

Obtaining Diagnostic Classification Model Estimates with Mplus

Syntax and Output Handout

To demonstrate how Diagnostic Classification Models (DCMs) can be estimated using Mplus, input syntax and output are included in this document.

Analysis Data Set:

- ☐ Seven items
- ☐ Three attributes
- ☐ 10,000 respondents

Analysis Q-matrix:

Item	Attribute 1	Attribute 2	Attribute 3
1	1	0	0
2	0	1	0
3	0	0	1
4	1	1	0
5	1	0	1
6	0	1	1
7	1	1	1

To create Mplus syntax, we will follow several steps:

1. Creating a Latent Class-to-Attribute Profile Table
 - ☐ Mplus uses generic latent classes in estimation – we must make these into DCM attribute profiles.
2. Creating an Item-to-Profile Table
 - ☐ Specifies the form of the LCDM for each combination of item and profile. It will be used to build model syntax.
3. Creating Item Response Function Labels
 - ☐ Defines the set of unique item response functions for each item (based on the set of attributes measured by the Q-matrix). Used by Mplus to specify LCDM parameters.
4. Creating the Structural Model
 - ☐ For limiting the number of correlational parameters needed; aids in estimation speed and convergence.
5. Specifying Initial Mplus Syntax
 - ☐ Commands for input and parsing of data files.
6. Building Mplus MODEL Command Syntax
 - ☐ Places labels on all Mplus parameters (thereby enforcing confirmatory model on classes).
7. Building Mplus MODEL CONSTRAINT Command Syntax
 - ☐ Specifies LCDM model parameters.

Creating a Latent Class-to-Attribute Profile Table

Mplus uses latent classes to model categorical data generally. We must represent each possible attribute profiles as a latent class. For DCMs that measure A attributes, a total of 2^A attribute profiles are possible. It is our job to map each profile onto a latent class. To do so, we use the following process. Recall our example data set specifics:

Number of attributes in example: 3

Number of possible attribute profiles: $2^3 = 8$

Number of latent classes needed: 8

First, we need a table that has the number of latent classes represented in the rows and the number of attributes represented in the columns.

The following figure shows how to populate the classes with attribute profiles through a sequence of partitions of the table:

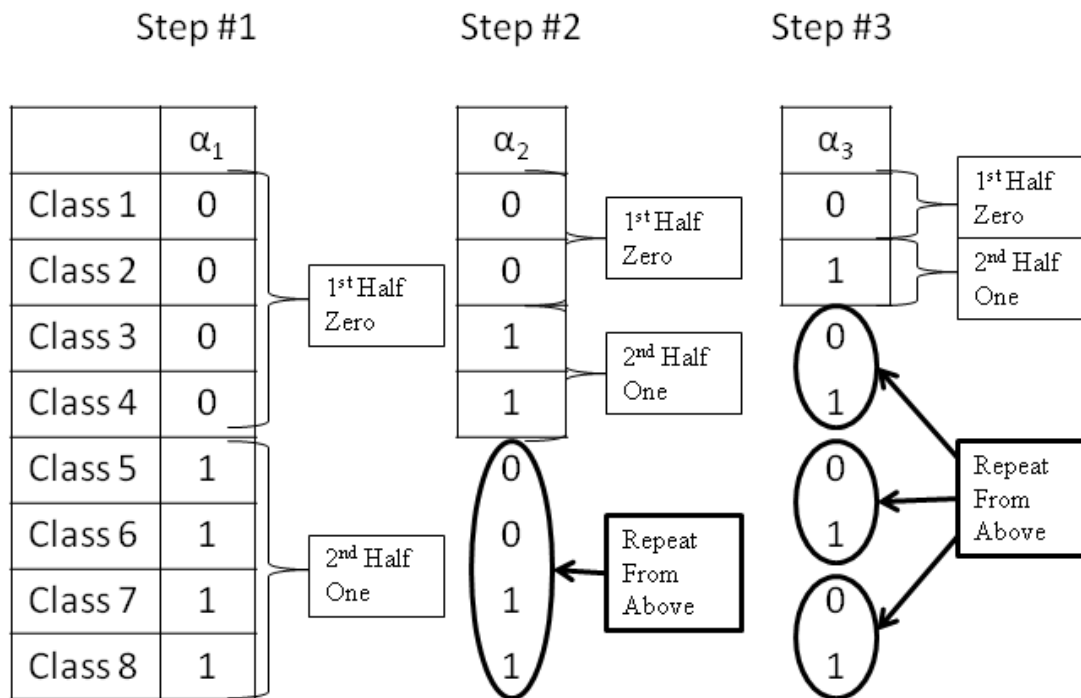


Figure 9.7 from Rupp, Templin, & Henson (2010). Creating a class-to-profile table.

Creating an Item-to-Profile Table

The next step is to develop the LCDM model specification for each combination of items and attribute profiles, the item response function for respondents with a given attribute profile. In DCMs, not all attributes are measured by each item. Therefore, there will be repeated item response functions. This table will help to denote which are redundant and therefore able to be omitted. We will use the Q-matrix to help form what model parameters should be present for each combination of item and attribute profile.

Analysis Q-matrix:

Item	Attribute 1	Attribute 2	Attribute 3
1	1	0	0
2	0	1	0
3	0	0	1
4	1	1	0
5	1	0	1
6	0	1	1
7	1	1	1

Item-to-Profile Table

Class	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈
α_c	[0, 0, 0]	[0, 0, 1]	[0, 1, 0]	[0, 1, 1]	[1, 0, 0]	[1, 0, 1]	[1, 1, 0]	[1, 1, 1]
Item 1	$\lambda_{1,0}$	$\lambda_{1,0}$	$\lambda_{1,0}$	$\lambda_{1,0}$	$\lambda_{1,0} + \lambda_{1,1,(1)}$	$\lambda_{1,0} + \lambda_{1,1,(1)}$	$\lambda_{1,0} + \lambda_{1,1,(1)}$	$\lambda_{1,0} + \lambda_{1,1,(1)}$
Item 2	$\lambda_{2,0}$	$\lambda_{2,0}$	$\lambda_{2,0} + \lambda_{2,1,(2)}$	$\lambda_{2,0} + \lambda_{2,1,(2)}$	$\lambda_{2,0}$	$\lambda_{2,0}$	$\lambda_{2,0} + \lambda_{2,1,(2)}$	$\lambda_{2,0} + \lambda_{2,1,(2)}$
Item 3	$\lambda_{3,0}$	$\lambda_{3,0} + \lambda_{3,1,(3)}$	$\lambda_{3,0}$	$\lambda_{3,0} + \lambda_{3,1,(3)}$	$\lambda_{3,0}$	$\lambda_{3,0} + \lambda_{3,1,(3)}$	$\lambda_{3,0}$	$\lambda_{3,0} + \lambda_{3,1,(3)}$
Item 4	$\lambda_{4,0}$	$\lambda_{4,0}$	$\lambda_{4,0} + \lambda_{4,1,(2)}$	$\lambda_{4,0} + \lambda_{4,1,(2)}$	$\lambda_{4,0} + \lambda_{4,1,(1)}$	$\lambda_{4,0} + \lambda_{4,1,(1)}$	$\lambda_{4,0} + \lambda_{4,1,(1)} + \lambda_{4,1,(2)} + \lambda_{4,2,(1,2)}$	$\lambda_{4,0} + \lambda_{4,1,(1)} + \lambda_{4,1,(2)} + \lambda_{4,2,(1,2)}$
Item 5	$\lambda_{5,0}$	$\lambda_{5,0} + \lambda_{5,1,(3)}$	$\lambda_{5,0}$	$\lambda_{5,0} + \lambda_{5,1,(3)}$	$\lambda_{5,0} + \lambda_{5,1,(1)}$	$\lambda_{5,0} + \lambda_{5,1,(1)} + \lambda_{5,1,(3)} + \lambda_{5,2,(1,3)}$	$\lambda_{5,0} + \lambda_{5,1,(1)}$	$\lambda_{5,0} + \lambda_{5,1,(1)} + \lambda_{5,1,(3)} + \lambda_{5,2,(1,3)}$
Item 6	$\lambda_{6,0}$	$\lambda_{6,0} + \lambda_{6,1,(3)}$	$\lambda_{6,0} + \lambda_{6,1,(2)}$	$\lambda_{6,0} + \lambda_{6,1,(2)} + \lambda_{6,1,(3)} + \lambda_{6,2,(2,3)}$	$\lambda_{6,0}$	$\lambda_{6,0} + \lambda_{6,1,(3)}$	$\lambda_{6,0} + \lambda_{6,1,(2)}$	$\lambda_{6,0} + \lambda_{6,1,(2)} + \lambda_{6,1,(3)} + \lambda_{6,2,(2,3)}$
Item 7	$\lambda_{7,0}$	$\lambda_{7,0} + \lambda_{7,1,(3)}$	$\lambda_{7,0} + \lambda_{7,1,(2)}$	$\lambda_{7,0} + \lambda_{7,1,(2)} + \lambda_{7,1,(3)} + \lambda_{7,2,(2,3)}$	$\lambda_{7,0} + \lambda_{7,1,(1)}$	$\lambda_{7,0} + \lambda_{7,1,(1)} + \lambda_{7,1,(3)} + \lambda_{7,2,(1,3)}$	$\lambda_{7,0} + \lambda_{7,1,(1)} + \lambda_{7,1,(2)} + \lambda_{7,2,(1,2)}$	$\lambda_{7,0} + \lambda_{7,1,(1)} + \lambda_{7,1,(2)} + \lambda_{7,1,(3)} + \lambda_{7,2,(1,2)} + \lambda_{7,2,(1,3)} + \lambda_{7,2,(2,3)} + \lambda_{7,3,(1,2,3)}$

Creating Item Response Function Labels

The next step in the process is to label each unique item response function for each *item* in the Item-to-Profile table. The labeling convention we will use will follow the form of $t[i]_{[#]}$:

- ☐ t represents that label is a threshold (Mplus definition for LCDM item response function)
- ☐ $[i]$ is the item used (omit brackets)
- ☐ $_{[#]}$ is the index for unique item response function for an item.

The labels are created by reading left-to-right for each row of the Item-to-Profile table. The first entry for the first cell of the first item receives the label $t1_1$, as do all other entries that are the same. The next unique entry receives the label $t1_2$, as do all other entries that look the same. The process continues until all labels have been assigned.

Item Response Function Labels

	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈
α_c	[0,0,0]	[0,0,1]	[0,1,0]	[0,1,1]	[1,0,0]	[1,0,1]	[1,1,0]	[1,1,1]
Item 1	t1_1	t1_1	t1_1	t1_1	t1_2	t1_2	t1_2	t1_2
Item 2	t2_1	t2_1	t2_2	t2_2	t2_1	t2_1	t2_2	t2_2
Item 3	t3_1	t3_2	t3_1	t3_2	t3_1	t3_2	t3_1	t3_2
Item 4	t4_1	t4_1	t4_2	t4_2	t4_3	t4_3	t4_4	t4_4
Item 5	t5_1	t5_2	t5_1	t5_2	t5_3	t5_4	t5_3	t5_4
Item 6	t6_1	t6_2	t6_3	t6_4	t6_1	t6_2	t6_3	t6_4
Item 7	t7_1	t7_2	t7_3	t7_4	t7_5	t7_6	t7_7	t7_8

Creating the Structural Model [Optional]

The next step is to define the structural model – the model that produces estimates of the probability any respondent has a given attribute profile. The structural model is how attribute association (i.e., correlation) is modeled in DCMs.

This step is optional as Mplus will fit a saturated model if none is specified. Specification of the structural model, however, will improve estimation speed and convergence. Mplus uses a log-linear model for the structural component, meaning the model itself will look like a linear model with intercepts, main effects, and interactions. These terms are all specific to attributes and not to the interaction of attributes to produce item responses.

By definition (and for identification), Mplus sets the value of the last class to zero, causing a few inconveniences in syntax building. The table below shows the label for each structural model parameter along with the actual modeling term used. Note that the first row is a new parameter created to be the intercept (defined because the last term is fixed at zero).

Note: a reasonable approach to a structural model would be to have all main effects and two-way interactions, allowing all attributes to be correlated.

Structural Model Specification Table

Class	Attribute Profile	Mplus Label	Saturated Log-linear Model
-	-	g0 (Intercept)	$\gamma_0 - (\gamma_{1,(1)} + \gamma_{1,(2)} + \gamma_{2,(1,2)} + \gamma_{1,(1)} + \gamma_{1,(2)} + \gamma_{1,(3)} + \gamma_{2,(1,2)} + \gamma_{2,(1,3)} + \gamma_{2,(2,3)} + \gamma_{3,(1,2,3)})$
1	$\alpha_1 = [0,0,0]$	m1	$\gamma_1 + \gamma_0$
2	$\alpha_2 = [0,0,1]$	m2	$\gamma_2 + \gamma_0 + \gamma_{1,(3)}$
3	$\alpha_3 = [0,1,0]$	m3	$\gamma_3 + \gamma_0 + \gamma_{1,(2)}$
4	$\alpha_4 = [0,1,1]$	m4	$\gamma_4 + \gamma_0 + \gamma_{1,(2)} + \gamma_{1,(3)} + \gamma_{2,(2,3)}$
5	$\alpha_5 = [1,0,0]$	m5	$\gamma_5 + \gamma_0 + \gamma_{1,(1)}$
6	$\alpha_6 = [1,0,1]$	m6	$\gamma_6 + \gamma_0 + \gamma_{1,(1)} + \gamma_{1,(3)} + \gamma_{2,(1,3)}$
7	$\alpha_7 = [1,1,0]$	m7	$\gamma_7 + \gamma_0 + \gamma_{1,(1)} + \gamma_{1,(2)} + \gamma_{2,(1,2)}$
8	$\alpha_8 = [1,1,1]$	NONE (Fixed by Mplus)	$\gamma_8 + 0$

Specifying Initial Mplus Syntax

The initial Mplus syntax contains information about the data set, items, and types of variables.

Note: this comes from file chapter9c.inp

Mplus Syntax	Comments
TITLE: Chapter 9 - LCDM Estimation, simulated data set.	Provides the title for the analysis that appears in output.
DATA: FILE IS lcdmch9a.dat;	Provides location of input data file. Assumes same folder as input file if no path given.
VARIABLE: NAMES = x1-x7 c; USEVARIABLE = x1-x7; CATEGORICAL = x1-x7; CLASSES = c(8);	The variable section lists details about the data – variables and their types. <input type="checkbox"/> NAMES: labels variables in data file <input type="checkbox"/> USEVARIABLE: defines which variables are used in the analysis <input type="checkbox"/> CATEGORICAL: lists which variables are categorical (default is continuous) <input type="checkbox"/> CLASSES: provides number of latent classes to be estimated – 2^A for A measured attributes
ANALYSIS: TYPE=MIXTURE; STARTS=0;	The analysis section lists details about the estimation procedure. <input type="checkbox"/> TYPE: Mixture indicates latent classes will be used – mandatory for DCMs <input type="checkbox"/> STARTS: Turns off default multiple random starts option
OUTPUT: TECH1 TECH5 TECH8 TECH10;	Requests additional output statistics (convergence history; goodness of fit).
SAVEDATA: FORMAT IS f10.5; FILE IS respondent_lcdm2.dat; SAVE = CPROBABILITIES;	Instructs Mplus to save respondent estimates to file named respondent_lcdm2.dat. File located in same folder as input syntax file.

The remaining two sections provide annotated Mplus syntax for the rest of the analysis.

Building Mplus MODEL Command Syntax

Mplus Syntax	Comments
MODEL:	<p>The MODEL command lists the specifics for the LCDM. It consists of two portions:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Class model labels (offset by %class% statements) <ul style="list-style-type: none"> <input type="checkbox"/> Entire item response labels table is entered <input type="checkbox"/> Model constraints (where LCDM parameters are defined) <ul style="list-style-type: none"> <input type="checkbox"/> Labels are set equal to item response functions
<pre>%OVERALL% [C#1] (m1); !profile [000] [C#2] (m2); !profile [001] [C#3] (m3); !profile [010] [C#4] (m4); !profile [011] [C#5] (m5); !profile [100] [C#6] (m6); !profile [101] [C#7] (m7); !profile [110]</pre>	<p>The %OVERALL% section is for the structural model.</p> <ul style="list-style-type: none"> <input type="checkbox"/> [C#1] is the Mplus syntax for the value of the first class mean <input type="checkbox"/> (m1) is our label (to be used in the model constraints section) <input type="checkbox"/> NOTE: [C#8] (m8) is not listed – mean for last class set to zero by Mplus
<pre>!column #1 of item response function labels table !for profile [000] %c#1% [x1\$1] (t1_1); !item 1 _ threshold 1 [x2\$1] (t2_1); !item 2 _ threshold 1 [x3\$1] (t3_1); !item 3 _ threshold 1 [x4\$1] (t4_1); !item 4 _ threshold 1 [x5\$1] (t5_1); !item 5 _ threshold 1 [x6\$1] (t6_1); !item 6 _ threshold 1 [x7\$1] (t7_1); !item 7 _ threshold 1</pre>	<p>The %c#1% section specifies the labels for item thresholds for profile [000] (class #1).</p> <ul style="list-style-type: none"> <input type="checkbox"/> Comes from column 1 of item response function labels table <ul style="list-style-type: none"> <input type="checkbox"/> Repeated for all columns of table <input type="checkbox"/> [x1\$1] is the threshold for item x1 <input type="checkbox"/> (t1_1) is our label for item 1 – threshold 1
<pre>!column #2 of item respond function labels table !for profile [001] %c#2% [x1\$1] (t1_1); !item 1 _ threshold 1 [x2\$1] (t2_1); !item 2 _ threshold 1 [x3\$1] (t3_2); !item 3 _ threshold 2 [x4\$1] (t4_1); !item 4 _ threshold 1 [x5\$1] (t5_2); !item 5 _ threshold 2 [x6\$1] (t6_2); !item 6 _ threshold 2 [x7\$1] (t7_2); !item 7 _ threshold 2</pre>	<p>The %c#2% section specifies the labels for item thresholds for profile [001] (class #2).</p> <ul style="list-style-type: none"> <input type="checkbox"/> Comes from column 2 of item response function labels table <ul style="list-style-type: none"> <input type="checkbox"/> Repeated for all columns of table <input type="checkbox"/> [x1\$1] is the threshold for item x1 <input type="checkbox"/> (t1_1) is our label for item 1 – threshold 1
<pre>!column #3 of item respond function labels table !for profile [010] %c#3% [x1\$1] (t1_1); !item 1 _ threshold 1 [x2\$1] (t2_2); !item 2 _ threshold 2 [x3\$1] (t3_1); !item 3 _ threshold 1 [x4\$1] (t4_2); !item 4 _ threshold 2 [x5\$1] (t5_1); !item 5 _ threshold 1 [x6\$1] (t6_3); !item 6 _ threshold 3 [x7\$1] (t7_3); !item 7 _ threshold 3</pre>	<p>The %c#3% section specifies the labels for item thresholds for profile [010] (class #3).</p> <ul style="list-style-type: none"> <input type="checkbox"/> Comes from column 3 of item response function labels table <ul style="list-style-type: none"> <input type="checkbox"/> Repeated for all columns of table <input type="checkbox"/> [x1\$1] is the threshold for item x1 <input type="checkbox"/> (t1_1) is our label for item 1 – threshold 1

Mplus Syntax	Comments
<pre>!column #4 of item respond function labels table !for profile [011] %c#4% [x1\$1] (t1_1); !item 1 _ threshold 1 [x2\$1] (t2_2); !item 2 _ threshold 2 [x3\$1] (t3_2); !item 3 _ threshold 2 [x4\$1] (t4_2); !item 4 _ threshold 2 [x5\$1] (t5_2); !item 5 _ threshold 2 [x6\$1] (t6_4); !item 6 _ threshold 4 [x7\$1] (t7_4); !item 7 _ threshold 4</pre>	<p>The %c#4% section specifies the labels for item thresholds for profile [011] (class #4).</p> <ul style="list-style-type: none"> <input type="checkbox"/> Comes from column 4 of item response function labels table <ul style="list-style-type: none"> <input type="checkbox"/> Repeated for all columns of table <input type="checkbox"/> [x1\$1] is the threshold for item x1 <input type="checkbox"/> (t1_1) is our label for item 1 – threshold 1
<pre>!column #5 of item respond function labels table !for profile [100] %c#5% [x1\$1] (t1_2); !item 1 _ threshold 2 [x2\$1] (t2_1); !item 2 _ threshold 1 [x3\$1] (t3_1); !item 3 _ threshold 1 [x4\$1] (t4_3); !item 4 _ threshold 3 [x5\$1] (t5_3); !item 5 _ threshold 3 [x6\$1] (t6_1); !item 6 _ threshold 1 [x7\$1] (t7_5); !item 7 _ threshold 5</pre>	<p>The %c#5% section specifies the labels for item thresholds for profile [100] (class #5).</p> <ul style="list-style-type: none"> <input type="checkbox"/> Comes from column 5 of item response function labels table <ul style="list-style-type: none"> <input type="checkbox"/> Repeated for all columns of table <input type="checkbox"/> [x1\$1] is the threshold for item x1 <input type="checkbox"/> (t1_2) is our label for item 1 – threshold 2
<pre>!column #6 of item respond function labels table !for profile [101] %c#6% [x1\$1] (t1_2); !item 1 _ threshold 2 [x2\$1] (t2_1); !item 2 _ threshold 1 [x3\$1] (t3_2); !item 3 _ threshold 2 [x4\$1] (t4_3); !item 4 _ threshold 3 [x5\$1] (t5_4); !item 5 _ threshold 4 [x6\$1] (t6_2); !item 6 _ threshold 2 [x7\$1] (t7_6); !item 7 _ threshold 6</pre>	<p>The %c#6% section specifies the labels for item thresholds for profile [101] (class #6).</p> <ul style="list-style-type: none"> <input type="checkbox"/> Comes from column 6 of item response function labels table <ul style="list-style-type: none"> <input type="checkbox"/> Repeated for all columns of table <input type="checkbox"/> [x1\$1] is the threshold for item x1 <input type="checkbox"/> (t1_2) is our label for item 1 – threshold 2
<pre>!column #7 of item respond function labels table !for profile [110] %c#7% [x1\$1] (t1_2); !item 1 _ threshold 2 [x2\$1] (t2_2); !item 2 _ threshold 2 [x3\$1] (t3_1); !item 3 _ threshold 1 [x4\$1] (t4_4); !item 4 _ threshold 4 [x5\$1] (t5_3); !item 5 _ threshold 3 [x6\$1] (t6_3); !item 6 _ threshold 3 [x7\$1] (t7_7); !item 7 _ threshold 7</pre>	<p>The %c#7% section specifies the labels for item thresholds for profile [110] (class #7).</p> <ul style="list-style-type: none"> <input type="checkbox"/> Comes from column 7 of item response function labels table <ul style="list-style-type: none"> <input type="checkbox"/> Repeated for all columns of table <input type="checkbox"/> [x1\$1] is the threshold for item x1 <input type="checkbox"/> (t1_2) is our label for item 1 – threshold 2
<pre>!column #8 of item respond function labels table !for profile [111] %c#8% [x1\$1] (t1_2); !item 1 _ threshold 2 [x2\$1] (t2_2); !item 2 _ threshold 2 [x3\$1] (t3_2); !item 3 _ threshold 2 [x4\$1] (t4_4); !item 4 _ threshold 4 [x5\$1] (t5_4); !item 5 _ threshold 4 [x6\$1] (t6_4); !item 6 _ threshold 4 [x7\$1] (t7_8); !item 7 _ threshold 8</pre>	<p>The %c#8% section specifies the labels for item thresholds for profile [111] (class #8).</p> <ul style="list-style-type: none"> <input type="checkbox"/> Comes from column 8 of item response function labels table <ul style="list-style-type: none"> <input type="checkbox"/> Repeated for all columns of table <input type="checkbox"/> [x1\$1] is the threshold for item x1 <input type="checkbox"/> (t1_2) is our label for item 1 – threshold 2

Building Mplus MODEL CONSTRAINT Command Syntax

Mplus Syntax	Comments
MODEL CONSTRAINT:	<p>The MODEL CONSTRAINT command is where the LCDM parameters are defined and the item response function is given for each label.</p> <ul style="list-style-type: none"> <input type="checkbox"/> Structural model given [optional] <input type="checkbox"/> Syntax needed for all items
<pre>!STRUCTURAL MODEL PORTION; !define structural model parameters: NEW(g_0 g_11 g_12 g_13 g_212 g_213 g_223 g_3123); !from structural model specification table: !intercept: g_0=-(g_11+g_12+g_13+g_212+g_213+g_223+g_3123); m1=g_0; !profile [000]; m2=g_0+g_13; !profile [001]; m3=g_0+g_12; !profile [010]; m4=g_0+g_12+g_13+g_223; !profile [011]; m5=g_0+g_11; !profile [100]; m6=g_0+g_11+g_13+g_213; !profile [101]; m7=g_0+g_11+g_12+g_212; !profile [110];</pre>	<p>The structural model section.</p> <ul style="list-style-type: none"> <input type="checkbox"/> Taken from structural model specification table <input type="checkbox"/> NEW: creates new parameters for Mplus to use in estimation <input type="checkbox"/> g_[ea1...]: label for gamma parameter; structural model effect parameter <ul style="list-style-type: none"> <input type="checkbox"/> e: effect level (0- intercept; 1- main effect; 2 – two way interaction...) <input type="checkbox"/> a1...: attribute(s) to which effect applies; number of attributes is equal to effect level e
<pre>!ITEM 1; !Q-matrix entry: [100]; !define item 1 LCDM parameters: NEW(l1_0 l1_11); !link labels with LCDM item response function: t1_1=-(l1_0); t1_2=-(l1_0+l1_11); !main effect order constraint: l1_11>0;</pre>	<p>The LCDM item parameter section for item 1.</p> <ul style="list-style-type: none"> <input type="checkbox"/> Links label with item response function <input type="checkbox"/> NEW: creates new parameters for Mplus to use in estimation <input type="checkbox"/> l1_[ea1...]: label for lambda parameter; LCDM item parameter <ul style="list-style-type: none"> <input type="checkbox"/> 1: parameter for item 1 <input type="checkbox"/> e: effect level (0- intercept; 1- main effect; 2 – two way interaction...) <input type="checkbox"/> a1...: attribute(s) to which effect applies; number of attributes is equal to effect level e <input type="checkbox"/> LCDM item response function multiplied by -1 (Mplus modeling difference)
<pre>!ITEM 2; !Q-matrix entry: [010]; !define item 2 LCDM parameters: NEW(l2_0 l2_12); !link labels with LCDM item response function: t2_1=-(l2_0); t2_2=-(l2_0+l2_12); !main effect order constraint: l2_12>0;</pre>	<p>The LCDM item parameter section for item 2.</p> <ul style="list-style-type: none"> <input type="checkbox"/> Links label with item response function <input type="checkbox"/> NEW: creates new parameters for Mplus to use in estimation <input type="checkbox"/> l1_[ea1...]: label for lambda parameter; LCDM item parameter <ul style="list-style-type: none"> <input type="checkbox"/> 1: parameter for item 1 <input type="checkbox"/> e: effect level (0- intercept; 1- main effect; 2 – two way interaction...) <input type="checkbox"/> a1...: attribute(s) to which effect applies; number of attributes is equal to effect level e <input type="checkbox"/> LCDM item response function multiplied by -1 (Mplus modeling difference)

<pre> !ITEM 3; !Q-matrix entry: [001]; !define item 3 LCDM parameters: NEW(13_0 13_13); !link labels with LCDM item response function: t3_1=-(13_0); t3_2=-(13_0+13_13); !main effect order constraint: 13_13>0; </pre>	<p>The LCDM item parameter section for item 3.</p> <ul style="list-style-type: none"> <input type="checkbox"/> Links label with item response function <input type="checkbox"/> NEW: creates new parameters for Mplus to use in estimation <input type="checkbox"/> l1_[ea1...]: label for lambda parameter; LCDM item parameter <ul style="list-style-type: none"> <input type="checkbox"/> 1: parameter for item 1 <input type="checkbox"/> e: effect level (0- intercept; 1- main effect; 2 – two way interaction...) <input type="checkbox"/> a1...: attribute(s) to which effect applies; number of attributes is equal to effect level e <input type="checkbox"/> LCDM item response function multiplied by -1 (Mplus modeling difference)
<pre> !ITEM 4; !Q-matrix entry: [110]; !define item 4 LCDM parameters: NEW(14_0 14_11 14_12 14_212); !link labels with LCDM item response function: t4_1=-(14_0); t4_2=-(14_0+14_11); t4_3=-(14_0+14_12); t4_4=-(14_0+14_11+14_12+14_212); !main effect order constraints: 14_11>0; 14_12>0; !two-way interaction constraints: 14_212>-14_11; 14_212>-14_12; !DINA !14_11=0; !14_12=0; !14_212>0; </pre>	<p>The LCDM item parameter section for item 4.</p> <ul style="list-style-type: none"> <input type="checkbox"/> Links label with item response function <input type="checkbox"/> NEW: creates new parameters for Mplus to use in estimation <input type="checkbox"/> l1_[ea1...]: label for lambda parameter; LCDM item parameter <ul style="list-style-type: none"> <input type="checkbox"/> 1: parameter for item 1 <input type="checkbox"/> e: effect level (0- intercept; 1- main effect; 2 – two way interaction...) <input type="checkbox"/> a1...: attribute(s) to which effect applies; number of attributes is equal to effect level e LCDM item response function multiplied by -1 (Mplus modeling difference)
<pre> !ITEM 5; !Q-matrix entry: [101]; !define item 5 LCDM parameters: NEW(15_0 15_11 15_13 15_213); !link labels with LCDM item response function: t5_1=-(15_0); t5_2=-(15_0+15_11); t5_3=-(15_0+15_13); t5_4=-(15_0+15_11+15_13+15_213); !main effect order constraints: 15_11>0; 15_13>0; !two-way interaction constraints: 15_213>-15_11; 15_213>-15_13; </pre>	<p>The LCDM item parameter section for item 5.</p> <ul style="list-style-type: none"> <input type="checkbox"/> Links label with item response function <input type="checkbox"/> NEW: creates new parameters for Mplus to use in estimation <input type="checkbox"/> l1_[ea1...]: label for lambda parameter; LCDM item parameter <ul style="list-style-type: none"> <input type="checkbox"/> 1: parameter for item 1 <input type="checkbox"/> e: effect level (0- intercept; 1- main effect; 2 – two way interaction...) <input type="checkbox"/> a1...: attribute(s) to which effect applies; number of attributes is equal to effect level e LCDM item response function multiplied by -1 (Mplus modeling difference)

<pre> !ITEM 6; !Q-matrix entry: [011]; !define item 6 LCDM parameters: NEW(16_0 16_12 16_13 16_223); !link labels with LCDM item response function: t6_1=-(16_0); t6_2=-(16_0+16_12); t6_3=-(16_0+16_13); t6_4=-(16_0+16_12+16_13+16_223); !main effect order constraints: 16_12>0; 16_13>0; !two-way interaction constraints: 16_223>-16_12; 16_223>-16_13; </pre>	<p>The LCDM item parameter section for item 6.</p> <ul style="list-style-type: none"> <input type="checkbox"/> Links label with item response function <input type="checkbox"/> NEW: creates new parameters for Mplus to use in estimation <input type="checkbox"/> l1_[ea1...]: label for lambda parameter; LCDM item parameter <ul style="list-style-type: none"> <input type="checkbox"/> 1: parameter for item 1 <input type="checkbox"/> e: effect level (0- intercept; 1- main effect; 2 – two way interaction...) <input type="checkbox"/> a1...: attribute(s) to which effect applies; number of attributes is equal to effect level e <p>LCDM item response function multiplied by -1 (Mplus modeling difference)</p>
<pre> !ITEM 7; !Q-matrix entry: [111]; !define item 7 LCDM parameters: NEW(17_0 17_11 17_12 17_13 17_212 17_213 17_223 17_3123); !link labels with LCDM item response function: t7_1=-(17_0); t7_2=-(17_0+17_13); t7_3=-(17_0+17_12); t7_4=-(17_0+17_12+17_13+17_223); t7_5=-(17_0+17_11); t7_6=-(17_0+17_11+17_13+17_213); t7_7=-(17_0+17_11+17_12+17_212); t7_8=-(17_0+17_11+17_12+17_13+17_212+17_213+ 17_223+17_3123); !main effect order constraints: 17_11>0; 17_12>0; 17_13>0; !two-way interaction constraints: 17_212>-17_11; 17_212>-17_12; 17_213>-17_13; 17_213>-17_11; 17_223>-17_12; 17_223>-17_13; !three-way interaction constraints 17_3123>-(17_223+17_213+17_13); 17_3123>-(17_223+17_212+17_12); 17_3123>-(17_213+17_212+17_11); </pre>	<p>The LCDM item parameter section for item 7.</p> <ul style="list-style-type: none"> <input type="checkbox"/> Links label with item response function <input type="checkbox"/> NEW: creates new parameters for Mplus to use in estimation <input type="checkbox"/> l1_[ea1...]: label for lambda parameter; LCDM item parameter <ul style="list-style-type: none"> <input type="checkbox"/> 1: parameter for item 1 <input type="checkbox"/> e: effect level (0- intercept; 1- main effect; 2 – two way interaction...) <input type="checkbox"/> a1...: attribute(s) to which effect applies; number of attributes is equal to effect level e <p>LCDM item response function multiplied by -1 (Mplus modeling difference)</p>

Understanding Mplus Output

Once the syntax has been built and Mplus finishes estimating the model, the Mplus output contains all the information needed to evaluate the model run. Mplus syntax is voluminous in its size, with only a few sections of interest (and many that are redundant). Each section is discussed in the following pages, in order of appearance in the output file.

1. Tests of Model Fit Output Section
2. Final class counts and proportions
3. New/Additional parameters
4. Technical 10
5. Saved respondent Estimates

Tests of Model Fit Output Section

TESTS OF MODEL FIT

Loglikelihood

H0 Value	-42870.695
H0 Scaling Correction Factor for MLR	1.011

Information Criteria

Number of Free Parameters	33
Akaike (AIC)	85807.391
Bayesian (BIC)	86045.332
Sample-Size Adjusted BIC ($n^* = (n + 2) / 24$)	85940.463

Chi-Square Test of Model Fit for the Binary and Ordered Categorical
(Ordinal) Outcomes

Pearson Chi-Square

Value	101.677
Degrees of Freedom	94
P-Value	0.2764

Likelihood Ratio Chi-Square

Value	103.759
Degrees of Freedom	94
P-Value	0.2306

- ☐ Provides basic model fit information
- ☐ Information Criteria: Used to compare model fit for non-nested models (smaller is better)
- ☐ Chi-square Test: Absolute measure of fit (for small numbers of items only)

Final Class Counts and Estimated Proportions Output Section

FINAL CLASS COUNTS AND PROPORTIONS FOR THE LATENT CLASSES BASED ON THE ESTIMATED MODEL		
Latent Classes		
1	2480.96185	0.24810
2	735.54785	0.07355
3	992.74591	0.09927
4	911.95428	0.09120
5	863.41826	0.08634
6	913.48778	0.09135
7	935.85710	0.09359
8	2166.02696	0.21660

- ☐ Provides the probability an random respondent has a given attribute profile
 - ☐ 24.81% of sample has profile [0,0,0]
 - ☐ 9.12% of sample has profile [0,1,1]

New/Additional Parameters Output Section

New/Additional Parameters					
	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value	
G_0	0.136	0.113	1.203	0.229	Structural Model Parameters
G_11	-1.056	0.148	-7.121	0.000	
G_12	-0.916	0.156	-5.868	0.000	
G_13	-1.216	0.204	-5.970	0.000	
G_212	0.996	0.224	4.448	0.000	
G_213	1.272	0.266	4.784	0.000	
G_223	1.131	0.277	4.083	0.000	
G_3123	-0.348	0.363	-0.959	0.337	
L1_0	-0.913	0.053	-17.141	0.000	LCDM Item Parameters
L1_11	1.872	0.071	26.297	0.000	
L2_0	-1.006	0.069	-14.637	0.000	
L2_12	2.045	0.082	24.961	0.000	
L3_0	-0.961	0.062	-15.461	0.000	
L3_13	2.014	0.079	25.619	0.000	
L4_0	-2.437	0.157	-15.523	0.000	
L4_11	1.858	0.212	8.768	0.000	
L4_12	2.047	0.205	10.007	0.000	
L4_212	1.034	0.338	3.056	0.002	
L5_0	-2.242	0.121	-18.450	0.000	
L5_11	1.725	0.194	8.894	0.000	
L5_13	1.789	0.185	9.652	0.000	
L5_213	1.383	0.340	4.071	0.000	
L6_0	-2.537	0.176	-14.385	0.000	
L6_12	2.102	0.226	9.310	0.000	
L6_13	2.151	0.218	9.851	0.000	
L6_223	1.110	0.376	2.947	0.003	
L7_0	-3.629	0.482	-7.535	0.000	
L7_11	2.468	0.626	3.943	0.000	
L7_12	2.128	0.662	3.216	0.001	
L7_13	2.061	0.702	2.935	0.003	
L7_212	0.815	0.858	0.950	0.342	
L7_213	0.755	0.892	0.846	0.397	
L7_223	0.982	0.927	1.058	0.290	
L7_3123	-1.297	1.376	-0.942	0.346	

- ☐ Provides each parameter estimate and standard error
- ☐ Hypothesis test provides way of testing whether each parameter is equal to zero
 - ☐ Works for all structural model parameters
 - ☐ Works for LCDM intercept item parameters (although test isn't informative)
 - ☐ Will not work for LCDM main effect parameters
 - ☐ Is only approximate for interaction parameters

Technical 10 Output Section

		Estimated Probabilities		
Variable	Variable	H1	H0	Standardized Residual (z-score)
X1	X2			
Category 1	Category 1	0.260	0.262	-0.409
Category 1	Category 2	0.240	0.239	0.422
Category 2	Category 1	0.236	0.234	0.424
Category 2	Category 2	0.263	0.265	-0.407
Bivariate Pearson Chi-Square				0.518
Bivariate Log-Likelihood Chi-Square				0.518

☐ Provides quick goodness of fit check for pairs of items – similar to raw residuals in SEM

Saved Respondents Estimates File

Item Response Pattern							EAP Estimates								MAP Estimate
1	2	3	4	5	6	7	$\hat{\boldsymbol{\alpha}}_{r1}$	$\hat{\boldsymbol{\alpha}}_{r2}$	$\hat{\boldsymbol{\alpha}}_{r3}$	$\hat{\boldsymbol{\alpha}}_{r4}$	$\hat{\boldsymbol{\alpha}}_{r5}$	$\hat{\boldsymbol{\alpha}}_{r6}$	$\hat{\boldsymbol{\alpha}}_{r7}$	$\hat{\boldsymbol{\alpha}}_{r8}$	$\max[\hat{\boldsymbol{\alpha}}_r]$
0	0	1	0	1	0	0	.30	.52	.02	.00	.08	.08	.00	.00	2
0	0	0	0	0	0	0	.88	.04	.05	.00	.04	.00	.00	.00	1
0	0	1	1	0	0	0	.48	.15	.17	.01	.17	.01	.02	.00	1
0	0	0	0	0	0	0	.88	.04	.05	.00	.04	.00	.00	.00	1
1	0	1	0	1	1	0	.03	.42	.01	.07	.05	.41	.00	.01	2

☐ Gives respondent estimates in form of probability a respondent has a given attribute profile