Estimating DCMs Using Mplus

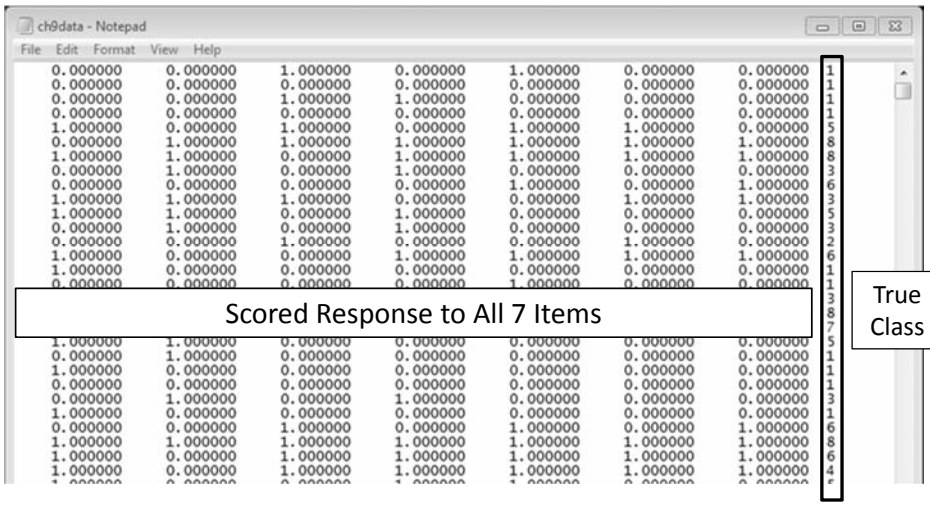
Chapter 9 Example Data

- Example assessment
  - 7 items
  - Measuring 3 attributes
- 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

Data File

- Generated 10,000 respondents
- Found on *Diagnostic Measurement* website: http://projects.coe.uga.edu/dcm/supplemental/chapter9.html
- Format: Tab delimited text file



True Parameters

- Simulated Item Parameters

Table 9.2

LCDM Parameter Values for Simulating Diagnostic Assessment Data

	$\lambda_{i,0}$	$\lambda_{i,1,(1)}$	$\lambda_{i,1,(2)}$	$\lambda_{i,1,(3)}$	$\lambda_{i,2,(1,2)}$	$\lambda_{i,2,(1,3)}$	$\lambda_{i,2,(2,3)}$	$\lambda_{i,3,(1,2,3)}$
Item 1	-1	2	0	0	0	0	0	0
Item 2	-1	0	2	0	0	0	0	0
Item 3	-1	0	0	2	0	0	0	0
Item 4	-2.5	2	2	0	1	0	0	0
Item 5	-2.5	2	0	2	0	1	0	0
Item 6	-2.5	0	2	2	0	0	1	0
Item 7	-4.5	2	2	2	1	1	1	-1

True Parameters

- Simulated Item Response Probabilities

Table 9.3

Item Response Probabilities for Mastery of Attributes for Items in Simulated Data Set

	Number of Required Attributes	Non-mastery of Any Attribute	Mastery of One Attribute	Mastery of Two Attributes	Mastery of Three Attributes
Item 1	1	.27	.73	---	---
Item 2	1	.27	.73	---	---
Item 3	1	.27	.73	---	---
Item 4	2	.08	.38	.92	---
Item 5	2	.08	.38	.92	---
Item 6	2	.08	.38	.92	---
Item 7	3	.01	.08	.82	.97

Getting started with Mplus

- Mplus syntax files are ASCII-text files
- Lines cannot exceed 80 characters in length
  - Start a new line to avoid exceeding the limit
- Statements end with a semicolon
  - If you start a new line, it will read until the semicolon
- Syntax is arranged by sections
- Syntax is case *in*sensitive
- Make comments in Mplus by using a ! before a line
  - Mplus will not process lines that begin with a !

Initial Syntax

x1-x7 are the labels for the 7 items

"truec" is the true latent class; this variable is not used in the analysis.

"c" is the label for the latent classes.

8 is the number of latent classes (2^A)

Mplus Syntax	Comments
TITLE: Chapter 9 - LCDM Estimation, simulated data set.	Provides the title for the analysis that appears in output. Title line doesn't end in a semicolon.
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 truec; USEVARIABLE = x1-x7; CATEGORICAL = x1-x7; CLASSES = c(8);	The variable section lists details about the data – variables and their types. • NAMES: labels variables in data file • USEVARIABLE: defines which variables are used in the analysis • CATEGORICAL: lists which variables are categorical (default is continuous) • 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. • TYPE: Mixture indicates latent classes will be used – mandatory for DCMs • STARTS: Turns off default multiple random starts option

Next steps to take

1. **Build Mplus MODEL CONSTRAINT Command Syntax**
   - Specifies LCDM model parameters.

2. **Build Mplus MODEL Command Syntax**
   - Places labels on all Mplus parameters (thereby enforcing confirmatory model on classes).

To do this, we need first to:

1. **Create a Latent Class-to-Attribute Profile Table**
   - Mplus uses generic latent classes in estimation – we must make these into DCM attribute profiles.

2. **Create 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. **Create 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. **Create the Structural Model**
   - For limiting the number of correlational parameters needed; aids in estimation speed and convergence.

   We will save this for later and use the default option in Mplus now.

1. Create a Latent Class-to-Attribute Profile Table

- 3 attributes yield $2^3 = 8$ attribute patterns or classes
- A standard (conventional) way to assign classes an attribute pattern or profile:

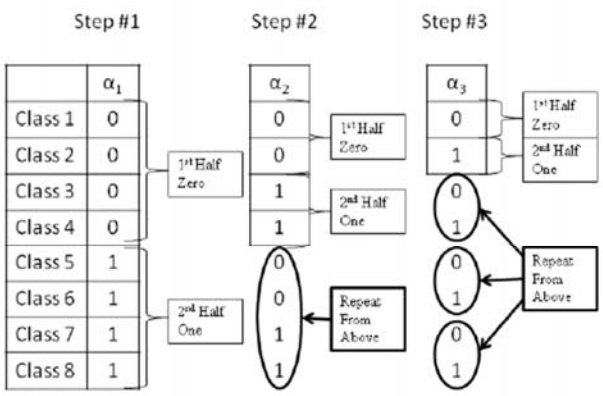


Figure 9.7 from Rupp, Templin, & Henson (2010). Creating a class-to-profile table.

Class	Attribute 1	Attribute 2	Attribute 3
1	0	0	0
2	0	0	1
3	0	1	0
4	0	1	1
5	1	0	0
6	1	0	1
7	1	1	0
8	1	1	1

2. Create an Item to Profile Table

- Specify the LCDM kernel for each class…and for each item

A1	A2	A3
1	0	0
0	1	0
0	0	1
1	1	0
1	0	1
0	1	1
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	$\lambda_{3,0}$	$\lambda_{3,0}+\lambda_{3,1,(3)}$	$\lambda_{3,0}$	$\lambda_{3,0}+\lambda_{3,1,(3)}$	$\lambda_{3,0}$	$\lambda_{3,}+\lambda_{3,1,(3)}$	$\lambda_{3,0}$	$\lambda_{3,0}+\lambda_{3,1,(3)}$
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	$\lambda_{7,0}$	$\lambda_{7,0}+\lambda_{7,1,(3)}$	$\lambda_{7,0}+\lambda_{7,1,(2)}$	$\lambda_{7,0}+\lambda_{7,1,(2)}+\lambda_{7,1(3)}+\lambda_{7,2,(2,3)}$	$\lambda_{7,0}+\lambda_{7,1,(1)}$	$\lambda_{7,0}+\lambda_{7,1,(1)}+\lambda_{7,1,(3)}+\lambda_{7,2,(1,3)}$	$\lambda_{7,0}+\lambda_{7,1,(1)}+\lambda_{7,1,(2)}+\lambda_{7,2,(1,2)}$	$\lambda_{7,0}+\lambda_{7,1,(1)}+\lambda_{7,1,(2)}+\lambda_{7,1,(3)}+\lambda_{7,2,(1,2)}+\lambda_{7,2,(1,3)}+\lambda_{7,2,(2,3)}+\lambda_{7,3,(1,2,3)}$

3. Create Item Response Function Labels

- Next, we need to specify the unique item response functions 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.

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

3. Create Item Response Function Labels

- Item 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	$\lambda_{1,0}$	$\lambda_{1,0}$	$\lambda_{1,0}$	$\lambda_{1,0}$	$\lambda_{1,0} + \lambda_{1,1,(1)}$	$\lambda_{1,0} + \lambda_{1,1,(1)}$	$\lambda_{1,0} + \lambda_{1,1,(1)}$	$\lambda_{1,0} + \lambda_{1,1,(1)}$

Same kernel; same threshold.

Same kernel; same threshold.

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

3. Create Item Response Function Labels

- Item 4

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 4	$\lambda_{4,0}$	$\lambda_{4,0}$	$\lambda_{4,0} + \lambda_{4,1,(2)}$	$\lambda_{4,0}+\lambda_{4,1,(2)}$	$\lambda_{4,0}+\lambda_{4,1,(1)}$	$\lambda_{4,0} + \lambda_{4,1,(1)}$	$\lambda_{4,0} + \lambda_{4,1,(1)} + \lambda_{4,1,(2)} + \lambda_{4,2,(1,2)}$	$\lambda_{4,0} + \lambda_{4,1,(1)} + \lambda_{4,1,(2)} + \lambda_{4,2,(1,2)}$

t4_1 t4_2 t4_3 t4_4

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 4	t4_1	t4_1	t4_2	t4_2	t4_3	t4_3	t4_4	t4_4

3. Create Item Response Function Labels

- Item 7
  - Each kernel is different for each class.
  - 8 different thresholds; one for each class

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 7	$\lambda_{7,0}$	$\lambda_{7,0} + \lambda_{7,1,(3)}$	$\lambda_{7,0} + \lambda_{7,1,(2)}$	$\lambda_{7,0} + \lambda_{7,1,(2)} + \lambda_{7,1,(3)} + \lambda_{7,2,(2,3)}$	$\lambda_{7,0}+\lambda_{7,1,(1)}$	$\lambda_{7,0} + \lambda_{7,1,(1)} + \lambda_{7,1,(3)} + \lambda_{7,2,(1,3)}$	$\lambda_{7,0} + \lambda_{7,1,(1)} + \lambda_{7,1,(2)} + \lambda_{7,2,(1,2)}$	$\lambda_{7,0} + \lambda_{7,1,(1)} + \lambda_{7,1,(2)} + \lambda_{7,1,(3)} + \lambda_{7,2,(1,2)} + \lambda_{7,2,(1,3)} + \lambda_{7,2,(2,3)} + \lambda_{7,3,(1,2,3)}$

Item Response Function Labels

Item 7	t7_1	t7_2	t7_3	t7_4	t7_5	t7_6	t7_7	t7_8

4. Create the Structural Model

- We will talk about this later.
- For now, we will use the Mplus default of a saturated log-linear structural model.

Thresholds in Mplus

- Mplus models the probability of an incorrect response instead of a correct response
- We need to make our thresholds (kernels) negative to model the probability of a correct response:
  - $P(X_{ir} = 0) = \frac{\exp(\tau_{ir})}{1+\exp(\tau_{ir})}$
  - $P(X_{ir} = 1) = \frac{\exp(-\tau_{ir})}{1+\exp(-\tau_{ir})}$
- Not sure? Try some numbers…let kernel (τ_{ir}) = -2:
  - $P(X_{ir} = 0) = \frac{\exp(\tau_{ir})}{1+\exp(\tau_{ir})} = \frac{\exp(-2)}{1+\exp(-2)} = .1193$
  - $P(X_{ir} = 1) = \frac{\exp(-\tau_{ir})}{1+\exp(-\tau_{ir})} = \frac{\exp(2)}{1+\exp(2)} = .8807$

Mplus MODEL CONSTRAINT section

Building Mplus MODEL CONSTRAINT Command Syntax

Mplus Syntax	Comments
MODEL CONSTRAINT:	The MODEL CONSTRAINT command is where the LCDM parameters are defined and the item response function is given for each label. • Structural model given [optional] • Syntax needed for all items

!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_11; !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];
	The structural model section.
	• Taken from structural model specification table
	• NEW: creates new parameters for Mplus to use in estimation
	• g_[ea1…]: label for gamma parameter; structural model effect parameter
	• e: effect level (0- intercept; 1- main effect; 2 – two way interaction…)
	• a1…: attribute(s) to which effect applies; number of attributes is equal to effect level e

LATER

MODEL CONSTRAINT section

- Items 1 & 2 (and 3) measure 1 attribute

!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;
 	
$P(X_{ir}=1)=\frac{\exp(-\tau_{ir})}{1+\exp(-\tau_{ir})}$
	The LCDM item parameter section for item 1.
	• Links label with item response function
	• NEW: creates new parameters for Mplus to use in estimation
	• l1_[ea1…]: label for lambda parameter; LCDM item parameter
	• 1: parameter for item 1
	• e: effect level (0- intercept; 1- main effect; 2 – two way interaction…)
	• 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)

!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;
	The LCDM item parameter section for item 2.
	• Links label with item response function
	• NEW: creates new parameters for Mplus to use in estimation
	• l1_[ea1…]: label for lambda parameter; LCDM item parameter
	• 1: parameter for item 1
	• e: effect level (0- intercept; 1- main effect; 2 – two way interaction…)
	• 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)

Main effects are constrained to be greater than zero.

Order constraints ensure monotonicity: possession of an attribute should never lead to a decrease in probability of answering an item correctly.

MODEL CONSTRAINT continued

- Item 6 (and 4 & 5) measures 2 attributes

```
!ITEM 6;
!Q-matrix entry: [011];
!define item 6 LCDM parameters:
NEW(l6_0 l6_12 l6_13 l6_223);
!link labels with LCDM item response function:
t6_1=-(l6_0);
t6_2=-(l6_0+l6_12);
t6_3=-(l6_0+l6_13);
t6_4=-(l6_0+l6_12+l6_13+l6_223);
!main effect order constraints:
l6_12>0; l6_13>0;
!two-way interaction constraints:
l6_223>-l6_12; l6_223>-l6_13;
```

The LCDM item parameter section for item 6.
- Links label with item response function
- NEW: creates new parameters for Mplus to use in estimation
- l1_[ea1…]: label for lambda parameter; LCDM item parameter
  - 1: parameter for item 1
  - e: effect level (0- intercept; 1- main effect; 2 – two way interaction…)
  - 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)

Two-way interactions must be greater than the negative of each main effect.

- These constraints stem from two inequalities:
  - L6_0 + L6_12 < L6_0 + L6_12 + L6_13 + L6_223
  - L6_0 + L6_13 < L6_0 + L6_12 + L6_13 + L6_223

MODEL CONSTRAINT continued

- Item 7 measures 3 attributes

```
!ITEM 7;
!Q-matrix entry: [111];
!define item 7 LCDM parameters:
NEW(l7_0 l7_11 l7_12 l7_13 l7_212 l7_213
    l7_223 l7_3123);
!link labels with LCDM item response function:
t7_1=-(l7_0);
t7_2=-(l7_0+l7_13);
t7_3=-(l7_0+l7_12);
t7_4=-(l7_0+l7_12+l7_13+l7_223);
t7_5=-(l7_0+l7_11);
t7_6=-(l7_0+l7_11+l7_13+l7_213);
t7_7=-(l7_0+l7_11+l7_12+l7_212);
t7_8=-(l7_0+l7_11+l7_12+l7_13+l7_212+l7_213+
       l7_223+l7_3123);
!main effect order constraints:
l7_11>0; l7_12>0; l7_13>0;
!two-way interaction constraints:
l7_212>-l7_11; l7_212>-l7_12; l7_213>-l7_11;
l7_213>-l7_13; l7_223>-l7_12; l7_223>-l7_13;
!three-way interaction constraints
l7_3123>-(l7_223+l7_213+l7_13);
l7_3123>-(l7_223+l7_212+l7_12);
l7_3123>-(l7_213+l7_212+l7_11);
```

The LCDM item parameter section for item 7.
- Links label with item response function
- NEW: creates new parameters for Mplus to use in estimation
- l1_[ea1…]: label for lambda parameter; LCDM item parameter
  - 1: parameter for item 1
  - e: effect level (0- intercept; 1- main effect; 2 – two way interaction…)
  - 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)

- This constraints stem from inequalities like:

L7_0 + L7_11+ L7_13 + L7_ 213 <

L7_0 + L7_11+ L7_12 + L7_13 + L7_212 + L7_ 213 + L7_223 + L7_3123

Mplus MODEL section

- Comes before MODEL CONSTRAINT in code, although we did MODEL CONSTRAINT first today.

Building Mplus MODEL Command Syntax

Mplus Syntax	Comments

MODEL:	The MODEL command lists the specifics for the LCDM. It consists of two portions:
	• Class model labels (offset by %class% statements)
	  • Entire item response labels table is entered
	• Model constraints (where LCDM parameters are defined)
	  • Labels are set equal to item response functions

%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]	The %OVERALL% section is for the structural model. • [C#1] is the Mplus syntax for the value of the first class mean • (m1) is our label (to be used in the model constraints section) • NOTE: [C#8] (m8) is not listed – mean for last class set to zero by Mplus

more later

MODEL section

Use item response function labels table to complete this section of code

!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	The %c#1% section specifies the labels for item thresholds for profile [000] (class #1). • Comes from column 1 of item response function labels table • Repeated for all columns of table • [x1$1] is the threshold for item x1 • (t1_1) is our label for item 1 – threshold 1
!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	The %c#2% section specifies the labels for item thresholds for profile [001] (class #2). • Comes from column 2 of item response function labels table • Repeated for all columns of table • [x1$1] is the threshold for item x1 • (t1_1) is our label for item 1 – threshold 1
!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	The %c#3% section specifies the labels for item thresholds for profile [010] (class #3). • Comes from column 3 of item response function labels table • Repeated for all columns of table • [x1$1] is the threshold for item x1 • (t1_1) is our label for item 1 – threshold 1

Output Options

Mplus Syntax	Comments
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.

- In this session, we will look at output that gives us parameter estimates for our respondents and items.
- In a later session, we will examine goodness-of-fit statistics in output that you get from TECH10.

Estimated Classifications

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
```

- Gives the proportion of respondents in each class
- 24.81% of respondents are in Class 1
  - Have attribute profile [000] (mastered no attributes)
- 21.66 % of respondents are in Class 8
  - Have attribute profile [111] (mastered all attributes)

Estimated Item Parameters

Ho: Parameter = 0

New/Additional Parameters

	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
				29
				00
				00
				00
				00
				00
				00
				37
L1_0	-0.913	0.053	-17.141	0.000
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

LATER

Structural Model Parameters

LCDM Item Parameters

We don't mind if the intercept is equal to zero. That would just mean non-masters have .50 probability of answering the item correctly.

This test is invalid because we constrain main effects to be greater than zero.

We use this test to see if the interactions are significant.

Interpreting Results for Item 4

Ho: Parameter = 0

	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
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

We reject the null hypothesis.

We keep the interaction parameter in the model.

- Compare to the simulated parameters:

Table 9.2

LCDM Parameter Values for Simulating Diagnostic Assessment Data

	$\lambda_{i,0}$	$\lambda_{i,1,(1)}$	$\lambda_{i,1,(2)}$	$\lambda_{i,1,(3)}$	$\lambda_{i,2,(1,2)}$	$\lambda_{i,2,(1,3)}$	$\lambda_{i,2,(2,3)}$	$\lambda_{i,3,(1,2,3)}$
Item 1	-1	2	0	0	0	0	0	0
Item 2	-1	0	2	0	0	0	0	0
Item 3	-1	0	0	2	0	0	0	0
Item 4	-2.5	2	2	0	1	0	0	0

Estimated Respondent Parameters

Saved Respondents Estimates File

Probability of Membership in Each Class

Most Likely Class

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

- These are from SAVE:CPROBABILITIES option.
- File respondent_ex9.1 is on book website: