X_{a}^{2}	d.f.	р	$X^2_{c a}$	d.f.	р
1	1	7.5	2	0.0235	2.2	1	0.1348	5.3	1	0.0219
2	2	0.5	2	0.7765	0.0	1	0.9516	0.5	1	0.4787
3	3	2.1	2	0.3544	1.4	1	0.2393	0.7	1	0.4069
4	4	8.2	2	0.0167	0.1	1	0.7164	8.1	1	0.0045

To return to the **Unidimensional Analysis** environment, close the output window and select this option from the **Analysis** option on the main menu bar. To proceed to setting up the second test, click the **Anchored** Tab and select **Description** to provide a title and comments. From the **Group** tab, Gender is again selected as the grouping variable and using the **Items** tab all four items are selected.

Unidimensional Analysis	X
Data File: C:\IRTPRO Examples\By Dataset\Spelling\Spelling.ssig	Read file
Sweep Anchored 1PL	
Description Group Items Models Scoring	
Spelling DIF	
Comments:	
Anchor items Infidelity, Panoramic, and Succumb; candidate Girder; 2PL	
Options OK Canc	el Run

Proceeding to the **Models** tab, it is seen that each item is associated with the 2PL model.

Data File: C:	IRTPRO Exa						
		mples\By Data	set\Spelling\	Spelling.ssig			<u>R</u> ead file
Current A. J	L) IN	1					
Sweep Ancr	nored IPL						
Descriptio	on 🛛 Group 🗍 I	tems Model	Scoring				
	G	ender					
<u>G</u> roupi	ng value:	G1] 1					•
	Item List	Categories	Data Codes	Item Score:	Model		
	Infidelity	2	0, 1	0, 1	2PL		
	Panoramic	2	0, 1	0, 1	2PL		
	Succumb	2	0, 1	0, 1	2PL		
	Girder	2	0, 1	0, 1	2PL		
Con	straints	<u>D</u> IF				Apply to all gre	oups
Options				ſ	ОК	Cancel	Run

Next, we click the **DIF** button to display the **DIF Analysis** window. Once this window is displayed, the **Test candidate items, estimate group difference with anchor items:** option is selected. Next Girder is selected as candidate item and the remaining three items as anchor items.

 Test all items, anchor all items. Test candidate items, randomized groups: Test candidate items, restimate group difference with anchor items: List of variables: Candidate Girder Girder Gender Add >> Add >> Infidelity Panoramic Succumb Girder Gender Add >> 	DIF Analysis			×
List of variables: Infidelity Panoramic Succumb Girder Gender Add >> Add >> Add >> Add >> Infidelity Panoramic Succumb Add >>	 Test all items, anchor all i Test candidate items, rand Test candidate items, esti 	tems. domized groups: mate group differenc	e with anchor items:	
Add >> Add >> Add >>	List of variables: Infidelity Panoramic Succumb Girder Gender	<u>A</u> dd >>	<u>C</u> andidate	×
		Add >>	Anchor Infidelity Panoramic Succumb	X

Once done, click the **OK** button to return to the **Models** window and click the **Run** button to initiate the analysis. Portions of the output are as follows.

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

Item	Label	a		s.e.	с		s.e.	b	s.e.
1	Infidelity	2	1.18	0.24	1	1.59	0.16	-1.34	0.24
2	Panoramic	4	1.47	0.28	3	0.67	0.16	-0.46	0.11
3	Succumb	6	1.51	0.30	5	-1.09	0.17	0.72	0.13
4	Girder	8	1.47	0.37	7	0.73	0.19	-0.50	0.13

2PL Model Item Parameter Estimates for Group 2, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

Item	Label	a		s.e.	с		s.e.	b	s.e.
1	Infidelity	2	1.18	0.24	1	1.59	0.16	-1.34	0.24
2	Panoramic	4	1.47	0.28	3	0.67	0.16	-0.46	0.11
3	Succumb	6	1.51	0.30	5	-1.09	0.17	0.72	0.13
4	Girder	10	1.77	0.54	9	-0.21	0.22	0.12	0.12

DIF Statistics for Graded Items (Back to TOC)

Item num	Item numbers in:														
Group 1	Group 2	Total X^2	d.f.	р	X_{a}^{2}	d.f.	р	$X^2_{c a}$	d.f.	р					
4	4	11.2	2	0.0036	0.2	1	0.6413	11.0	1	0.0009					

While the output is displayed, the **Graphs** option is available under the **Analysis** item on the main menu bar.

🔀 IRTPRO - [Spelling	g.Anchored-irt]
💷 File Edit View	w Analysis Window Help - & ×
] 🗅 🚅 🖬 🐰 🖻	Graphs
IRTPRO Version Output generate	2.0 d by IRTPRO estimation engine Version 4.54 (32-bit)
Project:	Spelling DIF
Description:	Anchor items Infidelity, Panoramix, and Succumb; candidate Girder; 2PL
Date:	04 July 2011
Time:	10:55 AM

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2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$



To return to the **Unidimensional Analysis** environment, close the graphics window (if it is open) and the output window, and select this option from the **Analysis** option on the main menu bar. To proceed to setting up the third test, click the **1PL** Tab.

Use the **Description** tab to provide a title and comments. From the **Group** tab, Gender is again selected as the grouping variable and using the **Items** tab all four items are selected.

Next, we click the **DIF** button to display the **DIF Analysis** window. Once this window is displayed, just as in the Anchored example, the **Test candidate items, estimate group difference with anchor items:** option is selected. Next Girder is selected as candidate item and the remaining three items as anchor items. Click **OK** to return to the **Models** tab.

Data File: C:W	nalysis IRTPRO 2 Exam	ples\By Dataset	\Spelling\Spelling	a.ssia		Read file
1PL Anchor	red Sweep					
Description	Group Item Gend	ns Models So	coring			
Grouping) value: [G1]	1				•
	Item List	Categories	Data Codes	Item Scores	Model	
	Infidelity	2	0, 1	0, 1	2PL	
	Panoramic	2	0, 1	0, 1	2PL	
	Succumb	2	0, 1	0, 1	2PL	
	Girder	2	0, 1	0, 1	2PL	
Const	raints DI	F			Apply to a	ll groups
Options				ОК	Cance	I Run

To use the 1PL model for the analysis, emulating Thissen, Steinberg, and Wainer (1993), we next click the **Constraints** button in the **Models** tab to bring up the **Constraints** dialog, and set all the slope (a) parameters for both groups equal:

Group	, Item							
G1, In	fidelity	а	1	С	2			
G1, Pa	noramic	a	3	С	4			
G1, St	Iccumb	a	5	с	6			
G1, 0	Girder	a	7	с	8			
G2, In	fidelity	a	1	с	2			
G2, 🎴	noramic	-	2	0	А	1		
G2,	Set Pa	ramet	ters Eq	ual				
G2	Fix Va	lue						
G1	Set Pa	ramet	ters Fre	e				
G1,	COV	01.1	1.0					
G2, I	leans	μ1	17					
G2,	Cov	σ1 1	18					

Note that it is important that such constraints are added after the DIF dialog, so that the constraints are in addition to a set of constraints automatically imposed by the anchored- DIF selection:

Item Parameter C	onstra	aints						2
Group: Gender								
Group, Item								
G1, Infidelity	a	13	С	2				
G1, Panoramic	а	13	С	4				
G1, Succumb	а	13	с	6				
G1, Girder	а	13	С	8				
G2, Infidelity	а	13	С	2				
G2, Panoramic	а	13	С	4				
G2, Succumb	a	13	С	6				
G2, Girder	a	13	С	16				
G1, Means	μ1	0.0						
G1, Cov	σ1 1	1.0						
G2, Means	μ1	17						
G2, Cov	σ1 1	18						
Set parameters equ	al acro	oss grou	ıps					
					0	ĸ	Cance	1
	_		_	_	 _			

Once done, click the **OK** button to return to the **Models** window and click the **Run** button to initiate the analysis. Portions of the output are as follows.

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

Item	Label	a		s.e.	с		s.e.	b	s.e.
1	Infidelity	6	1.41	0.15	1	1.70	0.16	-1.20	0.14
2	Panoramic	6	1.41	0.15	2	0.66	0.15	-0.47	0.10
3	Succumb	6	1.41	0.15	3	-1.08	0.14	0.76	0.13
4	Girder	6	1.41	0.15	4	0.72	0.17	-0.51	0.12
2PL Model Item Parameter Estimates for Group 2, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

Item	Label	a		s.e.	c		s.e.	b	s.e.
1	Infidelity	6	1.41	0.15	1	1.70	0.16	-1.20	0.14
2	Panoramic	6	1.41	0.15	2	0.66	0.15	-0.47	0.10
3	Succumb	6	1.41	0.15	3	-1.08	0.14	0.76	0.13
4	Girder	6	1.41	0.15	5	-0.21	0.18	0.15	0.13

DIF Statistics for Graded Items (Back to TOC)

Item num	bers in:									
Group 1	Group 2	Total X^2	d.f.	р	X_{a}^{2}	d.f.	р	$X^2_{c a}$	d.f.	р
4	4	14.4	2	0.0007	0.0	1	1.0000	14.4	1	0.0001

These DIF statistics are slightly deceptive; they list a two degrees of freedom total X^2 , and a X^2 test between the *a* parameters even though the *a* parameters are constrained equal (so the latter test must be 0.0), and there is only one degree of freedom for the test of the *b* parameter, which is the same as the overall test in this case. The software is not smart enough to count arbitrary constraints when doing DIF tests, and the user has to correct these things.

6.2 Analysis of the 2000 Program for International Student Assessment (PISA) data

The Program for International Student Assessment (PISA) is a worldwide evaluation of 15-year-old school pupils' scholastic performance, performed first in 2000 and repeated every three years. It is coordinated by the Organization for Economic Co-operation and Development (OECD), with a view to improving educational policies and outcomes.

In this section, three analyses based on the 2000 PISA (see Adams & Wu, 2002) data are discussed: traditional statistics, unidimensional IRT and unidimensional Rasch. Note that our "Rasch" model is Thissen's (1982) Rasch model, which differs from the traditional Rasch model where all slopes are assumed equal to 1.0. For the unidimensional analysis, 2PL (items with two categories) and GPCredit (items with more than two categories) models were fitted. Furthermore, the item parameters across groups were set equal and the mean and variance of the UK group relative to the US reference group were freely estimated. In the Rasch analysis, we imposed additional equality constraints across items (all items have the same slope). This turns the General Partial Credit (GPC) model into Partial Credit (PC) model. Fit indices and log-likelihood all point to the less constrained IRT model as a better fitting model when compared to the Rasch model.

The dataset contains responses by a subset of students to 14 items from math booklet 1. The grouping variable is Country, defined as follows: group 1 is the United States (US) and Group 2 is the United Kingdom (UK). There are 358 students in the US group and 889 in the UK group.

A fourth analysis, testlet response theory (TRT), based on this dataset is given in Section 7.2. For the TRT analysis, a multidimensional model for more than one group is fitted. The mean/variance of the primary math dimension is freely estimated in the UK group and the additional dimensions are there to account for local dependence among items in the same testlet.

The dataset **PISAMathBook1USUK.ssig** is located in the folder **IRTPRO Examples\By Data Set\PISA MathBook1** and when opened is displayed as a spreadsheet. Below we show the first 15 cases for items Walking3 to Grow2 and the grouping variable Country.

IRTI	Pro - [Pisan	MathBook1U	SUK.ssig]	-					_ 0	X
📑 Fil	le Edit Da	ta Manipu	late Graphi	ics Analysi	s View W	indow Help	p		_ 8	×
🗋 🗅 🚔	: 🖪 X 🖻	8 8 ?								
	Walking3	Apples1	Apples2	Apples3	Continent	Grow1	Grow3	Grow2	Country	
1	0	0	0	0	0	0	0	1	1	Ξ
2	0	1	1	0	0	1	0	1	1	
3	0	0	0	0	0	0	0	1	1	
4	2	1	1	1	0	1	1	2	1	
5	1	0	0	0	1	1	1	0	1	
6	0	1	0	0	0	0	1	1	1	
7	2	1	1	1	0	1	1	1	1	
8	0	0	0	0	0	0	0	0	1	
9	0	0	0	0	0	0	0	0	1	
10	0	1	0	0	0	0	0	1	1	
11	0	0	0	0	1	1	0	1	1	
12	0	0	0	0	0	0	0	2	1	_
13	0	1	0	0	0	0	0	2	1	_
14	0	0	0	0	0	0	1	1	1	_
15	0	0	0	0	0	0	0	0	1	Ψ.
1						111			•	
Ready									NUM	

Missing values in the data are coded as 9. To define the missing code, select the **Missing Value Code...** from the **Data** drop-down menu.

🔀 IRTI	KING - [PISAMathBook1USUK.ssig]									
📑 Fil	File Edit Data Manipulate Graphics Analys								Win	idow Help
0 🖻	8		Insert Varia	ables			1			
	Cube		Delete Var	iables				Farms	4	Walking1
1	0		Insert Case	,				1		0
2	1		Delete Car							0
3	1		Delete Cas	ses				1		0
4	1		Variable P	ropert	ies			1		1
5	1		Missing Value Code					1		0
6	1		Wilsong Value Code					0		0
7	1		Recalculate Item Counts					0		1
8	0	_	1	0 0						0

Enter the missing value and click **OK** when done. Save the .ssig file to make this change permanent.

	X
9	ОК
	Cancel
	9

6.2.1 Traditional Statistics

To view the statistics for these data, select **Traditional Summed-Score Statistics** ... from the **Analysis** menu.

ſ	🔀 IRTE	Pro - [Pisan	MathBook1U	SUK.ssig]	-		-	-		
l	File Edit Data Manipulate Graphics Analysis View Window Help									
l	🗋 🗅 🗳	📙 🐰 🖻	6 3 1			Т	adi	itional Summed-Score Statistics		
L		Cube1	Cube3	Cube4		U	nidi	limensional IRT		
ł	1	0	0	0	0	Multidimensional IRT				
h	2	1	1	1	0		тс			
	3	1	1	0	0	11	1.20	scoring		
	4	1	1	0	1	Advanced Options				
	5	1	1	1	1	Show Progress Box				
	6	1	1	0	0					

Right click on the **Test1** tab and rename **Test1** to **Traditional**. The **Traditional Summed-Score Statistics** dialog appears. Enter the title and comments in the **Description** tab as shown below.

Traditional Summed-Score Statistics
Data File: C:\IRTPRO Examples\By Dataset\PISA MathBook1\PISAMathBook1USUK.ssig
Traditional
Description Group Ttems Categories
Title:
Classical summed score statistics
<u>C</u> omments:
Grouping variable is country - United States and United Kingdom
Options OK Cancel Run

Proceed to the **Group** tab and select Country form the list of variables. The reference group (by default) is the United States (Country = 1).

Traditional Summed-Score Statistics Data File: C:\IRTPRO Examples\By Dat Traditional	aset\PISA MathBook1\PIS	SAMathBook1USUK.ssig	Read file
List of variables:	<u>A</u> dd >> [Ref] N ☑ G1 □ G2	Group: Country ame Country 1 2	
Options		ОК	ancel Run

Next we proceed to the **Items** tab and select all 14 items for the first group.

ditional Summed-Sco Data File: C:\IRTPRO E Traditional Description Group <u>G</u> rouping value:	re Statistics xamples\By Da Items Cate Country [G1] 1	taset\PISA MathBook1\ gories	PISAMathBook1USUK.ssig	Read file
List of variables: Walking1 Walking3 Apples1 Apples2 Apples3 Continent Grow1 Grow3 Grow2 ◀		Add >>	Items: Cube1 Cube3 Cube4 Farms1 Farms4 Walking1 Walking3 Apples1 ▲ □□□□ Apply to all group	
Options			OK Can	cel Run

Since the responses from the second group (UK) are based on the same 14 items, click the Apply to all groups button to automatically select these items. Select the Yes option from the Apply to All

Groups pop-up message box.

Apply to All Groups
Previous settings will be lost. Do you want to continue?
Yes No

IRTPRO computes the number of categories and associated values for each item. By clicking the **Categories** tab, these values are displayed as shown next for the first group. To see the corresponding values for the second group, this group may be selected from the **Grouping value**: drop down list.

Traditional	I Summed-Score	Statistics	-				X
<u>D</u> ata File	e: C:\IRTPRO Exa	mples\By Data	set\PISA M	athBook1\PIS	AMathBook1US	UK.ssig	<u>R</u> ead file
Traditio	onal						
	I						
Des	cription Group I	items Catego	ries				
		Secontra :					
	ر میں ایک ا	ountry					
9	Grouping value:	[G1] 1					
	Item List	Categories	Data Code	sitem Score	e		
	Cube1	2	0, 1	0, 1	_		
	Cube3	2	0, 1	0, 1			
	Cube4	2	0, 1	0, 1			-
	Farms1	2	0, 1	0, 1			-
	Farms4	2	0, 1	0, 1			
	Walking1	2	0, 1	0, 1			
	Walking3	4	0, 1, 2, 3	0, 1, 2, 3			
	Apples1	2	0, 1	0, 1			
	Apples2	2	0, 1	0, 1			
	Apples3	3	0, 1, 2	0, 1, 2			-
	Road parameters	alues				Apply to all grou	sdr
l		alues					
Options	5				ОК	Cancel	Run
						,	

When the **Run** button is clicked, the output appears, excerpts of which are listed below.

IRTPRO Version 2.0 Output generated by IRTPRO estimation engine Version 4.54 (32-bit)

Project:	Classical summed score statistics
Description:	Grouping variable is country - United States and United Kingdom
Date:	19 May 2011
Time:	12:33 PM

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Item and (Weighted) Summed-Score Statistics for Group 1 Item and (Weighted) Summed-Score Statistics for Group 2 Summary of the Data and Control Parameters

Coefficient Alpha, calculated using listwise deletion is 0.8317 for the US group.

Item and (Weighted) Summed-Score Statistics for Group 1 (Back to TOC) Coefficient alpha: 0.8317 Complete data N: 357

The table below is a summary of the coefficient Alpha, if each item in turn is deleted. For example, if item 7 is deleted, the reliability coefficient based on the remaining 13 items equals 0.8151.

The following Statistics are Computed only for the Listwise-Complete Data:

			With Item [Deleted
	Respons	se	Item-Total	Coefficient
Item	n Average	Std. Dev.	Correlation	α
1	0.557	0.497	0.4262	0.8234
2	0.754	0.432	0.3913	0.8255
3	0.333	0.472	0.4115	0.8243
4	0.462	0.499	0.5342	0.8166
5	0.594	0.492	0.4546	0.8217
6	0.238	0.427	0.5609	0.8165
7	0.524	0.713	0.5510	0.8151
8	0.499	0.501	0.4629	0.8211
9	0.227	0.419	0.5859	0.8153
10	0.232	0.589	0.5044	0.8181
11	0.345	0.582	0.4890	0.8193
12	0.443	0.497	0.4930	0.8192
13	0.507	0.501	0.4216	0.8237
14	1.168	0.757	0.3577	0.8341

The tables for Item 1 and Item 7 below give the frequency count for each category of an item as well as the number of missing values for the item in question. Similar results are produced for the remaining 12 items, but are not shown here.

Item	Cube1			(Back)
1	Category:	0	1	Missing
Frequen	cies:	159	199	0
For listw	ise-complete data:			
Frequen	cies:	158	199	
Average	(wtd) Score:	4.43	8.83	
Std. Dev	. (wtd) Score:	3.10	3.94	

Results for item numbers 2 to 6 and 8 to 14 appear in the output, but are not shown here.

Item	Walking3					(Back)
7	Category:	0	1	2	3	Missing
Frequen	cies:	207	125	16	10	0
For listwi	ise-complete data:					
Frequen	cies:	206	125	16	10	
Average	(wtd) Score:	4.74	9.01	12.25	15.90	
Std. Dev	. (wtd) Score:	3.05	3.43	2.82	1.52	

The corresponding results for the UK group are given below.

Item and (Weighted) Summed-Score Statistics for Group 2 (Back to TOC) Coefficient alpha: 0.8175 Complete data N: 887

The following Statistics are Computed only for the Listwise-Complete Data:

			With Item D	Deleted
	Respons	se	Item-Total	Coefficient
Item	Average	Std. Dev.	Correlation	α
1	0.717	0.451	0.3210	0.8139
2	0.840	0.367	0.3981	0.8103
3	0.391	0.488	0.3858	0.8100
4	0.676	0.468	0.5266	0.8013
5	0.609	0.488	0.2446	0.8188
6	0.398	0.490	0.6016	0.7959
7	0.611	0.880	0.6007	0.7947
8	0.689	0.463	0.3988	0.8092
9	0.278	0.448	0.5831	0.7983
10	0.360	0.657	0.5692	0.7955
11	0.583	0.695	0.5731	0.7951
12	0.630	0.483	0.3485	0.8123
13	0.696	0.460	0.4328	0.8072
14	1.374	0.675	0.3202	0.8178

The distribution of values over categories for the second group (UK) is listed next. Results for item numbers 2 to 6 and 8 to 14 appear in the output, but are not shown here.

Item	Cube1			(Back)		
1	Category:	0	1	Missing	3	
Frequen	cies:	252	637	0	_	
For listw	ise-complete data:					
Frequen	cies:	251	636			
Average	(wtd) Score:	6.07	9.95			
Std. Dev	. (wtd) Score:	3.46	3.97			
					_	
Item	Walking3					(Back)
7	Category:	0	1	2	3	Missing
Frequen	cies:	534	219	85	51	0
For listw	ise-complete data:					
Frequen	cies:	532	219	85	51	
Average	(wtd) Score:	6.49	11.03	3 13.85	15.78	
Std. Dev	. (wtd) Score:	2.96	2.86	2.40	2.20	

The final part of the output is a summary of sample sizes and number of items per group.

Summary of the Data and Control Parameters (Back to TOC)

Group:	Group 1	Group 2
Sample Size	358	889
Number of Items	14	14

6.2.2 Unidimensional IRT

In this example a mixture of 2PL and general partial credit models are fitted to the data. Since the previous example dealt with traditional summed-score statistics, the following steps need to be followed to fit unidimensional models to the data:

- o Close the spreadsheet and then re-open PISAMathbook1USUK.ssig
- Select the Analysis, Unidimensional IRT... option from the main menu bar

ĺ	🔀 IRTF	PRO - [PISAN	/lathBook1U	SUK.ssig]		
	🔳 Fil	e Edit Da	ta Manipu	late Graphi	cs	s Analysis View Window Help
	🗋 🗅 🚅	📙 🐰 🖻	6 3 1			Traditional Summed-Score Statistics
		Cube1	Cube3	Cube4		Unidimensional IRT
	1	0	0	0	0	Multidimensional IRT
	2	1	1	1	0	IPT Scoring
	3	1	1	0	0	IKT Scoring
	4	1	1	0	1	Advanced Options
	5	1	1	1	1	Show Progress Box
	6	1	1	0	0	

Click **Yes** to use the same command file.



This action produces the **Unidimensional Analysis** window. To proceed, right-click next to the **Traditional** test tab (right-hand side) to insert a second test. The default tab is **Test2**. Rename to **IRT** by right-clicking this tab and then selecting the **Rename** option.

Unid	limensional	Anal	ysis	· Manual Address of the	-
D	ata File: C:	IRTP	RO Examples\By Dataset\PIS	A MathBook1\PISAMathBook1USUK.ssig	
1	Fraditional		Incort Tost		
			Delete Test		
	Descriptio	on	Rename		
	Title:				
	Class	ica	Manage Test		

Once this is action is completed a title and comments may be added in the **Description** window as shown below.

Unidimensional Analysis
Data File: C:\IRTPRO Examples\By Dataset\PISA MathBook1\PISAMathBook1USUK.ssig
Traditional IRT
Description Group II Items Models Scoring
2-group IRT Analysis (GPC model for polytomous items)
<u>C</u> omments:
Mixture of 2PL and General Partial Credit Models
Options OK Cancel Apply

Proceed to the **Group** tab and select Country as the group variable.

Unidimensional Analysis Data File: C:\IRTPRO Examples\By Dataset\PIS Traditional IRT Description Group Items Models	SA MathBook1\PISAMathBook1USUK.ssig Read file
List of variables:	Add >> [Ref] Name Country G1 G2 2 G2 G2 G2 G2 G2
Options	OK Cancel Run

Using the **Items** tab, select all 14 items and click the **Apply to all groups** button. To demonstrate that these items were also selected for the second group, we change the value of the group variable from the first group (US) to the second group via the **Grouping variable**: drop-down list.

Unidimensional Analysis			1	X
Data File: C:\IRTPRO E	xamples\By Datase	t\PISA MathBook1\	PISAMathBook1USUK.ssig	<u>R</u> ead file
Description Group	Items Models	Scoring		· ·
List of variables:			Items:	×
Cube1 Cube3 Cube4 Farms1 Farms4 Walking1 Walking3 Apples1 Apples2		Add >>	Cube1 Cube3 Cube4 Farms1 Farms4 Walking3 Apples1 < Apply to all grout	▶ ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
Options			ОК Са	ncel Run

The default model for all items with 2 categories is 2PL and for those items with more than two categories it is Graded. For this example, we replace all the graded models with general partial credit models by selecting all the items in question. Next right-click on any of the selected cells and choose the GPCredit option.

Unidimensiona	I Analysis				-	on Lorge	
Data File: C	:\IRTPRO Exa	mples\By Dat	aset\PISA M	athBook1\PISA	MathBook1	JSUK.ssig	Read file
Traditional	IRT						
Descripti	on Group	Items Mode	Is Scoring				
		Country (· · · ·				
Consum		ountry					
Group	oing value:	[G1] 1					•
	Item List	Categories	Data Code	sitem Score	Model		
	Walking1	2	0, 1	0, 1	2PL		
	Walking3	4	0, 1, 2, 3	0, 1, 2, 3	Graded		
	Apples1	2	0, 1	0, 1	2PL		
	Apples2	2	0, 1	0, 1	2PL		
	Apples3	3	0, 1, 2	0, 1, 2	Graded		
	Continent	3	0, 1, 2	0, 1, 2	Graded		=
	Grow1	2	0, 1	0, 1	2PL		-
	Grow3	2	0, 1	0, 1	2PL		
	Grow2	3	0, 1, 2	0, 1, 2	Grade	2PL	
						3PI	-
Cor	nstraints	DIF R	lead parame	ter values		Graded)S
						CDCradit	
GPCredit							
						Nominal	
Options					ОК	Cancel	Run

This action produces a revised Models window. Click Apply to all groups.

nidimensi	onal Analysis			-		1	X
<u>D</u> ata File:	C:\IRTPRO Exar	mples\By Dat	taset\PISA Ma	thBook1\PISA	MathBook1US	UK.ssig	Read file
Tradition	ial IRT						
Deer	vintion II Crown II T	toma Ltada	La Cooring				
Desc	ription Group 1	tems mode	scoring				
	C	ountry					
G	rouping value:	[G2] 2					•
	6						
_	Item List	Categorie	sData Codes	Item Scores	Model		^
_	Walking1	2	0,1	0,1	2PL		
_	Waiking3	4	0, 1, 2, 3	0, 1, 2, 3	GP Credit		
	Appies1	2	0, 1	0, 1	2PL		
	Apples2	2	0, 1	0, 1	2PL		
_	Apples3	3	0, 1, 2	0, 1, 2	GP Credit		
_	Continent	3	0, 1, 2	0, 1, 2	GP Credit		Ξ
	Grow1	2	0, 1	0, 1	2PL		
	Grow3	2	0, 1	0, 1	2PL		
_	Grow2	3	0, 1, 2	0, 1, 2	GP Credit		-
r	Construints					Analysis all analy	
	Constraints	<u>D</u> IF	<u>k</u> ead paramete	er values		Apply to a <u>i</u> l grou	ps
				ſ			
Options.	••				ОК	Cancel	Run

In this example, the item parameters across groups were set equal and the mean and variance of the UK group relative to the US reference group were freely estimated. To set parameters equal across groups, click the **Constraints...** button (see the **Models** window above.)

Group, Country											
Group, Item											
G1, Cube1	a	1	с	2							
G1, Cube3	а	3	с	4							
G1, Cube4	а	5	с	6							
G1, Farms1	a	7	с	8							
G1, Farms4	a	9	с	10							-
G1, Walking1	а	11	с	12							
G1, Walking3	а	13	c1		c2		c3		c4		
			Trend	•	γ1	14	γ2	15	γ3	16	
G1, Apples1	а	17	с	18							
G1, Apples2	a	19	с	20							
G1, Apples3	а	21	c1		c2		c3				
			Trend	•	γ1	22	γ2	23			
G1, Continent	а	24	c1		c2		c3				
			Trend	•	γ1	25	γ2	26			
G1, Grow1	а	27	с	28							
G1, Grow3	а	29	с	30							
G1, Grow2	а	31	c1		c2		c3				
			Trend	•	γ1	32	γ2	33			
G2, Cube1	а	34	с	35							-
Set parameters eq	ual ac	ross ar	uns								

This action produces the **Item Parameter Constraints** window. By clicking the **Set parameters equal across groups** button IRTPRO sets corresponding parameters equal across groups. Note that this action is only performed for items that are present in all groups and have the same number of categories for each group. To get a clearer picture of the imposed contraints, double-click on the **Group**, **Item** tab to change the sorting to **Item**, **Group** as shown below. The **Item Parameter Constraints** window also shows that the mean and variance parameters of the second group (UK) are estimated freely.

Item, Group											-
			Trend		γ1	26	γ2	27	γ3	28	
Apples1, G1	а	36	С	37							
Apples1, G2	а	36	С	37							
Apples2, G1	а	40	с	41							
Apples2, G2	а	40	с	41			-				
Apples3, G1	a	44	C1		c2		C3				
			Trend	•	γ1	45	γ2	46			
Apples3, G2	а	44	C1		c2	10	C3				
Carling and Ct	_	50	I rend	•	γ1 -2	45	γ2 -2	46			
Continent, G1	a	52	C1	_	c2	50	C3	5.4			
Cartinant CD	_	50	I rend	•	γ1 -2	- 23	γ2 -2	54			
Continent, G2	a	52	C1	_	c2	50	C3	5.4			
C1 C1	_	60	Trend		γ1	23	γz	54			
Grow1, GI	a	60	c	61							
Grow1, GZ	a	64	C C	61							
Grow3, GI	a 2	64	с с	65							
Grow3, GZ	a 2	69	c1	05	67		c2				Ξ
GIUWZ, GI	a	00	Trond	-	v1	60	ພ ທ	70			
Grow2 G2	a	68	c1		(1 (2	09	(2 (3	70			
31042, 32	u	00	Trend	+	v1	69	·2	70			
G1. Means	u1	0.0	Trend	_	11		12				
G1. Cov	σ1 1	1.0									
G2. Means	u1	76									
G2, Cov	σ1 1	77									
₹											

Click **OK** to return to the **Models** window, then click the **Run** button to start the analysis. Portions of the output file is given below.

Item	Label	а		s.e.	С		s.e.	b	s.e.
1	Cube1	2	1.11	0.17	1	0.47	0.12	-0.42	0.12
2	Cube3	4	1.57	0.22	3	1.48	0.17	-0.94	0.14
3	Cube4	6	1.12	0.18	5	-1.04	0.13	0.93	0.20
4	Farms1	8	2.14	0.33	7	-0.02	0.22	0.01	0.10
5	Farms4	10	0.79	0.14	9	0.19	0.10	-0.24	0.13
6	Walking1	12	2.68	0.44	11	-2.18	0.30	0.81	0.18
8	Apples1	18	1.46	0.22	17	0.21	0.15	-0.14	0.10
9	Apples2	20	2.79	0.50	19	-3.05	0.33	1.09	0.22
12	Grow1	28	1.24	0.20	27	-0.06	0.13	0.05	0.11
13	Grow3	30	1.46	0.22	29	0.26	0.15	-0.18	0.10

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

GPC Model Item Parameter Estimates, logit: $a[k(\theta - b) + \Sigma dk]$

Item	Label	а	s.e.	b	s.e.	d_1	d_2	s.e.	d_{3}	s.e.	d_4	s.e.
7	Walking3	3 ¹³ 1.65	0.25	1.52	0.27	0.00	0.69	0.13	-0.30	0.09	-0.39	0.12
10	Apples3	²¹ 2.24	0.38	1.50	0.27	0.00	0.07	0.07	-0.07	0.07		
11	Continen	t ²⁴ 1.64	0.32	1.32	0.25	0.00	0.55	0.08	-0.55	0.08		
14	Grow2	³¹ 0.69	0.10	-0.66	0.14	0.00	0.94	0.19	-0.94	0.19		

Nominal Model Slopes and Scoring Function Contrasts for Group 1, logit: (a sk θ + ck); s = T α (Back to TOC)

Item	Label	а	s.e.	Contrasts a1		s.e.	α ₂	s.e.	α3	s.e.
7	Walking3	¹³ 1.65	0.25	Trend	1.00		0.00		0.00	
10	Apples3	²¹ 2.24	0.38	Trend	1.00		0.00			
11	Continent	t ²⁴ 1.64	0.32	Trend	1.00		0.00			
14	Grow2	³¹ 0.69	0.10	Trend	1.00		0.00			

Nominal Model Scoring Function Values for Group 1, logit: (a sk θ + ck); s = T α (Back to TOC)

Item	Category s_1	S_2	S_3	S_4
7	Walking3 0.00	1.00	2.00	3.00
10	Apples3 0.00	1.00	2.00	
11	Continent 0.00	1.00	2.00	
14	Grow2 0.00	1.00	2.00	

Nominal Model Intercept Contrasts for Group 1, logit: (a sk θ + ck); c = Ty (Back to TOC)

Item	Label	Contrasts	Y 1	s.e.	Y 2	s.e.	γ ₃	s.e.
7	Walking3	Trend	¹⁴ -2.51	0.26	¹⁵ 1.03	0.16	16 0.29	0.07
10	Apples3	Trend	²² -3.36	0.44	²³ 0.15	0.16		
11	Continent	t Trend	²⁵ -2.17	0.17	²⁶ 0.89	0.12		
14	Grow2	Trend	³² 0.46	0.07	³³ 0.65	0.08		

Item	Label	а	s.e.	С	s.e.	b	s.e.
1	Cube1	² 1.11	0.17	¹ 0.4	47 0.12	-0.42	0.12
2	Cube3	⁴ 1.57	0.22	³ 1.4	48 0.17	-0.94	0.14
3	Cube4	⁶ 1.12	0.18	⁵ -1.	04 0.13	0.93	0.20
4	Farms1	⁸ 2.14	0.33	⁷ -0.	02 0.22	0.01	0.10
5	Farms4	¹⁰ 0.79	0.14	⁹ 0.1	9 0.10	-0.24	0.13
6	Walking1	¹² 2.68	0.44	¹¹ -2.	18 0.30	0.81	0.18
8	Apples1	¹⁸ 1.46	0.22	¹⁷ 0.2	21 0.15	-0.14	0.10
9	Apples2	²⁰ 2.79	0.50	¹⁹ -3.	05 0.33	1.09	0.22
12	Grow1	²⁸ 1.24	0.20	²⁷ -0.	06 0.13	0.05	0.11
13	Grow3	³⁰ 1.46	0.22	²⁹ 0.2	26 0.15	-0.18	0.10

2PL Model Item Parameter Estimates for Group 2, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

GPC Model Item Parameter Estimates, logit: $a[k(\theta - b) + \Sigma dk]$

Item	Label	а	s.e.	b	s.e.	d_1	d_2	s.e.	d_{3}	s.e.	d_4	s.e.
7	Walking3	3 ¹³ 1.65	0.25	1.52	0.27	0.00	0.69	0.13	-0.30	0.09	-0.39	0.12
10	Apples3	²¹ 2.24	0.38	1.50	0.27	0.00	0.07	0.07	-0.07	0.07		
11	Continen	t ²⁴ 1.64	0.32	1.32	0.25	0.00	0.55	0.08	-0.55	0.08		
14	Grow2	³¹ 0.69	0.10	-0.66	0.14	0.00	0.94	0.19	-0.94	0.19		

Nominal Model Slopes and Scoring Function Contrasts for Group 2, logit: (a sk θ + ck); s = T α (Back to TOC)

Item	Label	а	s.e.	Contrasts a1		s.e.	α ₂	s.e.	α3	s.e.
7	Walking3	¹³ 1.65	0.25	Trend	1.00		0.00		0.00	
10	Apples3	²¹ 2.24	0.38	Trend	1.00		0.00			
11	Continent	t ²⁴ 1.64	0.32	Trend	1.00		0.00			
14	Grow2	³¹ 0.69	0.10	Trend	1.00		0.00			

Nominal Model Scoring Function Values for Group 2, logit: (a sk θ + ck); s = T α (Back to TOC)

Item	Category	S ₁	S ₂	S ₃	S ₄
7	Walking3	0.00	1.00	2.00	3.00
10	Apples3	0.00	1.00	2.00	
11	Continent	0.00	1.00	2.00	
14	Grow2	0.00	1.00	2.00	

Nominal Model Intercept Contrasts for Group 2, logit: (a sk θ + ck); c = Ty (Back to TOC)

Item	Label	Contrasts	Y 1	s.e.	Y ₂	s.e.	γ ₃	s.e.
7	Walking3	Trend	¹⁴ -2.51	0.26	¹⁵ 1.03	0.16	¹⁶ 0.29	0.07
10	Apples3	Trend	²² -3.36	0.44	²³ 0.15	0.16		
11	Continent	Trend	²⁵ -2.17	0.17	²⁶ 0.89	0.12		
14	Grow2	Trend	³² 0.46	0.07	³³ 0.65	0.08		

Likelihood-based Values and Goodness of Fit Statistics (Back to TOC)

Statistics based on the loglikelihood									
-2loglikeli	ihood:		21233.40						
Akaike Information Criterion (AIC): 21303.40									
Bayesian Information Criterion (BIC): 21482.90									
Statistics based on one- and two-way marginal tables									
M ₂	Degrees of freedom	Probability	RMSEA						
785.98	333	0.0001	0.03						
Note: M ₂	Note: M_2 is based on full marginal tables.								
Note: Mo	Note: Model-based weight matrix is used.								

Group Parameter Estimates (Back to TOC)

Group	Label	μ	s.e.	σ^2	s.e.	σ	s.e.
1	G1	0.	00	1.00		1.	00
2	G2	⁶⁷ -0	.13 0.09	⁶⁸ 0.85	0.18	⁶⁸ 0.	92 0.10

The option to display trace lines, information curves and test characteristic curves are available for all types of unidimensional analyses. While the output file is displayed, select the **Analysis**, **Graphs** option.

IRTPRO - [P	ISAMathBook1USUK.IRT-irt.htm]
File Edit	View Analysis Window Help
0 🖻 🖬 %	🖻 💼 Graphs
IRTPRO Ve Output gen	rsion 2.0 erated by IRTPRO estimation engine Version 4.54 (32-bit)
Project:	2-group IRT Analysis (GPC model for polytomous items)
Description:	Mixture of 2PL and General Partial Credit Models
Date:	24 May 2011
Time:	04:43 PM
Table of Co 2PL Model Item Nominal Model	Intents Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ Slopes and Scoring Function Contrasts for Group 1, logit: ($a s_k \theta + c_k$); s = T α

The default display shows the trace lines for the items in each group. To illustrate, the trace lines for the items Continent, Grow1, Grow3 and Grow2 are shown for the second (UK) group.



6.2.3 Unidimensional Rasch

In the Rasch analysis to be considered next, we imposed additional equality constraints across items (all items have the same slope). This turns the general partial credit (GPC) model into the partial credit (PC) model. Close the output file generated in the previous section to display the data **PISAMathbook1USUK.ssig**. Select the **Unidimensional IRT...** option from the **Analysis** menu.

Right click on the righthand-side of the **IRT** tab to insert **Test3**. Once the **Test3** tab is displayed, right click on this tab and rename it to **Rasch**.

Unidimensional Analysis	1000	
Data File: C:\IRTPRO Examp	oles\By Dataset\PISA Mathl	Book1\PISAMathBook1USUK.ssig
Traditional IRT	Insert Test	1
Description Group	Delete Test	
Title:	Rename	
2-group IRT Analy	Manage Test	ems)

Once this is done, enter a title and comments.

Unidimensional Analysis
Data File: C:\IRTPRO Examples\By Dataset\PISA MathBook1\PISAMathBook1USUK.ssig
Traditional IRT Rasch
Description Group Tems Models Scoring
<u>T</u> itle:
2-group unidimensional Rasch (PC model for polytomous items)
<u>C</u> omments:
Rasch model obtained by constraining slope parameters to be equal
Options OK Cancel Run

Follow the steps described in the previous section to select the group variable and items. Next click the **Constraints** button on the **Models** window. Click the **Set parameters equal across groups** button. Then, for both groups, select all the cells containing the slope parameters (denoted as "a").

Group: (Country												
Grou	up, Item												
G1,	Apples2	а	19	с	20								
G1,	Apples3	а	21	c1		c2		c3				1	
				Trend	-	γ1	22	γ2	23				
G1, 0	Continent	а	24	c1		c2		c3					
				Trend	•	γ1 –	25	γ2	25]	
G1,	Grow1	а	27	с	28								
G1,	Grow3	а	29	С	30								
G1,	Grow2	а	31	c1		c2		c3					
				Trend	•	γ1	32	γ2	33				
G2,	Cube1	а	1	С	2								
G2,	Cube3	a	3	с	4								
G2,	Cube4	а	5	с	6								
G2,	Farms1	а	7	с	8	_							
G	Set Par	amete	ers Equ	lal									
G2	Fix Valu	ie				-2		-0		- 4			Ξ
Gź	Set Par	amete	ers Fre	e		c2 v1	14		15	C4	16		
62.	Apples1	a	17	C	18	1.7	14	1-		12	10		
G2,	Apples2	a	19	c	20								
G2,	Apples3	а	21	c1		c2		c3					
				Trend	•	γ1	22	γ2	23				
G2, 0	Continent	а	24	c1		c2		c3				1	
				Trend	•	γ1	25	γ2	25]	
G2,	Grow1	а	27	С	28								
G2,	Grow3	a	29	с	30								
G2,	Gruw2	d	31	c1		<u>د</u> 2		c 3					
				Trend	•	γ1	32	γ2	33				-
Catro	Maane		0.0									I	
Set pa	rameters eq	uai ac	ross gro	bups									

Right click on any one of the selected cells and select the **Set Parameters Equal** option from the drop-down menu. This action results in all the slope parameter numbers being set to a single number as shown in the **Constraints** window below. Click **OK** to return to the **Models** window.

Group, Item											
G1. Apples2	а	69	с	20							
G1, Apples3	a	69	c1		c2		c3			-	
			Trend	-	γ1	22	γ2	23		-	
G1, Continent	а	69	c1		c2		c3			-	
			Trend	-	γ1	25	γ2	26		-	
G1, Grow1	a	69	с	28						1	
G1, Grow3	а	69	с	30							Γ
G1, Grow2	a	69	c1		c2		c3				
			Trend	•	γ1	32	γ2	33		_	
G2, Cube1	a	69	с	2							
G2, Cube3	a	69	с	4							
G2, Cube4	a	69	с	6						_	
G2, Farms1	а	69	с	8						_	
G2, Farms4	а	69	с	10						_	
G2, Walking1	а	69	с	12						-	
G2, Walking3	a	69	c1		c2		c3		c4		
			Trend	-	γ1	14	γ2	15	γ3 16	5	
G2, Apples1	a	69	с	18						_	
G2, Apples2	a	69	C	20	-2		-2			-	
GZ, Appless	a	09	Trond	-	CZ	22		22		-	
62 Continent	2	60	c1		(1 (2	22	12 C3	23		-	
oz, continent		09	Trend	-	71	25	12	26		-	
G2, Grow1	а	69	c	28		- 25	12	20		-	
G2, Grow3	а	69	с	30						-	
G2, Grow2	а	69	c1		c2		c3			-	
			Trend	-	71	32	72	33		-	

To start the analysis, click the **Run** button. Portions of the output is given next.

2PL Model Item Parameter Estimates for Group	1, logit: $a\theta + c$ or $a(\theta - b)$	(Back to TOC)
--	--	---------------

Item	Label	а	s.e.	С	s.e.	b	s.e.
1	Cube1	²⁰ 1.39	0.11	¹ 0.45	0.10	-0.32	0.09
2	Cube3	20 1.39	0.11	² 1.45	0.11	-1.04	0.14
3	Cube4	²⁰ 1.39	0.11	³ -1.19	0.11	0.86	0.06
4	Farms1	²⁰ 1.39	0.11	4 0.12	0.11	-0.09	0.08
5	Farms4	²⁰ 1.39	0.11	⁵ 0.06	0.11	-0.05	0.08
6	Walking1	²⁰ 1.39	0.11	⁶ -1.33	0.11	0.96	0.07
8	Apples1	²⁰ 1.39	0.11	10 0.23	0.10	-0.16	0.08
9	Apples2	²⁰ 1.39	0.11	¹¹ -1 .88	0.12	1.35	0.08
12	Grow1	²⁰ 1.39	0.11	¹⁶ -0.09	0.10	0.06	0.07
13	Grow3	²⁰ 1.39	0.11	¹⁷ 0.28	0.10	-0.20	0.08

GPC Model Item Parameter Estimates, logit: $a[k(\theta - b) + \Sigma dk]$

ltem	Label	а	s.e.	b	s.e.	d_1	d_2	s.e.	d ₃	s.e.	d_4	s.e.
7	Walking3	²⁰ 1.39	0.11	1.62	0.08	0.00	0.73	0.07	-0.33	0.09	-0.39	0.10
10	Apples3	²⁰ 1.39	0.11	1.70	0.09	0.00	-0.13	0.07	0.13	0.07		
11	Continen	t ²⁰ 1.39	0.11	1.41	0.08	0.00	0.58	0.06	-0.58	0.06		
14	Grow2	²⁰ 1.39	0.11	-0.32	0.08	0.00	0.74	0.06	-0.74	0.06		

Group Parameter Estimates (Back to TOC)

Group	Label	μ	s.e.	σ^2	s.e.	σ	s.e.
1	G1	0.00		1.00		1.00	
2	G2	²¹ 0.51	0.07	²² 0.84	0.09	²² 0.92	0.05

Marginal Reliability for Response Pattern Scores: 0.82

Likelihood-based Values and Goodness of Fit Statistics (Back to TOC)

Statistics based on the loglikelihood							
-2loglikelihood: 21597.38							
Akaike Info	rmation Criteri	on (AIC):	21641.38				
Bayesian Information Criterion (BIC): 21754.20							
Statistics based on one- and two-way marginal tables							
M ₂	M ₂ Degrees Probability RMSEA						
1214.58	1214.58 346 0.0001 0.04						
Note: M ₂ is based on full marginal tables.							
Note: Mode	l-based weigh	it matrix is us	ed.				

The deviance statistic (-2 log likelihood) for the Rasch model is reported above as 21597.38. The corresponding value for the IRT model (see previous section) is 21233.40. The chi-squared difference test therefore yields a value of 21597.38 - 21233.40 = 363.98. The degrees of freedom for testing between the IRT and Rasch models is 13 (14 slope parameters were estimated in the case of the IRT model versus one for the Rasch model). Since the chi-squared difference test is highly significant, we conclude that the IRT model provides a better fit to the item responses when compared to the Rasch model. Information-theoretic indices of fit (AIC and BIC) also point to the IRT model as better fitting.

7. Multidimensional analysis

7.1 Multidimensional analysis of the Affect Adjective Check List (AACL)

To obtain a better fit than was obtained with a unidimensional model in Section 5.4, we consider a two-dimensional model that fits one factor (latent variable) for the "anxiety-plus" items and a second (correlated) factor for the "anxiety-minus" items. See Section 5.4 for a description of the data and the recoding of item scores. Open the file AACL_21Items.ssig stored in the folder C:\IRTPRO Examples\by DataSet\AACL, and then select Multidimensional IRT ... under the Analysis menu. A Use Saved Command File dialog appears. Click the Yes button and insert a second test by right-clicking on the right-hand side of the UniDallItems tab.

Use Saved Command File
A command file AACL3_21Items.irtpro is found in the following folder C:\IRTPRO Examples\By Dataset\AACL\
Do you want to use this file? Press [No] to save command with a new name
Yes No

Rename the **Test2** tab to **TwoFactor**, enter a title and comments and select all 21 items. Change the number of dimensions to two as shown below.

Multidimensional Analysis	s camples\By D	Pataset\AACL\AACL3_21Itr	ems.ssig	. <u>R</u> ead file
Description Group	Items Mod Single Group No Group V	dels Scoring p Analysis ariable		•
List of variables: Cheerful Contented Happy Joyful Loving Pleasant Secure Steady Thoughtful ◀ III		Add >> Number of latent dimensions: 2	Items: Contented Happy Joyful Loving Pleasant Secure Steady Thoughtful III Apply to all groups	
Options			OK Cance	Run

The particular two-dimensional model to be fitted to these data is a "simple structure" confirmatory factor analysis (CFA) model, which has non-zero slopes (or factor loadings) for the first eleven "anxiety-plus" adjectives on the first factor, non-zero slopes (or factor loadings) for the final ten "anxiety-minus" adjectives on the second factor, and zero slopes (or loadings) for the other combinations.

In addition, the correlation between the two latent variables (for the "anxiety-plus" adjectives and the "anxiety-minus" adjectives) is estimated.

To set up the constraints in the IRTPRO graphical user interface (GUI), we click on the **Models** tab. Recode item scores of the first eleven items as explained in Section 5.4.

<u>D</u> ata File:	C:\IRTPRO Exa	mples∖By Da	taset\AACL\A	ACL3_21Items	s.ssig	<u>R</u> ead f	ìle
Descrip	tion 🛛 Group 🗍 I	tems Mode	s Scoring				
<u>G</u> rou	ping value:	lo Group Va	riable	1	1	•	
_	Item List	Categorie	sData Code	sitem Score	Model	^	
	Afraid	2	1, 2	1,0	2PL		
_	Desperate	2	1, 2	1,0	2PL 2DI	Ξ.	
	Fedriu	2	1, 2	1,0	261	-	
	Noprous	2	1, 2	1,0	261	-	
	Panicky	2	1,2	1.0	2PL		
_	Shaky	2	1,2	1.0	2PL		
	Tense	2	1.2	1.0	2PI		
	Terrified	2	1.2	1.0	2PL		
_	Upset	2	1, 2	1, 0	2PL	· ·	
	onstraints	<u>D</u> IF			_	Apply to all groups	

Once done, click on the **Constraints** button beneath the item list, and that shows the **Item Parameter Constraints** window:

Item	1					1			
Afraid	a1	1	a2	2	с	3			ſ
Desperate	a1	4	a2	5	с	6			
Fearful	a1	7	a2	8	с	9			
Frightened	a1	10	a2	11	с	12			1
Nervous	a1	13	a2	14	с	15			
Panicky	a1	16	a2	17	с	18			
Shaky	a1	19	a2	20	с	21			
Tense	a1	22	a2	23	c	74	1		L
Terrified		Set Pa	arame	ters Ed	qual				
Upset		Fix Va	lue						
Worrying		Set Pa	rame	ters Fr	PP		1		
Calm	.01	90000	uz		00				
Cheerful	a1	37	a2	38	с	39			
Contented	a1	40	a2	41	с	42			

The **Item Parameter Constraints** window lists the items in the leftmost column, and then, for each item, the model parameters are indicated symbolically (*a* for slopes, and *c* for intercepts).

Select the a_2 cells for items Afraid to Worrying and right click to invoke the dialog for setting parameters equal, to free parameters or to fix parameter values. Select the **Fix Value**... option and since the default value is 0.0, click the **OK** button. For convenience, blocks of item parameters may be selected using standard conventions, such as shift-clicking, so that constraints may be applied to several parameters at a time.

Starting Value	X
Enter Value: 0.0	OK

Next, select the a_1 cells for items Calm to Thoughtful and right click to invoke the dialog for setting parameters equal, to free parameters or to fix parameter values. Select the **Fix Value**... option and click the **OK**.

Finally, select the covariance cell (σ_{21}) and right-click to select the **Set Parameters Free** option. Integers in blue cells with the parameter symbol indicate the numbers for parameters that will be estimated. Real values in the red cells indicate fixed parameter values as shown below.

Item	-1	4	- 2				4
Arraid	-1	1	a2	0.0	C a	э с	
Desperace	-1	7	a2 52	0.0	ι c	0	
Frightopod	a1 a1	10	az a2	0.0	د د	12	
Nervous	al	13	a2	0.0	c c	15	
Panicky	al	16	a2	0.0	c	18	
Shaky	a1	19	a2	0.0	- c	21	
Tense	a1	22	a2	0.0	- C	24	
Terrified	a1	25	a2	0.0	с	27	
Upset	al	28	a2	0.0	с	30	
Worrying	a1	31	a2	0.0	с	33	
Calm	a1	0.0	a2	35	с	36	
Cheerful	ai	0.0	a2	38	с	39	
Contended	a1	0.0	a2	41	с	42	
Нарру	a1	0.0	a2	44	с	45	
Joyful	a1	0.0	a2	47	c	48	
Loving	a1	0.0	a2	50	с	51	
Pleasant	a1	0.0	a2	53	с	54	
Secure	a1	0.0	a2	56	c	57	
Steady	a1	0.0	a2	59	с	60	
Thoughtful	a1	0.0	a2	62	c	63	
Means	μ1	0.0	μ2	0.0			
Covariances	σ1 1	1.0					
	σ2 1	64	σ2.2	1.0			1

The elements of the mean vector and covariance matrix of the latent variables are also model parameters; they are shown at the bottom of the **Item Parameter Constraints** window. In this example, the means and variances are fixed (at 0.0 and 1.0, respectively) to standardize the two latent variables. The covariance between those two standardized variables (σ_{21}) is estimated – that is the correlation between the two latent variables.

When the parameters are as desired, we click **OK** in the **Item Parameter Constraints** window, then **Run** in the **Multidimensional Analysis** dialog box, and wait... longer than for the unidimensional run, because multidimensional runs take more time.

When the parameters have been estimated, the output appears. We note that among the item parameter estimates, there are two columns of slopes, labeled a_1 and a_2 — those are slopes on the two latent dimensions. We also note that there are c (intercept) parameters, but no b (threshold) parameters, because the latter do not have meaning for multidimensional models.

Item	Label	<i>a</i> 1		s.e.	a2		s.e.	С		s.e.
1	Afraid	2	3.47	0.69		0.00		1	-4.33	0.75
2	Desperate	4	3.28	0.62		0.00		3	-3.97	0.65
3	Fearful	6	5.08	1.21		0.00		5	-5.76	1.26
4	Frightened	8	8.16	3.02		0.00		7	-10.35	3.63
5	Nervous	10	3.14	0.52		0.00		9	-1.69	0.35
6	Panicky	12	2.68	0.45		0.00		11	-2.76	0.41
7	Shaky	14	2.27	0.40		0.00		13	-2.92	0.40
8	Tense	16	2.93	0.46		0.00		15	-0.71	0.27
9	Terrified	18	4.88	1.82		0.00		17	-9.49	3.14
10	Upset	20	2.06	0.34		0.00		19	-2.31	0.32
11	Worrying	22	3.71	0.76		0.00		21	0.16	0.31
12	Calm		0.00		24	1.51	0.25	23	-1.17	0.20
13	Cheerful		0.00		26	2.16	0.35	25	-1.04	0.24
14	Contended		0.00		28	2.94	0.49	27	-1.26	0.30
15	Нарру		0.00		30	3.60	0.70	29	-1.93	0.43
16	Joyful		0.00		32	2.68	0.48	31	1.01	0.27
17	Loving		0.00		34	1.50	0.24	33	-0.66	0.18
18	Pleasant		0.00		36	2.66	0.49	35	-2.99	0.46
19	Secure		0.00		38	2.13	0.34	37	-1.00	0.23
20	Steady		0.00		40	2.01	0.34	39	-1.63	0.26
21	Thoughtful		0.00		42	1.48	0.27	41	-1.90	0.24

2PL Model Item Parameter Estimates for Group 1, logit: aθ + c (Back to TOC)

To see the estimated correlation between the two latent variables, we click on the entry **Group** Latent Variable Means in the table of contents; below the means IRTPRO lists the latent variable variance-covariance matrix:

Latent Variable Variance-Covariance Matrix for Group 1, (Back)

θ_1		s.e.	θ_2	s.e.	
_	1.00				
4 3	0.55	0.06	1.00		

We observe that the correlation between the latent variables that account for the covariation among the "anxiety-plus" and "anxiety-minus" adjectives is only 0.55. That value would have needed to be 1.0 for a unidimensional model to fit, which explains why the unidimensional model we fitted in Section 5.4 not appear to fit well.

The M_2 statistic for this model suggests much better fit:

Statistics based on one- and two-way marginal tables								
M ₂	RMSEA	SEA						
463.91	188	0.0001	0.07	7				
Note: M_2 is based on full marginal tables.								
Note: Mo	del-based weight	matrix is used.						

The difference between the values of -2 loglikelihood for the unidimensional model (5058.51) and for this two-dimensional model (4748.47) may be interpreted as a χ^2 -distributed statistic on 1 degree of freedom (because the unidimensional model is nested within this two-dimensional model, and the two-dimensional model uses one more fitted parameter. That difference is 310.1, which is incredibly significant. So there is strong evidence that these data need a two dimensional model to be fitted.

With the two-dimensional model, the standardized LD X^2 statistics no longer suggest strong residual covariance. There are few extremely large values and no obvious red clusters:

	Marginal										
Item	X ²	1	2	3	4	5	6	7	8	9	10
1	0.0										
2	0.0	0.9									
3	0.0	0.4	-0.3								
4	0.0	-0.7	1.1	1.1							
5	0.0	0.2	-0.7	-0.6	-0.6						
6	0.0	-0.5	-0.7	1.8	5.0	-0.3					
7	0.0	0.1	0.6	-0.1	-0.7	-0.7	0.1				
8	0.0	0.2	-0.5	1.6		0.0	-0.0	-0.7			
9	0.1	0.0	-0.6				0.0	0.7			
10	0.0	0.3	0.1	0.2	0.1	-0.7	-0.7	0.1	-0.3	-0.5	
11	0.0	-0.2	0.4			-0.2	1.2	-0.6	0.4		-0.1
12	0.0	0.3	9.6	2.8	3.3	3.7	11.4	4.2	9.1	0.1	2.0
13	0.0	3.0	-0.6	2.1	1.1	2.2	-0.7	-0.3	0.2	0.1	-0.3
14	0.0	-0.7	0.6	-0.6	-0.7	-0.7	-0.5	-0.5	-0.2	0.6	-0.7
15	0.0	-0.2	-0.5	-0.5	-0.7	0.1	-0.6	-0.7	-0.1	-0.5	-0.7
16	0.0	-0.4	-0.7	-0.5	-0.2	0.6	-0.4	-0.6	1.5		-0.7
17	0.0	8.5	1.1	5.2	5.7	5.5	0.2	0.1	4.5	1.0	0.2
18	0.0	2.5	2.3	-0.7	-0.6	-0.1	0.7	0.0	-0.7	-0.6	-0.6
19	0.0	-0.5	0.7	1.6	1.0	-0.2	0.5	1.8	0.1	-0.6	0.5
20	0.0	1.4	3.1	3.4	3.6	-0.6	2.2	4.0	0.8	0.1	0.2
21	0.0	0.3	-0.6	-0.7	-0.7	0.6	-0.6	-0.6	1.1	-0.6	0.0
	Marginal										
Item	X ²	11	12	13	14	15	16	17	18	19	20
11	0.0										
12	0.0	5.5									
13	0.0	1.8	0.5								
14	0.0	-0.1	3.1	1.2							
15	0.0	-0.4	-0.1	3.9	-0.6						
16	0.0	3.7	0.5	1.9	-0.7	1.3					
17	0.0	6.3	2.6	0.1	1.1	-0.7	5.7				
18	0.0	-0.4	-0.7	0.6	0.8	1.8	-0.6	-0.5			
19	0.0	1.1	-0.7	5.9	-0.2	1.0	2.3	-0.2	-0.7		
20	0.0	1.5	0.4	4.5	-0.7	2.6	1.6	3.8	-0.7	9.8	
21	0.0	0.6	1.8	-0.7	1.4	-0.2	-0.5	2.0	-0.4	-0.6	-0.0

Marginal fit (X2) and Standardized LD X2 Statistics for Group 1 (Back to TOC)

One value of the pairwise LD statistics that stands out is the 11.4 for items 6 and 12; those adjectives are "panicky" and "calm" (the latter reverse scored). It is likely that there is additional un-modeled local dependence between those two near-antonyms. That *could* be modeled as well,

but we leave that exercise to the reader.

7.2 Analysis of Quality of Life data

7.2.1 Exploratory Factor Analysis (EFA)

To illustrate the implementation of exploratory factor analysis for graded response data, the "Quality of Life Interview for the Chronically Mentally III" (Lehman, 1988) was analyzed based on the item responses of 586 chronically mentally ill patients. The scale consists of seven subdomains (Family, Finance, Health, Leisure, Living, Safety, and Social), each with 4 to 6 items for a total of 34 items. In addition, there is one global life satisfaction item, yielding a total of 35 items. Each item is rated on a 7-point scale with the following response categories: 1 = terrible; 2 = unhappy; 3 = mostly dissatisfied; 4 = mixed, about equally satisfied and dissatisfied; 5 = mostly satisfied; 6 = pleased; and 7 = delighted. The table below provides a brief description of each of the 35 items.

Global	Health	Living
Item1: Global life satisfaction	Item10: Health in general	Item22: Living arrangements
as a whole	Item11: Medical care	Item23: Food
	Item12: How often see doctor	Item24: Privacy
Family	Item13: Talk to therapist	Item25: Amount of freedom
Item2: Family	Item14: Physical condition	Item26: Prospect of staying
Item3: Amount of family	Item15: Emotional well-being	
contact		Safety
Item4: Family with interaction	Leisure	Item27: Neighborhood safety
Item5: General family stuff	Item16: Way spend free time	Item28: Safe at home
	Item17: Amount of free time	Item29: Police access
Finance	Item18: Chance to enjoy time	Item30: Protect robbed/attack
Item6: Total money you get	Item19: Amount of fun	Item31: Personal safety
Item7: Amount pay for basic	Item20: Amount of relaxation	
needs	Item21: Pleasure from TV	Social
Item8: Financial well-being		Item32: Do things with others
Item9: Money for fun		Item33: Time with others
-		Item34: Social interactions
		Item35: People in general

Table 7.1: Description of items in the Lehman (1988) Quality-of-Life Rating Scale Data (N = 586)

To open the data file, select the file **QolLife.ssig** from the **IRTPRO Examples\By Data Set\Quality of Life** folder. The first 15 cases for Item1 to Item9 are displayed below in spreadsheet format. Each of the items has seven categories and therefore the available models are graded, general partial credit and nominal.

×	IRTF	RO - [QofLif	fe.ssig]							_ 🗆 🗾	۲
	<u> </u>	e <u>E</u> dit <u>D</u> a	ta <u>M</u> anipul	ate <u>G</u> raphi	cs <u>A</u> nalysis	<u>V</u> iew <u>W</u> i	ndow <u>H</u> elp)		- 8	×
	D 🖆 🖬 🕹 🛍 🗁 💡										
		ltem1	ltem2	Item3	Item4	ltem5	ltem6	Item7	Item8	Item9	
	1	3	3	3	4	4	0	0	3	3	
	2	5	3	4	5	4	5	5	6	5	
	3	6	6	6	6	6	6	6	4	6	
	4	6	6	6	5	6	4	5	4	5	
	5	5	5	5	5	5	5	5	5	5	
	6	5	6	4	4	4	5	5	5	4	
	7	5	5	4	5	5	5	5	5	4	
	8	4	5	6	6	6	6	6	6	6	
	9	3	6	2	4	4	1	1	1	1	
·	10	4	4	4	4	4	4	4	4	2	
·	11	5	6	6	6	6	5	5	5	5	
	12	5	5	5	5	5	4	5	4	4	
	13	4	6	4	6	6	0	1	0	0	
·	14	3	3	3	3	3	3	3	3	6	
· ·	15	2	1	0	0	2	5	6	4	5	-
•		III									
Rea	ady										at

From the main menu bar, select the **Graphics**, **Univariate**... option to obtain bar chart representations of the distribution of the items over category values.

ſ	IRTPRO - [QofLife.ssig]											
	🖃 File	e Edit Da	ta Manipu	late	Graphics Analysis View	Window Help						
	🗋 🗅 🚔	📙 🕺 🖻	e 8 💡		Univariate							
		ltem1	ltem2		Diversiete	Item6						
	1	3	3	3	Bivariate	0						
	2	5	3	4	Item Response	5						
	3	6	6	6	b b	6						
	4	6	6	6	5 6	4						

By selecting this option, the **Univariate Graph** window is displayed enabling one to select a list of items to be displayed graphically. To illustrate, the first six items are selected as shown.

Univariate Graph	X
Select one or more Y Variable(s)	
📝 Item1	
Item2	
Ttem3	=
Item4	
Item5	
✓ Item6	
Item7	
Item8	
Item9	
Item11	
Item12	
Item13	-
Litemis	
OK Cancel	

Next, click the **OK** button to obtain the bar charts. Each chart presents the distributions of responses over the seven categories.



To start the exploratory factor analysis (EFA), select the **Analysis**, **Multidimensional**... option from the main menu bar and use the **Title** and **Comments** text boxes to describe the analysis.

Multidimensional Analysis	X
Data File: C:\IRTPRO Examples\By Dataset\Quality of Life\QofLife.ssig	<u> </u>
Test1 Test2	1
Description Group Items Models Scoring	
<u>T</u> itle:	
Exploratory analysis of quality of life data	
<u>C</u> omments:	
Seven factors, based on items 2 to 35, estimation method used is MH-RM. Factor roration is orthogonal CF-varimax. Graded model fitted to each item.	
Options	Cancel Run

Since the dataset consists of a single group, the **Group** tab is not used and we skip to the **Items** tab to select Item2 to Item35. In the **Number of latent dimensions:** field enter "7".

Multidimensional Analysi	S xamples\By Dataset\Qua	ality of Life\QofLife	.ssig	Read file
Test1 Description Group <u>G</u> rouping value:	Items Models Scori Single Group Analysis No Group Variable	ng		
List of variables: Item27 Item28 Item30 Item31 Item32 Item33 Item34 Item35 < III	Number dimensi	Add >>	Items: Item28 Item29 Item30 Item31 Item32 Item33 Item34 Item35 < III Apply to all gro	× + + + pups
Options		(ОК	Cancel Run

To change the estimation method from the default (Bock-Aitkin) to MH-RM, check the **Options** button (bottom-left on screen displayed above).

Ivance	d Options
Test:	Test1 Apply to all tests
Estim	ation Starting Values Priors Miscellaneous Save Simulate
Est	imation MH-RM
<u>C</u> on	vergence Controls
Co	nvergence monitor window 3 Convergence criterion: 0.0001
Cont	rol <u>P</u> arameters
Nu	mber of stage I 200 Number of stage II cycles: 100
	Maximum number 2000 Stage III cycles: Monte Carlo size for final 10000
T <u>u</u> ni	ng Parameters
Nu	mber of 1 🚔 Burn-in: 10 🚔 Thinning: 0 🖨
Ini	tialization <u>ga</u> in 0.1 Alpha: 1 Epsilon: 1
Me	etropolis sampler Spherical Covariance Matrix Computation
Me	etropolis proposal density std. dev.: 0.3
	Default
	OK Cancel Apply

To obtain a listing of factor loading in the output file, select the Miscellaneous tab in the Advanced

Options window and click the **Print Factor Loadings** check box.

Advanced Options
Test: Test1 Apply to all tests
Estimation Starting Values Priors Miscellaneous Save Simulate
Number of decimal places in tabular
Number of processors: 2
Print table of standardized residuals
Compute Chen-Thissen LD and item fit statistics
Compute limited-information overall model fit statistics
Print each item's goodness of fit frequency table Minimum expected 1
Print factor loadings
Print parameter numbers
Print diagnostic information
Print dump file Print full dump file
OK Cancel Apply

Next, proceed to the **Models** tab. Click the **EFA** button to continue.

Multidimensi <u>D</u> ata File: Test1	ional Analysis C:\IRTPRO Exa	mples\By Da	ataset\Quality	of Life\QofLife.	ssig		Read file
Descri	ption Group I	tems Mod	els Scoring				
<u>G</u> ro	ouping value:	No Group Va	ariable				•
	Item List	Categorie	sData Cod	esitern Scores	Model		A
	Item2	7	0, 1, 2, 3,	4, 0, 1, 2, 3, 4,	Graded		
	Item3	7	0, 1, 2, 3,	4, 0, 1, 2, 3, 4,	Graded		=
	Item4	7	0, 1, 2, 3,	4, 0, 1, 2, 3, 4,	Graded		
	Item5	7	0, 1, 2, 3,	4, 0, 1, 2, 3, 4,	Graded		
	Item6	7	0, 1, 2, 3,	4, 0, 1, 2, 3, 4,	Graded		
	Item7	7	0, 1, 2, 3,	4, 0, 1, 2, 3, 4,	Graded		
	Item8	7	0, 1, 2, 3,	4, 0, 1, 2, 3, 4,	Graded		
	Item9	7	0, 1, 2, 3,	4, 0, 1, 2, 3, 4,	Graded		
	Item10	7	0, 1, 2, 3,	4, 0, 1, 2, 3, 4,	Graded		
	Item11	7	0, 1, 2, 3,	4, 0, 1, 2, 3, 4,	Graded		T
<u>(</u>	Constraints	<u>E</u> FA	Bifactor	Read parame	ter values	Apply to all group	os
Options				(ОК	Cancel	Run

To confirm that you intend to do an exploratory item factor analysis, click the appropriate checkbox. In doing so, IRTPRO automatically sets up the EFA parameter constraints and the **Constraints** button, **Models** tab, is disabled. There are four rotation types available as shown in the dialogue below. For this analysis, the **Orthogonal CF-Varimax** method is selected.

Exploratory Factor Analysis
Evploratory item factor analysis
Treat item responses as ordered
Rotation
Orthogonal CE-Quartimax
Oblique CF- <u>V</u> arimax
OK Cancel

Portion of the output, listing the rotated factor loadings of the first five factors for item2 to item20, is displayed below.

K IRTPR	RO - [QofL	ifeBiFac.Test1-	-irt.htm]	4								
Eile	<u>E</u> dit <u>V</u> i	ew <u>A</u> nalysis	<u>W</u> indo	w <u>H</u> elp							- 8	×
0 🛩 1	.	E 🖨 📍										
Orthogo	nal CF-Varin	nax Rotated Loa	dings for	Group 1 (Ba	ick to TO	C)						*
Item	Label	л ₁	s.e.	λ2	s.e.	л ₃	s.e.	λ ₄	s.e.	λ ₅	s.e.	
1	ltem2	-0.79	0.00	0.11	0.02	0.13	0.02	-0.08	0.02	-0.14	0.02	-
2	Item3	-0.69	0.01	0.12	0.02	0.18	0.04	-0.18	0.04	-0.15	0.02	
3	ltem4	-0.83	0.01	0.13	0.02	0.20	0.04	-0.16	0.04	-0.18	0.03	
4	ltem5	-0.83	0.02	0.16	0.02	0.18	0.04	-0.19	0.04	-0.20	0.03	
5	Item6	-0.14	0.04	0.10	0.04	0.18	0.05	-0.83	0.03	-0.10	0.04	
6	Item7	-0.13	0.06	0.14	0.04	0.12	0.06	-0.67	0.04	-0.13	0.06	
7	Item8	-0.15	0.04	0.14	0.05	0.14	0.05	-0.84	0.02	-0.14	0.05	
8	Item9	-0.14	0.05	0.17	0.06	0.13	0.05	-0.81	0.03	-0.11	0.05	=
9	ltem10	-0.13	0.07	0.23	0.07	0.21	0.07	-0.11	0.07	-0.30	0.07	
10	Item11	-0.19	0.06	0.15	0.06	0.16	0.06	-0.18	0.06	-0.17	0.06	
11	Item12	-0.19	0.06	0.18	0.07	0.07	0.06	-0.16	0.06	-0.17	0.06	
12	Item13	-0.18	0.06	0.10	0.07	0.21	0.06	-0.17	0.06	-0.22	0.06	
13	Item14	-0.22	0.06	0.24	0.07	0.18	0.06	-0.19	0.06	-0.26	0.06	
14	Item15	-0.27	0.06	0.30	0.07	0.07	0.06	-0.21	0.06	-0.30	0.06	
15	Item16	-0.19	0.05	0.53	0.05	0.13	0.06	-0.26	0.05	-0.30	0.05	
16	Item17	-0.19	0.06	0.59	0.06	0.15	0.06	-0.16	0.06	-0.19	0.06	
17	Item18	-0.19	0.05	0.62	0.05	0.18	0.06	-0.21	0.06	-0.21	0.06	
18	Item19	-0.19	0.05	0.70	0.05	0.14	0.07	-0.26	0.05	-0.17	0.06	
19	Item20	-0.23	0.06	0.61	0.05	0.19	0.07	-0.22	0.06	-0.11	0.06	Ŧ
•				111							•	
										NU	M	

By looking at all factor loadings that exceed 0.40 in absolute value, the EFA confirms the presence of seven subdomains (F1 = Family, F2 = Leisure, F3 = Living, F4 = Finance, F5 = Safety, F6 = Social and F7 = Health) listed in the table at the beginning of this section.

7.2.2 Bifactor Analysis

A plausible factorial structure for many types of psychological and educational tests exhibits a general factor and one or more group or method factors. A bifactor model can represent this type of factorial structure. The bifactor structure results from the constraint that each item has a nonzero loading on the primary dimension and, at most, one of the group factors. Using maximum marginal likelihood estimation of item parameters, the bifactor restriction leads to a major simplification of the likelihood equations and (a) permits analysis of models with large numbers of group factors, (b) permits conditional dependence within identified subsets of items, and (c) provides more parsimonious factor solutions than an unrestricted full-information item factor analysis in some cases. Analysis of data obtained from 586 chronically mentally ill patients, described in the previous section, reveals a clear bifactor structure, partially demonstrated by fitting an EFA model to the data with orthogonal rotation of the factors.

The bifactor model was originally introduced to extend the Spearman one-factor model for intelligence tests to include so-called "group" factors. Including these mutually uncorrelated factors enables the researcher to explain departures from the common (general) factor. The mutually uncorrelated factors assumption makes it possible to do numerical quadrature in two dimensions.

To define the analysis using the user's interface, select the **Analysis**, **Multidimensional IRT**... option from the main menu bar. For this analysis, we assume a total of eight factors, these being a general factor and seven additional mutually uncorrelated factors.

	C:\IRTPRO Examples\By Dataset\Quality of Life\QofLife.ssig
Tort1	Total
Testi	
Des	cription Group Items Models Scoring
	Fitle:
	- BiFactor Analysis based on the Quality of Life data
<u> </u>	omments:
	The General Factor (Factor 1) is based on the set of 35 items.
	There are seven specific (group) factors, assigned as follows
	Factor2: Items 6 to 0
	Factor4: Items 10 to 15
	Factor5: Items 16 to 21
	Factor5: Items 16 to 21 Factor5: Items 22 to 26
	Factor5: Items 16 to 21 Factor5: Items 22 to 26 Factor7: Items 27 to 31
	Factor5: Rems 16 to 21 Factor6: Items 22 to 26 Factor7: Items 27 to 31 Factor7: Items 32 to 35
	Factor5: Items 16 to 21 Factor6: Items 22 to 26 Factor7: Items 27 to 31 Factor8: Items 32 to 35
	Factor5: Items 16 to 21 Factor6: Items 22 to 26 Factor7: Items 27 to 31 Factor8: Items 32 to 35
	Factor5: Items 16 to 21 Factor6: Items 22 to 26 Factor7: Items 27 to 31 Factor8: Items 32 to 35
	Factor5: Items 16 to 21 Factor6: Items 22 to 26 Factor7: Items 27 to 31 Factor8: Items 32 to 35
	Factor5: Items 16 to 21 Factor6: Items 22 to 26 Factor7: Items 27 to 31 Factor8: Items 32 to 35

The **Description** tab shows the assignment of items to the group factors. Note that the mutually uncorrelated factors assumption implies that any given item can be assigned to only one group

factor. Also, note that one or more of the 35 items do not have to be assigned to any group factor. In this illustration, item1 is not assigned to any one of the additional factors. Since the dataset consists of a single group, the **Groups** tab is skipped and under the **Items** tab all 35 items are selected.

In the case of a multidimensional analysis, the **Models** tab contains a field for the number of latent dimensions, the number to be entered being 8 in the present example.

Multidimensional Analysis	5			X
Data File: C:\IRTPRO E	kamples\By [Dataset\Quality of Life\Qof	Life.ssig Read file	
Test1 Test2				
Description	Items Mo	dels Scoring		
	Single Grou	p Analysis		
<u>G</u> rouping value:	No Group \	/ariable	-	
List of variables:			Items:	
Item1 Item2 Item3	•	Add >>	Item1 Item2 Item3 Item4	
Item5 Item6 Item7		Number of latent	Item5 Item6 Item7	
Item8 Item9	-	dimensions:	Item8	
Options			OK Cancel Apply	/

The graded model (the default model when the number of categories for an item is greater than two) is used for each item and hence we click the **Bifactor** button to assign items to the additional factors.

Multidimensional Analysis				
Data File: C:\IRTPRO Exa	mples\By Dataset\Quality of Life\QofLife.ssig			
Test1 Test2				
Description	tems Models Scoring			
<u>G</u> rouping value:	No Group Variable	•		
Item List	Categories Data Codes Item Scores Model	A		
Item1	7 0, 1, 2, 3, 4, 0, 1, 2, 3, 4, Graded			
Item2	7 0, 1, 2, 3, 4, 0, 1, 2, 3, 4, Graded	=		
Item3	7 0, 1, 2, 3, 4, 0, 1, 2, 3, 4, Graded			
Item4	7 0, 1, 2, 3, 4, 0, 1, 2, 3, 4, Graded			
Item5	7 0, 1, 2, 3, 4, 0, 1, 2, 3, 4, Graded			
Item6	7 0, 1, 2, 3, 4, 0, 1, 2, 3, 4, Graded			
Item7	7 0, 1, 2, 3, 4, 0, 1, 2, 3, 4, Graded			
Item8	7 0, 1, 2, 3, 4, 0, 1, 2, 3, 4, Graded			
Item9	7 0, 1, 2, 3, 4, 0, 1, 2, 3, 4, Graded			
Item10	7 0, 1, 2, 3, 4, 0, 1, 2, 3, 4, Graded			
<u>C</u> onstraints	<u>EFA</u> <u>Bifactor</u> <u>R</u> ead parameter values	Apply to all groups		
Options	ОК	Cancel Apply		

Selection of the **Bifactor** option activates a **Bifactor Analysis** window, allowing one to select items from the **List of variables** for each additional factor. Below, Factor 2 is selected and Item2 to Item5 are assigned to this factor.

Bifactor Analysis		X
<u>G</u> rouping value:	Single Group Analysis	▼
List of variables: Item1 Item2 Item3 Item4	▲	Factor 2 Kem2 Rem3 Rem4
Item5 Item6 Item7 Item8 Item9 Item10		<u>Item5</u>
Item11 Item12 III		OK Cancel

The next dialog illustrates the selection of Item6 to Item9 and of Factor 3 using the drop-down list.

Bifactor Analysis		X
<u>G</u> rouping value:	Single Group Analysis	•
List of variables:		Factor 2 V
Item1 Item2 Item3		Factor 2 Factor 3 Factor 4
Item5	<u>A</u> dd >>	Factor 5 Factor 6 Factor 7
Item6 Item7		Factor 8
Item8 Item9 Item10		
Item11 Item12	-	
	4	
		OK Cancel

Note that when either an **EFA** or **Bifactor** analysis is specified, the **Constraints** option is no longer available since parameter constraints are, in these cases, generated by the user's interface.

Access to the Advanced Options window is obtained by clicking the Options button on the Multidimensional Analysis window. For the current analysis, the Bock-Aitkin estimation method is selected and the Convergence information, Quadrature details, and method to be used to calculate the standard errors are specified.

Advanced Options	X			
Test: Test2	 Apply to all tests 			
Estimation Starting Values Priors Miscellaneous Save Simulate				
Estimation Bock-Aitkin	•			
Converge information				
Maximum number of cycles 500	Convergence criterion: 1e-003			
M-Step maximum iterations 50	Convergence criterion: 1e-005			
Quadrature details Number of 49	Ma <u>x</u> imum value: 6			
Standard Ynd 👻	Apply dimension reduction			
-	Group Gen Dim			
Default	Single Group 1			
	OK Cancel Apply			
A portion of the output is shown below. Note that all the slope parameters (a_1) for the general factor are estimated. In the case of the additional factors, slopes are only estimated for the list of items assigned to a group factor.

	IRTPR	RO - [QofL	ife.Tes	t2-irt.h	tm]						-			
ſ	Eile	<u>E</u> dit <u>V</u> i	ew <u>A</u>	nalysis	Window	<u>H</u> elp							- 8	×
	D 🚅	. X 🖻	8	3 ?										
ſ	Likelihoo	d-based Va	lues an	d Goodr	ness of Fit Sta	atistics								-
	Summar	y of the Data	a and C	ontrol Pa	rameters									
			_											Ξ
	Graded I	l abel	arame	ter Estir	nates for Gro	oup 1, logi an	t:aθ+c (Ba	CK to 10	0C)	а,	50	a.	50	
	1	Item1	7	2 39	0.25	2 0.00		0.00		4 0.00		0.00		-
	2	Item2	14	1.70	0.21 15	1.93	0.20	0.00		0.00		0.00		
	3	Item3	22	1.58	0.20 23	1.45	0.15	0.00		0.00		0.00		
1	4	ltem4	30	2.79	0.34 31	3.27	0.35	0.00		0.00		0.00		
	5	ltem5	38	2.83	0.33 39	2.84	0.27	0.00		0.00		0.00		
	6	ltem6	46	1.73	0.23	0.00	47	2.49	0.26	0.00		0.00		
	7	ltem7	54	1.09	0.16	0.00	55	1.38	0.17	0.00		0.00		
	8	Item8	62	2.15	0.26	0.00	63	2.74	0.30	0.00		0.00		
	9	Item9	70	1.95	0.26	0.00	71	2.52	0.28	0.00		0.00		
	10	ltem10	78	1.25	0.16	0.00		0.00	79	0.37	0.15	0.00		
	11	ltem11	86	1.61	0.20	0.00		0.00	87	1.55	0.24	0.00		
	12	ltem12	94	1.41	0.20	0.00		0.00	95	1.49	0.22	0.00		
	13	ltem13	102	1.66	0.22	0.00		0.00	103	1.68	0.26	0.00		
	14	ltem14	110	1.68	0.18	0.00		0.00	111	0.54	0.17	0.00		
	15	Item15	118	1.83	0.19	0.00		0.00	119	0.27	0.14	0.00		Ŧ
	<		_	_	111	_		_					+	
	Jone													ti

In many practical applications, the bifactor model provides a natural alternative to the traditional conditionally independent unidimensional IRT model. When conditional dependence is likely, as in the case of paragraph comprehension tests, tests in which there are two or more methods of item presentation, or personality or other items that have a two-level structure with an underlying general factor, the item bifactor solution provides an excellent alternative. An attractive by-product of this model is that it requires only the evaluation of a two-dimensional integral, regardless of the number of subtests, paragraphs, or content areas.

In the ordinal response case, the bifactor model provides a very general multidimensional model for graded response data. In mental health measurement, rating scales are typically constructed by sampling items from domains related to a single underlying construct, as in the quality-of-life scale analyzed in the illustration. In these cases, a priori knowledge of which item belongs to which subdomain is available, and the bifactor model is a natural choice. Similarly, in educational measurement problems, tests are often constructed by creating a series of subtests or so-called "testlets" (Wainer & Kiely, 1987) within which items have similar content or focus, and these testlets are then combined to form a test. In this case, item groupings are also known in advance, and the bifactor model applies. Regardless of the number of testlets, the relevant integrals in the full-information maximum marginal likelihood solution always reduce to 2 and can be approximated to any practical degree of accuracy.

7.3 Testlet Response Theory (TRT) analysis of the PISA data

The Program for International Student Assessment (PISA), conducted triennially by the Organization for Economic Co-operation and Development (OECD) since year 2000, is an international educational assessment system that focuses on the 15-year olds' reading literacy, mathematics literacy, and science literacy. The format of the PISA can be best described as testlet-based. A testlet in this instance is a collection of test items organized around the same stimulus. For instance, it is standard practice in reading assessments to base several questions on one reading passage so that each question can measure a different aspect of the examinee's comprehension of the passage. PISA is noteworthy in that testlets are employed in all three sections namely reading, math, and science. For instance, a typical form of PISA mathematics assessment (in year 2000) consists of 14 items that can be divided into five testlets made up of nonoverlapping sets of items. Some testlets are longer, with more than two items, and some are shorter, with only 2 items. Critically, an item belongs to one and only one testlet.

Section 6.2 provides a more detailed description of the data. The analysis of a testlet response theory (TRT) model based on the PISA data is given in this section. For the TRT analysis, a multidimensional model for more than one group is fitted. The mean and variance of the primary math dimension is freely estimated in the UK group and the additional dimensions are there to account for local item dependence in the same testlet.

The dataset PISAMathBook1USUK.ssig is located in the folder IRTPRO Examples\By Data Set\PISA MathBook1\. To start the analysis open this file and from the main-menu bar select the Analysis, Multidimensional IRT... option.

🔀 IRTE	S IRTPRO - [PISAMathBook1USUK.ssig]														
🔳 File	e Edit Da	ta Manipul	late Graphi	ics	Analysis View Window Help										
🗋 🗅 🚔	📙 🐰 🖻	e \delta 🤋			Traditional Summed-Score Statistics										
	Cube1	Cube3	Cube4		Unidimensional IRT										
1	0	0	0	0	Multidimensional IRT										
2	1	1	1	0	IDT Cooring										
3	1	1	0	0	IKT Scoring										
4	1	1	0	1	Advanced Options										
5	1	1	1	1	J Show Progress Boy										
6	1	1	0	0											

Once this option is selected, the following message will be displayed if the analyses described in Sections 6.2.1 to 6.2.3 were performed.

Use Saved Command File
A command file PISAMathBook1USUK.irtpro is found in the following folder C:\IRTPRO Examples\By Dataset\PISA MathBook1\ Do you want to use this file? Press [No] to save command with a new name
Yes No

Click **Yes** to use the same command file. This action produces the **Multidimensional Analysis** window. To proceed, right-click next to the **Rasch** test tab (right-hand side) to insert a fourth test. The default tab is **Test4**. Rename to **TRT** by right-clicking this tab and then selecting the **Rename** option. Once done, add a title and (optional) comments.

Multidimensional Analysis			X
Data File: C:\IRTPRO Examples\By [Dataset\PISA MathBook1\PISAM	lathBook1USUK.ssig	Read file
Traditional IRT Rasch TRT	Insert Test		
Description Group Items	Delete Test		
Testlet Response Theory	Manage Test		
Comments: This example is similar to bi- are imposed here by the use	factor analysis, except that par r.	ameter constraints	
Options		OK	cel Run

Once this action is completed, click the **Group** tab and select Country as the grouping variable (1 = US, 2 = UK). Next, use the **Items** tab to select the 14 items for the first group and the click the **Apply to all groups** button to select the same set of items for the UK group. As mentioned at the start, the 14 items can be regarded as consisting of five testlets. The five testlets are as follows:

- Testlet 1: Cube1, Cube2 and Cube3
- o Testlet 2: Farms1 and Farms4
- Testlet 3: Walking1 and Walking3
- Testlet 4: Apples1, Apples2 and Apples3
- Testlet 5: Grow1, Grow3 and Grow2

In what follows, we postulate that there are six factors, the first being a general mathematics achievement factor and the last five describing each testlet. It is further assumed that these testlets are mutually uncorrelated. The testlets are related to the general factor, but the testlet-specific factors in the TRT model are not correlated with the first/general dimension. This assumption allows one to solve the likelihood and derivatives equations using two-dimensional, rather than six-dimensional quadrature. Note that the item Continent is assigned to the general factor only.

Before proceeding to the Models tab, change the Number of latent dimensions to 6 as shown.

Multidimensional Analysi	S		1 1	X
Data File: C:\IRTPRO E	xamples\By [Dataset\PISA MathBook1\F	PISAMathBook1USUK.ssig	<u>R</u> ead file
Traditional IRT Ra	sch TRT			1
Description Group	Items Mo	dels		
	Country			
<u>G</u> rouping value:	[G1] 1			▼
List of variables:			Items:	×
Cube1 Cube3 Cube4 Farms1 Farms4 Walking1 Walking3 Apples1 Apples2		Add >> Number of latent dimensions: 6	Cube1 Cube3 Cube4 Farms1 Farms4 Walking1 Walking3 Apples1 < III Apply to all gro	↓ ↓ ups
Options			ОК Са	ancel Run

For illustrative purposes, the default model types (2PL and Graded) are used.

Data F	File: C:\IRTPRO Exa	amples\By ch TRT Items M	Dataset\PISA M	lathBook1\PIS	AMathBook1US	UK.ssig <u></u> <u>R</u> ead	l file
		Country					
	Grouping value:	[G1] 1				•	
	Item List	Catego	rios Data Code	sitem Score	Model		
	Cube1	2	0, 1	0, 1	2PL	<u></u>	
	Cube3	2	0, 1	0, 1	2PL		
	Cube4	2	0, 1	0, 1	2PL	-	
	Farms1	2	0, 1	0, 1	2PL	=	
	Farms4	2	0, 1	0, 1	2PL		
	Walking1	2	0, 1	0, 1	2PL		
	Walking3	4	0, 1, 2, 3	0, 1, 2, 3	Graded		
	Apples1	2	0, 1	0, 1	2PL		
	Apples2	2	0, 1	0, 1	2PL		
	Apples3	3	0, 1, 2	0, 1, 2	Graded	*	
	Constraints	<u>E</u> FA	Bifactor	Read param	eter values	Apply to all groups	
L							
Ontio	inc				OK	Cancol	Pup

To specify that the five testlets are mutually uncorrelated, contraints are imposed on the slope parameters. Access to the **Item Parameter Constraints** window is obtained by clicking on the **Constraints...** button in the **Models** window.

Item Parameter (Constr	aints											_			-			X
Group: Country																			
Group, Item																			
G1, Cube1	a1	1	a2	2	a3	3	a4	4	a5	5	a6	6	с	7					
G1, Cube3	a1	8	a2	9	a3	10	a4	11	a5	12	a6	13	с	14					
G1, Cube4	a1	15	a2	16	a3	17	a4	18	a5	19	a6	20	с	21					=
G1, Farms1	a1	22	a2	23	a3	24	a4	25	a5	26	a6	27	с	28					
G1, Farms4	a1	29	a2	30	a3	31	a4	32	a5	33	a6	34	С	35					
G1, Walking1	a1	36	a2	37	a3	38	a4	39	a5	40	a6	41	С	42					
G1, Walking3	a1	43	a2	44	a3	45	a4	46	a5	47	a6	48	c1	49	c2	50	c 3	51	
G1, Apples1	a1	52	a2	53	a3	54	a4	55	a5	56	a6	57	с	58					
G1, Apples2	a1	59	a2	60	a3	61	a4	62	a5	63	a6	64	с	65					
G1, Apples3	a1	66	a2	67	a3	68	a4	69	a5	70	a6	71	c1	72	c2	73			
G1, Continent	a1	74	a2	75	a3	76	a4	77	a5	78	a6	79	c1	80	c2	81			
G1, Grow1	a1	82	a2	83	a3	84	a4	85	a5	86	a6	87	с	88					
G1, Grow3	a1	89	a2	90	a3	91	a4	92	a5	93	a6	94	с	95					
G1, Grow2	a1	96	a2	97	a3	98	a4	99	a5	100	a6	101	c1	102	c2	103			Ŧ
Set parameters eq	ual acr	oss grou	ıps																
																ОК		Canc	el
																on		Curre	. .

Double click the **Group**, **Item** button to change the sorting order to Item, Group. Once this is done, click the **Set parameters equal across groups** button and then start by selecting all the a2 cells below the Cube4, G2 cell. Right click and from the drop-down menu, select the **Fix Value**... option.

ОК
Cancel

The default value is 0.0 and by clicking OK, all the selected cells will become red in color and show a value of 0.0.

💶 Item Parameter (Constr	aints																	X
Group: Country																			
Item, Group																			
Cube1, G1	a1	1	a2	2	a3	3	a4	4	a5	5	a6	6	с	7					
Cube1, G2	a1	1	a2	2	a3	3	a4	4	a5	5	a6	6	с	7					
Cube3, G1	a1	15	a2	16	a3	17	a4	18	a5	19	a6	20	с	21					Ξ
Cube3, G2	a1	15	a2	16	a3	17	a4	18	a5	19	a6	20	с	21					
Cube4, G1	a1	29	a2	30	a3	31	a4	32	a5	33	a6	34	с	35					
Cube4, G2	a1	29	a2	30	a3	31	a4	32	a5	33	<u>a6</u>	34	С	35					
Farms1, G1	a1	43	a2	44	a3	45	a4	46	a5	47	a6	48	С	49					
Farms1, G2	a1	43	a2	44	a3	45	a4	46	a5	47	a6	48	С	49					
Farms4, G1	a1	57	a2	58	a3	59	a4	60	a5	61	a6	62	с	63					
Farms4, G2	a:	Set P	aram	eters E	qual		a4	60	a5	61	a6	62	с	63					
Walking1, G1	a:	Fix V	alue				a4	74	a5	75	a6	76	с	77					
Walking1, G2	a:	Set P	aram	eters Fr	ree		a4	74	a5	75	a6	76	С	77					
Walking3, G1	ai —		-		-		a4	88	a5	89	a6	90	c1	91	c2	92	c3	93	
Walking3, G2	a1	85	a2	86	a3	87	a4	88	a5	89	a6	90	c1	91	c2	92	c3	93	Ψ.
Set parameters eq	ual acr	ips													ОК		Cano	:el	

Repeat this procedure for testlets 2 to 5 by fixing all the cells, not belonging to a specific testlet, equal to zero as shown below.

Group, Item																		
G1, Farms1	a1	57	a2	0.0	a3	57	a4	0.0	a5	0.0	a6	0.0	с	12				
G1, Farms4	a1	59	a2	0.0	a3	59	a4	0.0	a5	0.0	a6	0.0	с	15				
G1, Walking1	a1	66	a2	0.0	a3	0.0	a4	66	a5	0.0	a6	0.0	С	18				
G1, Walking3	a1	66	a2	0.0	a3	0.0	a4	66	a5	0.0	a6	0.0	c1	21	c2	22	c3	23
G1, Apples1	a1	71	a2	0.0	a3	0.0	a4	0.0	a5	71	a6	0.0	с	26				
G1, Apples2	a1	/4	a2	0.0	a3	0.0	a4	0.0	a5	/4	a6	0.0	C	29	-0			
GI, Apples3	a1	//	a2	0.0	a3 - 0	0.0	a4	0.0	a5	//	a6	0.0	C1	32	C2	33		
GI, Continent	a1	34	a2	0.0	a3 =2	0.0	a4	0.0	a5 -5	0.0	a6	0.0	C1	35	C2	30		
G1, Grow1	a1	84	az 22 -	0.0	a3 	0.0	a4	0.0	35	0.0	ao 26	84	c	39				
G1, GTOW3	d1 a1	00	az a2	0.0	32	0.0	34	0.0	35	0.0	a0 26	00	C 1	42	c2	45		
C2 Cube1	a1	90	a2 a2	49	32	0.0	34	0.0	35	0.0	36	90	CI C	3	12	40		
G2, Cuber	a1	- 48	a2 a2	51	a3 _	0.0	a4 a4	0.0	a5 a5	0.0	a0 a6	0.0	C	6				
G2, Cubed	al	52	a2	52	a3 _	0.0	a4	0.0	a5 -	0.0	36	0.0	0	9				
G2, Farms1	a1	57	a2	0.0	a3	57	a4	0.0	a5	0.0	a6	0.0	c	12				
G2, Farms4	a1	59	a2	0.0	a3	59	a4	0.0	a5	0.0	a6	0.0	c	15				
G2. Walking1	a1	66	a2	0.0	a3	0.0	a4	66	a5	0.0	a6	0.0	c	18				
G2, Walking3	a1	66	a2	0.0	a3	0.0	a4	66	a5	0.0	a6	0.0	c1	21	c2	22	c3	23
G2. Apples1	a1	71	a2	0.0	a3	0.0	a4	0.0	a5	71	a6	0.0	c	26				
G2. Apples2	a1	74	a2	0.0	a3	0.0	a4	0.0	a5	74	a6	0.0	c	29				
G2, Apples3	a1	77	a2	0.0	a3	0.0	a4	0.0	a5	77	a6	0.0	c1	32	c2	33		
G2, Continent	a1	34	a2	0.0	a3	0.0	a4	0.0	a5	0.0	a6	0.0	c1	35	c2	36		
G2, Grow1	a1	84	a2	0.0	a3	0.0	a4	0.0	a5	0.0	a6	84	с	39				
G2, Grow3	a1	86	a2	0.0	a3	0.0	a4	0.0	a5	0.0	a6	86	с	42				
G2, Grow2	a1	90	a2	0.0	a3	0.0	a4	0.0	a5	0.0	a6	90	c1	45	c2	46		
G1, Means	μ1	0.0	μ2	0.0	μ3	0.0	μ4	0.0	μS	0.0	μб	0.0						
G1, Cov	σ1 1	1.0																
	σ2 1	0.0	σ2 2	100														
	σ3 1	0.0	σ3 2	0.0	σ3 3	101												
	σ4 1	0.0	σ4 2	0.0	σ4 3	0.0	σ4 4	102										
	σ5 1	0.0	σ5 2	0.0	σ53	0.0	σ5 4	0.0	σ5 5	103								
	σ6 1	0.0	σ6 2	0.0	σ6 3	0.0	σ6 4	0.0	σ6 5	0.0	<u>σ6 6</u>	104						
G2, Means	μ1	98	μ2	0.0	μ3	0.0	μ4	0.0	Σμ	0.0	μб	0.0						
G2, Cov	σ1 1	99																
	σ2 1	0.0	σ2 2	100														
	σ3 1	0.0	σ3 2	0.0	σ3 3	101												
	σ4 1	0.0	σ4 2	0.0	σ4 3	0.0	σ4 4	102										
	σ5 1	0.0	σ52	0.0	σ53	0.0	σ54	0.0	σ5 5	103								
	σ6 1	0.0	σ6 2	0.0	σ6 3	0.0	σ6 4	0.0	o6 5	0.0	6 6 6	104						

A crucial step for the TRT model involves setting all the second tier slopes equal to each respective item's general–f actor slope, as shown above. Note also that the variances of factors two to six have been freed, and set equal across groups.

When done, click the **OK** button to return to the **Models** window, then click the **Options** button to obtain the **Advanced Options** window. Select the **Estimation** tab and set the number of quadrature points equal to 21 and the integration range from -5 to 5 (**Maximum value**: 5). Change the **Standard error estimation** method to **Xpd** and select the **Apply dimension reduction** option and set the number of general dimensions to 1 for both groups. Also change the convergence criteria values to those shown below.

Advanced Options	X
Test: TRT	Apply to all tests
Estimation Starting Values Priors Miscellaneous	Save Simulate
Estimation Bock-Aitkin •	
Converge information	
Maximum number of cycles 500	Convergence criterion: 0.001
M-Step maximum iterations 50	Convergence criterion: 1e-005
Quadrature details Number of 21	Ma <u>x</u> imum value: 5
Standard Xnd	Apply dimension reduction
- kipa	Group Gen Dim
	G1 1 G2 1
Default	
	OK Cancel Apply

Click **OK** and then the **Run** button to start the analysis. Portions of the output is listed below. First, the parameter estimates and estimated standard errors are given for all the items that have only two categories (2PL model) followed by the parameter estimates for the items associated with the Graded model.

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$	(Back to TOC)
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Item	Label	a ₁	s.e.	a_2	s.e.	a_3	s.e.	a_4	s.e.	a_5	s.e.	a_6	s.e.	С	s.e.
1	Cube1	²¹ 0.99	9 0.12	²¹ 0.9	9 0.12	0.0)	0.0	0	0.0	00	0.00)	1 0.62	2 0.10
2	Cube3	²² 3.34	4 1.08	²² 3.34	4 1.08	0.0)	0.0	0	0.0	00	0.00)	² 3.5′	1 1.05
3	Cube4	²³ 1.24	4 0.15	²³ 1.24	4 0.15	0.0)	0.0	0	0.0	00	0.00)	³ -1.2	6 0.15
4	Farms1	²⁴ 2.47	7 0.35	0.0	0	²⁴ 2.4	7 0.35	0.0	0	0.0	00	0.00)	4 -0.0	1 0.17
5	Farms4	²⁵ 0.75	5 0.09	0.0	0	²⁵ 0.7	5 0.09	0.0	0	0.0	00	0.00)	⁵ 0.20	0.08
6	Walking1	1 ²⁶ 2.65	5 0.20	0.0	0	0.0)	²⁶ 2.6	5 0.20	0.0	00	0.00)	⁶ -2.3	1 0.22
8	Apples1	²⁷ 1.5′	1 0.15	0.0	0	0.0)	0.0	0	²⁷ 1.	51 0.15	0.00)	¹⁰ 0.25	5 0.12
9	Apples2	²⁸ 2.76	5 0.28	0.0	0	0.0)	0.0	0	²⁸ 2.	76 0.28	0.00)	¹¹ -3.2	7 0.31
12	Grow1	³⁰ 1.25	5 0.13	0.0	0	0.0)	0.0	0	0.0	00	³⁰ 1.25	5 0.13	¹⁷ -0.0	4 0.11
13	Grow3	³¹ 1.53	3 0.16	0.0	0	0.0)	0.0	0	0.0	00	³¹ 1.53	3 0.16	¹⁸ 0.3	1 0.12

Graded Model Item Parameter Estimates for Group 1, logit: $a\theta + c$	(Back to TOC)
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Item	Label	a ₁	s.e.	a_2	s.e.	a ₃	s.e.	a ₄	s.e.	a_5	s.e.	a_6	s.e.
7	Walking3	²⁶ 2.65	0.20	0.00		0.00		²⁶ 2.65	0.20	0.00		0.00	
10	Apples3	²⁹ 3.05	0.37	0.00		0.00		0.00		²⁹ 3.05	0.37	0.00	
11	Continent	¹⁶ 1.97	0.17	0.00		0.00		0.00		0.00		0.00	
14	Grow2	³² 0.88	0.08	0.00		0.00		0.00		0.00		³² 0.88	0.08

Graded Model Item Parameter Estimates for Group 1, logit: aθ + c

Item	Label	C ₁	s.e.	C ₂	s.e.	C ₃	s.e.
7	Walking3	⁷ -1.80	0.20	⁸ -4.87	0.30	⁹ -6.69	0.37
10	Apples3	¹² -4.04	4 0.44	¹³ -6.14	0.57		
11	Continen	t ¹⁴ -1.33	3 0.16	¹⁵ -4.07	0.22		
14	Grow2	¹⁹ 1.81	0.11	²⁰ -0.55	60.08		

Since the parameter estimates were constrained to be equal across groups, the corresponding results for the second group are not shown here. Note, however, that there are small differences between the factor loadings for the two groups. This can be attributed to the fact that the mean and variance associated with the general factor were estimated freely for the UK group. The factor loadings for the general factor and those associated with each testlet are larger or equal to 0.40 and highly significant (z-value = parameter estimate divided by standard error).

Factor Loadings for Group 1	(Back to TOC)
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Item	Label	λ ₁	s.e.	λ ₂	s.e.	λ ₃	s.e.	λ_4	s.e.	λ_5	s.e.	λ_6	s.e.
1	Cube1	0.44	0.06	0.44	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Cube3	0.64	0.03	0.64	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Cube4	0.50	0.05	0.50	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Farms1	0.78	0.03	0.00	0.00	0.78	0.03	0.00	0.00	0.00	0.00	0.00	0.00
5	Farms4	0.40	0.07	0.00	0.00	0.40	0.07	0.00	0.00	0.00	0.00	0.00	0.00
6	Walking1	0.77	0.03	0.00	0.00	0.00	0.00	0.77	0.03	0.00	0.00	0.00	0.00
7	Walking3	0.77	0.03	0.00	0.00	0.00	0.00	0.77	0.03	0.00	0.00	0.00	0.00
8	Apples1	0.64	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.06	0.00	0.00
9	Apples2	0.79	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.04	0.00	0.00
10	Apples3	0.81	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.04	0.00	0.00
11	Continent	t 0.76	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	Grow1	0.56	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.06
13	Grow3	0.63	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.05
14	Grow2	0.44	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.06

Factor Loadings for Group 2 (Back to TOC)

Item	Label	λ ₁	s.e.	λ ₂	s.e.	λ_3	s.e.	λ_4	s.e.	λ_5	s.e.	λ ₆	s.e.
1	Cube1	0.45	0.06	0.45	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Cube3	0.65	0.04	0.65	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Cube4	0.50	0.06	0.50	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Farms1	0.81	0.05	0.00	0.00	0.81	0.05	0.00	0.00	0.00	0.00	0.00	0.00
5	Farms4	0.40	0.07	0.00	0.00	0.40	0.07	0.00	0.00	0.00	0.00	0.00	0.00
6	Walking1	0.80	0.05	0.00	0.00	0.00	0.00	0.80	0.05	0.00	0.00	0.00	0.00
7	Walking3	0.80	0.05	0.00	0.00	0.00	0.00	0.80	0.05	0.00	0.00	0.00	0.00
8	Apples1	0.65	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.07	0.00	0.00
9	Apples2	0.82	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.05	0.00	0.00
10	Apples3	0.84	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.05	0.00	0.00
11	Continent	t 0.78	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	Grow1	0.57	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.06
13	Grow3	0.64	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.06
14	Grow2	0.45	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.06

Group Parameter Estimates: (Back to TOC)

Group	Label	μ_1	s.e.	µ ₂	s.e.	μ ₃	s.e.	μ_4	s.e.	μ_5	s.e.	μ_6	s.e.
1	G1	0.00		0.00		0.00		0.00		0.00		0.00	
2	G2	³³ 0.51	0.07	0.00		0.00		0.00		0.00		0.00	

Latent Variable Variance-Covariance Matrix for Group 1 (Back)

θ1	s.e.	θ2	s.e.	θ_3	s.e.	θ_4	s.e.	θ_5	s.e.	θ_6	s.e.
1.00											
0.00		³⁵ 1.19	0.22								
0.00		0.00		³⁶ 0.15	0.12						
0.00		0.00		0.00		³⁷ 0.26	0.06				
0.00		0.00		0.00		0.00		³⁸ 0.21	0.06		
0.00		0.00		0.00		0.00		0.00		³⁹ 0.32	0.10

Latent Variable Variance-Covariance Matrix for Group 2 (Back)

θ_1 s.e.	θ_2	s.e.	θ_3	s.e.	θ_4	s.e.	θ_5	s.e.	θ_6	s.e.
³⁴ 0.91 0.12	2									
0.00	³⁵ 1.1	9 0.22								
0.00	0.0	0	³⁶ 0.15	0.12						
0.00	0.0	0	0.00		³⁷ 0.26	0.06				
0.00	0.0	0	0.00		0.00		³⁸ 0.21	0.06		
0.00	0.0	0	0.00		0.00		0.00		³⁹ 0.32	0.10

Likelihood-based Values and Goodness of Fit Statistics (Back to TOC)

Statistics based on the loglikelihood	
-2loglikelihood:	21001.78
Akaike Information Criterion (AIC):	21079.78
Bayesian Information Criterion (BIC):	21279.79

The deviance statistic (-2 log likelihood) for the TRT model is reported above as 21001.78. The corresponding value for the IRT model (see Section 6.2.2) is 21233.40. The chi-squared difference test therefore yields a value of 21233.40 - 21001.78 = 231.62. The degrees of freedom for testing between which of the TRT or IRT models provide the better fit are 17 (39 parameters were estimated in the case of the TRT model versus 22 for the IRT model). Since the chi-squared difference test is highly significant, we conclude that the TRT model provides a better fit to the item responses when compared to the IRT model. Information-theoretic indices of fit (AIC and BIC) also point to the TRT model as better fitting.

7.4 Two-tier analysis of PISA Read and Math items

Cai (2010) proposed a two-tier item factor analysis model that subsumes standard multidimensional IRT models, bifactor IRT models, and testlet response theory (TRT) models as special cases. Features of the model lead to a reduction in the dimensionality of the latent variable space and consequently significant computational savings.

Similar to the success story of full-information item bifactor analysis (see *e.g.*, Gibbons *et al.*, 2007, 2008), the existence of certain special features and restrictions can result in significant computational savings for maximum marginal likelihood estimation while keeping the model flexible enough to represent a variety of structures commonly found in educational and psychological measurement.

The two-tier model also generalizes the bifactor or testlet models in the types of observed variables that can be included, permitting an arbitrary mixture of dichotomous, ordinal, and nominal items. Extending the subdomain scoring strategies discussed by Gibbons *et al.* (2007) for item bifactor models, the two-tier model conveniently provides individual response pattern based IRT scale scores (as posterior expected values) for all latent variables in the model. Finally, the two-tier item factor analysis (IFA) model highlights the benefit of analytically reducing the dimensionality of latent variable space whenever possible.

The key to the two-tier modeling framework rests on the recognition that the dimensions (latent variables, factors, latent traits, etc.) in an IFA model can be grouped into two tiers or classes: 1) primary dimensions, and 2) specific dimensions. The distinction is not based so much on the theoretical importance or breadth of the measured latent constructs as on the pattern of factor loadings and the factor inter-correlations. In the two-tier model, the primary dimensions and specific dimensions are uncorrelated. In addition, the specific dimensions are assumed mutually orthogonal and an item can load on at most one specific dimension, just as in a bifactor or testlet response model. On the other hand, the primary dimensions may be correlated among themselves, and the model imposes no further restrictions on the relation between items and primary dimensions beyond necessary conditions for identification.

As mentioned in Section 7.3, the format of the PISA can be best described as testlet-based. For instance, it is standard practice in reading assessments to base several questions on one reading passage so that each question can measure a different aspect of the examinee's comprehension of the passage. PISA is noteworthy in that testlets are employed in all three sections, namely reading, math, and science. For instance, a typical form of PISA reading assessment (in year 2000) consists of about 30 items that can be divided into 8 or 9 testlets made up of non-overlapping sets of items. Some testlets are longer, with 4 or 5 items, and some are shorter, with only 2 items. Critically, an item belongs to one and only one testlet.

As an illustration, consider only the reading and mathematics sections. By design, the reading items measure reading literacy (primary dimension 1) and the math items measure mathematics literacy (primary dimension 2). Test construction results in two dimensions that are strongly correlated (Adams & Wu, 2002), which is understandable because before solving a math problem one must be able to read the instructions first. However, a two-factor model does not entirely reflect the underlying structure of PISA. A dominating feature of testlet-based assessments is that the item responses from within the same testlet tend to be more correlated than across testlets. In the case of PISA, within-testlet residual dependence remains even after controlling for the influence of the two primary dimensions.

One approach to analyzing the data would be to break the analysis into two parts and fit standard item bifactor (or testlet) models to the first set of math items and the second set of reading items separately. However, if indeed the two primary dimensions are correlated, the two-tier model can utilize that correlation to produce more accurate scores. The ability to "borrow strength" from other parts of the model to enhance statistical prediction is an essential benefit of the two-tier model over separate bifactor analyses that would ignore the correlations among the primary factors.

A set of examples based on the PISA math and read items is contained in the command file **PISAReadMathBook8.irtpro** and is based on the IRTPRO dataset **PISAReadMathBook8.ssig**. These files are located in the folder **IRTPRO Examples\By Dataset\PISA Read_Math**. The first 15 cases for a number of reading items are shown below. The reader is referred to Cai (2011) for a detailed description of this two-tier analysis.

X	< IRTPRO - [PISA00ReadMathBook8.ssig]											
] <u>E</u> ile	e <u>E</u> dit <u>D</u> a	ta <u>M</u> anipul	ate <u>G</u> raphi	cs <u>A</u> nalysis	<u>V</u> iew <u>W</u> i	ndow <u>H</u> elp)			- 8	×
C) 🖻	🔒 X 🖻	8 8 ?									
Ľ		AmandaQ3FR2	AmandaQ4FR2	AmandaQ6MC4	NewRulesQ1F	NewRulesQ2F	JobInterviewQ	JobInterviewQ	AllergiesQ1FR2	AllergiesQ2FR2	ContactEmploy	(🔺
	1	1	1	1	0	1	1	1	1	1	1	
	2	1	1	1	0	1	1	1	1	1	1	
	3	1	0	1	0	1	0	1	1	1	1	
	4	0	0	1	0	1	0	0	0	0	0	Ι
	5	0	1	1	0	1	1	1	1	1	0	Ι
	6	0	0	1	0	0	0	0	0	1	1	
	7	0	0	0	0	0	0	0	0	0	1	
	8	0	0	1	0	0	1	0	0	0	0	
	9	0	0	0	0	0	0	0	1	1	0	1
	10	0	0	0	0	0	0	0	1	1	0	1
	11	0	0	0	0	0	1	1	1	1	1	-
	12	0	0	0	1	0	0	0	0	1	1	-
	13	0	0	1	0	0	0	1	1	1	1	-
	14	0	0	1	0	0	1	1	0	0	1	+
	15	0	0	0	0	0	0	0	0	1	0	Ψ.
•										111	•	
Rea	ady											d

Select the **Analysis**, **Multidimensional** option and click **Yes** when prompted to use the existing command file. Select the **2Tier** test tab and then click the **Items** tab to obtain the display below. Note that there are two general dimensions and 12 testlets yielding a total of 14 dimensions.

Iultidimensional Analysis Data File: C:\IRTPRO Ex EFA1 EFA2 EFA3 Description Grouping value:	amples\By I CFA Ma Items Mo Single Grou No Group \	Dataset\PISA Read_Math\ thTRT MathBifac Readi idels Scoring ip Analysis /ariable	PISA00ReadMathBook8.ssig ingBifac ReadingTRT 2Tier	Read file
List of variables: ApplesQ1FR2 ApplesQ2FR2 ApplesQ3FR3 ContinentAreaFR GrowingUpQ1FR2 GrowingUpQ2FR2 GrowingUpQ3FR2 RacingCarQ1MC4 RacingCarQ2MC4 Continent		Add >> Number of latent dimensions:	Items: ApplesQ1FR2 ApplesQ2FR2 ApplesQ3FR3 ContinentAreaFR3 GrowingUpQ1FR2 GrowingUpQ2FR3 GrowingUpQ3FR2 RacingCarQ1MC4 ✓ III ↓ Apply to all groups	
Qptions			OK Cance	el Run

To view the estimation settings that were selected for the two-tier analysis, click the **Options...** button (see above). Note that the **Apply dimension reduction** option is selected and that the number of general dimensions is set to two. Also note that no grouping variable was selected for ths analysis thus assuming a single group.

Advanced	Options		-	
Test:	2Tier		•	Apply to all tests
Estima	tion Starting V	alues Priors Miscellaneous	Save Simulate	1
Esţi	mation	Bock-Aitkin	•	
_ <u>C</u> or	verge informatio	on		
, I	Maximum numbe	er of cycles 500	Convergence criterion	: 0.001
1	<u>M</u> -Step maximur	n iterations 50	Convergence criterion	: 1e-005
Qua	adrature details			
	Number of	19	Ma <u>x</u> imum value	4.5
<u>S</u> ta	ndard	Xpd 🔻	Apply dimension	reduction
	U		Group	Gen Dim
<u> </u>	<u>p</u> efault		Single Group	2
			ОК	ancel <u>A</u> pply

Click the **OK** button to return to the **Multidimensional Analysis** window then click the **Models** tab to see the list of models that were selected.

Aultidimens Data File:	sional Analysis C:\IRTPRO Exar	nples\By I	Dataset\PISA R	ead_Math\PIS	A00ReadMath	Book8.ssig	Read file
EFA1	EFA2 EFA3 (CFA Ma	thTRT MathB	ifac Readingl	Bifac∥Reading	JTRT 2Tier	
Descr	ription Group It	ems Mo	dels Scoring				
<u>G</u> r	ouping value: N	lo Group \	/ariable				•
	Item List	Categor	iesData Cod	esitem Score	Model		A
	FluQ2MC4	2	0, 1	0, 1	2PL	_	=
	FluQ3FR3	3	0, 1, 2	0, 1, 2	Graded		
	FluQ4MC4	2	0, 1	0, 1	2PL		
	FluQ5FR2	2	0, 1	0, 1	2PL		
	FluQ6MC4	2	0, 1	0, 1	2PL		
	LaborQ1MC4	2	0, 1	0, 1	2PL		
	LaborQ3FR3	3	0, 1, 2	0, 1, 2	Graded		
	LaborQ4CM(3	0, 1, 2	0, 1, 2	Graded		
	LaborQ5CM(2	0, 1	0, 1	2PL		
	LaborQ7MC4	2	0, 1	0, 1	2PL		~
	Constraints	<u>E</u> FA	Bifactor	Read param	eter values	Apply to all grou	ups
							_
Options					ОК	Cancel	Run

Next click the **Constraints...** button to view the **Item Parameter Constraints** window. This window graphically illustrates that all the slope parameters are fixed at zero, except those belonging to the two main dimesions and to the various testlets.

Item																		
Apples01FR2	a1	1	a2	0.0	a3	2	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	0.0
ApplesQ2FR2	a1	4	a2	0.0	a3	5	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	0.0
ApplesQ3FR3	a1	7	a2	0.0	a3	8	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	0.0
ContinentAreaFR3	a1	11	a2	0.0	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	0.0
GrowingUpQ1FR2	a1	14	a2	0.0	a3	0.0	a4	15	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	0.0
GrowingUpQ2FR3	a1	17	a2	0.0	a3	0.0	a4	18	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	0.0
GrowingUpQ3FR2	a1	21	a2	0.0	a3	0.0	a4	22	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	0.0
RacingCarQ1MC4	a1	24	a2	0.0	a3	0.0	a4	0.0	a5	25	a6	0.0	a7	0.0	a8	0.0	a9	0.0
RacingCarQ2MC4	a1	27	a2	0.0	a3	0.0	a4	0.0	a5	28	a6	0.0	a7	0.0	a8	0.0	a9	0.0
RacingCarQ3MC4	a1	30	a2	0.0	a3	0.0	a4	0.0	a5	31	a6	0.0	a7	0.0	a8	0.0	a9	0.0
RacingCarQ5MC5	a1	33	a2	0.0	a3	0.0	a4	0.0	a5	34	a6	0.0	a7	0.0	a8	0.0	a9	0.0
TrianglesMC5	a1	36	a2	0.0	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	0.0
RobberiesFR3	a1	38	a2	0.0	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	0.0
CarpenterCMC2	a1	41	a2	0.0	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	0.0
PipelinesCMC2	a1	43	a2	0.0	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	0.0
LakeChadQ2MC5	a1	0.0	a2	45	a3	0.0	a4	0.0	a5	0.0	a6	46	a7	0.0	a8	0.0	a9	0.0
LakeChadQ3AFR2	a1	0.0	a2	48	a3	0.0	a4	0.0	a5	0.0	a6	49	a7	0.0	a8	0.0	a9	0.0
LakeChadQ3BFR2	a1	0.0	a2	51	a3	0.0	a4	0.0	a5	0.0	a6	52	a7	0.0	a8	0.0	a9	0.0
LakeChadQ4MC4	a1	0.0	a2	54	a3	0.0	a4	0.0	a5	0.0	a6	55	a7	0.0	a8	0.0	a9	0.0
LakeChadQ6MC4	a1	0.0	a2	57	a3	0.0	a4	0.0	a5	0.0	a6	58	a7	0.0	a8	0.0	a9	0.0
FluQ2MC4	a1	0.0	a2	60	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	61	a8	0.0	a9	0.0
FluQ3FR3	a1	0.0	a2	63	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	64	a8	0.0	a9	0.0
FluQ4MC4	a1	0.0	a2	67	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	68	a8	0.0	a9	0.0
FluQ5FR2	a1	0.0	a2	70	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	71	a8	0.0	a9	0.0
FluQ6MC4	a1	0.0	a2	73	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	74	a8	0.0	a9	0.0
LaborQ1MC4	a1	0.0	a2	76	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	77	a9	0.0
LaborQ3FR3	a1	0.0	a2	79	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	80	a9	0.0
LaborQ4CMC3	a1	0.0	a2	83	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	84	a9	0.0
LaborQ5CMC4	a1	0.0	a2	87	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	88	a9	0.0
LaborQ7MC4	a1	0.0	a2	90	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	91	a9	0.0
RunnersQ1MC4	a1	0.0	a2	93	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	94
RunnersQ4FR2	a1	0.0	a2	96	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	97
RunnersQ5FR2	a1	0.0	a2	99	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	10
RunnersQ6MC4	a1	0.0	a2	102	a3	0.0	a4	0.0	a5	0.0	a6	0.0	a7	0.0	a8	0.0	a9	10
		111								-								

8. IRT scoring

8.1 Introduction

Unlike classical test theory, IRT does not in general base the estimate of the respondent's ability (or other attribute) on the number-correct (NC) or summed score. To distinguish IRT scores from their classical counterparts, we refer to them as "scale" scores. There are two instances under which the IRT scale scores may be one-to-one related (in a nonlinear fashion) to summed scores. First, when the one-parameter logistic (or in general, Rasch) model is used, the summed scores are sufficient statistics for the latent ability variable. Second, when the scale scores are based on summed-score posteriors for any IRT model, the summed scores can be directly translated into scale scores.

The main advantages of scale scores are that they:

- Remain comparable when items are added to or deleted from the tests.
- Weight the individual items optimally according to their discriminating powers.
- Have more accurate standard errors.
- Provide more flexible and robust adjustments for guessing than the classical corrections.
- Are on the same continuum as the item locations.

There are three types of IRT scale score estimation methods that IRTPRO supports:

- Bayes estimation (EAP)
- Summed Score EAP (SSEAP)
- Bayes modal estimation (MAP)

The three types of IRT scale score estimation methods are discussed in the sections to follow.

8.1.1 Bayes estimation (EAP)

The Bayes estimate is the mean of the posterior distribution of θ , given the observed response pattern x_i (Bock & Mislevy, 1982). It can be approximated as accurately as required by the Gaussian quadrature (see the section on MML estimation):

$$\overline{\theta_i} \cong \frac{\sum_{k=1}^q X_k P(\mathbf{x}_i \mid X_k) A(X_k)}{\sum_{k=1}^q P(\mathbf{x}_i \mid X_k) A(X_k)}.$$

This function of the response pattern \mathbf{x}_i has also been called the expected a posteriori (EAP) estimator. A measure of its precision is the posterior standard deviation (PSD) approximated by

$$PSD(\overline{\theta_i}) \cong \frac{\sum_{k=1}^q (X_k - \overline{\theta_i})^2 P(\mathbf{x}_i \mid X_k) A(X_k)}{\sum_{k=1}^q P(\mathbf{x}_i \mid X_k) A(X_k)}.$$

The weights, $A(X_k)$, in these formulas depend on the assumed distribution of θ . Theoretical weights, empirical weights, $A^*(X_k)$, or subjective weights are possibilities.

The EAP estimator exists for any answer pattern and has a smaller average error in the population than any other estimator, including the ML estimator. It is in general biased toward the population mean, but the bias is small within $\pm 3\sigma$ of the mean when the PSD is small (*e.g.*, less than 0.2σ). Although the sample mean of EAP estimates is an unbiased estimator of the mean of the latent population, the sample standard deviation is in general smaller than that of the latent population. This is not a serious problem if all the respondents are measured within the same PSD. But it could be a problem if respondents are compared using alternative test forms that have much different PSDs. The same problem occurs, of course, when number-right scores from alternative test forms with differing reliabilities are used to compare respondents. Tests administrators should avoid making comparisons between respondents who have taken alternative forms that differed appreciably in their psychometric properties. A further implication is that, if EAP estimates are used in computerized adaptive testing, the trials should not terminate after a fixed number of items, but should continue until a prespecified PSD is reached.

8.1.2 Summed Score EAP (SSEAP)

IRT models also imply posteriors for the summed scores, even if the IRT model used is not among the Rasch family of models. Without loss of generality, consider the dichotomous case first. For any IRT model with dichotomous item scores $(u_i = 0, 1)$, the likelihood for any summed score $x = \sum_{i} u_i$ is

$$L_{x}(\theta) = \sum_{\sum u_{i}=x} L(\mathbf{u}/\theta)$$

where

$$L(\mathbf{u}/\theta) = \prod_{i} T(u_i/\theta)$$

and $T(u_i/\theta)$ is the traceline for response *u* to item *i*. The first summation is over all such response patterns that the summed score equals *x*. The probability of each score is

$$P_{x} = \int L_{x}(\theta) g(\theta)$$

and the expected θ associated with each summed score x is

$$E(\theta/x) = \frac{\int \theta L_x(\theta) g(\theta)}{P_x}$$

with posterior standard deviation given by

$$PSD(\theta/x = \sum u_i) = \left(\frac{\int \left[\theta - E(\theta/x)\right]^2 L_x(\theta) g(\theta)}{P_x}\right)^{\frac{1}{2}}.$$

8.1.3 Bayes modal estimation (MAP)

Similar to the Bayes estimator, but with a somewhat larger average error, is the Bayes modal or socalled maximum a posteriori (MAP) estimator. It is the value of θ that maximizes

$$P(\theta \mid x_i) = \sum_{j=1}^{n} \{ x_{ij} \log_e P_i(\theta) + (1 - x_{ij}) \log_e [1 - P_i(\theta)] \} + \log_e g(\theta),$$

where $g(\theta)$ is the density function of a continuous population distribution of θ . The likelihood equation is

$$\sum_{j=1}^{n} \frac{x_{ij} - P_j(\theta)}{P_j(\theta)[1 - P_j(\theta)]} \cdot \frac{\partial P_j(\theta)}{\partial \theta} + \frac{\partial \log_e g(\theta)}{\partial \theta} = 0.$$

Analogous to the maximum likelihood estimate, the MAP estimate is calculated by Fisher scoring, employing the *posterior information*,

$$J(\theta) = I(\theta) + \frac{\partial^2 \log_e g(\theta)}{\partial \theta^2},$$

where the right-most term is the second derivative of the population log density of θ .

In the case of the 2PL model and a normal distribution of θ with variance σ^2 , the posterior information is

$$I(\theta) = \sum_{j=1}^{n} a_j^2 P_j(\theta) [1 - P_j(\theta)] + \frac{1}{\sigma^2}.$$

The PSD of the MAP estimate, θ , is approximated by

$$PSD(\theta) = \sqrt{1/I(\hat{\theta})}.$$

Like the EAP estimator, the MAP estimator exists for all response patterns, but is generally biased toward the population mean.

8.2 Scoring using a social life feelings (SLF) dataset

The dataset used in this section is taken from an extensive study of social life feelings reported in Schuessler (1982) and Krebs and Schuessler (1987). The aim was to establish scales for use in social research. According to Bartholomew (1998) the aim of the study was to establish scales for use in social research that were comparable in quality with those used in ability testing. For illustration purposes, the data used in this section is from the German sample consisting of the following five items:

- 1. Anyone can raise his standard of living if he is willing to work at it (SLS1).
- 2. Our country has too many poor people who can do little to raise their standard of living (SLS2).
- 3. Individuals are poor because of the lack of effort on their part (SLS3).
- 4. Poor people could improve their lot if they tried (SLS4).
- 5. Most people have a good deal of freedom in deciding how to live (SLS5).

Responses are based on a sample size of 1490 individuals. The spreadsheet below displays item values for cases 680 to 690. The name of the dataset is **SLF.ssig** and is stored in the folder **IRTPRO Examples\By Dataset\Social Life Feelings**

🔀 IRTI	PRO - [SLF.ss	ig]				
File Edit Data Manipulate Graphics Analysis View Window						ndow
<u>H</u> elp						- 8 ×
🗅 🖻	🔒 X 🖻	8 8 ?				
	SLF1	SLF2	SLF3	SLF4	SLF5	^
680	0	1	0	1	0	
681	0	1	0	1	0	
682	0	1	0	1	0	
683	0	1	0	1	0	
684	0	1	0	1	0	Ξ
685	0	1	0	1	0	
686	0	1	0	1	1	
687	0	1	0	1	1	
688	0	1	0	1	1	
689	0	1	0	1	1	
690	0	1	0	1	1	~
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Ready						.đ

In order to display the frequency distribution of the five items visually, the **Graphics**, **Univariate**... option is selected from the main menu bar.

🔀 IRTE	PRO - [SLF.ss	ig]					
🖃 File	e Edit Da	ta Manipu	late	Gra	phics	Analysis	View
🗋 🗅 🗳	📙 X 🖻	e \delta 💡			Univa	ariate	
	SLF1	SLF2			Diver	iata	
1	0	0	0		Bivar	late	
2	0	0	0		Item	Response	

By making this selection, a Univariate Graph dialog is displayed.

Univariate Graph	×
Select one or more Y Variable(s)	
SLF1	
▼ SLF2 ▼ SLF3	
✓ SLF4	
✓ SLF5	
OK Cancel	

After selecting the items (see above), click OK to obtain a bar chart presentation for each item. From this display, it can be concluded, for example, that a relatively small proportion of individuals have selected the category corresponding to "1" for the item SLF1.



The frequency counts for each item can be displayed by clicking the **Table** icon in the **Graph** window. From this display it follows that all items are binary. We further conclude that there are no missing values present since the total count of the datavalues 0 and 1 equals 1490 for each item.

SLF.ssig - IRTProGraphs	-	-				x
<u>File E</u> dit <u>V</u> iew <u>G</u> raphs Ch ☞ ⓑ 🎮 🔿 🤋	nart <u>T</u> ype <u>T</u> o	ols <u>H</u> elp				
□- □ Univariate Graphs □ SIE1	🛍 Graph	🖽 Table				
- ☑ SLF2	SLF1	SLF2	SLF3	SLF4	SLF5	
🗹 SLF3 🗹 SLF4	0 = 1295 1 = 195	0 = 489 1 = 1001	0 = 495 1 = 995	0 = 874 1 = 616	0 = 1070 1 = 420	
Bivariate Graphs						
	•		111			•
Ready	-	-	_			

In Sections 8.2.1 and 8.2.2, examples that illustrate item scoring are presented. In the example presented in Section 8.2.1, 2PL models are fitted to the five items, labeled SLS1 to SLS5 respectively and EAP scores are computed. Use is made of the Advanced Options, Miscellaneous; Save selection to specify that the estimated parameters must be saved in a file with extension - prm.txt. The example in Section 8.2.2 demonstrates item scoring using a -prm.txt parameter file obtained from a previously executed IRT (calibration) run.

8.2.1 Calibration and Scoring

In this section 2PL models are fitted to the five items, labeled SLS1 to SLS5 respectively, and the estimated parameters are saved to a text file with extension **-prm.txt**. EAP scores (See Section 8.1.1) are also computed.

Unidimensio	onal Analysis			×
<u>D</u> ata File:	C:\IRTPRO Examples\By Dataset\Social Life Feelings\SLF.ssig			<u>R</u> ead file
Test1				
Descr	iption Group II Items Models Scoring			
<u> </u>	tle:			
S	ocial Life Feelings - Five items			
Co	mments:			
C	alibration (2PL) and EAP Scoring, using the Scoring tab.			
Options		Ж	Cancel	Run

From the main menu bar, select the **Analysis**, **Unidimensional IRT...** option to obtain the **Unidimensional Analysis** window shown below. Use the **Description** tab to enter a title and comments.

Since the dataset **SLF.ssig** is based on a single group (Germany, 1490 individuals), the **Group** tab is skipped and we proceed to the **Items** tab to select all five items.

Data File: C:\JRTPRO Ex	amples\By Dataset\Social Life Feeling Items Models Scoring Single Group Analysis No Group Variable	gs\SLF.ssig Read file
List of variables: SLF1 SLF2 SLF3 SLF4 SLF5	<u>A</u> dd >>	Items: SLF1 SLF2 SLF3 SLF4 SLF5 Apply to all groups
Options		OK Cancel Run

The **Models** dialog displays the model-type to be fitted to each item. Since all items are binary, the default model is 2PL.

Unidimensio	nal Analysis	-		_	_	_	X
<u>D</u> ata File:	C:\IRTPRO Exa	mples\By Da	taset\Social Li	fe Feelings\SI	LF.ssig	<u>R</u> ead	file
Test1							
Descri	iption Group I	tems Mode	ls Scoring				
Gro	ouping value:	lo Group Va	iable			-	
	Item List	Categorie	Data Codes	Item Score	Model		
	SLF1	2	0, 1	0, 1	2PL		
	SLF2	2	0, 1	0, 1	2PL		
	SLF3	2	0, 1	0, 1	2PL		
	SLF4	2	0, 1	0, 1	2PL		
	SLF5	2	0, 1	0, 1	2PL		
1	Constraints	<u>D</u> IF				Apply to all groups	
Options				ſ	ОК	Cancel	Run
<u></u> pao.io.ii				l			

To ensure that the estimated parameters are save to a **-prm.txt** file, click the **Options**... button (bottom right-hand corner of the previous display). This action invokes the **Advance Options** window. Click the **Save** tab and make sure that **Item parameters estimates** (**-prm.txt**) is selected.

lvance	d Options
Test:	Test1 Apply to all tests
Estim	ation Starting Values Priors Miscellaneous Save Simulate
	Item parameter estimates (-prm.txt)
	Asymptotic covariance matrix of the parameter estimates (-cov.txt)
	Information values, for unidimensional models only (-inf.txt)
	Inter-item polychoric correlations, for EFA models only (-pol.txt)
	Factor loadings (-fac.txt)
	Main output in ASCII text format (-irt.txt, -sss.txt, or .ssc.txt)
	OK Cancel Apply

Click **OK** to return to the **Unidimensional Analysis** window and click on the **Scoring** tab to display the **Scoring** dialog.

Using this dialog, make the following selections:

- Scoring method: EAP
- \circ Scaling: Mean = 0; Standard deviation = 1 (the defaults)
- Scale: Population distribution

When done, click the **Run** button to start calibration and scoring.

Unidimensional Analysis	
Data File: C:\IRTPRO Examples\By Dataset\Social Life Feeli	ngs\SLF.ssig Read file
Test1	
Description Group Items Models Scoring	
Person ID:	Compute response pattern
<u>Create</u> summed-score to scale conversion table	✓ Score persons
Scaling	
Integer scores Mean: 0	Standard deviation: 1
Mi <u>n</u> imum:	Maximum:
Scale Population distribution	
	OK Cancel Run

If the analysis completes successfully, two output files are created with extensions:

- \circ -irt.htm (calibration), and
- -ssc.htm (Scoring).

The Window menu (below) shows the selection of the IRT analysis (calibration) output.



Portions of the output are listed next. The first table gives the parameter estimates and standard error estimates for the five items.

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

Item	Label	а		s.e.	С		s.e.	b	s.e.
1	SLF1	2	1.20	0.15	1	-2.35	0.13	1.97	0.18
2	SLF2	4	0.71	0.09	3	0.80	0.06	-1.11	0.14
3	SLF3	6	1.53	0.17	5	0.99	0.09	-0.65	0.06
4	SLF4	8	2.55	0.39	7	-0.67	0.12	0.26	0.04
5	SLF5	10	0.92	0.10	9	-1.10	0.07	1.19	0.12

Likelihood based statistics and fit statistics are given in the output shown below. The statistic: -2loglikelihood (also called the deviance statistic) is used to compare nested models. Both the AIC and BIC statistics are used as a model selection tool.

Likelihood-based Values and Goodness of Fit Statistics (Back to TOC)

Statistics based on the loglikelihood	
-2loglikelihood:	8258.37
Akaike Information Criterion (AIC):	8278.37
Bayesian Information Criterion (BIC):	8331.43

The RMSEA value of 0.02 indicates a relatively good fit using the 2PL model.

Statistics	Statistics based on the full item x item x classification				
G ²	Degrees of freedom	Probability	RMSEA		
39.09	21	0.0095	0.02		
X ²	Degrees of freedom	Probability	RMSEA		
38.92	21	0.0100	0.02		

Next, we select the output file generated for the scoring part of the analysis (**-ssc.htm**). Selected output is shown below. The first portion is a table containing the parameter estimates obtained in the calibration phase.

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

Item	l Label	а	С	b
1	SLF1	1.20	-2.35	1.97
2	SLF2	0.71	0.80	-1.11
3	SLF3	1.53	0.99	-0.65
4	SLF4	2.55	-0.67	0.26
5	SLF5	0.92	-1.10	1.19

The next portion of the output shows that the item scores are saved to the text file **SLF.Test-sco.txt**. Text files can be opened with any text editor such as Notepad.

Summary of the Data and Control Parameters (Back to TOC)

Sample Size1490Number of Items5Number of Dimensions1

Scoring Control Values

Response pattern EAPs are computed

Output Files

HTML results and control parameters:SLF.Test1-ssc.htmText scaled score file:SLF.Test1-sco.txt

8.2.2 Scoring based on a parameter file

In this section, the summed-score EAP (SSEAP) and maximum a posteriori (MAP) scoring methods are considered. Use is made of the IRTPRO dataset **SLS.ssig** and the parameter estimates, obtained as described in the previous section, are read from a **-prm.txt** parameter file. Scoring is accomplished by selecting the **Analysis**, **IRT Scoring**... option from the main menu bar.

Start by opening the IRTPRO data file **SLS.ssig** located in the folder **IRTPRO Examples\By Dataset\Social Life Feelings\.** If this file is still open from a previous session, close it first and then re-open it, otherwise the **IRT Scoring...** option might be disabled.



By selecting **IRT Scoring...**, a **Use Save Command File** message box is displayed. Since we do not want to overwrite the existing command file (generated in Section 8.2.1), the **No** button is clicked.



Use the **Insert Test...** and **Rename** options (obtained by right-clicking next to an existing test tab to insert a new test or on a tab to rename a test) to insert a second test and to rename the **Test1** and **Test2** tabs to **SSEAP** and **MAP** respectively as shown below.

IRT Scoring	-		Date reaction	1	×
Data File: C:\]	RTPRO Examples\By Dataset\S	ocial Life Feelings\S)LF.ssig	R	ead file
SSEAP MAP Description Title: Social	Insert Test Delete Test Rename Manage Test	ng			
Comme	nts:				
Summe	ed score EAP				
Options			ОК	Cancel	Run

Starting with the **SSEAP** tab, enter a title and (optionally) comments as illustrated. Proceed to the **Items** tab and select the items SLF1 to SLF5.

IRT Scoring			X
Data File: C:\IRTPRO E	kamples\By Dataset\Social Life Feelings	s\SLF.ssig	<u>R</u> ead file
Description Group	Items Models Scoring		
<u>G</u> rouping value:	Single Group Analysis No Group Variable		•
List of variables:		Items: X	
SLF1 SLF2 SLF3 SLF4 SLF5	Add >>	SLF1 SLF2 SLF3 SLF4 SLF5	↑ ↓
	Number of latent dimensions:	Apply to all groups	
Options		OK Cancel	Run

Click the **Options**... button (lower right-hand corner in display above) to activate the **Advanced Options** window and click the **Starting Values** tab to obtain the dialog shown below.

Advance	d Options	The second second	X
Test:	SSEAP	•	Apply to all tests
Estim	ition Starting Values	Priors Miscellaneous Save Simulate	
		Enter starting values	
		Read starting values from a file	
		ОК	Cancel <u>A</u> pply

Next click the **Read starting values from a file...** button to display the **Open** dialog, then select **SLF.Test1-prm.txt**. Click the **Open** button to return to the IRT scoring menu.

🔀 Open	-			X
Look <u>i</u> n:	👢 Social Life Feel	lings 🗸	G 🧊 🖻	ፆ▼
Recent Places	Name	n.txt		Date modified 6/16/2011 10:27 AM
Desktop				
Libraries				
Computer				
	•	III		۱.
Network	File <u>n</u> ame:	SLF.Test1-prm.txt		<u>Open</u>
	Files of <u>type</u> :	Parameter File (*-prm.bt)		▼ Cancel

Click the **Scoring** tab and make the following selections:

- Check the Create summed-score to scale conversion table option.
- Check the **Score persons** option.
- Select Scale: Population distribution.

IRT Scoring		-	X
Data File:	C:\IRTPRO Examples\By Dataset\Social Life Fee	lings\SLF.ssig Read fil	le
SSEAP M	AP		1
Descrip	tion Group Items Models Scoring		
Ē	erson ID:	Compute response pattern	
<u>₹</u>	reate summed-score to scale conversion table	✓ Score persons	
	Integer scores Mean: 0	Standard deviation: 1	
	Mi <u>n</u> imum:	Ma <u>x</u> imum:	
5	Scale Sc		
Options]	OK Cancel R	un

Finally, select the MAP test tab and repeat all the steps (**Description**, **Items**, **Starting values**) described above. However, the **Scoring** dialog should now contain the following selections:

- Check the **MAP scores** option.
- Select Scale: Population distribution.

IRT Scoring	
Data File: C:\IRTPRO Examples\By Dataset\Social Life Fee	lings\SLF.ssig Read file
SSEAP MAP	1
Description Group Items Models Scoring	
Person ID:	Compute response pattern
Create summed-score to scale conversion table	✓ Score persons
Scaling	
Integer scores Mean: 0	Standard deviation: 1
Mi <u>n</u> imum:	Ma <u>x</u> imum:
Scale O Population distribution	
Sample distribution	
Options	OK Cancel Run

The scoring procedure is started by clicking the **Run** button. At this stage, the user will have the opportunity to save the command file under a new name. In this case, the default name **SLF.irtpro** is changed to **SLF-Score.irtpro** to ensure that the command file generated in Section 8.2.1 is not overwritten. Click the **OK** button to start the analysis.

Save Command File	
Location:	
Examples\By Dataset\S	Social Life Feelings\SLF-Score.irtpro
	OK Cancel

Selections of the output for the SSEAP scoring procedure are shown below:

Project:	Social Life Feelings
Description:	Summed score EAP
Date:	16 June 2011
Time:	11:03 AM

Table of Contents

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ Group Parameter Estimates Summed Score to Scale Score Conversion Table Summary of the Data and Control Parameters

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

Item	Label	а	С	b
1	SLF1	1.20	-2.35	1.97
2	SLF2	0.71	0.80	-1.11
3	SLF3	1.53	0.99	-0.65
4	SLF4	2.55	-0.67	0.26
5	SLF5	0.92	-1.10	1.19

Summed Score to Scale Score Conversion Table (Back to TOC)

Summed Score	EAP[θ x]	SD[θ x]	Modeled Proportion
0	-1.191	0.717	0.1087594
1	-0.679	0.682	0.2286010
2	-0.110	0.652	0.2617982
3	0.511	0.649	0.2268359
4	1.022	0.653	0.1359492
5	1.544	0.701	0.0380563

Marginal reliability of the scaled scores for summed scores = 0.55444

Scoring Control Values

Scale scores for summed scores are tabulated and computed Summed score equivalence threshold: 0.000010

Note that the file containing the scores is saved as **SL-Score.SSEAP-sco.txt** and can be opened with any text editor.

Output Files

HTML results and control parameters:SLF-Score.SSEAP-ssc.htmText scaled score file:SLF-Score.SSEAP-sco.txt

The results shown next were obtained for the MAP scoring procedure. The parameter estimates are those obtained from the parameter file created as described in Section 8.2.1.

Project:	Social Life Feelings
Description:	Response Pattern MAP
Date:	16 June 2011
Time:	11:03 AM

Table of Contents

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ Group Parameter Estimates Summary of the Data and Control Parameters

2PL Model Item Parameter Estimates for Group 1, logit: $a\theta + c$ or $a(\theta - b)$ (Back to TOC)

Item	Label	а	С	b
1	SLF1	1.20	-2.35	1.97
2	SLF2	0.71	0.80	-1.11
3	SLF3	1.53	0.99	-0.65
4	SLF4	2.55	-0.67	0.26
5	SLF5	0.92	-1.10	1.19

Scoring Control Values

Response pattern MAPs are computed

Output Files

HTML results and control parameters:SLF-Score.MAP-ssc.htmText scaled score file:SLF-Score.MAP-sco.txt

A matrix plot of the three sets of scores reveals an almost perfect correlation between the scores obtained with EAP and MAP. A plot of the SSEAP scores against the EAP and against the MAP scores shows strong positive correlation.

a creation and a sol	0000 0000000 00000000 00000000	1.45 Map
0 ⁰⁰	8	-1.1
o o o o o o o o o o o o o o o o o o o	1.54	
0000 00000	SSEAP	
0000 0	-1.19	
1.54		
ЕАР		
-1.19		

Conclusions drawn from the matrix scatter plot, are substantiated by calculating the sample statistics of the three sets of scores, the results being reported below:

Descriptive Statistics for three scoring methods				
Correlation	Matrix			
	EAP	SSEAP	MAP	
EAP SSEAP MAD	1.000 0.962	1.000	1 000	
Means	1.000	0.964	1.000	
	EAP	SSEAP	MAP	
	0.000	-0.001	0.016	
Standard Dev	viations			
	EAP	SSEAP	MAP	
	0.773	0.746	0.704	

The correlations between the three scoring methods are shown below, followed by the means and standard errors of EAP, SSEAP and MAP. There is almost perfect correlation between EAP and MAP (1.000 to three decimal places).

In applied testing situations, the larger standard errors (about 10%) associated with the SSEAPs may be considered a reasonable penalty offset by the ease of summed score based IRT scoring.

9. Model-based graphics

9.1 Introduction

The model-based graphics option in IRTPRO is only available for unidimensional IRT models. There are five different display types available, these being:

- Trace lines (Section 9.2).
- Item information curves (Section 9.3).
- Combined display of trace lines and item information curves (Section 9.4).
- Total information curve (Section 9.5).
- Test characteristic curve (Section 9.6).

There are two ways to display IRT graphics. The first method is to run a unidimensional analysis. On successful completion of the analysis, an output file with extension -irt.htm is produced. With the -irt.htm content displayed, select Analysis, Graphs to obtain trace lines, information and test characteristic curves.

File Edit	View	Analysis	Window	Help
🗅 🚅 🖬 🐰	Þ C	Grap	ohs	
IRTPRO Ve	rsion 2	.0		
IRTPRO Ver Output gen	rsion 2 erated	by IRTP	RO estim	nation engine Version 4.54 (32-
Project: Description:	rsion 2 erated asthm	by IRTP	RO estim	ation engine Version 4.54 (32- lel
Project: Description: Date:	asthm Unidin 19 Jun	by IRTP na34 datase mensional a ne 2011	RO estim t graded mod malysis, sing	nation engine Version 4.54 (32- Jel le group.

Alternatively, on successful completion of a run, IRTPRO produces a plot file with the extension - irt.irtplot. One can use the File, Open option to locate this file.

🔀 Open			X
Look <u>i</u> n:	📙 Asthma34	•	G 🌶 📂 🖽 -
Recent Places Desktop Libraries	Name Asthma_34.s Asthma_34.ss Asthma34.cs Asthma34.irt Asthma34.ps Asthma34.ps Asthma34.re Asthma34.Te	av sig vv tpro sf ig est1-irt.htm est1-irt.irtplot	Date modified 6/5/2011 12:11 PM 6/5/2011 12:21 PM 2/11/2011 9:55 AM 6/19/2011 11:05 AM 6/5/2011 12:09 PM 2/11/2011 9:55 AM 6/19/2011 11:05 AM 6/19/2011 11:05 AM 6/19/2011 11:05 AM 6/19/2011 11:05 AM
Computer (Computer Network	 ✓	III All Files (*.*) IRTPRO Command File (*.irtpro) IRTPRO Data File (*.ssig) Fixed Format Data (*.fixed) IRTPRO HTML Output File (*.htm) IRTPRO Plot Files (*.irtplot) All Files (*.*)	Open Cancel

The **Graphics** window is displayed by either selecting the **Analysis**, **Graphs** option or by opening the plot file. By default, trace lines are displayed when this window is opened.



9.2 Trace lines

A trace line (item characteristic curve) is a nonlinear function that portrays the regression of the item score on the trait or ability measured in a test.

In the case of binary data, two trace lines are shown, one for the positive response and the other it's complement. In polytomous models such as the graded response model and nominal response models, trace lines for each response category are plotted. Each curve shows the selection

probability of a category of the item as a function of θ .

By default, trace lines for all the items selected under the **Models** tab are displayed simultaneously for each group. Trace lines for the first four items of Group number 1 of a two-group analysis are shown below.



To view the trace lines for any specific item, double click on the relevant graphics box, or, if for example the item PAIS3 of the second group is of interest, click on the **Group 2**, **PAIS3** link using the trace line tree expansion shown below.



9.3 Item Information

Item information is a function of θ ; it provides valuable insight about the precision of measurement provided by the item. It is of particular use in test construction, where these curves can be used to ensure the inclusion of different items that maximize the precision of measurement at different levels of θ in the test.

In the case of the 2PL model, for example, the item information function is given by (Hambleton & Swaminathan, 1985, Table 6-1)

$$a_i^2 \left\{ l + exp\left[-\left(\theta - b_i\right)\right] \right\}^{-l} \left\{ l - \left(1 + exp\left[-\left(\theta - b_i\right)\right]\right)^{-l} \right\}$$

with the maximum value directly proportional to the square of the item discrimination parameter, a. A larger value of a is associated with greater information. The maximum information is obtained at b_i .

For the three-parameter model, the information function is (Hambleton & Swaminathan, 1985, Table 6-1)

$$\frac{a_{i}^{2}\left\{1-\left(1+exp\left[-\left(\theta-b_{i}\right)\right]\right)^{-1}\right\}\left\{1+exp\left[-\left(\theta-b_{i}\right)\right]^{-1}-c_{i}\right\}^{2}}{\left\{1-c_{i}\right\}^{2}}$$
The maximum information is reached at

$$b_i + \frac{1}{a_i} ln \left[\frac{1}{2} + \frac{1}{2} \sqrt{1 + 8c_i} \right]$$

An increase in information is associated with a decrease in c_i . The maximum information is obtained when $c_i = 0$. Baker & Kim (2004) contains information function equations for most of the IRT models available in IRTPRO.

The slope of the trace line plays an important role in the information provided by an item. An increase in the slope means the item provides more information. The use of items with more information leads to smaller standard errors of measurement. By assessing these curves, items that contribute little information, and therefore contribute little to precision, may be identified and discarded.

To obtain the item information curves, click on the **Information** link. As before, simultaneous displays of all the item information curves are obtained. By scrolling up or down, all items can be viewed if there are many items in a test.



One can also change the number of columns of plots from three (see above) to less or more columns. This is accomplished by clicking **Tools** on the main graphics menu bar to select the **Options** dialog shown below.

Options 💌
Number of columns on simultaneous plots
Combined charts Show on single chart Show two charts
Univariate / Multivariate Charts Show on single chart Show multiple charts Show Missing Values
Superimpose groups (DIF) OK Cancel

Just as in the case of trace lines one can view one information curve at a time by expanding the Information tree and by clicking on the item to be displayed. This is illustrated below for PedsQL-A2 (item 5 of the second group).



To view the co-ordinates used to plot a graph, the **Table** icon next to the **Graph** icon in the graphics window can be selected. Use **Edit**, **Copy** (**Ctrl**+**C**) to copy the contents of the table to the clipboard if you need to paste these values into another document.

X Asthma28.Graded_2GRP-irt.irtplot - IRTProGraphs							
File Edit View Graphs Ch	art Type Tools Help						
🗃 🛛 Copy Ctrl+C							
Find Ctrl+F	🛍 Graph 🌐 Table						
Arrownaddi Group 1 Group 2 Arrownaddi PAIS1 Arrownaddi PAIS2 Arrownaddi PadsQL-A1 PedsQL-A2 Combined Total Information Curve Test Characteristic Curv	Theta PedsOL-A2 -3.00 0.001 -2.90 0.001 -2.80 0.002 -2.70 0.003 -2.60 0.004 -2.50 0.006 -2.40 0.009 -2.30 0.014 -2.20 0.020 -2.10 0.029 -2.00 0.043 -1.90 0.062 -1.80 0.091						
	···· · ··· · · · · · · · · · · · · · ·						
Copy the selection and put it or	the Cliphoard						
copy the selection and put it of	i ule clipboalu						

9.4 Combined trace lines-information curves

The user additionally has the option to obtain a combined trace lines-information curve presentation. This is illustrated below for Group1, item 5 (PedsQL-A2). Just as in the previous cases, the default selection is the simultaneous display of all the items that are obtained by clicking on **Combined**. Note that the information curve is displayed as a dashed line and that the information scale is shown on the right side of the graph.



For reporting purposes, a researcher may prefer to display the trace lines and information curves as two separate vertically stacked plots. This is achieved by selecting the **Tools**, **Option** dialog and by making the appropriate choice (**Show two charts**) in the **Combined charts** pane.

Options
Number of columns on simultaneous plots
01
③ 3
© 4 © 5
Combined charts
Show on single chart
Show two charts
Univariate / Multivariate Charts
Show on single chart
Show multiple charts
Show Missing Values
Superimpose groups (DIF)
OK Cancel

The **Show two charts** choice results in a trace lines graph stacked above the information graph for the item selected.



9.5 Total Information

The total information (or test information) function summarizes the information function for a set of items or test. The contribution of each item in the test to the total information is additive.

The slope of the trace line plays an important role in the information provided by an item. An increase in the slope means the item provides more information. The use of items with more

information leads to smaller standard errors of measurement. By assessing these curves, items that contribute little information, and therefore contribute little to precision, may be identified and discarded.

The measurement error variance of the MAP scale score is (on average) inversely related to the amount of information provided by a set of test items at any level of θ , so on average, the standard error of MAP estimates at ability level θ can be written as

$$SE(\theta) = \frac{1}{\sqrt{I(\theta)}}.$$

The contribution of both item and test information curves are summarized by Hambleton & Swaminathan (1985) as follows:

"The item and test information functions provide viable alternatives to the classical concepts of reliability and standard error. The information functions are defined independently of any specific group of examinees and represent the standard error of measurement at any chose ability level. Thus, the precision of measurement can be determined at any level of ability that is of interest. Furthermore, through the information function, the test constructor can precisely assess the contribution of each item to the precision of the total test and hence choose items in a manner that is not contradictory with other aspects of test construction."

The graph shown below is obtained by clicking on the **Total Information Curve** link. The solid line shows the total information curve at various value of theta. The corresponding standard errors are presented by the dashed line. The standard error scale is given on the right hand vertical axis. The curves below are based on all the items that are included in the model.



The next graphical presentation shows the total information and standard errors when Items 2 and 3 (PAIS2 and PAIS3) are omitted.



9.6 Test Characteristic Curves

The test characteristic curve is the expected value of the summed score for a test, or a set of items, as a function of θ .

In the image below, the test characteristic curves for Groups 1 and 2 are displayed.



The next graphical presentation shows the test characteristic curve for group 2 when the item PedsQL-A2 is omitted.



Polytomous items each has expected score curves, which show the expected item score as a function of θ , computed by taking literally the numerically values of the item scores u = 0, 1, ..., m-1 where *m* is the number of response categories. Expected score curves are simpler than trace line plots for, say, five response categories, because the latter have five curves and the expected score is only curve. While it is difficult to compare two items' sets of five trace lines, it is easier to compare two items' expected score curves.

In **IRTPROGraphs**, expected score curves for individual items can be graphed by selecting *only one item* with the check boxes in the list at the left side of the graphics window.

9.7 Controlling the appearance of a graph

The visual appearance of a graphical display can be changed before the graph is copied to another document. This is accomplished by right clicking in the plot area of the display that is to be modified. This action activates the **2D Chart Control Properties** dialog that provides the user with several options (options available depends on the graph type). In the illustration below, we wish to change the colors of the total information and standard error curves of the first group.

X Asthma28.Graded_2GRP-irt.irtplot - IRTProGraphs	
File Edit View Graphs Chart Type Tools Help	
Trace lines Graph Table Graph Table Group 1, Total Information Curve Group 2, Total Information Group 2, Total Informa	
Image: Cancel Apply Help Ready Image: Cancel Apply Help	,

This is accomplished by selecting the **ChartStyles** tab and then by clicking on the **Name**: (of the color) arrow.

This action results in the display of a drop-down menu with a list of available colors. In the image shown below, the color Dark Turquoise was selected.

2D Chart Control Properties							
ChartArea PlotAr	ea ChartLabels View3D Markers AlarmZones						
Control Axes	ChartGroups ChartStyles Legend						
ChartGroup1	FillStyle LineStyle SymbolStyle SliceStyle Image: Comparison of the symbol style Background Color (pattern): RGB: Pattern:						
ChartGroup2	Name: (Automatic)						
Add	Foreground Color (solid):						
Remove	RGB: #00ced1						
Count: 4	Name: DarkTurquoise DarkGreen DarkKhaki						
3-	K DarkOliveGreen DarkOrange DarkOrchid DarkSalmon DarkSeaGreen						
2-	DarkSlateGray DarkViolet DarkViolet DeepPink DeepSkyBlue DodgerBlue						
1	Firebrick FloralWhite ForestGreen Gainsboro GhostWhite						

To change the color of the standard error curve from Black to Red, select **ChartGroup2**, **Style 1** and repeat the procedure described above.

2D Chart Control Properties								
ChartArea Control - Style1 - Style2 - Style3 - Style4 ChartGroup - Style1	PlotAre Axes	a ChartLabels View3D Markers AlarmZones ChartGroups ChartStyles Titles Legend FillStyle LineStyle SymbolStyle SliceStyle Background Color (pattern): RGB: Name: (Automatic)						
A <u>d</u> d <u>R</u> emov Count: 1	e	Foreground Color (solid): RG <u>B</u> : #ff0000 Na <u>m</u> e: Red •						
	OK Cancel Apply Help							

Click **OK** when done to obtain the revised graphical display shown next.



To change the format of the axes labels, select the **Axes** tab and click on the **TitleFont** selector button to display the **Font** dialog. To illustrate, we selected the Lucida Bright font, size 10.

ChartArea PlotA Control Axes	ChartLa ChartGrou	bels View ps Char	/3D Mari tStyles	kers / Titles	AlarmZones Legend
Axes - X - Y - Y - Y - Y - Y - Y - Y - Y	General A Text: Total Info Title Rot.: TitleFont	rmation S 90 MS Sans	cale Title) Axis/I	Grid L
:					
nt cida Bright Guat Stare attin hcida Bright ucida Calligraphy ucida Console ucida Fax Effects Strikeout Underline	Font st Regul Italic Demi Demi Samp	vle: ar bold bold Italic ole AaBbY	Size: 10 10 11 12 14 16 18 20 (yZz		OK Cancel
	Script	m		•	

Click **OK** when done to obtain the revised graphical display shown below. Chapter 10 contains additional examples illustrating the functionality of the **2D Chart Control Properties** dialog.



10. Data-based graphics

10.1 Introduction

Graphics are often useful for data exploration. Relationships and trends may be conveyed in an informal and simplified visual form via graphical displays. IRTPRO offers both data-based and model-based graphs (see Chapter 9). In the case of data-based graphs, IRTPRO distinguishes between univariate and bivariate graphs. Univariate graphs (see Section 10.2) are particularly useful to obtain an overview of the characteristics of a variable. However, they do not necessarily offer the tools needed to explore the relationship between a pair of variables. For that purpose, bivariate graphs (see Section 10.3) are more appropriate.

To make univariate or bivariate graphs, the IRTPRO dataset of interest must be the currently opened window. Click the **Graphics** button on the main menu-bar and make a selection between the **Univariate...** and **Bivariate...** options.

	🔀 IRTF	PRO - [Asthn	na_34.ssig]		-	-		-	-
	🖃 Fil	e Edit Da	ta Manipul	late	Gra	phics	Analysis	View	W
	🗅 🖻	📙 🐰 🖻	e 4 ?			Univa	ariate		
		DISAB_1	DISAB_2	D		Diver	inte		5
	1	2	1	0		Bivar	rate		
l	2	2	2	2		Item	Response		
l	3	2	2	2	_	2		2	
	4	0	0	1		1		0	
	5	3	0	2		3		2	
	6	3	3	2		4		1	

10.2 Univariate Graphs

The default graph-type is a bar chart for each item selected. A bar chart is a graphic representation of the frequency distribution of discrete or categorical data in which the values or categories are given on the horizontal axis and the frequencies are given on the vertical axis.

The image below shows the selection of the Graphics, Univariate... option.

🔀 IR	🔀 IRTPRO - [Asthma_34.ssig]								
E F	ile	e Edit Da	ta Manipu	late	Gra	phics	Analysis	View	
	Ĩ	🛛 🕺 🗳	C 4 ?			Univa	ariate		
		DISAB_1	DISAB_2	D		Diver	into		H
1		2	1	0		Bivar	iate		
2		2	2	2		Item	Response		
3		2	2	2	-	2		2	_

Selection of this option opens a **Univariate Graph** dialog that enables one to select one or more of the variables in the data set. By clicking on the **OK** button, a simultaneous display of bar charts is obtained. The default display is to show the bar charts after removal of missing values.



The data used to create the graphs can be viewed by selecting the **Table** "mode" as shown below. For example, for the DISAB_10 item, there are 160 values equal to 0, 110 values equal to 1, 197 values equal to 2, 87 values equal to 3, and 55 values equal to 4.

X Asthma_34.ssig - IRTPro	🔀 Asthma_34.ssig - IRTProGraphs 📃 🗖 🗮 🍋									
File Edit View Graphs	Elle <u>E</u> dit <u>V</u> iew <u>G</u> raphs Chart <u>Type Tools H</u> elp									
🗃 🖻 M 🗇 📍										
🖃 🚭 Univariate Graphs	*	🛍 Graph 🔳	Table							
DISAB_1										7
DISAB_2		DISAB_10	DISAB_11	DISAB_12	PEDS_EM1	PEDS_PA1	PEDS_PH1	PEDS_PH2	PED_D_1	
DISAB_3		0 = 160	0 = 258	0 = 333	0 = 272	0 = 132	0 = 360	0 = 220	0 = 277	
DISAB_4	Ξ	1 = 110	1 = 106	1 = 92	1 = 71	1 = 87	1 = 95	1 = 132	1 = 93	
DISAB_5		2 = 197	2 = 147	2 = 104	2 = 134	2 = 198	2 = 86	2 = 156	2 = 135	=
DISAB_6		3=8/	3 = 56 4 - 40	3 = 44	3 = 6U 4 - 60	3 = 101	3 = 39	3 = 58	3 = b2 4 - 39	
DISAB_7		4 = 55	4 = 40	4 = 34	4 = 03	4 = 30	4 = 32	4 = 40	4 = 30	
DISAB_8										
DISAB_9										
DISAB_10										
DISAB_11										
DISAB_12										
PEDS_EM1										
PEDS_PA1										
PEDS_PH1										
PEDS_PH2	Ŧ	٩							4	-
Ready										

To display the missing values, click on the **Tools** button and make sure that the **Show Missing Values** check box is selected. The **Options** dialog also enables the user to select the number of columns on the simultaneous plots.



Below we show the bar charts for the six items selected. As can be seen, all the items selected have missing values (coded -9). By right clicking in the DISAB_10 plot area (for example), the **Chart Properties** dialog is obtained that can be used to change the color of each bar.



In the illustration below, use is made of the **ChartStyles** tab to change the color of the bar corresponding to the value "0" to chocolate.



After making the desired color changes, click the **OK** button to view the modified display shown below.



As an illustration, suppose that we want to change the text and font of the current title (DISAB_10). Right-click in the DISAB_10 plot area to display the **Chart Properties** dialog and select the **Titles** tab. Use the **Titles** window to first select the **Label** tab and then the **Font** tab. Change the **Header**, **Text** as shown below.

2	D Chart Cont	rol Propert	ies	-	1 Terrar		×	
	ChartArea	PlotArea	Cha	artLabels	View3D	Markers	AlarmZones	
	Control	Axes	Chart(Groups	ChartStyle	s Titles	Legend	
	Titles	G	eneral	Label	Location F	Border Inte	erior F¢	
	L Footer		<u>T</u> ext:					
			DISA	B_10 (Mis	sing value co	ıde⊨-9)		
			•				4	
	OK Cancel Apply Help							

Next, use the **Font** tab to change to default font, font style and font size. In this case, it was changed to Georgia, Bold, 10.

2D Chart Control Prope ChartArea PlotAre Control Axes Titles Header	rties a ChartLabels View3D ChartGroups ChartStyles Label Location Border Inte	Markers AlarmZones Titles Legend erior Font Image ()
Font Georgia Georgia desclow Solid Harrington High Tower Text Impact Informet Ramen	Font style: Bold Regular Italic Bold Bold Italic	Size: 10 OK 10 OK 11 Cancel 12 E 14 E 16 18 20 V
Effects	Sample AaBbY Script Western	(yZz
This is an OpenType fo and your screen.	nt. This same font will be used on	both your printer

Click the **OK** button of the **Font** dialog to return to the **2D Chart Control Properties** dialog, then click **OK** to view the edited graph.



A pie chart display of the percentage distribution of a variable may be obtained by selecting the **Chart Type, Pie** option. A pie chart is a graphic representation of percentages or frequencies by means of a circle that is subdivided into slices in such a way that the areas of these slices are proportional to the percentages or frequencies. Pie charts may be customized by using the graph editing dialog boxes obtained by right-clicking in the plot area of the pie chart.



The distribution of frequencies over the categories of an item can also be displayed in the form of a stacked bar chart by selecting the **Chart Type, Stacking Bar** option. The bars in a stacked bar graph are divided into the categories of the item displayed. Each bar represents the number of examinees whose responses fell in that category.



10.3 Bivariate Graphs

The Graphics, Bivariate... option allows us to graphically display a two-way frequency table.

	K IRTPRO - [Spelling.ssig]									
File Edit Data Manipulate Graphics Analysis V										
	🗋 🗅 🚅	📙 X 🖻			Univa	ariate				
		Infidelity		Su		Divariata				
	1	0	0	0		DIVdi	late			
	2	0	0	0		Item	Response			
l	3	3 0 0		0	0			1		
ĺ	4	0	0	0		0		1		
	5	0	0	0		0		1		

Selection of this option results in the display of a **Bivariate Graph** dialog allowing the user to select an **X-variable** and one or more **Y-variables** to obtain a set of bivariate plots. In the following example, Gender is selected as the **X-variable** and the items Infidelity, Panoramic, Succumb and Girder as the **Y-variables**.

Bivariate Graph	X
Select <u>X</u> Variable	
Gender	•
Select one or more Y Variable(s)	
✓ Infidelity	
Panoramic	
Succumb	
Girder	
OK Cancel	

Clicking the **OK** button results in the following graphical display. Note that the categories of Gender (the **X-variable**) are displayed below the horizontal axis. Each category of a selected **Y-variable** corresponds to a color and the color legend is given at the bottom of the graph.



Note that in the left pane (above) all the items included in the model are listed. If a specific item is clicked, an expanded list of all the items (excluding the one selected) is displayed and any of these items may be selected as **Y-variables**.

A more informative display of the relationship between two variables might be stacked bar-charts, obtained by selecting the **Chart Type**, **Stacking Bar** option. In the display below, it can be observed that there are more Gender = 2 subjects compared to the number off Gender = 1 subjects. Furthermore, for the item Girder a larger percentage Gender = 2 individuals chose the "0" category than is the case for Gender = 1.



As mentioned earlier, one can switch to the **Table** mode to view the data generated for the plots requested. The frequencies listed in the table below, substantiate the conclusions drawn from the stacked bar-charts display.

Spelling.ssig - IRTProGraph	S and the second	-	-			X
File Edit View Graphs Ch	nart Type Tools	Help				
Univariate Graphs Sivariate Graphs	🛍 Graph 🎞	Table				
	Gender	Infidelity	Panoramic	Succumb	Girder	_
	1	0 = 70	0 = 104	0 = 194	0 = 106	=
	1	1 = 215	1 = 181	1 = 91	1 = 179	
Girder	2	0 = 69	0 = 144	0 = 265	0 = 203	
Girder	2	1 = 305	1 = 230	1 = 109	1 = 171	
Panoramic						
Girder						
	•		111			4
Ready	,					đ

In the next illustration, bivariate charts are requested for the item PED_D_1 versus the items DISAB_1, DISAB_2, DISAB_3 and DISAB_4, from the IRTPRO dataset **Asthma34.ssig**. This dataset were selected since each item has more than two categories. In this case, the stacked bars representation is less cluttered than the side-by-side bar charts representation and usually easier to interpret visually.



11. Estimation methods and settings

A brief discussion of the IRTPRO's estimation methods and their control parameters is provided in this chapter. To see the dialog boxes that permit access to the control parameters, open the syntax file (see Chapter 12) **Isat6.irtpro** from the **IRTPRO Examples\Unidimensional\2PL** folder, a portion of which is displayed below.

```
_ 🗆 🗙
🔀 IRTPRO - [lsat6.irtpro]
                                                _ 8 ×
Eile Edit Analysis View Window Help
🗅 🚅 🖬 👗 🖻 🛍 🎒 🌹
Project:
                                                      *
    Name = lsat6;
Data:
    File = .\lsat6.ssig;
Analysis:
    Name = 2PL;
    Mode = Calibration;
Title:
lsat6 data set
Comments:
2PL models fitted to each item
Estimation:
    Method = BAEM;
    E-Step = 500, 1e-005;
    SE = S-EM;
    M-Step = 500, 1e-009;
    Quadrature = 49, 6;
     SEM = 0.001;
     SS = 1e - 005;
```

Next, select the **Analysis**, **Unidimensional** option from the main menu bar and click the **Options** button shown at the bottom of the **Unidimensional Analysis** window on the left.

Unidimensional Analysis								
<u>D</u> ata File:	C:\IRTPRO Exar	mples\Unidim	nensional\2PL	\lsat6.ssig			<u>R</u> ead file	
2PL								
Descr	ription Group I	tems Mode	Scoring					
<u>G</u> r	ouping value:	lo Group Var	iable	1			•	
- 1	Item List	Categories	Data Codes	Item Score	Model			
		2	0, 1	0, 1	2FL 2PI			
	C3	2	0, 1	0, 1	2PL			
	C4	2	0, 1	0,1	2PL			
	C5	2	0, 1	0, 1	2PL			
	<u>C</u> onstraints	<u>D</u> IF				Apply to a <u>l</u> l gro	ups	
Options				(ОК	Cancel	Apply	

11.1 Bock-Aitkin EM

The default estimation method for a unidimensional analysis is the Bock-Aitkin method and the **Advanced Options** window shown below shows the default estimation settings. A researcher has the option to change these settings, for example, the number of quadrature points, the range over which these points are spread, the maximum number of cycles (E-step) and the maximum number of iterations (M-step).

Advanced Options	X
Test: 2PL	Apply to all tests
Estimation Starting Values Priors Miscellaneous	Save Simulate
Estimation Bock-Aitkin Bock-Aitkin	
Converge informatio Adaptive Quadrature MH-RM Maximum number of cycles 500	Convergence criterion: 1e-005
M-Step maximum iterations 500	Convergence criterion: 1e-009
Quadrature details Number of 49	Magimum value: 6
<u>S</u> tandard ▼	Apply dimension reduction
	Single Group 1
Default	
	OK Cancel Apply

A portion of the output, listing the parameter estimates for the Bock-Aitkin estimation method, is shown below.

船 IR TPRO	- [ls at6.2	PL-ssc.htm]								
<u> </u>	lit <u>V</u> iew	<u>A</u> nalysis <u>W</u> indow	<u>H</u> elp				_ 8 ×			
🗅 😅 🕻	. % @	a 🖬 🎒 🤗								
OmniLo	g						_			
Project:	Project: Isat6 data;									
Descripti	ion:	2pl models fitted	I to the items;				_			
Date:		15 December 20)09				_			
Time:		12:14 PM								
T-1-14		-								
Table of	Content	S								
2PL MOD	ei item Pa	rameter Estimate	is for Group 1,	, logit: a 0 +	c or a(θ – b)					
Factor Lo	adings fo	r Group 1								
Group Pa	rameter E	stimates								
Summan	of the Da	ta and Control Pa	arameters							
Cummun	01 110 20		andinotoro							
2PL Mode	el Item Pa	rameter Estimat	es for Group	1, logit: aθ	+ c or a(θ – b)	(Back to TOC)				
Item	Label	а	С	b						
1	C1	0.83	2.77	-3.36						
2	C2	0.72	0.99	-1.37						
3	C3	0.89	0.25	-0.28						
4	C4	0.69	1.28	-1.87						
5	C5	0.66	2.05	-3.13						
							-			

11.2 Adaptive Quadrature

A problem with standard numerical quadrature as employed in the Bock-Aitkin procedure is that it has a fixed set of quadrature nodes for the posterior distribution of all persons. This often requires the use of a large number of quadrature points to calculate the log-likelihood and derivatives to an acceptable level of accuracy. To overcome this problem, IRTPRO also offers a numeric integration procedure called adaptive quadrature. The adaptive quadrature procedure uses the empirical Bayes means and covariances, updated at each iteration to essentially shift and scale the quadrature locations of each case (person) in order to place them under the peak of the corresponding integral.

Advanced Options
Test: 2PL Apply to all tests
Estimation Starting Values Priors Miscellaneous Save Simulate
Estimation Adaptive Quadrature
Converge Information
Maximum number of cycles 100 Convergence criterion: 0.001
Quadrature Details
Number of 9 Integration method: Gauss Hermite V
Adaptation
Default
OK Cancel Apply

The default adaptive quadrature settings are shown above. These settings can be changed or reset to the default values by clicking the **Default** button. Select the **OK** button when done. A portion of the updated syntax file is shown below.

🔀 IRTPRO - [Isat6.irtpro]	٢
Eile Edit Analysis View Window Help	×
Project:	-
Name = ISato;	
Data:	
<pre>File = .\lsat6.ssig;</pre>	
Analysis.	Ξ
Name = 2PL;	
Mode = Calibration;	
mitle.	
lsat6 data set	
Comments:	
ZPL models litted to each item	
Estimation:	
Method = ADQ;	
E-Step = 100, 0.001; SE = S-EM:	
Quadrature = 9, GH;	
Adaptation = EAP;	
Trust = Fast;	÷
Ready	

Select the Analysis, Run option. The parameter estimates are shown below.

船 IRTPRO - [lsat6	2PL-ssc.htm]										
Eile Edit View	<u>A</u> nalysis <u>W</u> indow	Help			_ 8 ×						
🗅 🚅 🖶 X 🖻 🖻 🎒 🥐											
OmniLog					_						
Project:											
Description:	Description: Adaptive quadrature. 2pl models fitted to the items;										
Date:	15 December 20	009									
Time:	12:19 PM										
T-H- CO-t-											
Table of Conte	its			(0 , 1)							
2PL Model Item P	arameter Estimate	s for Group 1	, logit: a0 +	$c \text{ or } a(\theta - b)$							
Factor Loadings f	or Group 1										
Group Parameter	Estimates										
Summary of the D	ata and Control Pa	arameters									
2PL Model Item F	arameter Estimat	es for Group	1, logit: aθ	+ c or $a(\theta - b)$ (Back to TOC)							
Item Labe	а	С	b								
1 C1	0.83	2.77	-3.36								
2 C2	0.72	0.99	-1.37								
3 C3	0.89	0.25	-0.28								
4 C4	0.69	1.28	-1.87								
5 C5	0.66	2.05	-3.13								
					_						
Done											

11.3 MH-RM

Li Cai (2010-b and 2010-c) proposed a Metropolis-Hastings Robbins-Monro (MH-RM) algorithm to address the "curse of dimensionality" that has plagued multidimensional IRT and high-dimensional latent structural equation modeling. The MH-RM algorithm performs favorably in comparative studies against established gold-standard methods such as Gaussian quadrature. The MH-RM algorithm is much more efficient than the MCEM algorithm in the use of Monte Carlo because the simulation size in MH-RM is fixed and usually small throughout the iterations. In addition, MH-RM produces an estimate of the parameter information matrix as a by-product that can be used subsequently for standard error estimation and goodness-of-fit testing.

For practical data analysis, one can often achieve efficiency gains of several orders of magnitude over existing methods such as numerical quadrature if one uses MH-RM to estimate the parameters of the model. The MH-RM method is ideally suited for multi-dimensional analyses where the number of dimensions exceeds two or three.

Advanced Options
Test: 2PL Apply to all tests
Estimation Starting Values Priors Miscellaneous Save Simulate
Convergence Controls
Convergence monitor window 3 Convergence criterion: 0.001
Control Parameters
Number of stage I 200 🔪 Number of stage II cycles: 100 ਵ
Maximum number 2000 - Monte Carlo size for final 10000 - Ilog-likelihood approx.:
Tuning Parameters
Number of 1 Burn-in: 10 Thinning: 0
Initialization <u>ga</u> in 0.1 Alpha: 1 Epsilon: 1
Metropolis sampler Spherical Covariance Matrix Computation Metropolis proposal density std. dev.: 0.4 Ovariance Matrix Computation Metropolis proposal density std. dev.: 0.4 Ovariance Matrix Computation Metropolis proposal density std. dev.: 0.4 Ovariance Matrix Computation
Default
OK Cancel Apply

A portion of the revised syntax file is shown below.

<pre>File Edit Analysis View Window Help _ 5 × C File Edit Analysis View Window Help _ 5 × C Analysis: Name = 2PL; Mode = Calibration; Title: lsat6 data set Comments: 2PL models fitted to each item</pre>
□ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □
Analysis: Name = 2PL; Mode = Calibration; Title: lsat6 data set Comments: 2PL models fitted to each item
<pre>Name = 2PL; Mode = Calibration; Title: lsat6 data set Comments: 2PL models fitted to each item</pre>
Mode = Calibration; Title: lsat6 data set Comments: 2PL models fitted to each item
Title: lsat6 data set Comments: 2PL models fitted to each item
lsat6 data set Comments: 2PL models fitted to each item
Comments: 2PL models fitted to each item
Comments: 2PL models fitted to each item
2PL models fitted to each item
Estimation:
Method = MHRM;
Convergence=3, 0.001;
Stage1=200;
Stage2=100;
Stage3=2000;
MCsize=10000;
Imputation=1;
Thinning-0:
GainConst=0 1:
Alpha=1;
Epsilon=1;
Sampler=Spherical;
ProposalSD=0.4;
CovMethod=Accumulation;
Ready

To run the 2PL model using the MH-RM method, select the **Analysis**, **Run** option. Some of the parameter estimates shown below differs a small amount from those obtained using the previously described estimation methods.

📲 IRTPRO - [lsat6.2PL-ssc.htm]											
📃 <u>E</u> ile <u>E</u> dit <u>V</u> iew	<u>A</u> nalysis <u>W</u> indow	<u>H</u> elp			_ 8 ×						
OmniLog											
Project:	Project: Isat6 data;										
Description: MH-RM. 2pl models fitted to the items;											
Date:	15 December 20	09									
Time:	12:23 PM										
Table of Conter	nts										
2PL Model Item P	arameter Estimates	for Group 1,	logit: $a\theta$ +	$c \text{ or } a(\theta - b)$							
Factor Loadings f	or Group 1										
Group Parameter	Estimates										
0	ate and Orated De										
Summary of the D	ata and Control Pai	ameters									
2PL Model Item P	arameter Estimate	s for Group	1. logit: aθ	+ c or $a(\theta - b)$ (Back to TOC)							
Item Label	а	с	b								
1 C1	0.82	2.77	-3.39								
2 C2	0.73	0.99	-1.35								
3 C3	0.85	0.25	-0.29								
4 C4	0.70	1.29	-1.83								
5 C5	0.71	2.08	-2.92								
-1											
					1.						

12. Syntax

12.1 Introduction

Examples covering the range of models that the IRTPRO program handles are presented in Chapters 4 to 8 in the following sequence:

- Chapter 4: Traditional summed-scored statistics
- Chapter 5: Unidimensional IRT
- Chapter 6: Multiple groups and DIF
- Chapter 7: Multidimensional IRT
- Chapter 8: IRT Scoring

IRTPRO distinguishes between three analysis modes:

- Traditional (Chapter 4)
- Calibration (Chapters 5-7)
- Scoring (Chapter 8)

Each analysis created by the GUI produces a syntax file with extension .irtpro, essentially being a record of a user's selections from the sequence of dialogs. Using the same IRTPRO .ssig data file (referred to as the Project Name), more than one analysis can be specified by inserting additional test tabs in the Analysis window. In this case, the syntax associated with each analysis (test) are appended to the same .irtpro file. The advantage of having a syntax file is that it enables one to duplicate an analysis. Specifically, suppose that a person A sends a copy of the IRTPRO .ssig and .irtpro files to person B. The latter will be able to duplicate the results obtained by person A, without the need to recreate the analysis.

Note that if a syntax file is opened, IRTPRO automatically fills the relevant dialogs and these can be viewed and modified using the **Analysis** menu on the main menu-bar. The **IRTPRO Examples** folder contains many syntax files illustrating the capabilities of the program.

12.2 Structure of a syntax file

A syntax file consists of paragraphs (commands), each starting with a command keyword followed by a punctuation mark (:). For example, regardless of the mode of analysis, the first five commands of a syntax file have the following structure:

```
Project:
```

Name = <Name of the IRTPRO data file without the extension .ssig>;

```
Data:
```

File = <Name of the IRTPRO data file with the extension .ssig >;

```
Analysis :
```

Name = <Testn>;

Mode = <Analysis type>;

Title :

<Description of the analysis>

Comments :

<Additional comments about the analysis>

12.2.1 Project: and Data: commands

The first two commands are generated when a **.ssig** file is opened and an analysis mode (Section 12.1) is selected from the **Analysis** menu.

12.2.2 Analysis: command

This command contains two keywords (Name and Mode). The first keyword corresponds with the nth test tab in the analysis window, the default being Test1 for a new analysis, followed by Test2, Test3,... if additional tabs are inserted on the **Analysis** window. These test tabs can be renamed by the user.

The second keyword can be any one of the following choices:

- 1. Mode = Traditional;
- 2. Mode = Calibration;
- 3. Mode = Scoring;

12.2.3 Title: and Comments: commands

These commands are associated with the **Description** tab on the **Analysis** window and are optional. Note that text entered in the title and comments paragraphs does not end with a semi-colon (;). However, semi-colons are required when indicated in paragraphs.

A subset of the available IRTPRO commands has the same functionality, regardless of the analysis type. These commands will be elaborated upon in this section, whereas paragraphs specific to an analysis type will be discussed in Sections 12.3 to 12.5.

Below is a typical syntax file containing two tests. The commands that are common to each analysis type are marked in bold and will be discussed in this section.

Project: Name = Spelling; Data: File = .\Spelling.ssig; Analysis: Name = Test1; Mode = Calibration; Title: Four item spelling test

Comments: All item parameters constrained to be equal across groups

```
Estimation:
  Method = BAEM;
  E-Step = 500, 1e-005;
  SE = S-EM;
  M-Step = 50, 1e-009;
  Quadrature = 49, 6;
  SEM = 0.001;
  SS = 1e-005;
Save:
  PRM. INF
Scoring:
  Pattern = EAP:
  Score Persons;
  Mean = 0;
  SD = 1:
Miscellaneous:
  Decimal = 3;
  Processor = 2;
  Print M2, CTLD, Loadings, P-Nums, Diagnostic;
  Min Exp = 1;
Groups:
  Variable = gender;
Group G1:
  Value = (1);
  Dimension = 1;
  Items = item1, item2, item3, item4;
  Codes(item1, item2, item3, item4) = 0(0), 1(1);
  Model(item1, item2, item3, item4) = 2PL;
  Referenced :
  Mean = 0.0:
  Covariance = 1.0;
Group G2:
  Value = (2);
  Dimension = 1;
  Items = item1, item2, item3, item4;
  Codes(item1, item2, item3, item4) = 0(0), 1(1);
  Model(item1, item2, item3, item4) = 2PL;
  Mean = Free;
  Covariance = Free;
Constraints:
  Equal = (G2, item1, Slope[0]), (G1, item1, Slope[0]);
  Equal = (G2, item1, Intercept[0]), (G1, item1, Intercept[0]);
    •
  Equal = (G2, item4, Slope[0]), (G1, item4, Slope[0]);
  Equal = (G2, item4, Intercept[0]), (G1, item4, Intercept[0]);
```

Only a portion of the syntax for the second test is shown below. The important point to note is that each subsequent test starts with an **Analysis**: command.

Analysis: Name = Test2; Mode = Calibration; Title : Spelling test 4 items

Comments :

```
Parameters of items 1-3 equal, item 4 different
```

Next, we describe the remaining commands, common to the three modes of analyses. The commands that are mode specific will be discussed in Sections 12.3 to 12.5.

12.2.4 Estimation: command

The first keyword in the **Estimation**: command is the keyword **Method** = which has the following form:

Method = <estimation method>;

The method of estimation (<estimation method>) is BAEM (Bock-Aitkin), ADQ (Adaptive Quadrature) or MHRM (Metropolis-Hastings Robbins-Monro).

The keywords controlling the iterative procedure of each estimation method are listed below. For a further discussion, the reader is referred to Chapter 11.

12.2.4.1 BAEM

```
Estimation:

Method = BAEM;

E-Step = 500, 1e-005;

SE = S-EM;

M-Step = 500, 1e-009;

Quadrature = 49, 6;

SEM = 0.001;

SS = 1e-005;
```

12.2.4.2 ADQ

```
Estimation:
Method = ADQ;
E-Step = 100, 0.001;
SE = S-EM;
Quadrature = 9, GH;
Adaptation = EAP;
Trust = Fast;
```

12.2.4.3 MHRM

```
Estimation:
Method = MHRM;
Convergence=3, 0.001;
Stage1=200;
Stage2=100;
Stage3=2000;
```

MCsize=10000; Imputation=1; Burnin=10; Thinning=0; GainConst=0.1; Alpha=1; Epsilon=1; Sampler=Spherical; ProposalSD=1; CovMethod=Accumulation;

12.2.5 Save: command

The structure of the **Save:** command is as follows.

Save:

<List of files to be saved with .txt extension>

Each name in the selected list must be followed by a comma, except the last one. Valid names are:

- PRM (Item parameter estimates **-prm.txt**)
- COV (Asymptotic covariance matrix of the parameter estimates **-cov.txt**)
- INF (Information values, unidimensional models only **-inf.txt**)
- POL (Inter item polychoric correlations, unidimensional models only **-pol.txt**)
- FAC (Factor loadings -fac.txt)
- IRT (Main output in ASCII text format -irt.txt, -sss.txt and -ssc.txt)
- DBG (Debugging output -dbg.txt)

12.2.6 Miscellaneous: command

Keywords contained in this paragraph are :

Decimal = <Number of decimal places>; Processor = <Number of processors>;

Print <List of Additional results in addition to the standard output>;

A further description of the function of these keywords follows.

<Number of decimal places>; Can be a value of 2, 3 or 4 and controls the number of decimals to be written to the output file.

<Number of processors>; The number of processors requested for an analysis. If syntax is generated by the GUI, the default is the total number of processors available on a computer.

<List of Additional results>;

Each item in the list is followed by a comma, except for the last one. Available values are:

- StdRes (Print table of standardized residuals)
- CTLD (Compute Chen-Thissen LD and item fit statistics)
- M2 (Compute limited-information overall model fit statistics)
- GOF (Print each item's goodness of fit frequency table)
- Loadings (Print factor loadings)
- P-Nums (Print parameter numbers)

• Diagnostic (Print diagnostic information)

Note that if the printout of each item's goodness of fit frequency table (GOF) is requested, the keyword

Min Exp = <value>;

follows the **Print** ist>; statement, where <value> denotes the minimum expected frequency to be used when a frequency table is computed.

12.2.7 Groups: command

This paragraph is usually empty for a single group analysis, but for a multiple group analysis it has the form

Groups:

Variable = <variable) that defines the groups>;

Example: Variable = Language;

In the case of an exploratory factor analysis (EFA), this paragraph has the form

Groups:

Variable = <variable that defines the groups>; (multiple groups only) **EFA** = <Rotation Method>; (See Section 12.4.3)

12.2.8 Groups Gn: command

For a single group analysis, the command becomes **Groups**: and this statement appears only once in an analysis. For a multiple group analysis this command is followed by the keyword **Value** = (n) where n refers to the actual value assigned to a grouping variable.

The keywords **Dimension** =, **Items** =, Codes and **Model** (when the analysis mode is **Traditional** the **Model** keyword is not used) follows next and is repeated for each groups as shown below:

```
Group G1:
Value = (1);
Dimension = 1;
Items = item1, item2, item3, item4; (List of items selected)
Codes (item1, item2, item3, item4) = 0(0), 1(1); (Data values followed by scores shown in
parenthesis for a given subset of items)
Model(item1, item2, item3, item4) = 2PL; (Name of model selected for a given subset of items)
Referenced;
Mean = 0.0;
Covariance = 1.0;
```

```
Group G2:

Value = (2);

Dimension = 1;

Items = item1, item2, item3, item4;

Codes(item1, item2, item3, item4) = 0(0), 1(1);

Model(item1, item2, item3, item4) = 2PL;

Mean = free;

Covariance = free;

Group G3:

Value = (3);

:

:
```

For the reference group the keyword **Referenced**; appears just below the **Model** keyword, followed by fixed values for the **Mean(s) and Covariance(s)**. Typically the **Mean(s) and Covariance(s)** are set free in the remaining groups.

12.2.9 Remarks

The number of categories may vary from item to item. Therefore there can be several lines starting with the keyword **Codes**. Likewise, different models may be fitted to items and therefore there can be several lines starting with the keyword **Model**. The following example serves as illustration:

```
Codes(Item1) = 1(0), 2(1), 3(2), 4(2);
Codes(Item2, Item3) = 0(1), 1(0);
Codes(Item4) = 0(0), 1(1), 2(2);
```

Models(Item1) = Nominal; Models(Item2, Item3) = 2PL; Models(Item4) = Graded;

From the above, we note that the third and fourth categories of Item1 have been combined. Note also that the smallest score value is always 0, but does not have to be the first in the list. For example, Item2 and Item3 are recoded so that a "0" in the data set is assigned a score of "1" and a "1" in the data set is assigned a score of "0".

12.3 Traditional summed-scored statistics

Below we show a typical syntax file for a traditional summed-scored statistics analysis. The main difference between this syntax and the syntax for the remaining analysis modes is that in this case, there are no **Models** keywords and no **Constraints:** command.

```
Project:
  Name = Anxiety14itemsV7;
Data:
  File = .\Anxiety14itemsV7.ssig;
Analysis:
  Name = Test1;
  Mode = Traditional:
Title:
Six anxiety items selected from the file Anxiety14itemsV7.ssig
Comments:
To illustrate the computation of traditional statistics
Estimation:
  Method = BAEM;
  E-Step = 500, 1e-005;
  SE = S-EM:
  M-Step = 50, 1e-006;
  Quadrature = 49, 6;
  SEM = 0.001:
  SS = 1e-005;
Miscellaneous:
  Decimal = 2:
  Processors = 4;
  Print CTLD, P-Nums, Diagnostic;
  Min Exp = 1;
Groups:
Group:
  Dimension = 1;
  Items = Calm, Tense, Regretful, AtEase, Anxious, Nervous;
  Codes(Calm) = 1(0), 2(1), 3(2), 4(3), 5(4);
  Codes(Tense) = 1(0), 2(1), 3(2), 4(3), 5(4);
  Codes(Regretful) = 1(0), 2(1), 3(2), 4(3), 5(4);
  Codes(AtEase) = 1(0), 2(1), 3(2), 4(3), 5(4);
  Codes(Anxious) = 1(0), 2(1), 3(2), 4(3), 5(4);
  Codes(Nervous) = 1(0), 2(1), 3(2), 4(3), 5(4);
  Mean = 0.0;
  Covariance = 1.0;
```

12.4 Calibration

Calibration entails estimating parameters and standard errors for a wide range of IRT models. Although the general form of a syntax file contains many common features as pointed out in Section 12.2, there are keywords that are uniquely associated with the specific type of analysis selected. These aspects are discussed in more detail in Sections 12.4.1 to 12.4.3.

12.4.1 Unidimensional IRT

A typical syntax file for a multiple group unidimensional IRT analysis is shown below. Note that a multiple group analysis usually contains a **Constraints**: paragraph to ensure that the model fitted to the data is estimable. In the syntax file shown, corresponding item parameters are constrained to be equal across groups, but the elements of the mean (vector) and covariance (matrix) are set free in the groups that do not serve as the reference group. In this case, it is the mean and covariance of the second group that are set free.

Project: Name = PISAMathBook1USUK; Data: File = .\PISAMathBook1USUK.ssig; Analysis: Name = IRT; **Mode** = Calibration; Title: 2-group IRT Analysis (GPC model for polytomous items) Comments: Mixture of 2PL and General Partial Credit Models Estimation: Method = BAEM: E-Step = 500, 1e-005;SE = S-EM;M-Step = 50, 1e-006;Quadrature = 49, 6;SEM = 0.001; SS = 1e-005: Miscellaneous: Decimal = 2;Processors = 2: Print CTLD, P-Nums, Diagnostic; Min Exp = 1; Groups: Variable = Country; Group G1: Value = (1); Dimension = 1;Items = Cube1, Cube3, Cube4, Farms1, Farms4, Walking1, Walking3, Apples1, Apples2, Apples3, Continent, Grow1, Grow3, Grow2; Codes(Cube1, Cube3, Cube4, Farms1, Farms4, Walking1) = 0(0), 1(1); Codes(Walking3) = 0(0), 1(1), 2(2), 3(3);Codes(Apples1, Apples2) = 0(0), 1(1);Codes(Apples3, Continent) = 0(0), 1(1), 2(2); Codes(Grow1, Grow3) = 0(0), 1(1);Codes(Grow 2) = 0(0), 1(1), 2(2);Model(Cube1, Cube3, Cube4, Farms1, Farms4, Walking1) = 2PL; Model(Walking3) = GP Credit; GammaMatrix(Walking3) = Trend; Model(Apples1, Apples2) = 2PL: Model(Apples3, Continent) = GP Credit; GammaMatrix(Apples3 Continent) = Trend; Model(Grow1, Grow3) = 2PL; Model(Grow2) = GP Credit; GammaMatrix(Grow2) = Trend; Referenced: Mean = 0.0;Covariance = 1.0;Group G2: Value = (2); Dimension = 1: Items = Cube1, Cube3, Cube4, Farms1, Farms4, Walking1, Walking3, Apples1, Apples2, Apples3, Continent, Grow1, Grow3, Grow2; Codes(Cube1, Cube3, Cube4, Farms1, Farms4, Walking1) = 0(0), 1(1); Codes(Walking3) = 0(0), 1(1), 2(2), 3(3);
```
Codes(Apples1, Apples2) = 0(0), 1(1);
  Codes(Apples3, Continent) = 0(0), 1(1), 2(2);
  Codes(Grow1, Grow3) = 0(0), 1(1);
  Codes(Grow 2) = 0(0), 1(1), 2(2);
  Model(Cube1, Cube3, Cube4, Farms1, Farms4, Walking1) = 2PL;
  Model(Walking3) = GP Credit;
  GammaMatrix(Walking3) = Trend;
  Model(Apples1, Apples2) = 2PL;
  Model(Apples3, Continent) = GP Credit:
  GammaMatrix(Apples3 Continent) = Trend;
  Model(Grow1, Grow3) = 2PL;
  Model(Grow2) = GP Credit:
  GammaMatrix(Grow2) = Trend;
  Mean = Free;
  Covariance = Free:
Constraints:
  Equal = (G1, Cube1, Slope[0]), (G2, Cube1, Slope[0]);
  Equal = (G1, Cube1, Intercept[0]), (G2, Cube1, Intercept[0]);
  Equal = (G1, Cube3, Slope[0]), (G2, Cube3, Slope[0]);
  Equal = (G1, Cube3, Intercept[0]), (G2, Cube3, Intercept[0]);
  Equal = (G1, Cube4, Slope[0]), (G2, Cube4, Slope[0]);
  Equal = (G1, Cube4, Intercept[0]), (G2, Cube4, Intercept[0]);
  Equal = (G1, Farms1, Slope[0]), (G2, Farms1, Slope[0]);
  Equal = (G1, Farms1, Intercept[0]), (G2, Farms1, Intercept[0]);
  Equal = (G1, Farms4, Slope[0]), (G2, Farms4, Slope[0]);
  Equal = (G1, Farms4, Intercept[0]), (G2, Farms4, Intercept[0]);
  Equal = (G1, Walking1, Slope[0]), (G2, Walking1, Slope[0]);
  Equal = (G1, Walking1, Intercept[0]), (G2, Walking1, Intercept[0]);
  Equal = (G1, Walking3, Slope[0]), (G2, Walking3, Slope[0]);
  Equal = (G1, Walking3, Alpha[0]), (G2, Walking3, Alpha[0]);
  Equal = (G1, Walking3, Alpha[1]), (G2, Walking3, Alpha[1]);
  Equal = (G1, Walking3, Alpha[2]), (G2, Walking3, Alpha[2]);
  Equal = (G1, Walking3, Gamma[0]), (G2, Walking3, Gamma[0]);
  Equal = (G1, Walking3, Gamma[1]), (G2, Walking3, Gamma[1]);
  Equal = (G1, Walking3, Gamma[2]), (G2, Walking3, Gamma[2]);
  Equal = (G1, Apples1, Slope[0]), (G2, Apples1, Slope[0]);
  Equal = (G1, Apples1, Intercept[0]), (G2, Apples1, Intercept[0]);
  Equal = (G1, Apples2, Slope[0]), (G2, Apples2, Slope[0]);
  Equal = (G1, Apples2, Intercept[0]), (G2, Apples2, Intercept[0]);
  Equal = (G1, Apples3, Slope[0]), (G2, Apples3, Slope[0]);
  Equal = (G1, Apples3, Alpha[0]), (G2, Apples3, Alpha[0]);
  Equal = (G1, Apples3, Alpha[1]), (G2, Apples3, Alpha[1]);
  Equal = (G1, Apples3, Gamma[0]), (G2, Apples3, Gamma[0]);
  Equal = (G1, Apples3, Gamma[1]), (G2, Apples3, Gamma[1]);
  Equal = (G1, Continent, Slope[0]), (G2, Continent, Slope[0]);
  Equal = (G1, Continent, Alpha[0]), (G2, Continent, Alpha[0]);
  Equal = (G1, Continent, Alpha[1]), (G2, Continent, Alpha[1]);
  Equal = (G1, Continent, Gamma[0]), (G2, Continent, Gamma[0]);
  Equal = (G1, Continent, Gamma[1]), (G2, Continent, Gamma[1]);
  Equal = (G1, Grow1, Slope[0]), (G2, Grow1, Slope[0]);
  Equal = (G1, Grow1, Intercept[0]), (G2, Grow1, Intercept[0]);
  Equal = (G1, Grow3, Slope[0]), (G2, Grow3, Slope[0]);
  Equal = (G1, Grow3, Intercept[0]), (G2, Grow3, Intercept[0]);
  Equal = (G1, Grow2, Slope[0]), (G2, Grow2, Slope[0]);
  Equal = (G1, Grow2, Alpha[0]), (G2, Grow2, Alpha[0]);
  Equal = (G1, Grow2, Alpha[1]), (G2, Grow2, Alpha[1]);
  Equal = (G1, Grow2, Gamma[0]), (G2, Grow2, Gamma[0]);
  Equal = (G1, Grow2, Gamma[1]), (G2, Grow2, Gamma[1]);
```

12.4.1.1 The constraints: command

In the syntax file listed above, a set of **Equal** = (), (); keywords follow the **constraints**: command, each having the following structure.

Equal = (G1, Item Name, Parameter), (G2, Item Name, Parameter);

Note that the for all 2PL models there are two parameters; the slope (a1) and the intercept (c = Intercept[0]). For a two-dimensional model the slope parameters are denoted as a1 (Slope[0]) and a2 (Slope[1]). Consider, in this case, the statement:

Equal = (G1, Cube1, Intercept[0]), (G2, Cube1, Intercept[0]);

This statement instructs IRTPRO to set the c parameter of Cube1 in the first group equal to the c parameter of Cube1 in the second group.

12.4.2 DIF (Differential item functioning)

A typical syntax file for a DIF analysis is shown below. Note that a DIF analysis should always contain a **DIF <type>**; command where <type> equals one of the words Anchor, Random or All. This command should be inserted just before the **Constraints**: command. In the syntax file shown, the syntax for each type of DIF analysis is shown in red. Note that in an analysis (test) only one type can be specified at a time.

```
Project:
  Name = Spelling;
Data:
  File = .\Spelling.ssig;
Analysis:
  Name = Anchored;
  Mode = Calibration;
Title:
Spelling DIF
Comments:
Anchor items 1-2-3 candidate 4, 2PL
Estimation:
  Method = BAEM;
  E-Step = 500, 1e-005;
  SE = S-EM;
  M-Step = 50, 1e-009;
  Quadrature = 49, 6;
  SEM = 0.001;
  SS = 1e-005;
Save:
  PRM, COV
Miscellaneous:
  Decimal = 2:
  Processor = 1:
  Print GOF, P-Nums;
  Min Exp = 1;
```

Groups: Variable = Gender: Group G1: Value = (1); Dimension = 1;Items = Infidelity, Panoramic, Succumb, Girder; Codes(Infidelity, Panoramic, Succumb, Girder) = 0(0), 1(1); Model(Infidelity, Panoramic, Succumb, Girder) = 2PL; Referenced: Mean = 0.0: Covariance = 1.0; Group G2: Value = (2); Dimension = 1;Items = Infidelity, Panoramic, Succumb, Girder; Codes(Infidelity, Panoramic, Succumb, Girder) = 0(0), 1(1); Model(Infidelity, Panoramic, Succumb, Girder) = 2PL; Model(Panoramic) = 2PL; Model(Succumb) = 2PL; Model(Girder) = 2PL;Mean = Free: Covariance = Free: **DIF Anchor:** Candidate = Girder; Anchors = Infidelity, Panoramic, Succumb; Constraints: Equal = (G1, Infidelity, Slope[0]), (G2, Infidelity, Slope[0]); Equal = (G1, Infidelity, Intercept[0]), (G2, Infidelity, Intercept[0]); Equal = (G1, Panoramic, Slope[0]), (G2, Panoramic, Slope[0]); Equal = (G1, Panoramic, Intercept[0]), (G2, Panoramic, Intercept[0]); Equal = (G1, Succumb, Slope[0]), (G2, Succumb, Slope[0]); Equal = (G1, Succumb, Intercept[0]), (G2, Succumb, Intercept[0]);

The example above is for DIF analysis with a specified set of anchor items. Alternatively, the DIF paragraph could be either a randomized group analysis, or, for the two-stage analysis in which all items are examined for DIF, conditional on between–group differences estimated with all item parameters constrained equal across groups.

DIF Random: Candidate = Girder; Anchors = Infidelity, Panoramic, Succumb; Constraints: DIF AII: Constraints:

All items are constrained equal to the corresponding parameters in each group in the GUI– generated syntax file, and in the first stage of the two–stage DIF analysis, to estimate the mean and variance of the focal group(s).

12.4.2.1 The DIF <type>: command

IRTPRO distinguishes between three types of DIF (see Chapter 1 for details):

DIF Anchor:

Candidate = <List of candidate items names>; (Separate the names with a comma) **Anchors** = <List of anchor items>; (Separate the names with a comma)

```
DIF Random:
```

Candidate = <List of candidate items>; **Anchors** = <List of anchor items>;

DIF All:

(No keywords in this paragraph)

When selecting the DIF option, the GUI automatically generates the required equality constraints listed above.

12.4.3 Multidimensional (EFA, BIFAC and CFA)

In the multidimensional case, there are three modeling methods available in IRTPRO; these being exploratory factor analysis (EFA), bifactor analysis (BIFAC) and confirmatory factor analysis (CFA). Additional keywords, to be inserted in the general syntax framework, are uniquely associated with the specific type of analysis method selected. These keywords are printed in red in what follows.

12.4.3.1 Exploratory Factor Analysis (EFA), single group analysis

When either an EFA or BIFAC analysis is requested, the **Constraints**: command is not used. However, the keyword **EFA** = <Rotation Method>; must be inserted in the **Groups**: paragraph.

```
Groups:

EFA = <Rotation Method>;

Group:

Dimension = n; (n = 2, 3, 4 ...)

(Additional keywords not shown)
```

There are four rotation methods available in IRTPRO:

- EFA = ObDQ; (Oblique CF Quartimax)
- EFA = OrV; (Orthogonal CF Varimax)
- EFA = OrDQ; (Orthogonal CF Quartimax)
- EFA = ObV; (Oblique CF Varimax)

12.4.3.2 Exploratory Factor Analysis (EFA), multiple group analysis

```
Groups:
Variable = Country;
EFA = <Rotation Method>;
Group G1:
Value = (1);
Dimension = n;
```

12.4.3.3 Bifactor Analysis (BIFAC)

As noted previously, when either an EFA or BIFAC analysis is requested, the **Constraints:** command is not used. However, in the case of a bifactor analysis the keyword **GenDim = 1**; must be inserted in the **Groups:** paragraph. See Section 7.4 for an example where **GenDim = 2**; is used. A syntax file for doing a bifactor analysis (See Section 7.2) is shown below. Keywords that are unique to a

bifactor analysis are printed in a bold red typeface.

```
Project:
  Name = QofLife;
Data:
  File = .\QofLife.ssig;
Analysis:
  Name = BiFAC;
  Mode = Calibration;
Title:
Bifactor analysis of the quality of life data (35 items)
Comments:
One general factor and seven specific factors
Estimation:
  Method = BAEM;
  E-Step = 500, 0.001;
  SE = Xpd;
  M-Step = 50, 0.001;
  Quadrature = 36, 6;
  SEM = 0.001:
  SS = 1e-005;
Miscellaneous:
  Decimal = 2:
  Processors = 4;
  Print CTLD, P-Nums;
Groups:
Group:
  Dimension = 8;
  GenDim = 1;
  Items = Item1, Item2, Item3, Item4, Item5, Item6, Item7, Item8, Item9, Item10, Item11, Item12, Item13,
  Item14, Item15, Item16, Item17, Item18, Item19, Item20, Item21, Item22, Item23, Item24, Item25,
  Item26, Item27, Item28, Item29, Item30, Item31, Item32, Item33, Item34, Item35;
  Codes(Item1, Item2, Item3, Item4, Item5, Item6, Item7, Item8, Item9, Item10, Item11, Item12, Item13,
  Item14, Item15, Item16, Item17, Item18, Item19, Item20, Item21, Item22, Item23, Item24, Item25,
  Item26, Item27, Item28, Item29, Item30, Item31, Item32, Item33, Item34, Item35) = 0(0), 1(1), 2(2), 3(3),
  4(4), 5(5), 6(6);
  Model(Item1, Item2, Item3, Item4, Item5, Item6, Item7, Item8, Item9, Item10, Item11, Item12, Item13,
  Item14, Item15, Item16, Item17, Item18, Item19, Item20, Item21, Item22, Item23, Item24, Item25,
  Item26, Item27, Item28, Item29, Item30, Item31, Item32, Item33, Item34, Item35) = Graded;
  BFA(Item2, Item3, Item4, Item5) = 2;
  BFA(Item6, Item7, Item8, Item9) = 3;
  BFA(Item10, Item11, Item12, Item13, Item14, Item15) = 4;
  BFA(Item16, Item17, Item18, Item19, Item20, Item21) = 5:
  BFA(Item22, Item23, Item24, Item25, Item26) = 6;
  BFA(Item27, Item28, Item29, Item30, Item31) = 7;
  BFA(Item32, Item33, Item34, Item35) = 8;
```

As shown above, the last part of the **Groups**: paragraph contains one or more lines of the form:

BFA(list of item names) = <number of the associated group factor>;

Note that some items may be associated only with the general factor. In this example, Item1 is not included with any of the group factors. It is also important to note that the items included as group factors must form mutually exclusive sets.

12.4.3.4 Confirmatory Factor Analysis (CFA or IRT)

A syntax file for doing a confirmatory factor analysis (See Chapter 7) is shown below. Key to doing a CFA is the use of the **Constraints:** command to set parameters equal to zero. This part of the **Constraints:** paragraph is printed in red typeface. Note that for a CFA, one can additionally impose equality constraints (**Equal =**). This is typically required when doing a multiple group CFA.

```
Project:
  Name = AACL3 21Items;
Data:
  File = .\AACL3_21Items.ssig;
Analysis:
  Name = 2d-CFA;
  Mode = Calibration;
Title:
AACL dataset, 21 items
Comments:
2-Dimensional simple structure CFA
Estimation:
  Method = BAEM;
  E-Step = 500, 1e-005;
  SE = S-EM;
  M-Step = 50, 1e-006;
  Quadrature = 49, 6;
  SEM = 0.001;
  SS = 1e-005;
Scoring:
  Mean = 0;
  SD = 1:
Miscellaneous:
  Decimal = 2;
  Processors = 2:
  Print CTLD, Loadings, P-Nums, Diagnostic;
  Min Exp = 1;
Groups:
Group:
  Dimension = 2;
  Items = Afraid, Desperate, Fearful, Frightened, Nervous, Panicky, Shaky, Tense, Terrified, Upset,
Worrying, Calm, Cheerful, Contented, Happy, Joyful, Loving, Pleasant, Secure, Steady, Thoughtful;
  Codes(Afraid, Desperate, Fearful, Frightened, Nervous, Panicky, Shaky, Tense, Terrified, Upset,
Worrying, Calm, Cheerful, Contented, Happy, Joyful, Loving, Pleasant, Secure, Steady, Thoughtful) = 1(1),
2(0);
  Model(Afraid, Desperate, Fearful, Frightened, Nervous, Panicky, Shaky, Tense, Terrified, Upset,
Worrying, Calm, Cheerful, Contented, Happy, Joyful, Loving, Pleasant, Secure, Steady, Thoughtful) = 2PL;
  Means = 0.0, 0.0;
  Covariances = 1.0,
```

Free, 1.0;

Constraints:

```
(Afraid, Slope[1]) = 0.0;
(Desperate, Slope[1]) = 0.0;
(Fearful, Slope[1]) = 0.0;
(Frightened, Slope[1]) = 0.0;
(Nervous, Slope[1]) = 0.0;
(Panicky, Slope[1]) = 0.0;
(Shaky, Slope[1]) = 0.0;
(Tense, Slope[1]) = 0.0:
(Terrified, Slope[1]) = 0.0;
(Upset, Slope[1]) = 0.0;
(Worrying, Slope[1]) = 0.0;
(Calm, Slope[0]) = 0.0;
(Cheerful, Slope[0]) = 0.0;
(Contented, Slope[0]) = 0.0;
(Happy, Slope[0]) = 0.0;
(Joyful, Slope[0]) = 0.0;
(Loving, Slope[0]) = 0.0;
(Pleasant, Slope[0]) = 0.0;
(Secure, Slope[0]) = 0.0;
(Steady, Slope[0]) = 0.0;
(Thoughtful, Slope[0]) = 0.0;
```

12.5 Scoring

A syntax file for scoring (See Chapter 8) is shown below. This syntax file contains the **Scoring**: command which follows the **Estimation**: paragraph. Key to an item scoring analysis is the use of the **Constraints**: command to assign values (obtained from a previous calibration) to the model parameters. This part of the **Constraints**: paragraph is printed in red.

```
Project:
  Name = SLF;
Data:
  File = .\SLF.ssig;
Analysis:
  Name = SSEAP:
  Mode = Scoring;
Title:
Social Life Feelings
Comments:
Summed score EAP
Estimation:
  Method = BAEM;
  E-Step = 500, 1e-005;
  SE = S-EM;
  M-Step = 50, 1e-006;
  Quadrature = 49, 6;
  SEM = 0.001;
  SS = 1e-005;
Scoring:
  Create SS to SC table;
  Score Persons:
  Mean = 0:
  SD = 1;
```

Miscellaneous: Decimal = 2;Processor = 1; Print CTLD, P-Nums, Diagnostic; Min Exp = 1; Groups: Group: Dimension = 1: Items = SLF1, SLF2, SLF3, SLF4, SLF5; Codes(SLF1, SLF2, SLF3, SLF4, SLF5) = 0(0), 1(1); Model(SLF1, SLF2, SLF3, SLF4, SLF5) = 2PL; **Constraints**: (SLF1, Slope[0]) = 1.19684;(SLF1, Intercept[0]) = -2.35356;(SLF2, Slope[0]) = 0.71455; (SLF2, Intercept[0]) = 0.79647;(SLF3, Slope[0]) = 1.53051;(SLF3, Intercept[0]) = 0.99190; (SLF4, Slope[0]) = 2.54698;(SLF4, Intercept[0]) = -0.66874;(SLF5, Slope[0]) = 0.92269;(SLF5, Intercept[0]) = -1.09696;

12.5.1 Scoring: command

The Scoring: paragraph contains a number of optional keywords and has the following structure:

Scoring:

ID = <Variable name>; (*Optional*)

Followed by one of the following scoring methods

- **Create** SS to SC table;
- **Pattern = EAP**;
- **Pattern = MAP;**

13. References

Adams, R. & Wu, M. (2002). PISA 2000 Technical Report. Paris: OECD.

Akaike, Hirotugu (1974). A new look at the statistical model identification. *IEEE Transactions on Automatic Control*, **19**, 716–723.

Baker, F.B. & Kim, S. H. (2004). *Item response theory: Parameter estimation techniques*. New York, NY: Marcel Dekker, Inc.

Birnbaum, A. (1968). Some latent trait models and their use in inferring an examinee's ability. In F.M. Lord & M.R. Novick, *Statistical theories of mental test scores* (pp. 392-479). Reading, MA: Addison-Wesley.

Bock, R. D. (1972). Estimating item parameters and latent ability when responses are scored in two or more nominal categories. *Psychometrika*, **37**, 29-51.

Bock, R.D. (1997). The nominal categories model. In W. van der Linden & R.K. Hambleton (Eds.), *Handbook of modern item response theory* (pp. 33-50). N.Y.: Springer.

Bock, R.D., & Aitkin, M. (1981). Marginal maximum likelihood estimation of item parameters: an application of the EM algorithm. *Psychometrika*, **46**, 443-459.

Bock, R.D. & Lieberman, M. (1970). Fitting a response model for *n* dichotomously scored items. *Psychometrika*, **35**, 179-197.

Bock, R. D. & Mislevy, R. J. (1982). Adaptive EAP estimation of ability in a microcomputer environment. *Applied Psychological Measurement*, **6**, 431-444.

Cai, L. (2008). SEM of another flavour: Two new applications of the supplemented EM algorithm. *British Journal of Mathematical and Statistical Psychology*, **61**, 309-329.

Cai, L. (2010-a). A two-tier full-information item factor analysis model with applications. Psychometrika, **75**, 581-612.

Cai, L. (2010-b). High-dimensional exploratory item factor analysis by a Metropolis-Hastings Robbins-Monro algorithm. *Psychometrika*, **75**, 33-57.

Cai, L. (2010-c). Metropolis-Hastings Robbins-Monro Algorithm for Confirmatory Item Factor Analysis. *Journal of Educational and Behavioral Statistics*, **35**, 307-335.

Cai, L., Yang, J. S. & Hansen, M. (in press). Generalized full-information item bifactor analysis. *Psychological Methods*.

Cai, L., Maydeu-Olivares, A., Coffman, D.L., & Thissen, D. (2006). Limited information goodness-of-fit testing of item response theory models for sparse 2^p tables. *British Journal of Mathematical and Statistical Psychology*, **59**, 173-194.

Chen, W.-H., & Thissen, D. (1997). Local dependence indices for item pairs using item response theory. *Journal of Educational and Behavioral Statistics*, **22**, 265-289.

du Toit, M. (2003). IRT from SSI. Lincolnwood, IL: Scientific Software International.

Eysenck, H.J. & Eysenck, S.B.G. (1969). *Personality Structure and Measurement*. London: Routledge.

Gibbons, R.D., Bock, R.D., Hedeker, D., Weiss, D.J., Segawa, E., Bhaumik, D.K., Kupfer, D.J., Frank, E., Grochocinski, V.J., & Stover, A. (2007). Full-information item bifactor analysis of graded response data. *Applied Psychological Measurement*, **31**, 4-19.

Gibbons, R. D., & Hedeker, D. (1992). Full-information item bi-factor analysis. *Psychometrika*, **57**, 423-436.

Hambleton, R.K. & Swaminathan, H. (1985). Item Response Theory. Principles and applications. Boston: Kluwer.

Krebs, D. & Schuessler, K.F. (1987). Soziale Empfindunge: ein interkultureller Skalenvergleich bei *Deutschen und Amerikanern*. Monographien: *Sozialwissenschaftliche Methoden*, Frankfurt/Main, New York: Campus Verlag.

Lehman, A. F. (1988). A quality of life interview for the chronically mentally ill. *Evaluation and Program Planning*, **11**, 51–62.

Lord, F. M. (1977). A broad-range tailored test of verbal ability. *Applied Psychological Measurement*, **1**, 95-100.

Lord, F.M. (1980). Applications of item response theory to practical testing problems. Hillsdale, NJ: Erlbaum.

Maydeu-Olivares, A., & Joe, H. (2005). Limited and full information estimation and testing in 2^n contingency tables: A unified framework. *Journal of the American Statistical Association*, **100**, 1009–1020.

Maydeu-Olivares, A. & Joe, H. (2006). Limited information goodness-of-fit testing in multidimensional contingency tables. *Psychometrika*, **71**, 713-732.

Mislevy, R. (1984). Estimating latent distributions. *Psychometrika*, **49**, 359-381.

Mislevy, RJ. (1985). Estimation of latent group effects. *Journal of the American Statistical Association*, **80**, 993-997.

Muraki, E. (1992). A generalized partial credit model: Application of an EM algorithm. *Applied Psychological Measurement*, **16**, 159-176.

Muraki, E. (1997). A generalized partial credit model. In W. van der Linden & R. K. Hambleton (Eds.), *Handbook of modern item response theory* (pp. 153-164). NewYork: Springer.

Orlando, M., & Thissen, D. (2000). Likelihood-based item fit indices for dichotomous item response theory models. *Applied Psychological Measurement*, **24**, 50-64.

Orlando, M. & Thissen, D. (2003). Further investigation of the performance of $S-X^2$: An item fit index for use with dichotomous item response theory models. *Applied Psychological Measurement*, **27**, 289-298.

Revelle, W., Humphreys, M.S., Simon, L. & Gilliland, K. (1980). The Interactive Effect of Personality, Time of day, and Caffeine: A Test of the Arousal Model. *Journal of Experimental Psychology: General*, **109**, 1-31.

Samejima, F. (1969). Estimation of latent ability using a response pattern of graded scores. *Psychometric Monograph*, No. 17, **34**, Part 2.

Samejima, F. (1997). Graded response model. In W. van der Linden & R.K. Hambleton (Eds.), *Handbook of modern item response theory* (pp. 85-100). N.Y.: Springer.

Schilling, S., & Bock, R. D. (2005). High-dimensional maximum marginal likelihood item factor analysis by adaptive quadrature. *Psychometrika*, **70**, 533–555.

Schuessler, K.F. (1982). *Measuring Social Life Feelings*, The Jossey-Bass Social and Behavioral Science Series, Jossey-Bass.

Schwarz, Gideon E. (1978). Estimating the dimension of a model. Annals of Statistics, 6, 461–464.

Snyder, M. (1974). Self-monitoring of expressive behavior. *Journal of Personality and Social Psychology*, **30**, 526-537.

Snyder, M., & Gangestad, S. (1986). On the nature of self-monitoring: Matters of assessment,

matters of validity. Journal of Personality and Social Psychology, 51, 125-139.

Spielberger, C.D. (1983). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.

Stouffer, S.A., Guttman, L., Suchman, E.A., Lazarsfeld, P. F. Star, S. A., & Clausen, J. A. (1950). *Measurement and Prediction*. New York: Wiley.

Thissen, D. (1982). Marginal maximum likelihood estimation for the one-parameter logistic model. *Psychometrika*, **47**, 201-214.

Thissen, D., Cai, L., & Bock, R.D. (2010). The nominal item response model. In M. Nering & R. Ostini (Eds.), *Handbook of polytomous item response theory models: Developments and applications*.

Thissen, D., Nelson, L., Rosa, K., & McLeod, L.D. (2001). Item response theory for items scored in more than two categories. In D. Thissen & H. Wainer (Eds), *Test Scoring* (Pp. 141-186). Mahwah, NJ: Lawrence Erlbaum Associates.

Thissen, D., & Orlando, M. (2001). Item response theory for items scored in two categories. In D. Thissen & H. Wainer (Eds), *Test Scoring* (pp. 73-140). Mahwah, NJ: Lawrence Erlbaum Associates.

Thissen, D. & Steinberg, L. (2009). Item response theory. In R. Millsap & A. Maydeu-Olivares (Eds), *The Sage handbook of quantitative methods in psychology* (pp. 148-177). London: Sage Publications.

Wainer, H. & Kiely, G.L. (1987). Item clusters and computerized adaptive testing: A case for testlets. *Journal of Educational Measurement*, **24**, 185-201.

Zuckerman, M. (1980). The development of an affect adjective check list for the measurement of anxiety. *Journal of Consulting Psychology*, **24**, 457-462.