VERSION 2 – BETA (PLEASE EMAIL A.A.BROWN@KENT.AC.UK IF YOU FIND ANY BUGS)

MPLUS SYNTAX BUILDER FOR TESTING FORCED-CHOICE DATA WITH THE THURSTONIAN IRT MODEL

USER GUIDE

INTRODUCTION

Brown and Maydeu-Olivares (2011) have introduced an item response theory (IRT) model capable of modeling responses to any forced-choice questionnaire. The Thurstonian IRT model is a multidimensional item response model with some special features that can be straightforwardly estimated using the general modeling software M*plus* (Muthén & Muthén, 1998-2015). However, programming these models in M*plus* is tedious and error-prone except for very small models, as one need to impose parameter constraints that reflect the within-block patterned relationships among items. However, the model is conceptually so simple that the M*plus* programming can be easily automated.

This is a user guide to an Excel macro that writes the M*plus* syntax necessary to fit the IRT model to any forced-choice questionnaire. In this user guide, we describe how to code responses to forced-choice questionnaires and how to build Mplus syntax files for different forced-choice designs. We cover different block sizes (items presented in pairs, triplets, quads) and their common and specific features. We cover both full ranking and partial ranking designs, and both unidimensional and multidimensional comparisons. Furthermore, a detailed tutorial on how to model different types of forced-choice questionnaires and how to score respondents on the measured attributes is provided by Brown and Maydeu-Olivares (2012).

PREPARING THE DATA FILE

BINARY CODING OF PAIRWISE PREFERENCES

M*plus* syntax for the Thurstonian IRT model requires the forced-choice responses to be coded using binary outcomes (dummy variables).

The outcome of any pairwise comparison {A, B} is coded

1, if item A was preferred to item B

0, if item B was preferred to item A

In other words, it is coded 1 if the first item in the pair was preferred to the second, and 0 otherwise.

How to code full ranking blocks

Any rank ordering of *n* items can be equivalently coded as n(n-1)/2 pairwise comparisons using the binary coding above. For instance, to code a rank ordering of 4 items A, B, C and D, we need to consider outcomes of 6 pairwise comparisons:

{A, B} {A, C} {A, D} {B, C} {B, D} {C, D}

Then, the ordering {B, A, D, C} can be equivalently coded as follows:

{A,B}=0 {A,C}=1 {A,D}=1 {B,C}=1 {B,D}=1 {C,D}=0

Or simply

0 1 1 1 1 0

How to code partial ranking blocks ('most'-'least' response format and similar)

Sometimes respondents are only asked to report one item that best describes them and one that least describes them. Such partial ranking formats result in missing binary outcomes whenever the block size is 4 items or more.

For instance, if out of 4 items A, B, C and D the item B was selected as 'most' and item C was selected as 'least', the ordering of items A and D is not known:

{A, B}=0 {A, C}=1 {A, D}=* {B, C}=1 {B, D}=1 {C, D}=0

Or simply

0 1 * 1 1 0

The respondents might be only asked to report one item that best describes them. Such partial ranking formats result in missing binary outcomes whenever the block size is 3 items or more.

For instance, if out of 3 items A, B, and C, the item B was selected as 'most', the ordering of items A and C is not known:

{A, B}=0 {A, C}=* {B, C}=1

Or simply

0 * 1

Converting the rank orders or 'ipsative points' to binary outcomes

If the forced-choice data have been corded using rank orders of items within each block, or reversed rank orders as is often the case with already "ipsative scored" items, the responses should be recoded as binary outcomes of pairwise comparisons before submitting them to the M*plus* analysis. This recoding can be easily performed using standard statistical software prior to modeling with M*plus*.

For instance, in SPSS conditional statements are used:

```
IF (i1>i2) i1i2=1.
```

```
IF (i1<i2) i1i2=0.
RECODE  i1i2  (SYSMIS=99).
EXECUTE.
```

Alternatively, DEFINE commands can be used to recode the data within M*plus*.

For ranked items, binary outcomes of all pairwise combinations of *n* items within each block are computed as differences between the ranks of the second and the first items in the pair, as follows:

```
DEFINE:
i1i2 = item2-item1;
i1i3 = item3-item1;
etc.
```

For 'ipsative item scores', which are inverted rank orders, we use

```
DEFINE:
i1i2 = item1-item2;
i1i3 = item1-item3;
etc.
```

After all pairwise differences have been computed, they are cut at 0, creating binary variables with value 1 if the difference was greater than 0, and value 0 otherwise.

```
CUT i1i2 i1i3 … (0);
```

For incomplete rankings, outcomes of comparisons where preferences between items are not known should be coded as missing data, using conditional statements, for example:

```
IF (i2 GT i1) THEN i1i2=1;
IF (i2 LT i1) THEN i1i2=0;
IF (i2 EQ i1) THEN i1i2=_MISSING;
```

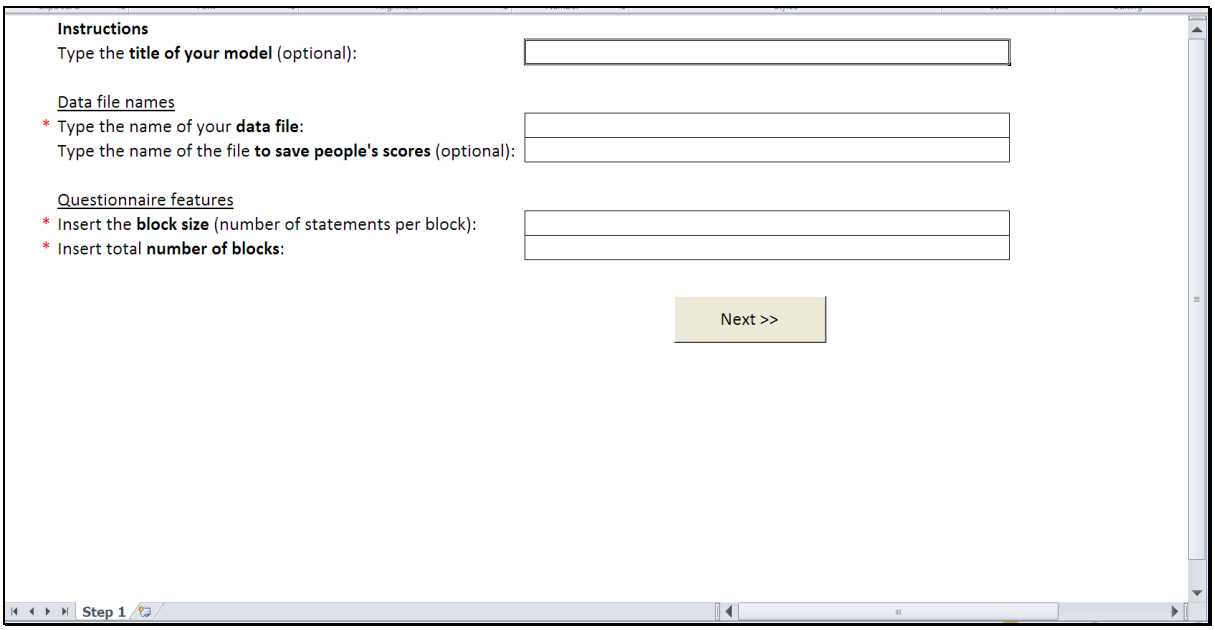
Importantly, when 'missing by design' data are present, which is the case in incomplete ranking tasks, the missing responses have to be imputed prior to model estimation. This is described in Example 2 below.

STEP-BY-STEP TUTORIAL FOR CREATING M*PLUS* SYNTAX

STEP 1. ENTERING FILE NAMES AND BASIC INFORMATION ABOUT THE QUESTIONNAIRE DESIGN

When the Excel application is first opened, the 'Step 1' page is presented.

This page requires as input the name of the data file containing the binary outcomes (the data file may contain additional variables), the name of a file to save the respondents scores (this is optional), the number of forced-choice blocks in the questionnaire and the block size. The page looks as follows:



All fields that require information are marked with an asterisk. If no file name is supplied for saving the people's scores, no corresponding line of Mplus syntax will be created.

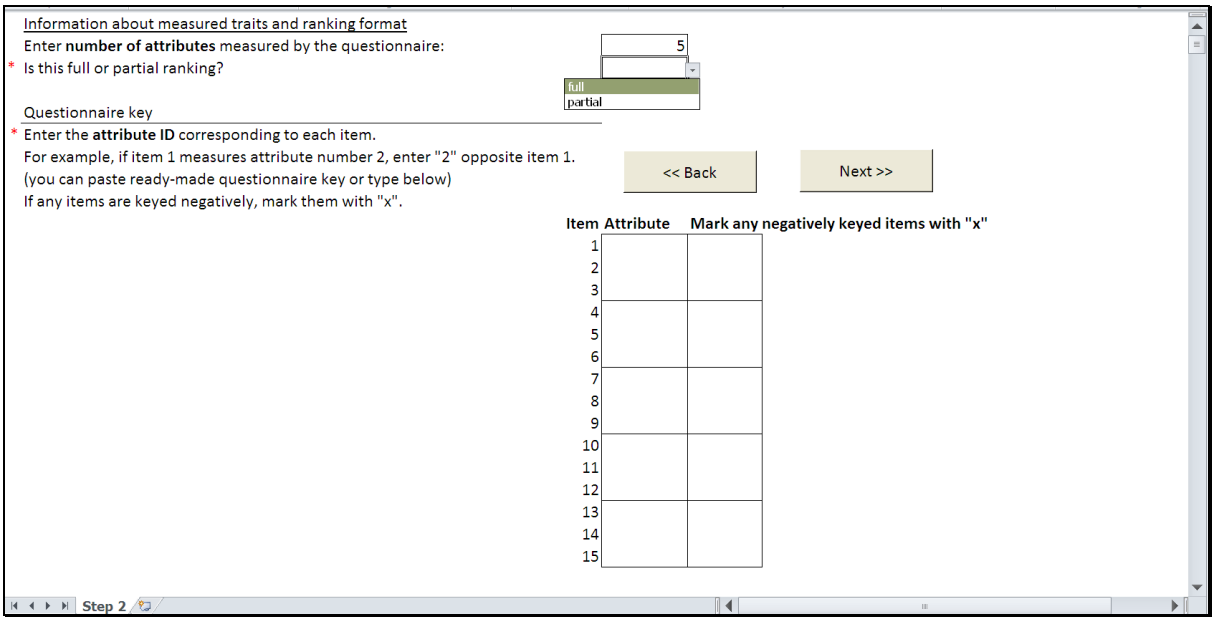
After the user presses the 'Next' button, the 'Step 2' page is presented.

STEP 2. ENTERING THE NUMBER OF MEASURED ATTRIBUTES AND THE QUESTIONNAIRE KEY

At Step 2, the user is required to enter the number of attributes measured by the questionnaire.

Next, the user specifies whether the data contains full or partial rankings by selecting either 'full' or 'partial' from the dropdown list. This question only appears if the block size is 3 or more.

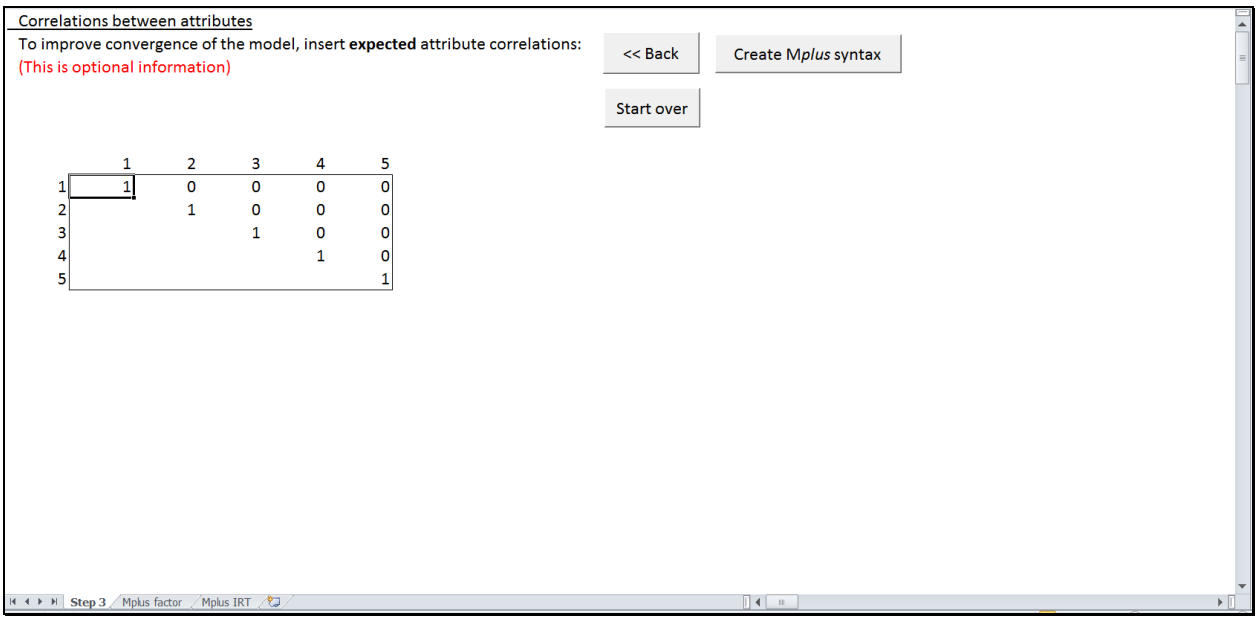
Next, the user must complete a questionnaire "key" table. This is simply a numbered list of all questionnaire items, and the user has to indicate which attribute (referred to by its number) each item measures. The user also has an option to indicate any negatively keyed items. These are items designed to represent the negative end of the attribute, such as "I keep in the background" to indicate Extraversion. This information is optional and is only used for assigning better (negative) starting values for factor loading parameters.



Pressing the 'Next' button takes the user to the 'Step 3' page.

Step 3. Entering expected correlations between attributes

Step 3 enables the user to provide starting values for the attribute correlation matrix (this is optional information).



Pressing the 'Create Mplus syntax' button takes the user to the pages showing generated syntax.

Pressing the 'Start over' button takes the user to the clean 'Step 1' page.

Step 4. Viewing and copying Mplus syntax

With all previously supplied information, the Excel macro creates Mplus syntax for **two mathematically equivalent models**. Forced-choice questionnaire data can be analysed using either a **Thurstonian factor model** as illustrated in Figure 1 of Brown and Maydeu-Olivares (2011), or a **Thurstonian IRT model** as illustrated in Figure 2. The IRT version has the same parameters and fit, but reparameterized as a first-order factor model to enable estimation of person attribute scores.

Syntax presented on page “Mplus factor” is for the Thurstonian factor model. This model is very simple to read and interpret, and this is why it is recommended at the model testing stage. However, it cannot be used for scoring because the uniquenesses in this second-order factor model are parameterised to be 0 (see Brown & Maydeu-Olivares, 2012).

Syntax presented on page “Mplus IRT” is for Thurstonian IRT model, which can be used for both parameter estimation and person score estimation. Both models should have the same fit and the same parameter estimates.

Both pages of syntax can be viewed immediately in Excel, and also copied to ready-to-execute Mplus input files. To copy the syntax, highlight all lines of syntax (it is written in one column) and copy it to the clipboard. The copied text can be pasted directly into an Mplus input file (.inp) and saved. Remember that two versions – factor and IRT – require two different Mplus input files!

Once the desired syntax has been obtained, the user may close the Excel application, or, alternatively press the ‘Start over’ button to return to the Step 1 and create a new Mplus syntax.

EXAMPLES

EXAMPLE 1. BUILDING SYNTAX FOR BLOCKS OF 3 ITEMS USING FULL RANKING FORMAT

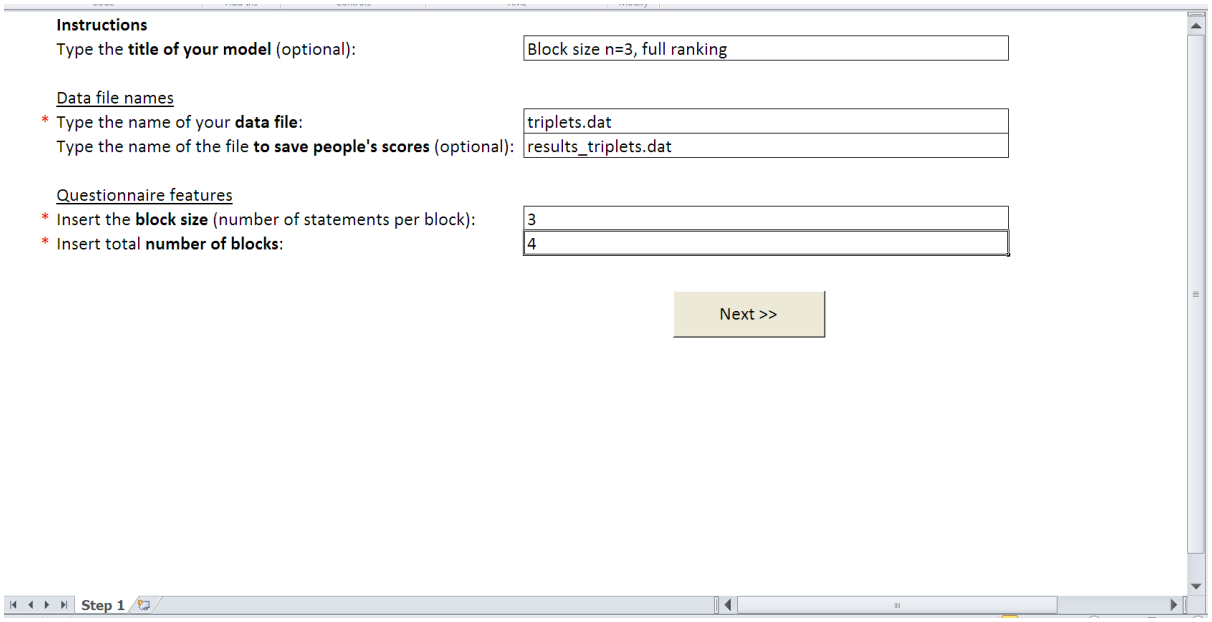
This is an example of creating Mplus syntax for testing forced-choice data arising from blocks of 3 items, using the **full ranking** format. In this case, the format is full ranking if the respondents are asked to rank order items, or to select one item that describes them most and on that describes them least. In both cases all outcomes of pairwise comparisons between items are known.

In this simple example, 3 attributes are measured by 4 blocks. The assignment of items to measured attributes is as follows:

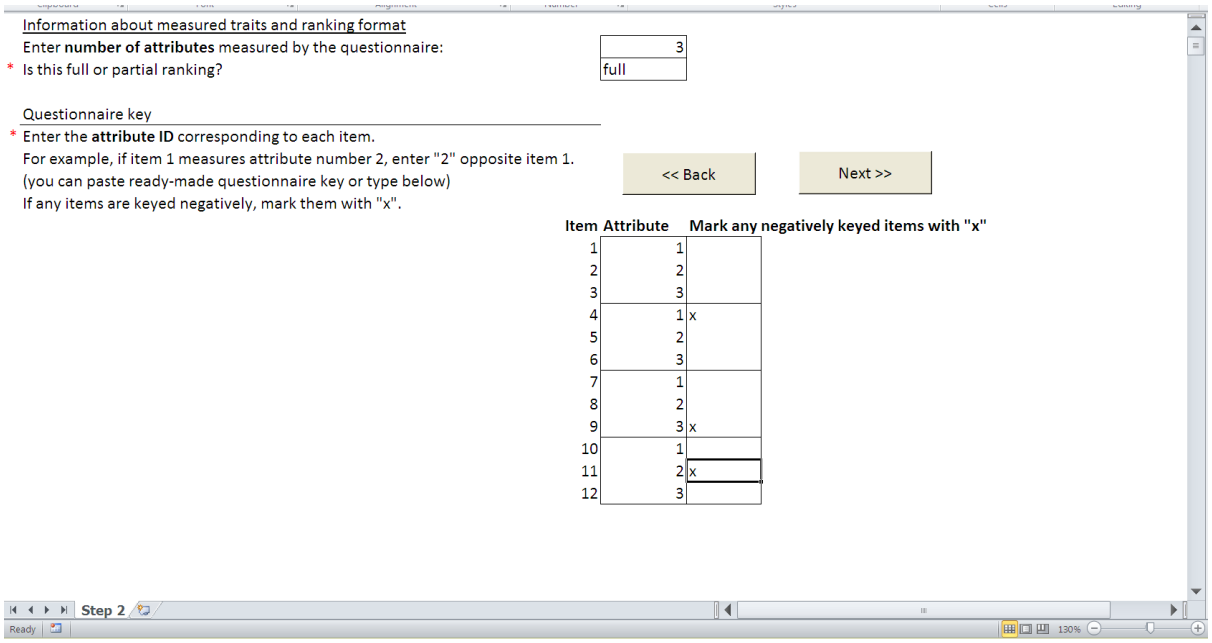
Item	Attribute	Keying
1	1	+
2	2	+
3	3	+
4	1	-
5	2	+
6	3	+
7	1	+
8	2	+
9	3	-
10	1	+
11	2	-
12	3	+

The technical detail for this design can be found in Brown and Maydeu-Olivares (2012), Example 1.

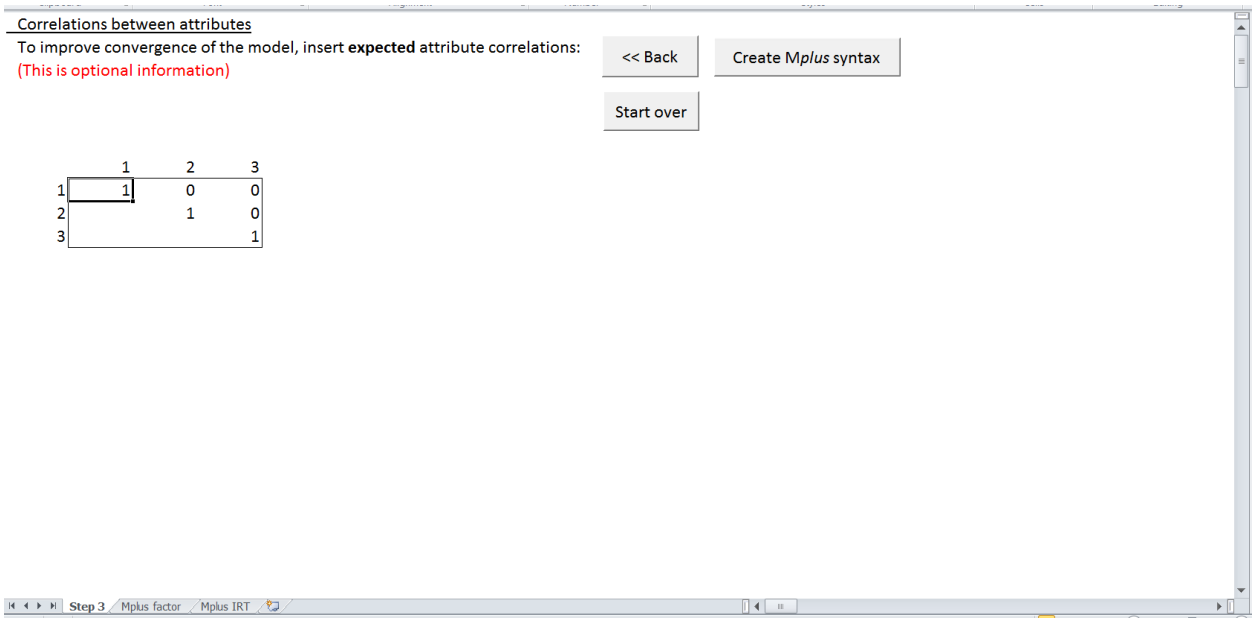
First, we enter the basic detail of this design into the ‘Step 1’ form and press ‘Next’:



Next, we specify that the number of measured attributes is 3, the data is full ranking, and enter the questionnaire "key", as follows:



After pressing the 'Next' button, we can enter expected correlations between the measured attributes. This step is optional. In the below screen shot, we do not change the default zero correlations.



After pressing the 'Create Mplus syntax' button, we can view two pages of the Mplus syntax, for the factor and IRT models, and copy and paste either or both to Mplus input files ready for execution.

EXAMPLE 2. BUILDING SYNTAX FOR BLOCKS OF 4 ITEMS USING 'MOST-LEAST' RANKING FORMAT

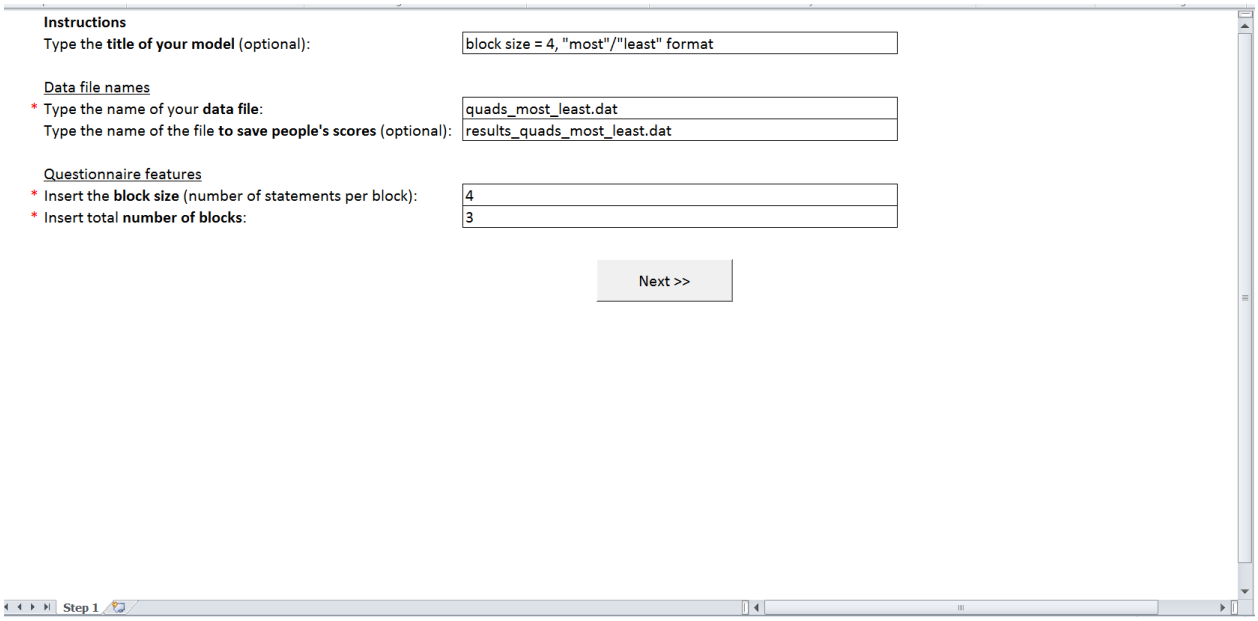
This is an example of creating Mplus syntax for testing forced-choice data arising from blocks of 4 items, using the **partial ranking** format. Partial ranking arises in blocks of 4 items if the respondents are asked to select one item that describes them most and on that describes them least. In this case, the outcome of one pairwise comparison is not known – this is the comparison between items that are not selected as 'most' or 'least'.

In this simple example, 4 attributes are measured by 3 blocks. The assignment of items to measured attributes is as follows:

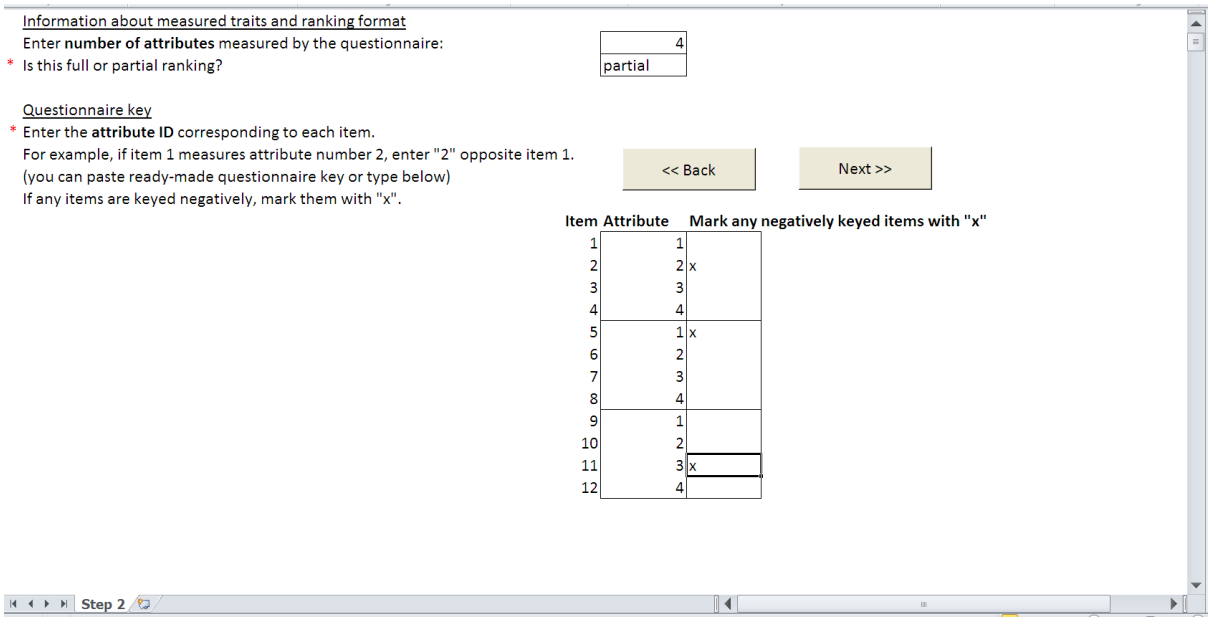
Item	Attribute	Keying
1	1	+
2	2	-
3	3	+
4	4	+
5	1	-
6	2	+
7	3	+
8	4	+
9	1	+
10	2	+
11	3	-
12	4	+

The technical detail for this design can be found in Brown and Maydeu-Olivares (2012), Example 2.

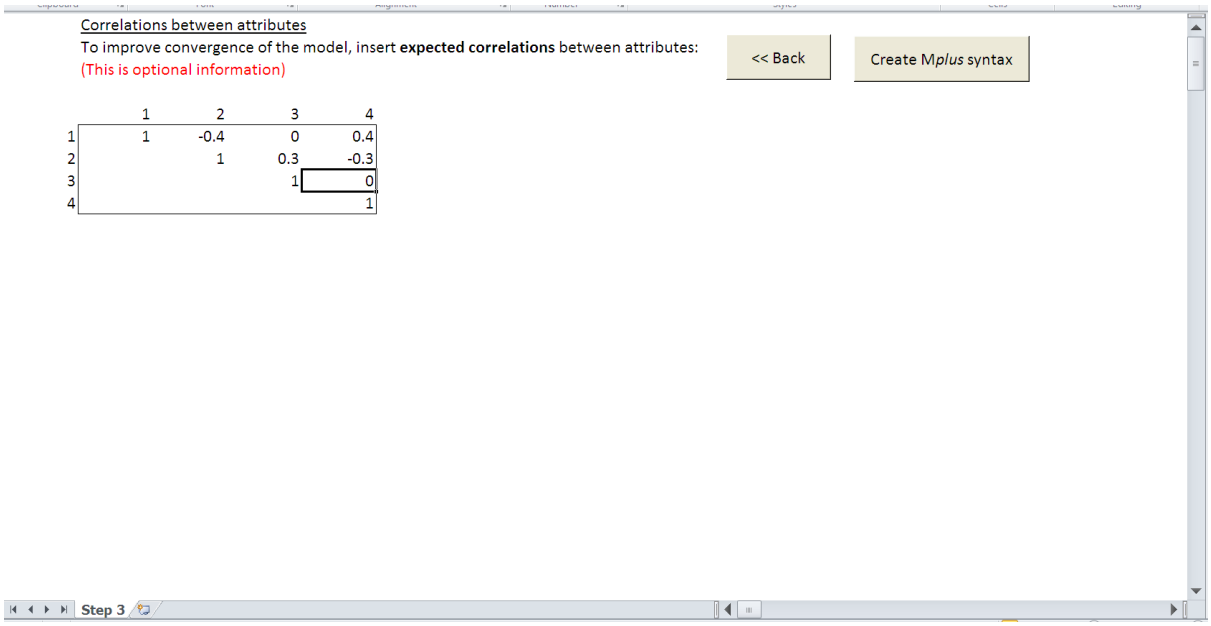
First, we enter the basic detail of this design into the 'Step 1' form and press 'Next':



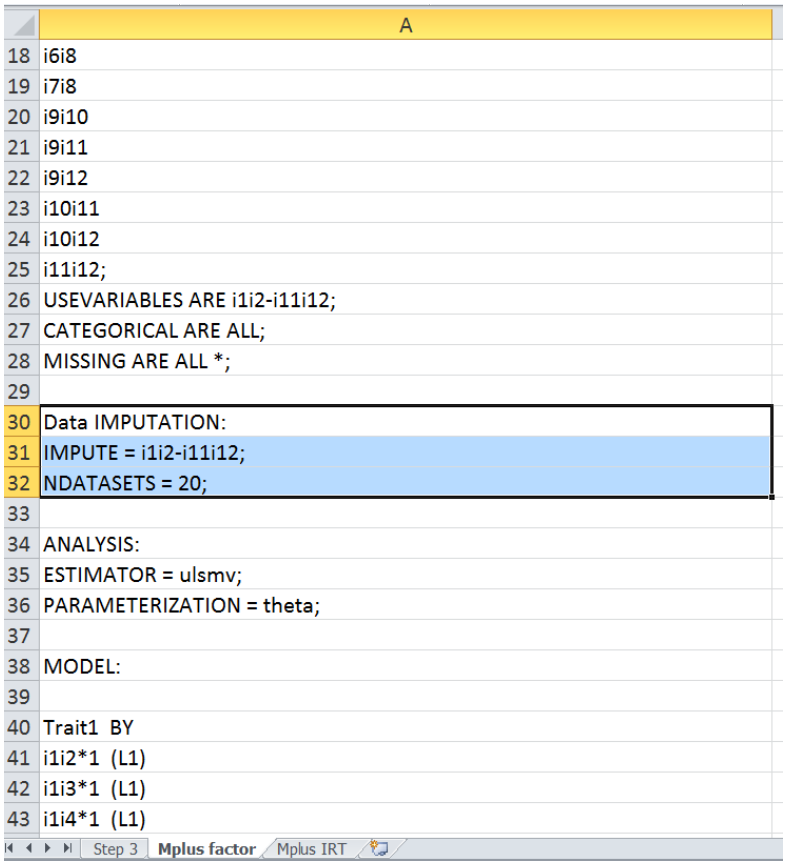
Next, we specify that the number of measured attributes is 4; the data is **partial** ranking, and enter the questionnaire "key", and indicate negatively keyed items (optional) as follows:



After pressing the 'Next' button, we can enter expected correlations between the measured attributes. This step is optional. In the below screen shot, we enter expected correlations. These will be used as starting values in Mplus estimation.



After pressing the 'Create Mplus syntax' button, we can view the Mplus syntax for both factor and IRT parameterizations, and copy and paste them to Mplus input files ready for execution. Below is the snapshot of the factor version.



It can be seen that in this case of partial ranking, the multiple imputation facility provided by Mplus is used. By default, the symbol used for recognising missing outcomes in the syntax is "*".

```
MISSING ARE ALL *;
```

If the missing outcomes were coded differently, the asterisk needs to be replaced with the appropriate code. For instance, if 99 is the missing indicator, use the following syntax

```
MISSING ARE ALL (99);
```

Example 3. Building syntax for blocks of 2 items (item-pairs) when the number of measured attributes is greater than 2

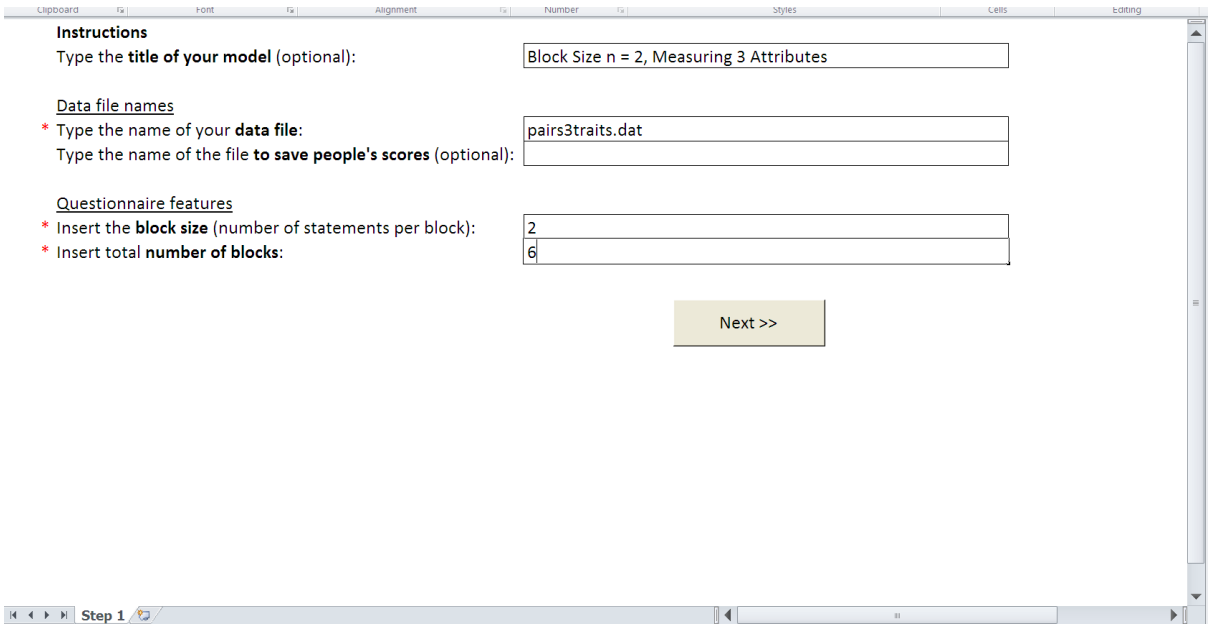
This is an example of creating Mplus syntax for testing forced-choice data arising from item-pairs, when more than 2 attributes are measured. In this case, no item uniqueness can be identified. It is convenient to assume that uniquenesses for bot item utilities involved in a comparison equal 0.5, so that uniqueness of each pair can be set to 1.

In this simple example, 3 attributes are measured by 6 item-pairs. The assignment of items to measured attributes is as follows:

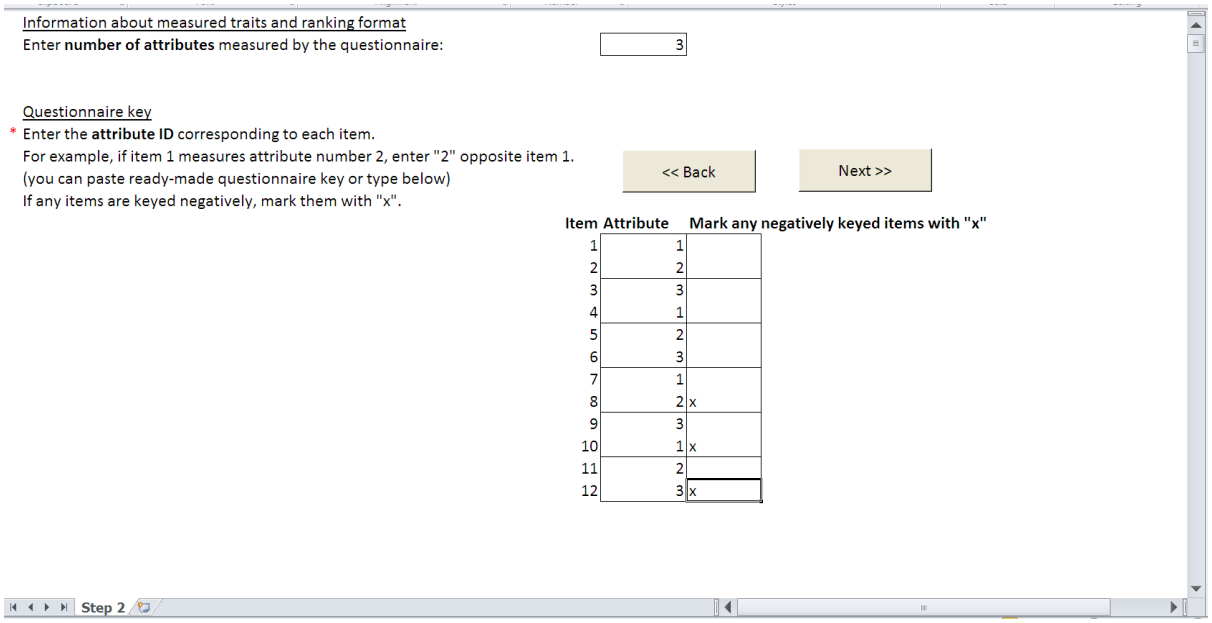
Item	Attribute	Keying
1 2	1 2	+ +
3 4	3 1	+ +
5 6	2 3	+ +
7 8	1 2	+ -
9 10	3 1	+ -
11 12	2 3	+ -

The technical detail for this design can be found in Brown and Maydeu-Olivares (2012), Example 3.

First, we enter the basic detail of this design into the 'Step 1' form and press 'Next':



Next, we specify that the number of measured attributes is 3, and enter the questionnaire "key", as follows:



After pressing the 'Next' button, we can enter expected correlations between the measured attributes. This step is optional, and is not different from specifying these correlations in Example 1.

After pressing the 'Create Mplus syntax' button, we can view the Mplus IRT syntax, and copy and paste it to an Mplus input file ready for execution. No Mplus factor syntax will be produced, because the factor representation is not possible for item pairs.

Example 4. Building syntax for blocks of 2 items (item-pairs) when the number of measured attributes is exactly 2

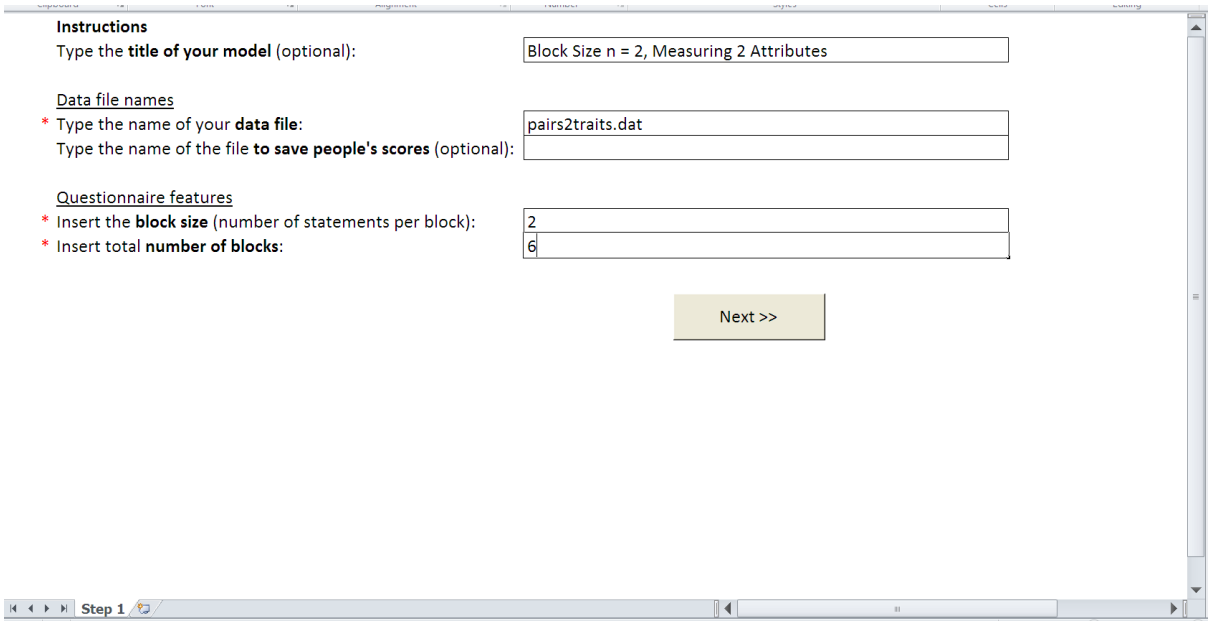
This is an example of Mplus syntax for testing forced-choice data arising from item-pairs, when exactly 2 attributes are measured. In this case, we have an exploratory two-factor analysis model with binary variables.

In this example, two attributes are measured by 6 item-pairs. The assignment of items to measured attributes is as follows:

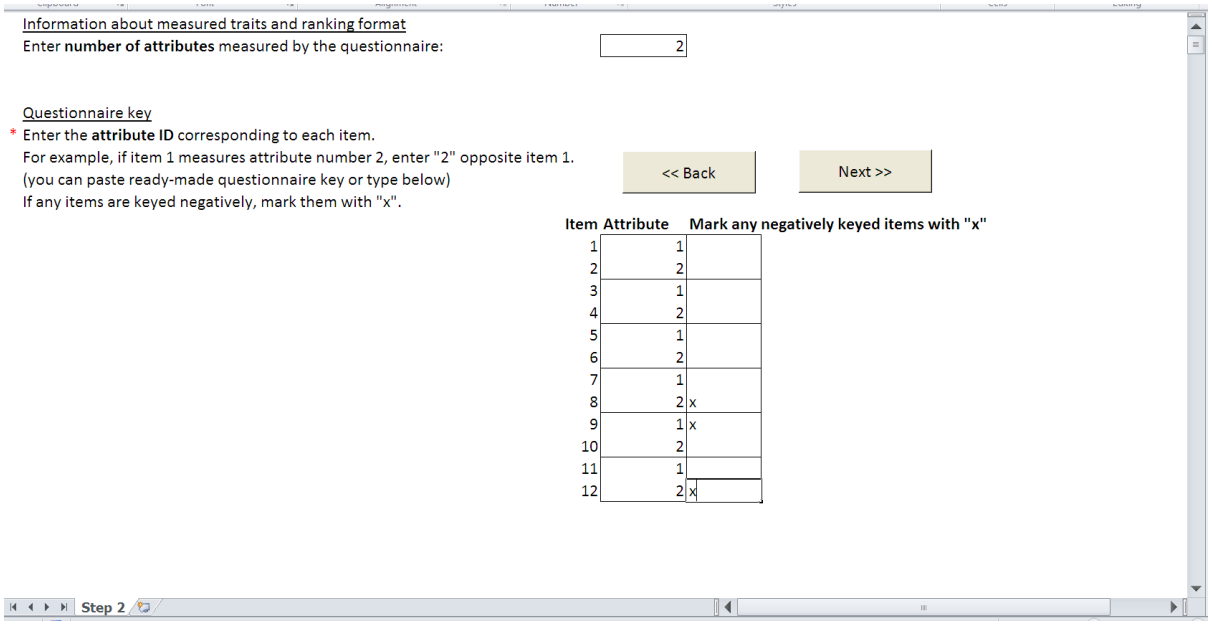
Item	Attribute	Keying
1 2	1 2	+ +
3 4	1 2	+ +
5 6	1 2	+ +
7 8	1 2	+ -
9 10	1 2	- +
11 12	1 2	+ -

The technical detail for this design can be found in Brown and Maydeu-Olivares (2012), Example 4.

First, we enter the basic detail of this design into the 'Step 1' form and press 'Next':



Next, we specify that the number of measured attributes is 2, and enter the questionnaire "key", as follows:



After pressing the 'Next' button, we can enter expected correlations between the measured attributes. This step is optional.

After pressing the 'Create Mplus syntax' button, we can view the Mplus IRT syntax, and copy and paste it to an Mplus input file ready for execution. No Mplus factor syntax will be produced, because the factor representation is not possible for item pairs.

EXAMPLE 5. BUILDING SYNTAX FOR 1 BLOCK OF 6 ITEMS MEASURING A SINGLE ATTRIBUTE

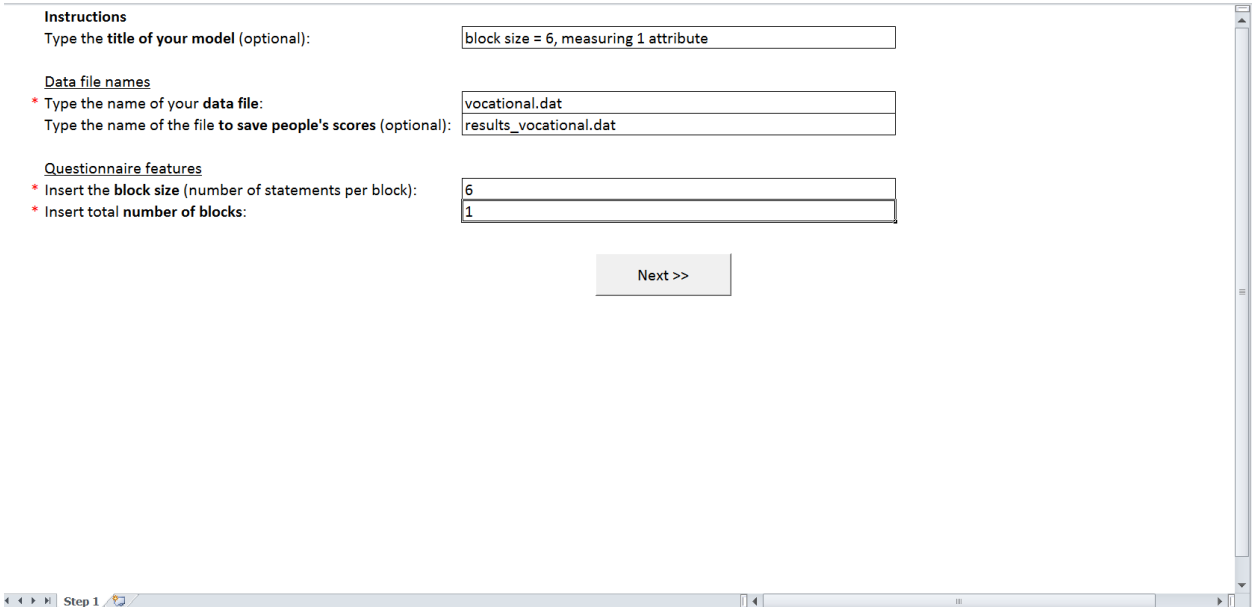
This is an example of Mplus syntax for testing forced-choice data arising from one single block of items measuring the same attribute (unidimensional forced choice).

The assignment of items to measured attributes is as follows:

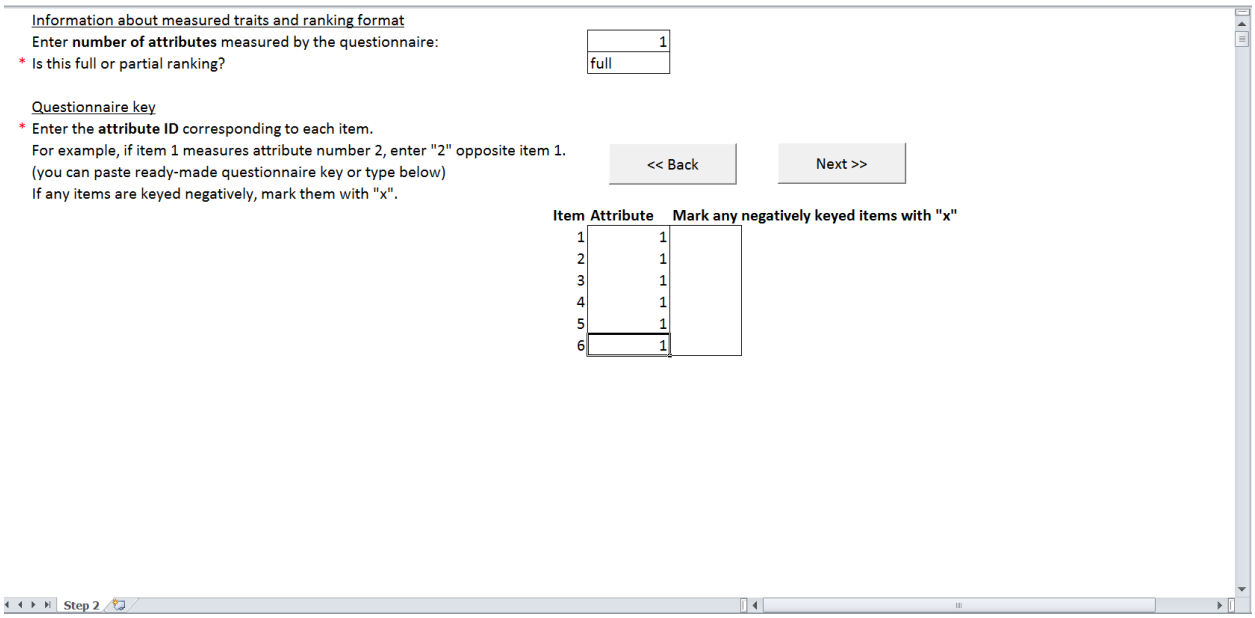
Item	Attribute	Keying
1	1	+
2	1	+
3	1	+
4	1	+
5	1	+
6	1	+

The technical detail and identification constraints for this design can be found in Maydeu-Olivares and Brown (2010), Example 1.

First, we enter the basic detail of this design into the 'Step 1' form and press 'Next':



Next, we specify that the number of measured attributes is 1, and enter the questionnaire "key", as follows:



After pressing the 'Next' button, we see the table of "expected correlations", but in this case of one single trait there is nothing to enter.

After pressing the 'Create Mplus syntax' button, we can view the Mplus syntax for both factor and IRT models, and copy and paste it to Mplus input files ready for execution.

The special feature of this example is constraints on factor loadings that are necessary because when all items within blocks measure the same attribute, the factor loadings are not identified unless one of them is fixed. The value to which the factor loading is fixed is arbitrary, because the differences of item factor loadings that determine the pair loadings are invariant to the choice of value (Maydeu-Olivares and Brown, 2010). We fix the loading of the first item in the block to 1 by default. If another value is desired for interpretation reasons, the user can change that manually.

Here is a fragment of factor syntax, in which the constraint can be seen:

```
t4  BY  i4i5@1; t5  BY  i4i5@-1;
t4  BY  i4i6@1; t6  BY  i4i6@-1;
t5  BY  i5i6@1; t6  BY  i5i6@-1;

! Errors of binary outcomes are zero
i1i2-i5i6@0;

! Utilities are caused by attributes (second-order factors)

Trait1  BY
t1@1   !identification constraint for block consisting of unidimensional comparisons only
t2*1
t3*1
t4*1
t5*1
t6*1;

! Variances for all traits are set to 1
Trait1@1;

! Fix one uniqueness per block for identification
t1@1;

! Trait scores for individuals cannot be estimated with the second-order factor model
 because the uniquenesses are zero. Use the TIRT syntax for trait score estimation.
```

Step 3 | **Mplus factor** | Mplus IRT

And here is a fragment of IRT syntax where the constraints on loadings are written out:

```
MODEL CONSTRAINT:
NEW
L1 L2 L3 L4 L5 L6 ;

!Constraints on factor loading parameters
L1 = 1;   !identification constraint for block consisting of unidimensional comparisons only
L1_2 = L1 - L2;
L1_3 = L1 - L3;
L1_4 = L1 - L4;
L1_5 = L1 - L5;
L1_6 = L1 - L6;
L2_3 = L2 - L3;
L2_4 = L2 - L4;
L2_5 = L2 - L5;
L2_6 = L2 - L6;
L3_4 = L3 - L4;
L3_5 = L3 - L5;
L3_6 = L3 - L6;
L4_5 = L4 - L5;
L4_6 = L4 - L6;
L5_6 = L5 - L6;

! Uniquenesses relating to the same item are equal
e_2 = -e2;
e_3 = -e3;
```

Step 3 | Mplus factor | **Mplus IRT**

REFERENCES

Brown, A. & Maydeu-Olivares, A. (2011). Item response modeling of forced-choice questionnaires. *Educational and Psychological Measurement, 71*, 460-502. doi: 10.1177/0013164410375112

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