LISREL Examples Guide

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Please download the examples from our website at https://ssicentral.com/index.php/products/lisrel/lisrel-examples and unzip them into a convenient folder location. The examples shown in the manual uses 'C:\LISREL Examples' and you are more than welcome to use the same or a different location. Please note that the actual location may be different on your machine.

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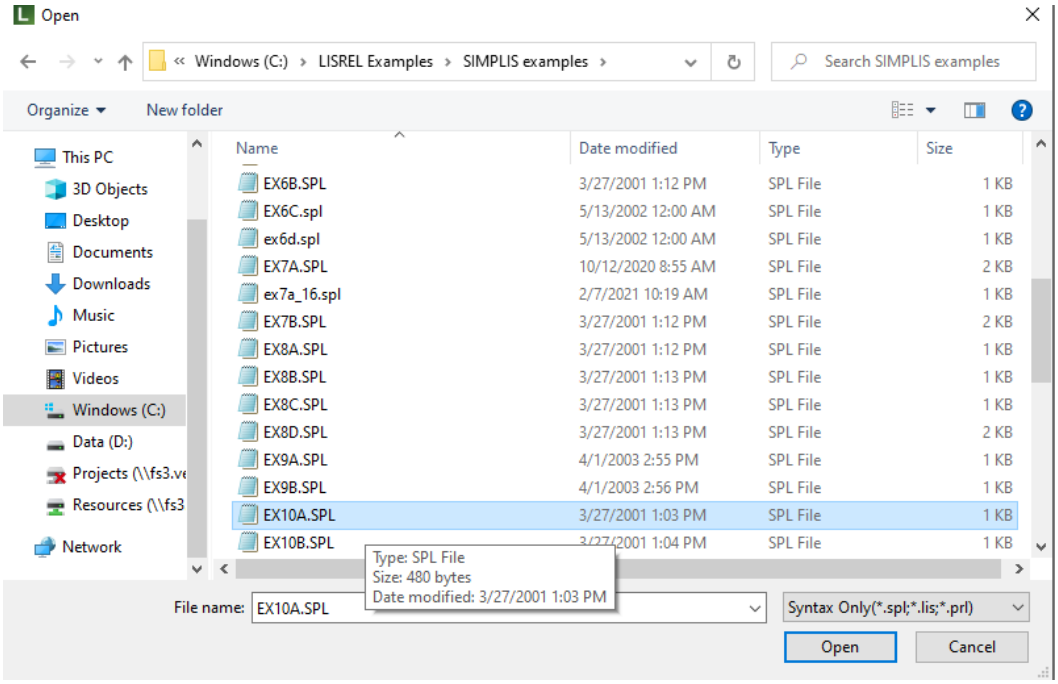
1 Using Existing SIMPLIS Syntax Files

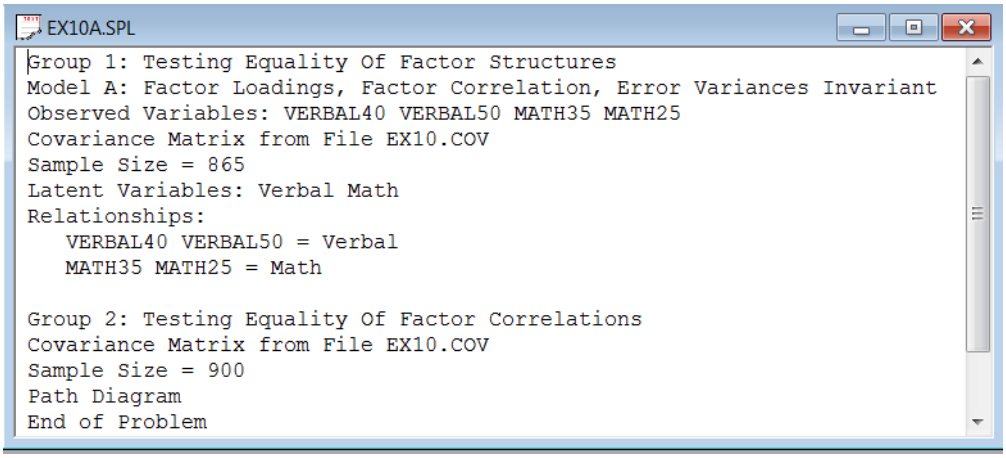
The additional SIMPLIS examples not discussed in this guide are listed below. All these examples are available in the **SIMPLIS examples** folder.

Example 1: Regression of GNP Data File: = None Input Files: EX1A.SPL, EX1B.SPL	**Example 2: Prediction of Grade Averages** Data File: None Input Files: EX2A.SPL, EX2B.SPL
Example 3: Union Sentiment of Textile Workers Data File: None Input Files: EX3A.SPL, EX3B.SPL	**Example 4: Ability and Aspiration** Data File: EX4.COR Input Files: EX4A.SPL, EX4B.SPL
Example 5: Nine Psychological Variables Data File: EX5.COR Input Files: EX5A.SPL, EX5B.SPL	**Example 6: Stability of Alienation** Data File: None Input Files: EX6A.SPL, EX6B.SPL, EX6C.SPL
Example 7: Performance and Satisfaction Data File: EX7.DAT Input Files: EX7A.SPL, EX7B.SPL	**Example 8: Peer Influences on Ambition** Data Files: EX8.LAB, EX8.COR, EX8.STD Input Files: EX8A.SPL, EX8B.SPL, EX8C.SPL,EX8D.SPL
Example 9: Panel Model for Political Efficacy Data Files: PANEL.LAB, PANELUSA.PME, PANELUSA.ACP Input Files: EX9A.SPL, EX9B.SPL	**Example 10: Testing Equality of Factor Structures** Data File: EX10.COV Input Files: EX10A.SPL, EX10B.SPL, EX10C.SPL, EX10D.SPL
Example 11: Parental Socioeconomic Characteristics Data File: None Input Files: EX11A.SPL, EX11B.SPL	**Example 12: Testing Equality of Regressions** Data File: EX12.DAT Input Files: EX12A.SPL, EX12B.SPL, EX12C.SPL
Example 13: Mean Difference in Verbal Ability Data File: EX12.DAT (Note: Same Data File as for Example 12) Input Files: EX13A.SPL, EX13B.SPL	**Example 14: Nine Psychological Variables with Factor Means** Data Files: EX14.LAB, EX14.DAT Input File: EX14.SPL
Example 15: Regression of Verbal7 on Verbal5 Data File: EX12.DAT (Note: Same Data File as for Example 12) Input Files: EX15A.SPL, EX15B.SPL	**Example 16: Head Start Summer Program** Data File: EX16.DAT Input Files: EX16A.SPL, EX16B.SPL, EX16C.SPL, EX16D.SPL
Example 17: Hypothetical Model Data Files: EX17.COV, EX17.COR Input Files: EX17A.SPL, EX17B.SPL	

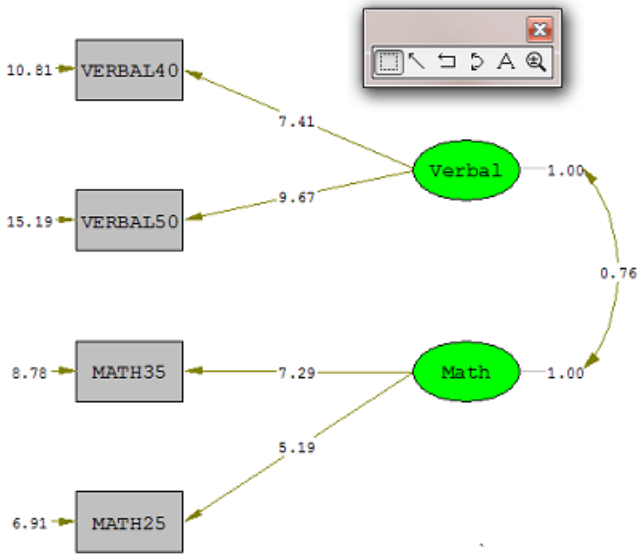
To run a SIMPLIS example, select the **Open** option from the **File** menu to obtain the **Open** dialog box. Select (for example) **ex10a.spl** from the **SIMPLIS examples** folder. Click **Open** when done.



Click the **Run LISREL** icon button to run **ex10a.spl**. Alternatively, use the **File**, **Run LISREL** option.

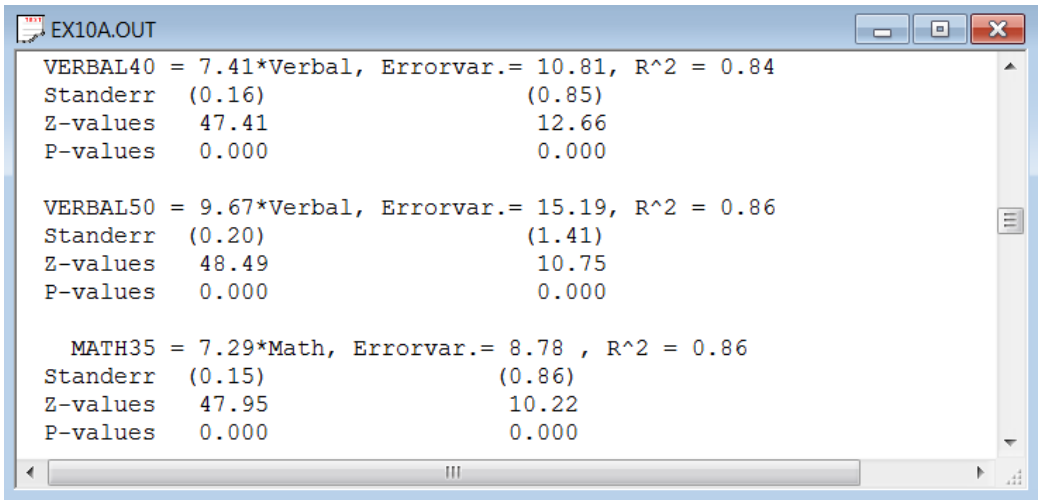


Note that a path diagram is obtained by entering the command "Path Diagram" in the file **ex10a.spl**, just below the line Sample Size = 900 as shown above. The path diagram is displayed in the path diagram window.

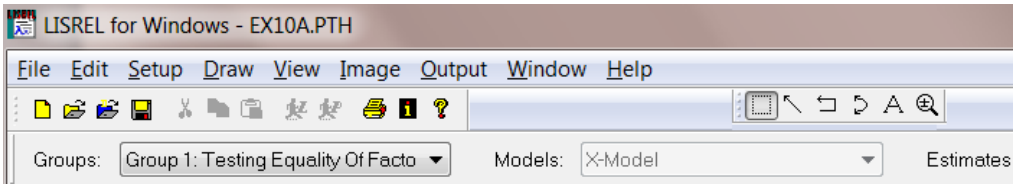


Chi-Square=33.78, df=11, P-value=0.00039, RMSEA=0.048

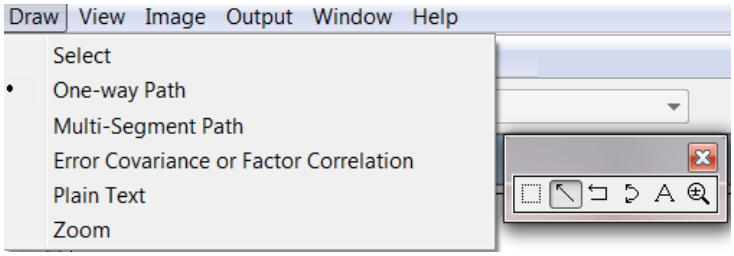
A text editor window is also opened. A selection of the output contained in **ex10a.out** is displayed below.



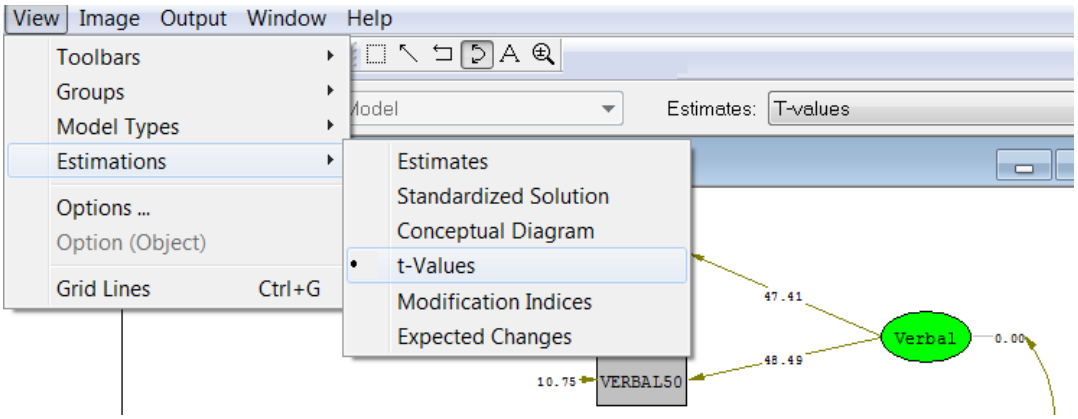
Once a path diagram is produced, the LISREL menu bar will display a different selection of options, as shown next.



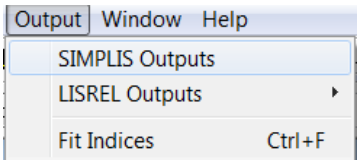
After a path diagram has been obtained, one may select the **Draw** menu to add paths, change text, etc. The items on this menu correspond to the **Draw** toolbox displayed next to it on the window shown below.



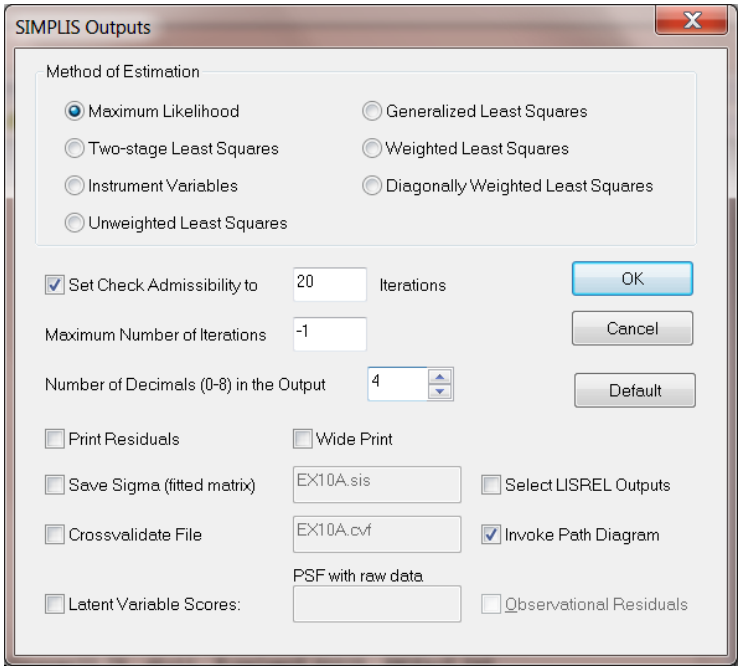
The default values shown on the path diagram are the parameter estimates. By selecting the **Estimations** option from the **View** menu, one may alternatively select the t-values, modification indices, etc.



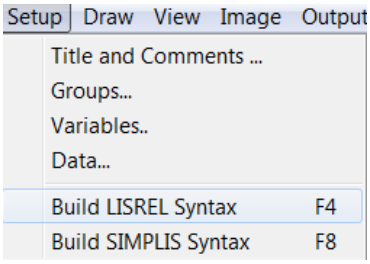
One may change the number of decimals displayed in the path diagram by selecting SIMPLIS **outputs** from the **Output** menu. On the dialog box displayed, change the number of decimals from the default value of 2.



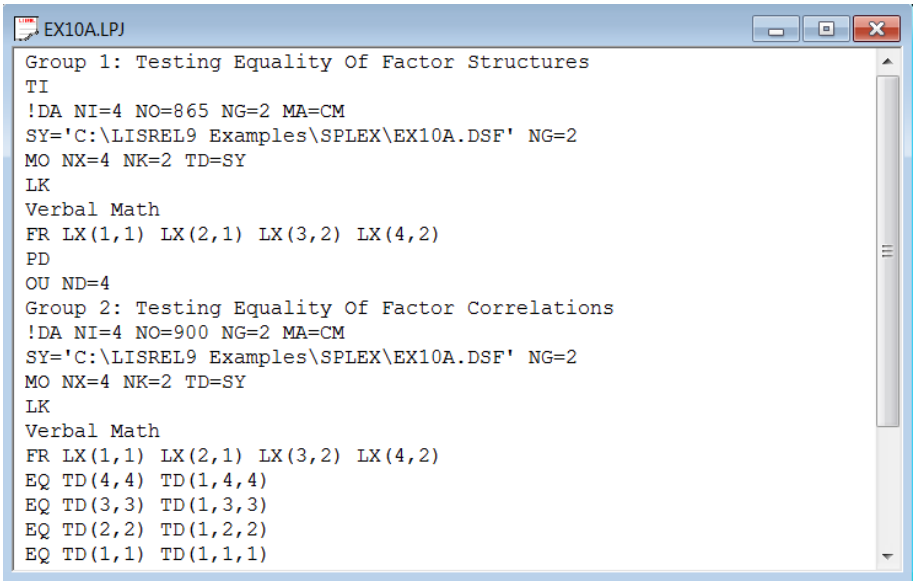
The SIMPLIS **Outputs** dialog box is shown below:



The LISREL syntax that corresponds to the SIMPLIS command language in **ex10a.spl** may be built from the path diagram. To do so, select the **Setup, Build LISREL Syntax** option as shown in the next image.

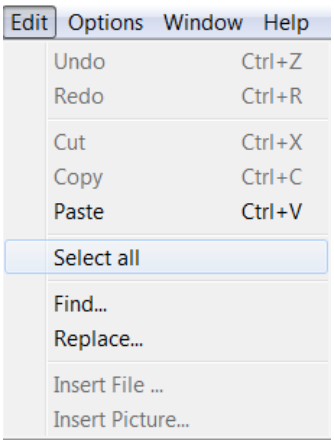


A LISREL project file (**ex10a.lpj**) is produced, containing the corresponding LISREL syntax, as shown below.



1.1 Changing the Appearance of the Output

While the output file is opened, one may use the **Edit** menu to perform various operations such as finding a keyword (**Find**), replacing text (**Replace**), inserting files (**Insert File**), etc.



When output is displayed, one may also use the **Options** menu to change the font type and size of the text.

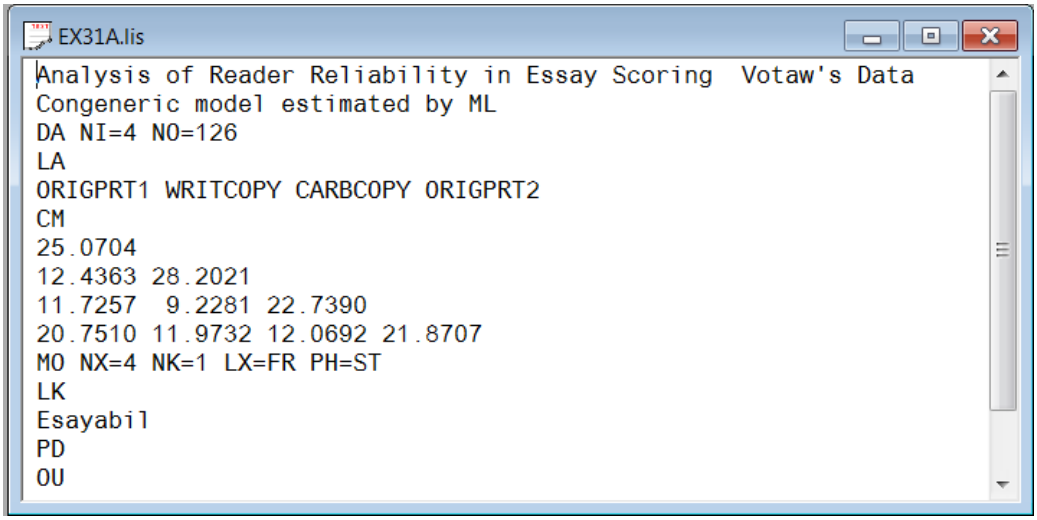
2 Using Existing LISREL Syntax Files

LISREL syntax examples not discussed in detail in this guide are contained in the **LISREL examples** folder, as shown in the table below. ***.prl** files are in the **PRELIS examples** folder.

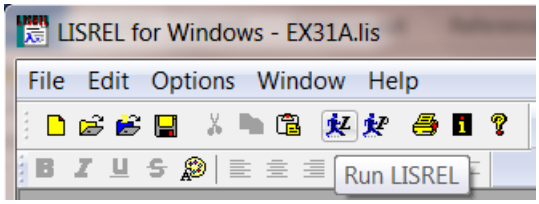
Example 1: Hypothetical model estimated by ML Data File: EX1.COV Input File: EX1.LIS	**Example 3.1: Analysis of reader reliability in essay scoring** Data File: None Input Files: EX31A.LIS, EX31B.LIS, EX31C.LIS
Example 3.2: Ability and aspiration Data File: None Input Files: EX32A.LIS, EX32B.LIS	**Example 3.3: Estimating the dis-attenuated correlation** Data File: EX33.COV Input File: EX33.LIS
Example 3.4: Nine Psychological Variables Data File: EX34.COR Input Files: EX34A.LIS, EX34B.LIS	**Example 4.1: Regression of GNP on economic factors** Data File: EX41.RAW Input File: EX41.LIS
Example 4.2: Stepwise regression Data File: EX42.COV Input File: EX42.LIS	**Example 4.3: ANOVA and ANCOVA** Data File: EX43.RAW Input Files: EX43A.LIS, EX43B.LIS, EX43C.LIS
Example 4.4: Bivariate regression Data File: EX44.RAW Input File: EX44.LIS	**Example 4.5: Ambition and attainment** Data File: None Input Files: EX45A.LIS, EX45B.LIS
Example 4.6: Klein's model I of US economy Data File: EX46.DAT Input Files: EX46A.LIS, EX46B.LIS, EX46C.LIS	**Example 5.1: Verbal ability in grades 4 and 5** Data File: EX51.COV Input File: EX51.LIS
Example 5.2: Role behavior of farm managers Data Files: EX52A.COV, EX52B.COV Input Files: EX52A.LIS, EX52B.LIS	**Example 5.3: Educational attainment** Data File: EX53.COR Input Files: EX53A.LIS, EX53B.LIS, EX53C.LIS
Example 5.4: Social status and social participation Data File: EX54.COR Input File: EX54.LIS	**Example 5.5: Peer influences on ambition** Data Files: EX55.LAB, EX55.COR Input Files: EX55A.LIS, EX55B.LIS

Example 5.6: Performance and satisfaction Data File: EX56.DAT Input File: EX56.LIS	Example 6.1: Three subtests of SAT **Data File: None** **Input File: EX61.LIS**
Example 6.2: Second-order factor analysis Data File: EX62.DAT Input File: EX62.LIS	**Example 6.3: The rod and frame test** Data File: EX63.COV Input File: EX63.LIS
Example 6.4: Stability of alienation Data File: EX64.COV Input Files: EX64A.LIS, EX64B.LIS, EX64C.LIS, EX64D.LIS	**Example 6.5: Change in verbal and quantitative ability between grades 7 and 9** Data File: EX65.DAT Input Files: EX65A.LIS, EX65B.LIS
Example 6.6: A simplex model for academic performance Data File: EX66.COR Input Files: EX66A.LIS, EX66B.LIS, EX66C.LIS, EX66D.LIS	Example 7.1: Attitudes of morality and equality Data Files: EX71.RAW, EX71.PML, EX71.ACP Input Files: EX71.PRL, EX71.LIS
Example 7.2: A panel model for political efficacy Data Files: PANEL.LAB, PANELUSA.RAW, PANELUSA.PME, PANELUSA.ACE, PANELUSA.ACP Input Files: EX72A.PRL, EX72B.PRL, EX72A.LIS, EX72B.LIS	**Example 7.3: Factor analysis of dichotomous variables** Data Files: LSAT6.DAT, EX73.PML, EX73.ACP Input Files: EX73.PRL, EX73.LIS
Example 7.4: Analysis of covariance matrices with WLS Data Files: EX74.RAW, EX74.CML, EX74.ACC Input Files: EX74.PRL, EX74.LIS	**Example 7.5: Estimating and testing a correlation structure** Data Files: EX75.KML, EX75.ACK Input File: EX75.LIS
Example 8.1: Gosta's bad sample Data Files: EX81.SIG, EX81.COV Input Files: EX81A.LIS, EX81B.LIS, EX81C.LIS, EX81D.LIS, EX81E.LIS	Example 8.2: Hypothesis testing and power calculation Data Files: EX82.COV, EX82.SIG Input Files: EX82A.LIS, EX82B.LIS, EX82C.LIS, EX82D.LIS
Example 9.1: Testing equality of factor structures Data File: EX91.DAT Input Files: EX91A.LIS, EX91B.LIS, EX91C.LIS, EX91D.LIS, EX91E.LIS	**Example 9.2: Testing equality of factor correlation matrices** Data File: EX92.COV Input File: EX92.LIS
Example 9.3: Son's and parents' reports of parental socioeconomic characteristics Data File: None Input File: EX93.LIS	**Example 9.4: Subjective and objective social class** Data File: EX94.DAT Input File: EX94.LIS
Example 10.1: Nine psychological variables with factor means Data File: EX101.DAT, EX101.LAB Input File: EX101.LIS	**Example 10.2: Head start summer program** Data File: EX102.DAT Input File: EX102.LIS
Example 10.3: Estimating a correlation from incomplete data Data File: EX103.DAT Input File: EX103.LIS	**Example 10.4: Berkeley guidance study** Data Files: GIRLS.COV, BOYS.COV, GIRLS.MEA, BOYS.MEA Input Files: EX104A.LIS, EX104B.LIS, EX104C.LIS

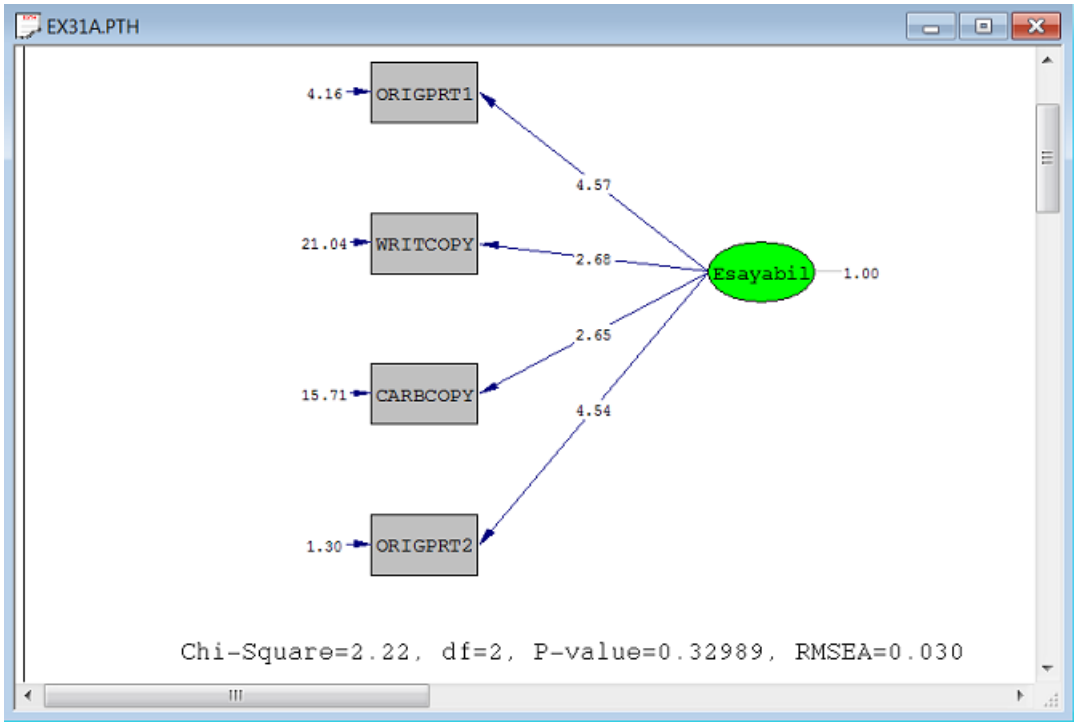
Select the **Open** option from the **File** menu to obtain the **Open** dialog box. Select (for example) the file **ex31a.lis**. Click **Open** when done. The contents of the file **ex31a.lis** are displayed.



To run LISREL, click the **Run LISREL** icon button. Make sure that the **Run LISREL** icon button is selected when running LISREL or SIMPLIS syntax and that the **Run** PRELIS icon button is selected when running PRELIS syntax.



To produce the path diagram shown below, the keyword PD (Path Diagram) was entered between the lines containing the words Esayabil and OU in **ex31a.lis**.



The file **ex31a.out** is also produced. This file may be viewed by either closing the path diagram window or by clicking on the output window, which is partially hidden behind the path diagram window.

2.1 Creating Syntax by Drawing Path Diagrams

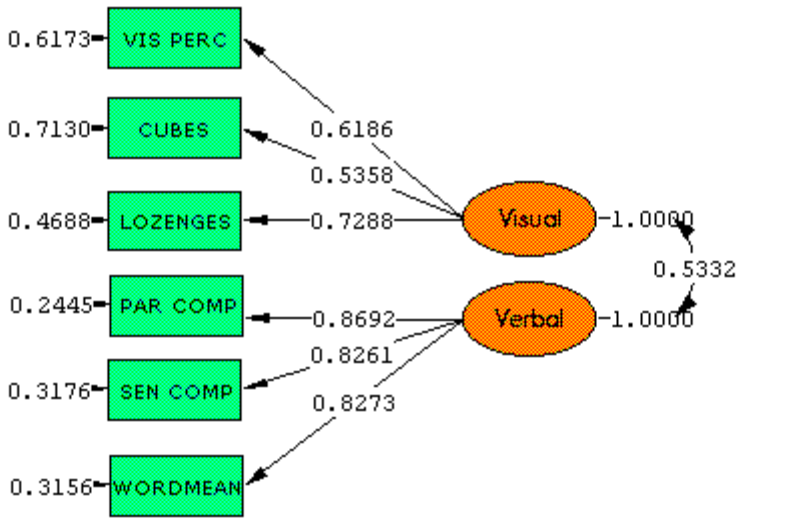
LISREL allows the user to create LISREL or SIMPLIS syntax by drawing the appropriate path diagram on the screen and then building the corresponding syntax directly from the path diagram. This procedure will be demonstrated by fitting a CFA (Confirmatory Factor Analysis) model to the data. To obtain correct standard errors of the estimators of the parameters, the CFA model should be fitted to the observed covariance matrix. However, in order to illustrate the various features of the program, the model will be fitted to the observed correlation matrix.

In confirmatory factor analysis, one builds a model assumed to describe or account for the empirical data in terms of relatively few parameters. The model is based on a priori information about the data structure in the form of a specified theory or hypothesis or knowledge from previous studies based on extensive data.

Holzinger & Swineford (1939) collected data on twenty-six psychological tests administered to 145 seventh- and eighth-grade children in the Grant-White school in Chicago. Six of these tests were selected and for this example it was hypothesized that these measure two common factors: visual perception and verbal ability such that the first three variables measure visual perception and the last three measure verbal ability. The six selected variables and their intercorrelations are given below:

VIS PERC	1.000					
CUBES	0.318	1.000				
LOZENGES	0.436	0.419	1.000			
PAR COMP	0.335	0.234	0.323	1.000		
SEN COMP	0.304	0.157	0.283	0.722	1.000	
WORDMEAN	0.326	0.195	0.350	0.714	0.685	1.000

The path diagram for this model is given below:



Chi-Square=4.37, df=8, P-value=0.82193, RMSEA=0.000

The corresponding SIMPLIS syntax file is:

```
Six Psychological Variables-A Confirmatory Factor Analysis
Observed variables
'VIS PERC' CUBES LOZENGES 'PAR COMP' 'SEN COMP' WORDMEAN
```

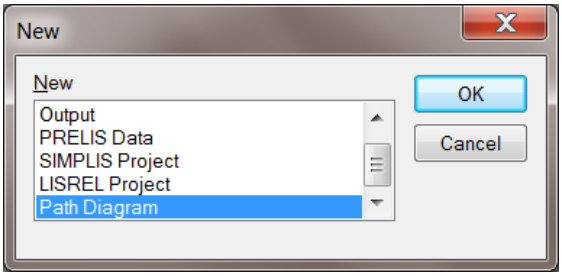
```
Correlation Matrix From File EX5.COR
Sample Size: 145
Latent Variables: Visual Verbal
Relationships:
'VIS PERC' - LOZENGES = Visual
'PAR COMP' - WORDMEAN = Verbal
Number of decimals = 4
Print Residuals
End of Problem
```

Some important aspects contained in the SIMPLIS syntax file given above are

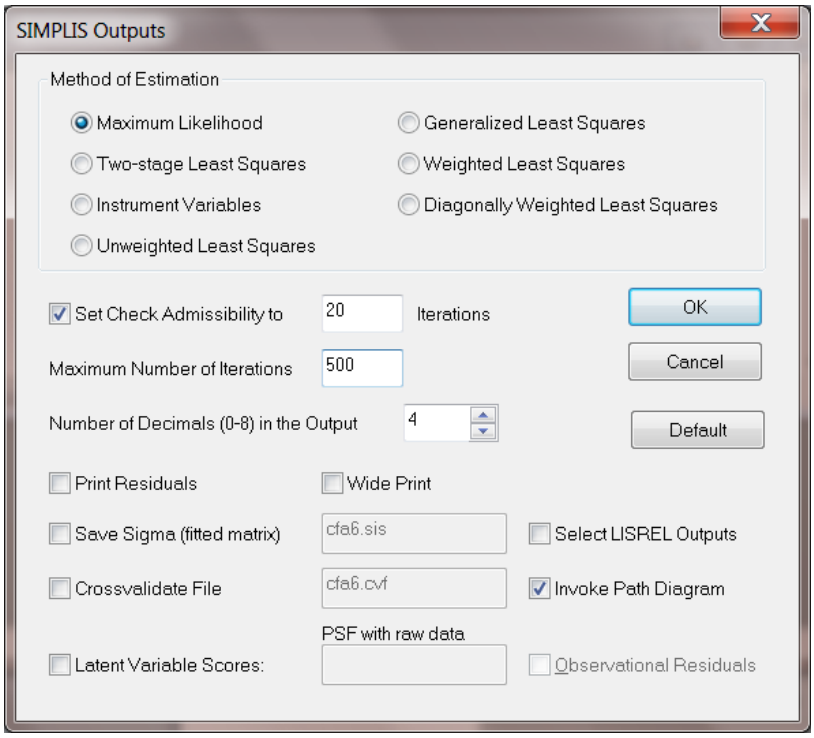
- The correlation matrix is read from an external file
- There are two latent variables in the model: Visual and Verbal
- The statement Number of decimals = 4 specifies that we wish to have the results in the output file given to an accuracy of four decimals. LISREL uses two decimals by default.

2.2 Title, Labels and Data

Select the **File, New** option and click on **Path Diagram**. In the **Save As** dialog box, select a filename and a folder in which the path diagram should be saved. For the present example the folder chosen is **splex** and the file name selected is **cfa6.pth**. When done, click **Save**.

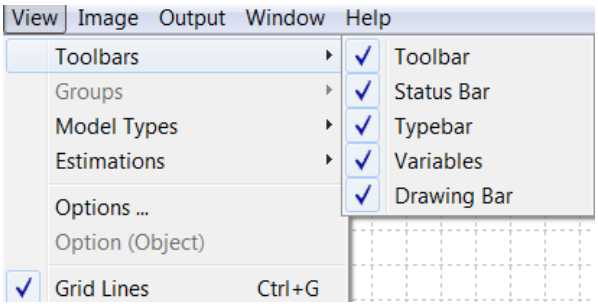


From the **Output** menu select **SIMPLIS Outputs**. The dialog box below will appear.

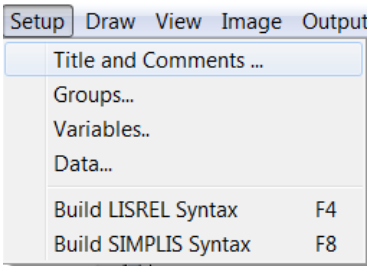


Customize this dialog box according to your preferences. For example, change the **Number of Decimals in the Output** option to 4. Make sure that the **Invoke Path Diagram** check box (the default) is checked. When done, click **OK**.

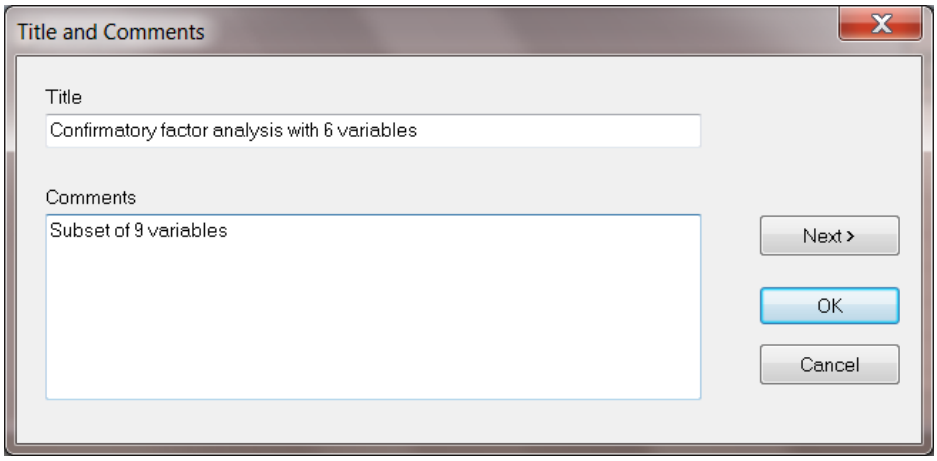
Before drawing the path diagram, select **Toolbars** from the **View** menu and ensure that the items shown below are selected. These are: **Toolbar, Status Bar, Typebar, Variables, Drawing Bar**. Also check the **Grid Lines** option.



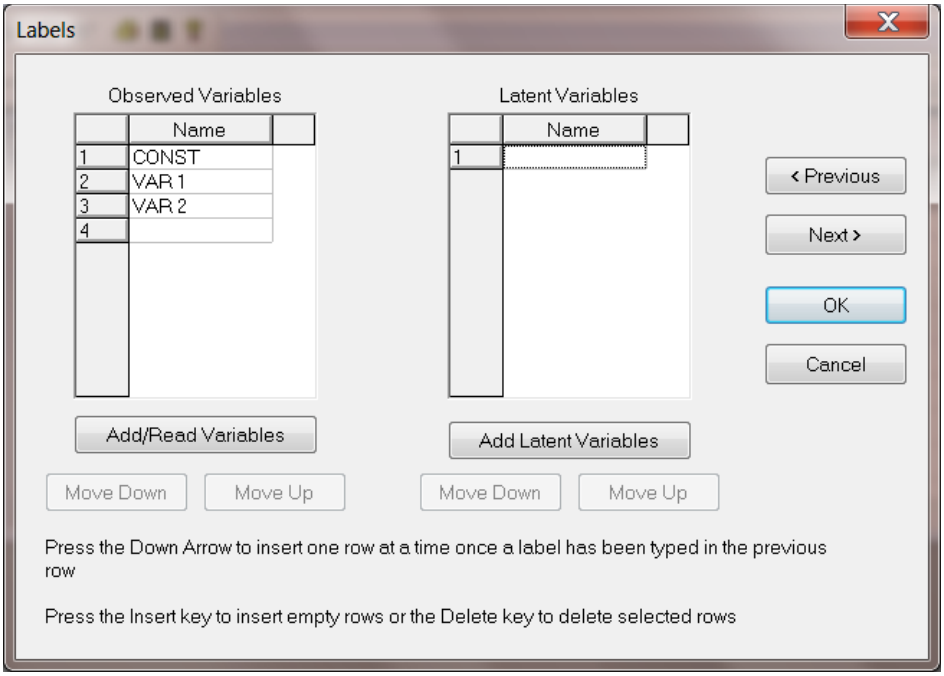
Select the **Title and Comments** option from the **Setup** menu to obtain the **Title and Comments** dialog box.



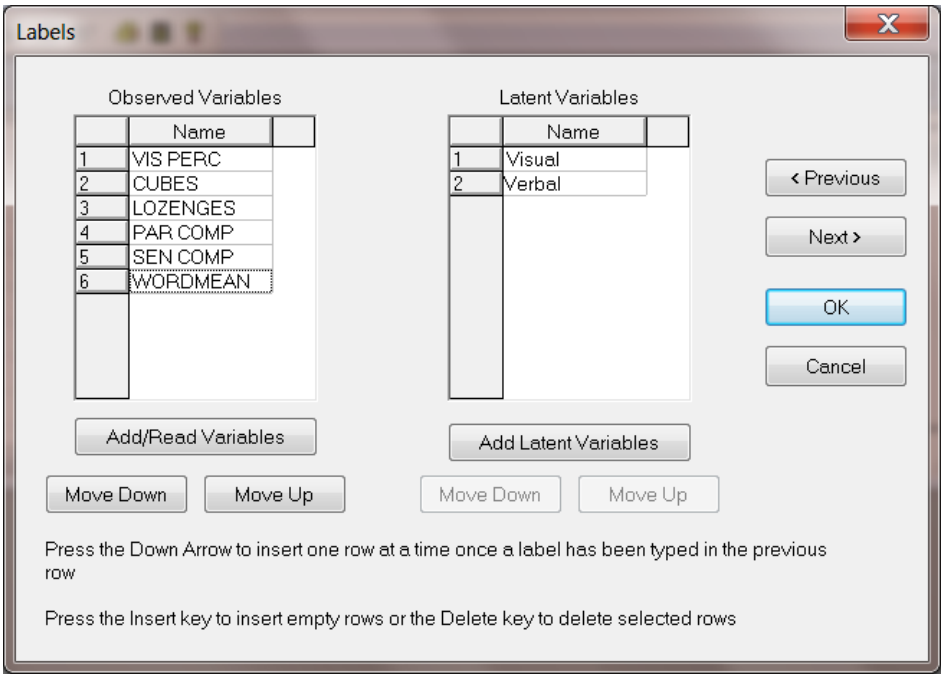
The first item on the **Title and Comments** dialog box is the **Title** for the analysis. Provision is also made for any additional **Comments** that the user may wish to enter. After typing in the title and (optionally) the comments, click on **Next** to go to the **Group Names** dialog box.



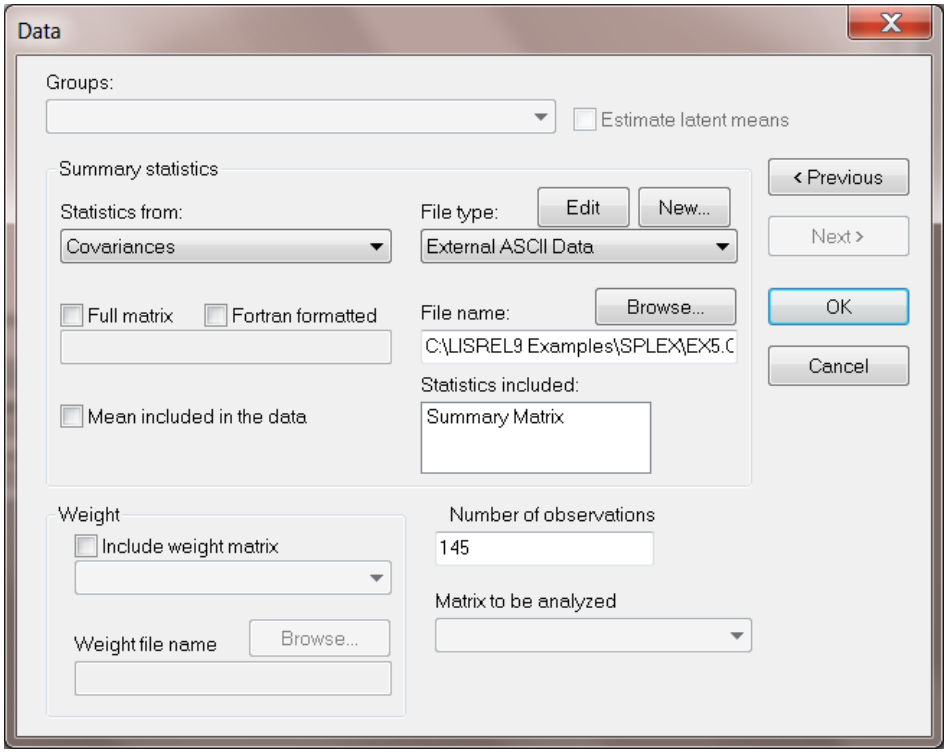
Since the present example is based on the analysis of one correlation matrix, nothing is entered in the space allowed for **Group Labels** and **Next** is clicked to go to the **Labels** dialog box. The default number of variables shown on the **Labels** dialog box is 3, these being CONST, VAR 1 and VAR 2. Click in the CONST textbox and change the name to VIS PERC. Enter the label CUBES in the VAR 1 textbox and LOZENGES in the VAR 2 text box. Move the mouse cursor into the LOZENGES textbox and use the down arrow to create a fourth text box. Type in PAR COMP and repeat the procedure for SEN COMP and WORMEAN.



In a similar manner, use the down arrow key to create text boxes in the **Latent Variables** column and enter the names Visual and Verbal.



When done with the assignment of names, click the **Next** button to go to the **Data** dialog box.



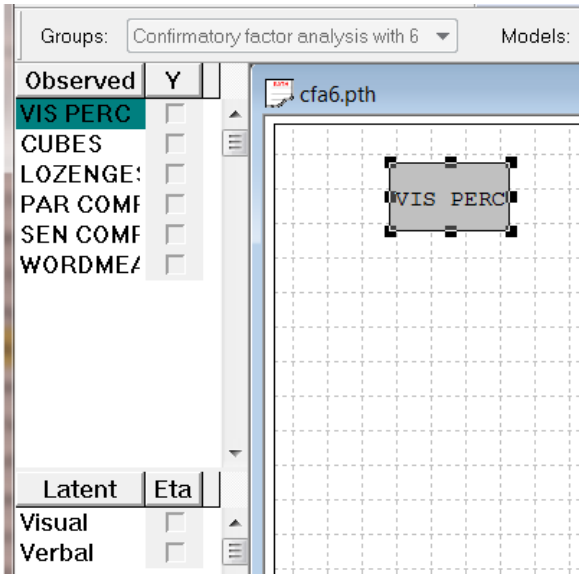
Select **Correlations** from the **Statistics from:** drop-down list box and also **Correlations** from the **Matrix to be analyzed** drop-down list box. In the **Number of Observations** string field type 145. For **File type**, select **External ASCII Data** and use the **Browse** button to locate **exs.cor** in the **SIMPLIS examples** folder. Click **OK** when done.

2.3 Drawing the Path Diagram

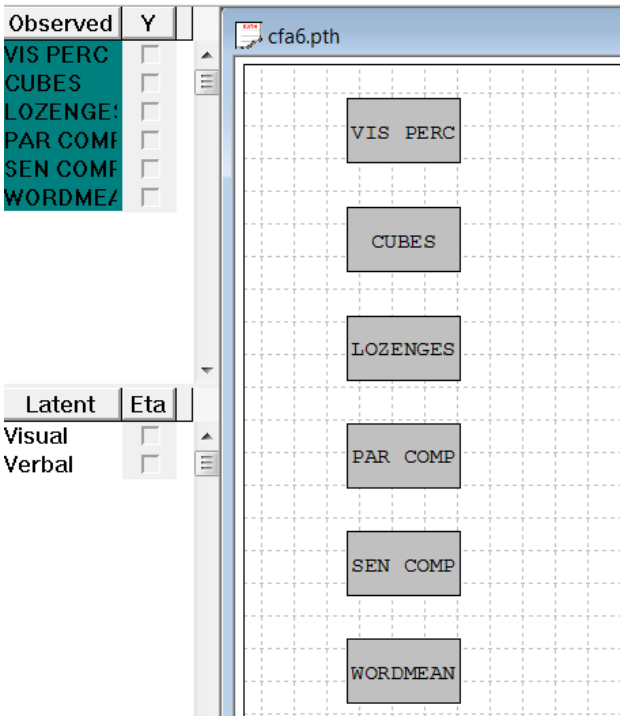
We now proceed with the actual drawing of the path diagram. Start by clicking on the VIS PERC label under the **Observed** variables portion of the **Labels** window. Hold the mouse button down and "drag" the label to the draw area indicated by the grid lines. A rectangular-shaped object will appear on this part of the screen when the mouse button is released as shown below. Note also that

- The observed variables are assumed to be X (or independent) variables unless appropriate squares under the **Y**-column are clicked.

- The latent variables are assumed to be KSI (or independent) variables unless appropriate squares under the **Eta**-column are clicked.



Repeat the same procedure for each of the remaining 5 variables by clicking on a label (left mouse button) and dragging the object to the draw area on the screen. The result of these operations should look similar to the image given below:

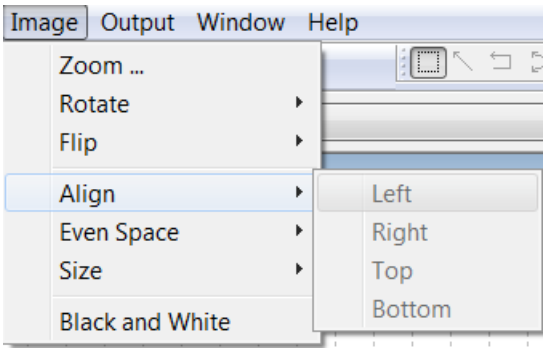


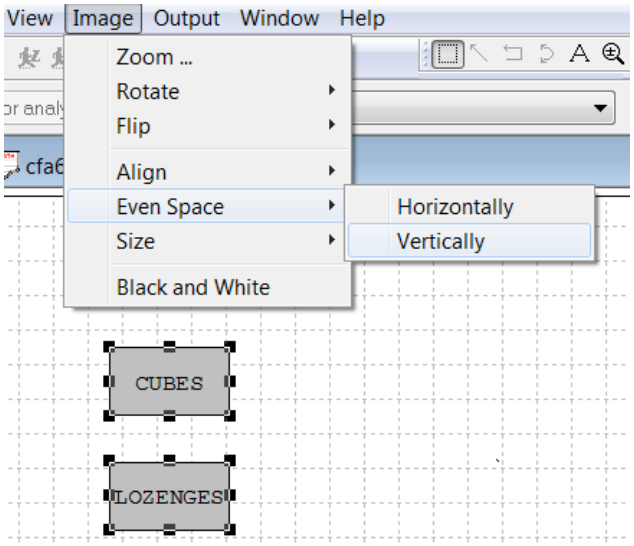
The rectangles representing the six observed variables can be properly aligned by going through the following steps:

- Choose **Select all** from the **Edit** menu or draw a rectangle with the mouse pointer around all the objects to be included.

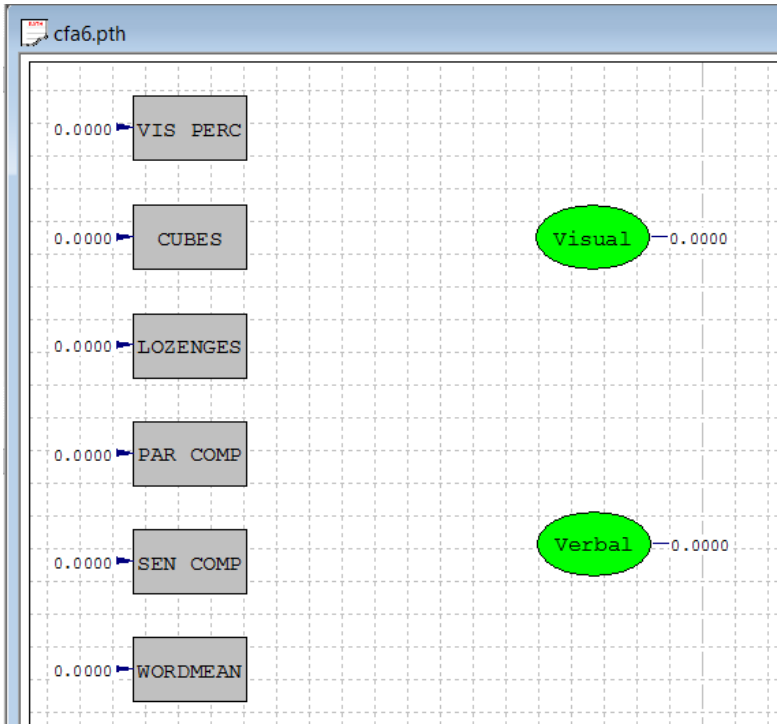
- Move the mouse pointer to the vicinity of the selected objects and click the right mouse button. The menu shown below will appear on the draw part of the screen.

- Select the **Align>Left** option. Once this is done, select the **Even Space** > **Vertically** option. One can, alternatively, use the **Align** option on the **Image** menu to achieve this.

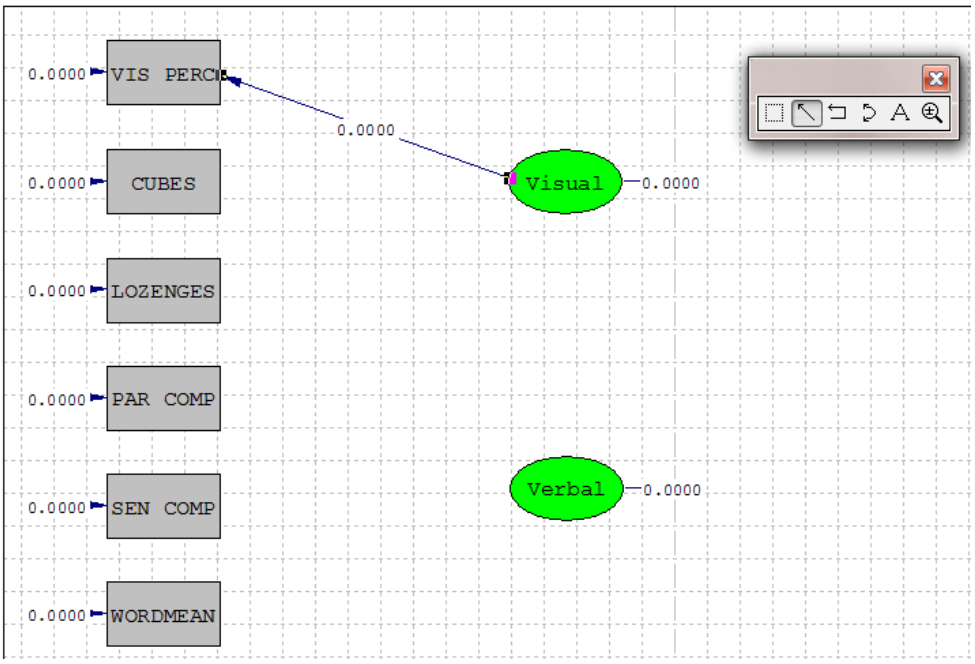




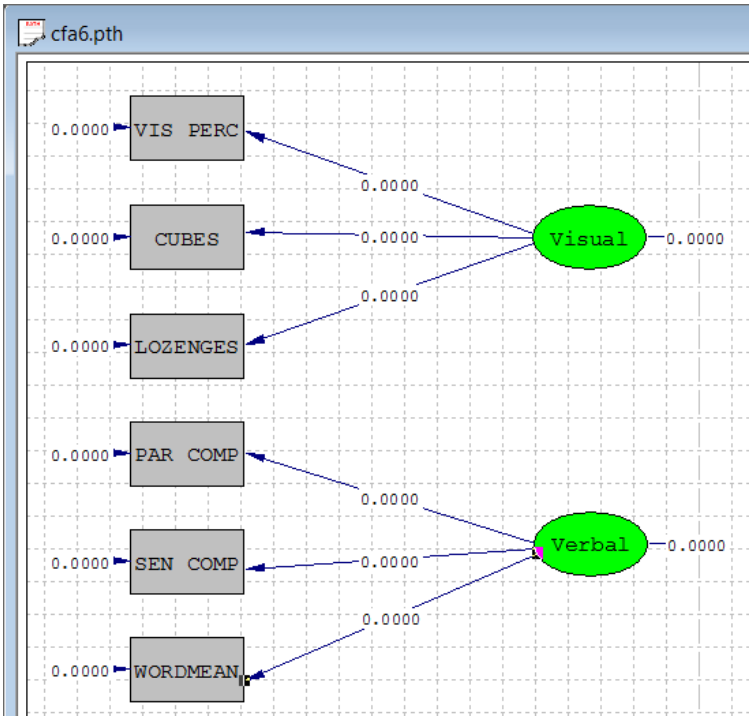
The rectangular objects will now be aligned and one can proceed by dragging the latent variables, Visual and Verbal to the path diagram window. Note that latent variables are represented by elliptically shaped objects.



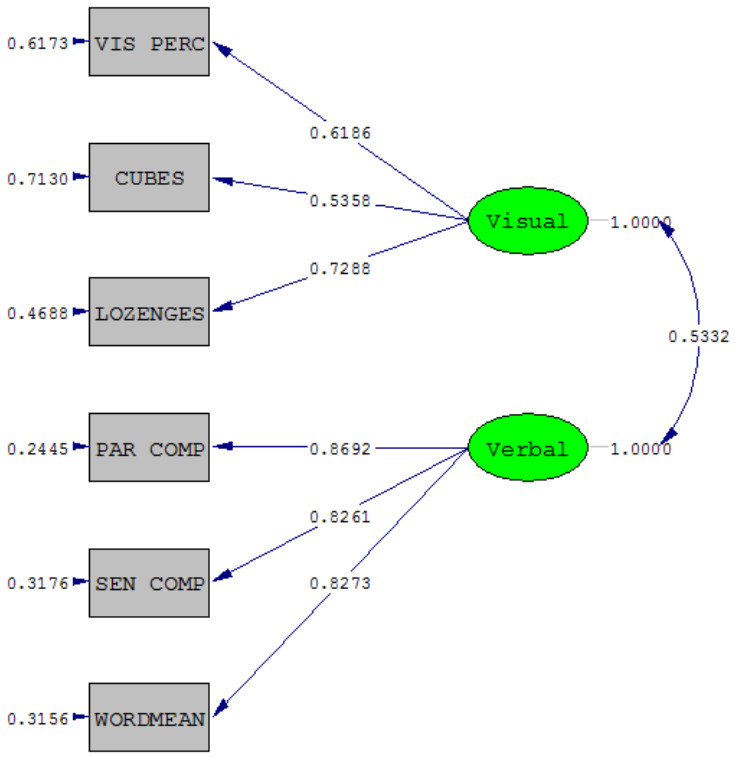
Finally, arrows can be drawn pointing from the latent variables to the observed variables. To accomplish this, click on the single-headed arrow of the **Draw** toolbar (seen on the right of the picture given below) and move the mouse pointer to within one of the elliptically shaped objects. With the left mouse button held down, drag the arrow to within a rectangular-shaped object. Release the mouse button when the colors of both objects change. Note that the **Draw** menu on the main menu bar can also be used when drawing path diagrams. Related draw tool options are contained in this menu.



Proceed in a similar fashion to graphically display the relationships between the observed and latent variables as shown on the next image.

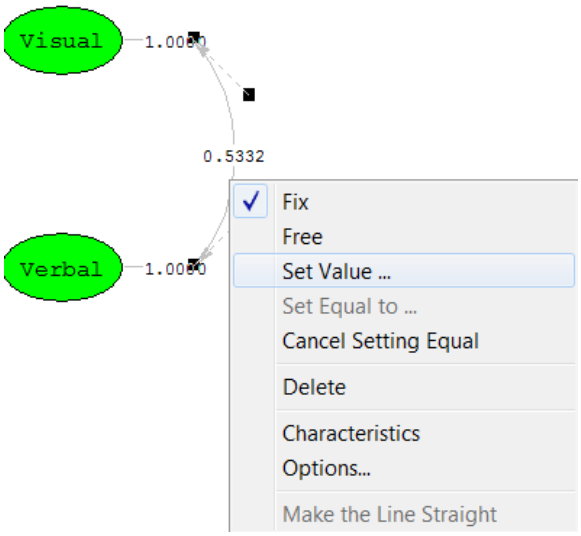


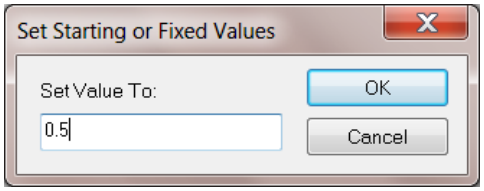
Select the **Build SIMPLIS Syntax** option from the **Setup** menu. SIMPLIS syntax (not shown below) will be built from the path diagram and is stored in a system file named **cfa6.spj**. Click the **Run LISREL** icon button to fit the CFA model to the data. Parameter estimates are shown on the path diagram given below.



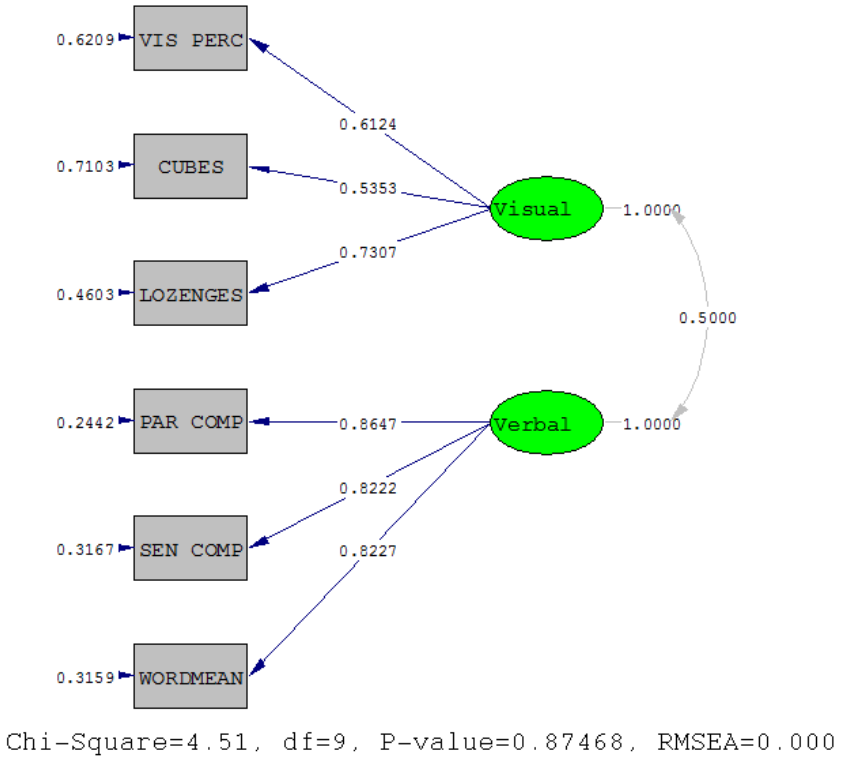
Chi-Square=4.42, df=8, P-value=0.81716, RMSEA=0.000

By modifying the path diagram, model specifications may be changed. The covariance between Visual and Verbal may, for example, be fixed at a value of 0.5 by clicking (right mouse button) on the two-headed arrow representing this covariance. This will enable the pop-up menu shown below. Select the **Fix** option using the left mouse button. Once done, select the **Set Value…** option.





Click the **Run LISREL** icon button to fit the revised CFA model to the data. The path diagram, χ^2-fit statistic and RMSEA are shown below.



3 Multi-Sample Analyses Using Path Diagrams

In the previous sections we showed how LISREL models may be specified and estimated by drawing the appropriate path diagram from which the SIMPLIS or LISREL syntax is created. The examples used were based on data from a single sample. The path diagram can, however, also be used to create syntax for models based on data from several samples simultaneously, according to a multiple-group LISREL model with some or all parameters constrained to be equal over groups.

Consider a set of G mutually exclusive groups of individuals. It is assumed that a number of variables have been measured on a number of individuals from each of these populations. This approach is particularly useful in comparing a number of treatment and control groups regardless of whether individuals have been assigned to the groups randomly or not.

Any LISREL model may be specified and fitted for each group of data. However, LISREL assumes by default that the models are identical over groups, i.e., all relationships and all parameters are the same in each group. Thus, only differences between groups need to be specified.

3.1 Testing Equality of Factor Structures

Table 1 below gives sample covariance matrices for two samples (N_1 = 865, N_2 = 900, respectively) of candidates who took the Scholastic Aptitude Test in January 1971. The four measures are, in order, VERBAL40, a 40-item verbal aptitude section, VERBAL50, a separately timed 50-item verbal aptitude section, MATH35, a 35-item math aptitude section, and MATH25, a separately timed 25-item math aptitude section.

Table 1: Covariance Matrices for SAT Verbal and Math Sections

Covariance Matrix for Group 1

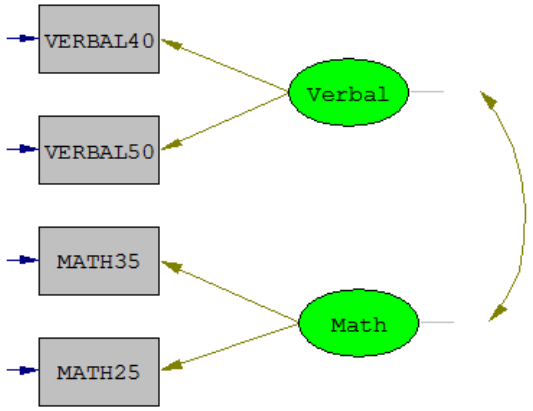
Tests	VERBAL40	VERBAL50	MATH35	MATH25
VERBAL40	63.382			
VERBAL50	70.984	110.237		
MATH35	41.710	52.747	60.584	
MATH25	30.218	37.489	36.392	32.295

Covariance Matrix for Group 2

	VERBAL40	VERBAL50	MATH35	MATH25
Tests				
VERBAL40	67.898			
VERBAL50	72.301	107.330		
MATH35	40.549	55.347	63.203	
MATH25	28.976	38.896	39.261	35.403

The data are used here to illustrate how one can test equality of factor loadings and factor correlations in a confirmatory factor analysis model, while allowing the error variances to be different.

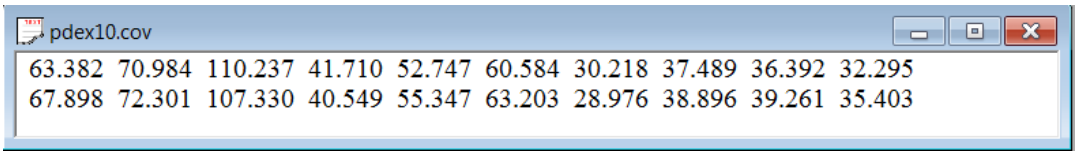
We regard VERBAL40 and VERBAL50 as indicators of a latent variable Verbal and MATH35 and MATH25 as indicators of a latent variable Math. The model we consider is shown in the figure below.



There are three sets of parameters in the model:

- the four factor loadings corresponding to the paths from Verbal and Math to the observed variables,
- the correlation between Verbal and Math, and
- the four error variances of the observed variables.

We begin by constructing a data file **pdex10.cov** containing the two covariance matrices. In free format, each covariance matrix can be written on one line.



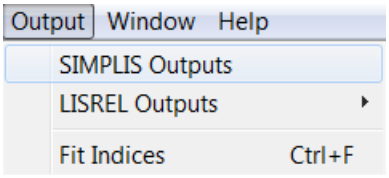
We assume that all parameters are the same in both groups. The syntax file **pdex10a.spl** is:

```
Group 1: Testing Equality Of Factor Structures Model A: Factor Loadings, Factor Correlation, Error Variances Invariant
Observed Variables: VERBAL40 VERBAL50 MATH35 MATH25
Covariance Matrix from File PDEX10.COV
Sample Size = 865
Latent Variables: Verbal Math
Relationships: VERBAL40 VERBAL50 = Verbal
MATH35 MATH25 = Math
Group 2: Testing Equality Of Factor Structures
Covariance Matrix from File PDEX10.COV
Sample Size = 900
Set the error variances of VERBAL40-MATH25 free
End of Problem
```

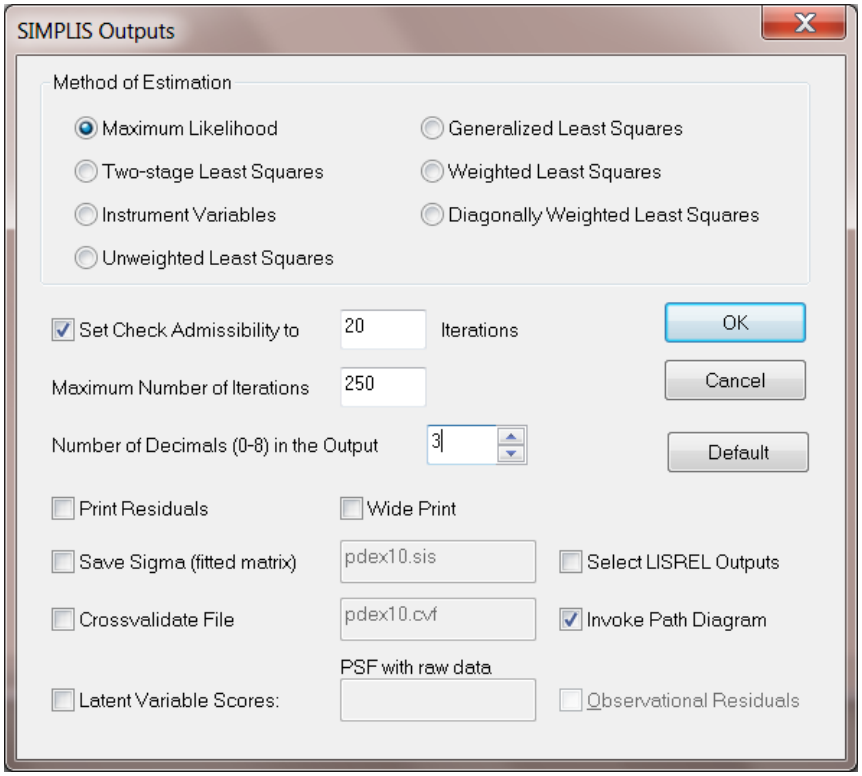
In the syntax above, the data in the covariance matrices and the sample sizes are different. The names of the variables, observed as well as latent, are the same, and the model is the same.

Select the **New** option from the **File** menu and select **Path Diagram** in the **New** dialog box. Click **OK** when done. Enter the name **pdex10.pth**. When done, click **Save**.

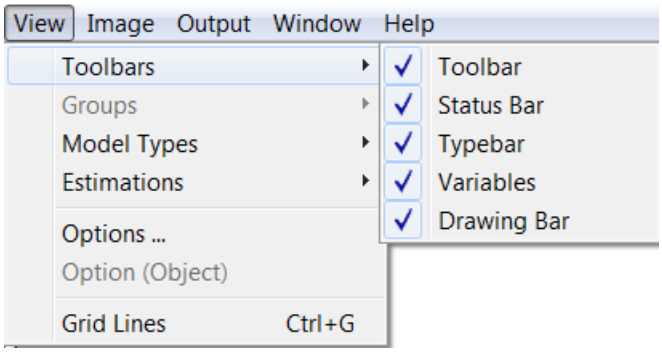
It is possible to control specific SIMPLIS default features such as **Maximum Number of Iterations** or **Method of Estimation**. From the **Output** menu, select **SIMPLIS Outputs**.



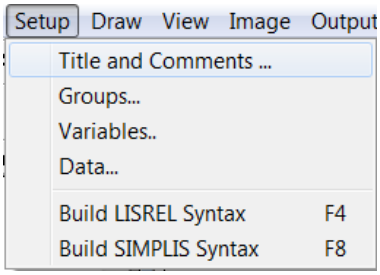
The **SIMPLIS Outputs** dialog box will appear. Customize this dialog box according to your preferences, for example, by changing the **Number of Decimals in the Output** option to 4 and by making sure that the **Invoke path diagram** option is selected. Click **OK** when done.



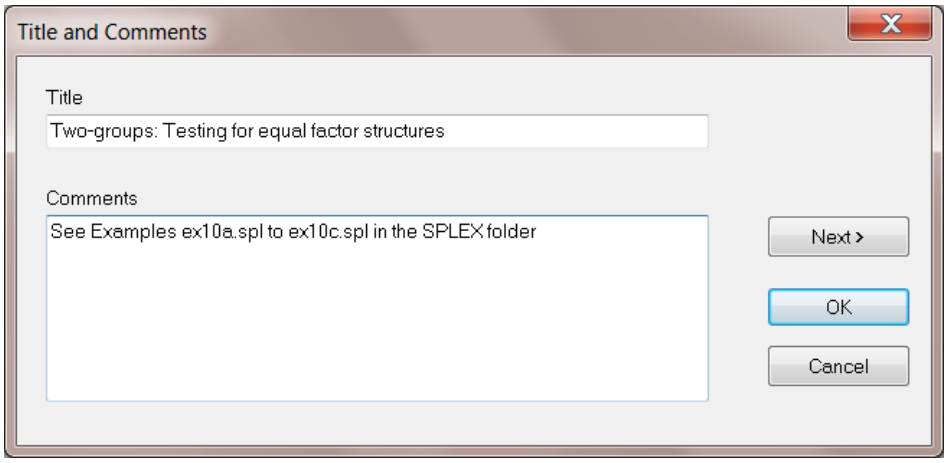
Before drawing the path diagram, select **Toolbars** from the **View** menu and ensure that the items shown below are selected. These are: **Toolbar**, **Status Bar**, **Typebar**, **Variables**, **Drawing Bar**. Optionally, check the **Grid Lines** option.



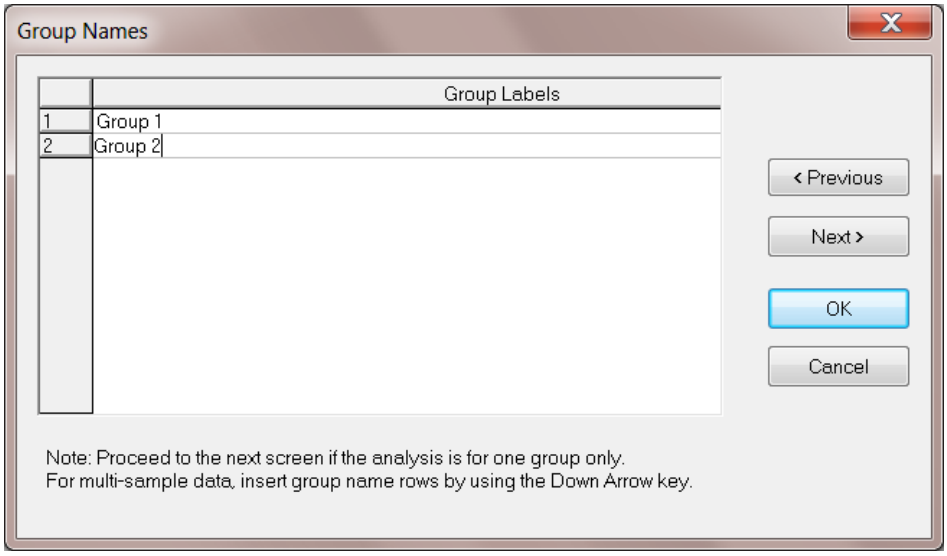
Select the **Title and Comments** option from the **Setup** menu to obtain the **Titles and Comments** dialog box.



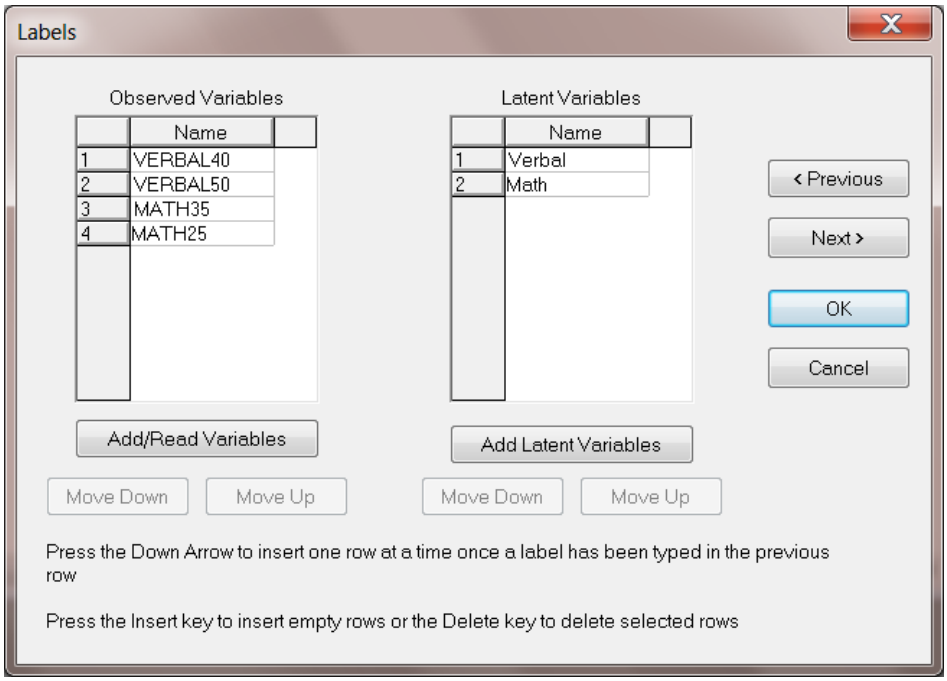
The first item on the **Setup** dialog box is the **Title** for the problem. Provision is also made for any additional **Comments** that the user may wish to enter. After typing in the title and (optionally) the comments, click **Next** to go to the **Group Names** dialog box.



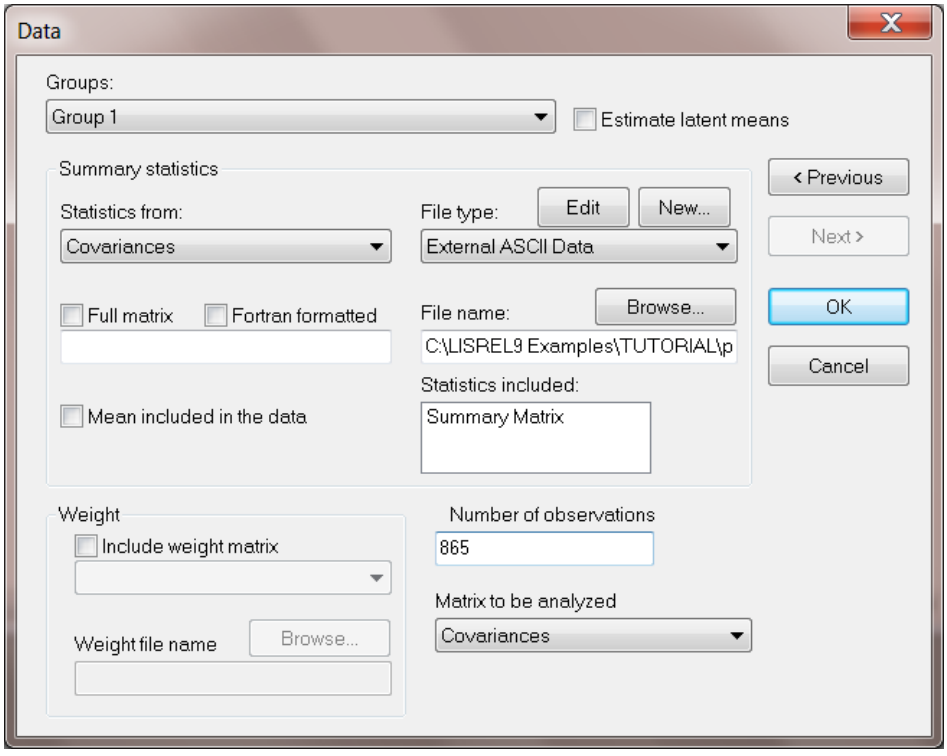
Next we enter a description for each group. Group labels can be inserted by clicking on the first string field, entering the label for the first group and then using the down arrow on the computer keyboard to create the next group's string field. When done, click **Next** to go to the **Labels** dialog box.



The default number of variables shown on the **Labels** dialog box is 3, these being CONST, VAR 1 and VAR 2. Move the mouse pointer to the **Observed Variables** box and click in the string field of CONST. Rename this variable to VERBAL40. Press the "down arrow" on the keyboard to move to the second observed variable string field and enter the label VERBAL50. Proceed in a similar way to enter the labels MATH35, MATH 25 and the labels Verbal and Math for the latent variables. Click **Next** when done to go to the **Data** dialog box.



From the **Data** dialog box, select **Covariances** from the **Statistics from:** drop-down list box and also **Covariances** from the **Matrix to be analyzed** drop-down list box. Enter 865 in the **Number of Observations** string field. For **File type** select **External ASCII Data.**



Click the **Browse** button to select the path and name of the file that contains the values of the covariance matrices of the 2 groups. For the present example, the file is **pdex10.cov**, which was created earlier in this section. Click **Open** when done.

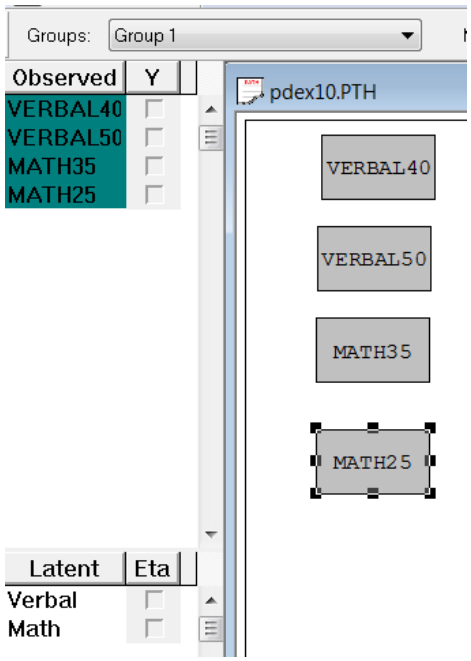
From the **Data** dialog box, select the second group from the **Groups:** drop-down list box. Proceed as outlined above to enter the number of observations (900), file type and matrix to be analyzed.

3.2 Drawing the Path Diagram

We now proceed with the actual drawing of the path diagram. Start by clicking on the VERBAL40 label under the **Observed** variables portion of the **Variables** window. Hold the mouse button down and drag the label to the draw area. A rectangular-shaped object will appear on this part of the screen when the mouse button is released as shown below. Repeat this procedure until all observed variables are dragged to the drawing area as shown in the next image.

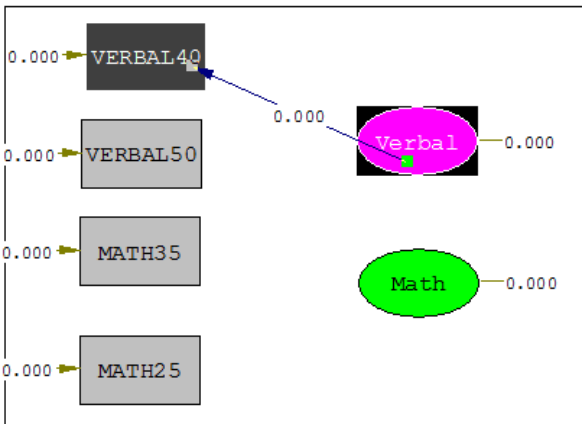
Note also that:

- The observed variables are assumed to be X (or independent) variables unless appropriate check boxes under the **Y**-column are checked.
- The latent variables are assumed to be Ksi (or independent) variables unless appropriate check boxes under the **Eta**-column are checked.

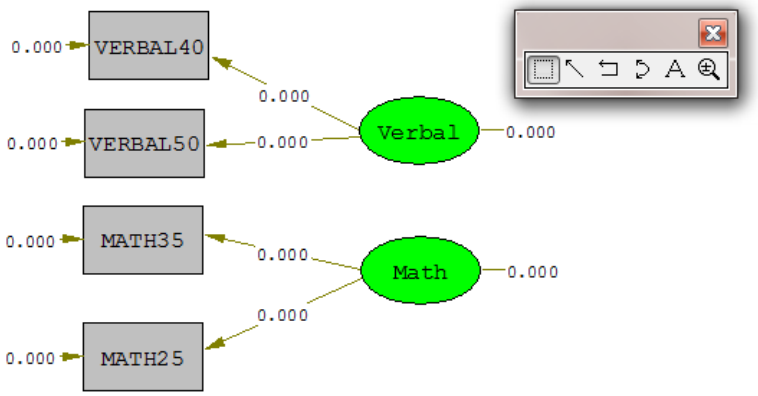


Proceed by dragging the latent variables, Verbal and Math, to the draw area of the path window. Note that the latent variables are represented by elliptically shaped objects.
Finally, arrows can be drawn pointing from the latent variables to the observed variables. To accomplish this, click on the single-headed arrow of the **Draw** toolbar (seen on the right of the picture given below). As an alternative, use the **Draw** menu on the main menu bar. The related drawing tool options may be selected from this menu.

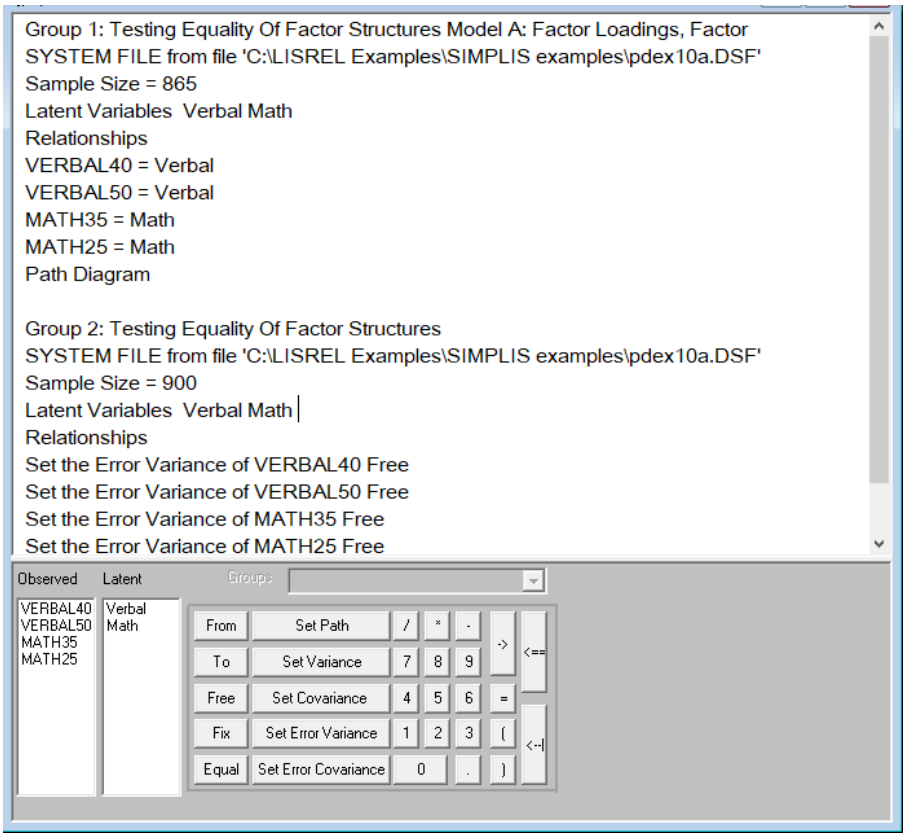
Once the single-headed arrow (or **One-way Path** option) has been selected, move the mouse pointer to within one of the elliptically shaped objects. With the left mouse button held down, "drag" the arrow to within a rectangular-shaped object. When the colors of both objects change (see diagram below) release the mouse button.



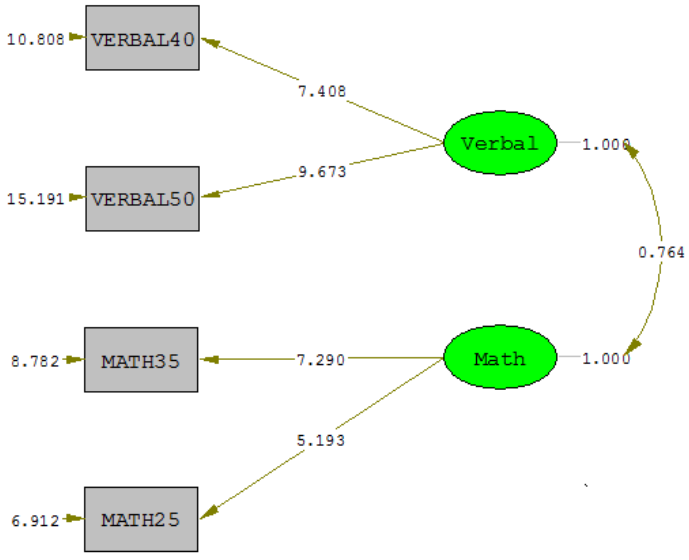
Proceed in a similar way to graphically display the relationships between the observed and latent variables:



Select **Build SIMPLIS Syntax** from the **Setup** menu. SIMPLIS syntax will be built from the path diagram and is stored in a system file named **pdex10.spj** shown below.



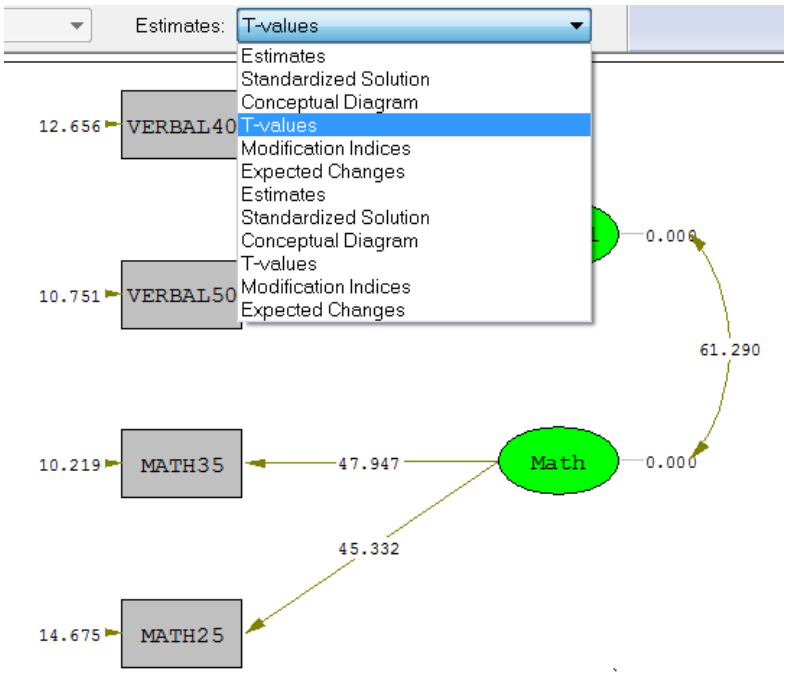
Click the **Run LISREL** icon button to fit the multi-sample model to the data. The parameter estimates and χ^2 goodness-of-fit index are shown on the path diagram displayed below:



Chi-Square=33.78, df=11, P-value=0.00039, RMSEA=0.048

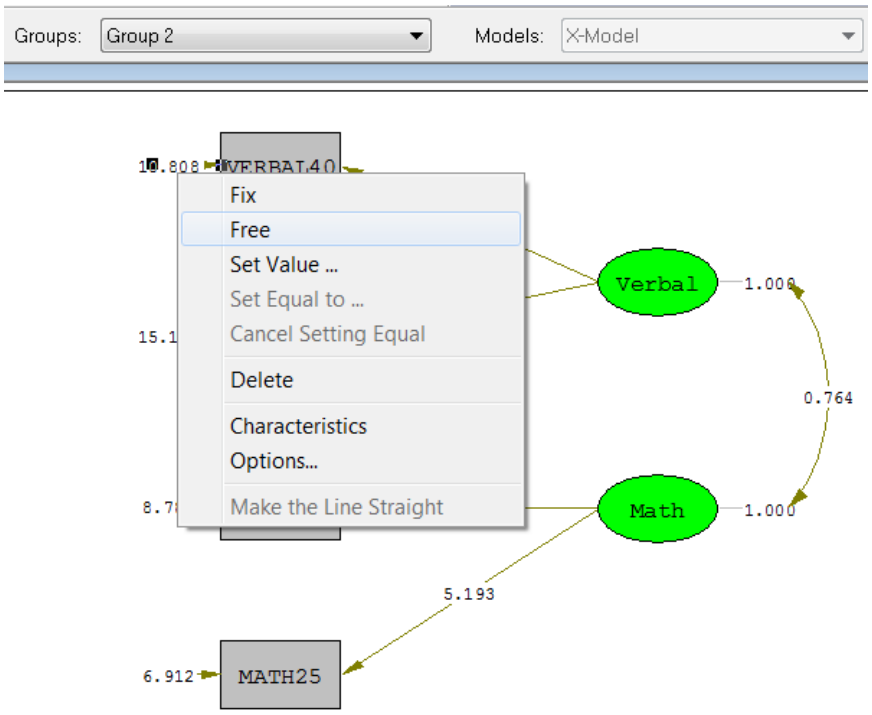
The values shown on the path diagram are the parameter estimates. This is the default selection. It is, however, also possible to view the t-values, modification indices or expected changes by selecting the **View** menu on the main menu bar. Alternatively, use the drop-down list by clicking in the **Estimates:** pane as shown below. To

view t-values, select the **T-values** option. The figure below shows how this is done and also indicates the t-values on the path diagram.



To view the corresponding t-values for the second group, select group 2 on the menu bar. The resultant changes in the path diagram are shown in the next image.

In the example above, the error variances, factor loadings and factor covariance are constrained to be equal (invariant) across the two groups. To test for invariance of factor loadings and covariance only, the error variances can be freed as follows. Make sure that the path diagram is displayed, and then select Group 2 from the **Groups:** text box. Right-click in the error variance of VERBAL40 and click the **Free** option. Repeat this procedure for the remaining three error variances, and then select the **Setup, Build SIMPLIS Syntax** option.



The actions described above result in a new SIMPLIS project file that contains the syntax required to free the error variances across groups.

When done, click the **Run LISREL** icon. The output file reveals two solutions, one for each group. The value of χ^2 is reported only after the second group.

In a multi-sample analysis, the χ^2 is a measure of fit of all models in all groups, and, in general, this χ^2 cannot be decomposed into a χ^2 for each group separately. For our example, χ^2 is 10.87 with 7 degrees of freedom (p = 0.14), so that the model does fit the data.

4 Analysis of Ordinal Data using an asymptotic covariance matrix.

Aish and Jöreskog (1990) analyzed data on political attitudes. Their data consist of six ordinal variables measured on the same people at two occasions. Labels assigned to the 12 variables are as follows: NOSAY1, VOTING1, COMPLEX1, NOCARE1, TOUCH1, INTERES1 (first occasion) and NOSAY2, VOTING2, COMPLEX2, NOCARE2, TOUCH2 and INTERES2 (second occasion). These data are saved in the LISREL system data file **panelusa.lsf**.

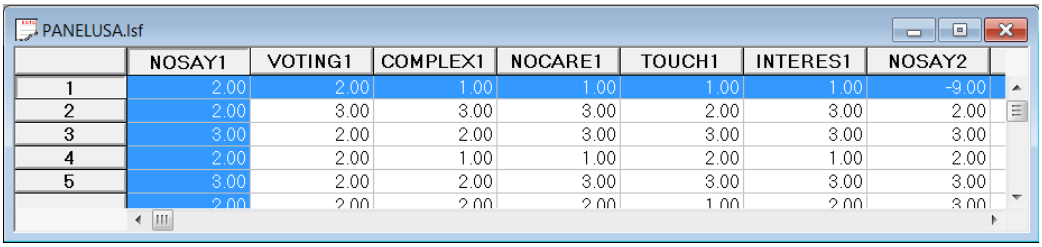
In this example, the following concepts are illustrated:

- calculation of polychoric correlations and asymptotic covariances
- drawing a path diagram for a given model
- creation of variable names for the path diagram
- creating LISREL and or SIMPLIS syntax from the path diagram
- the basic model and its components
- estimation types and the conceptual path diagram

- saving the path diagram in graphics format.

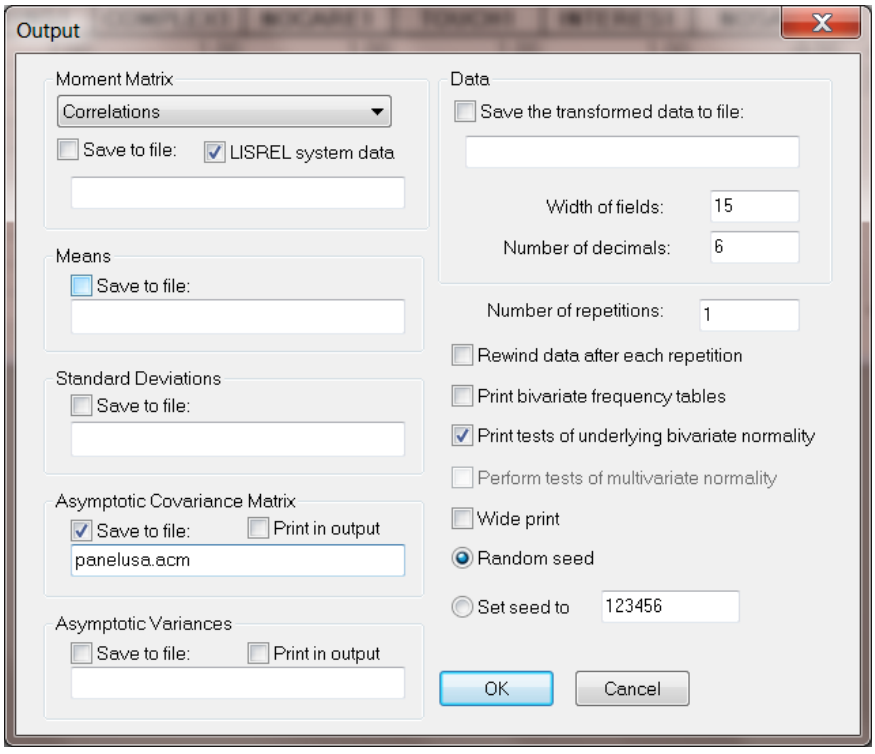
4.1 Calculation of Correlations and Asymptotic Covariance Matrix

Select the **Open** option from the **File** menu to obtain the **Open** dialog box. Select LISREL **Data** (*.**lsf**) from the **Files of type:** drop-down list box. Select **panelusa.lsf** and click **Open** when done. The PRELIS system file (*.**lsf)** is displayed in the form of a spreadsheet as shown below:

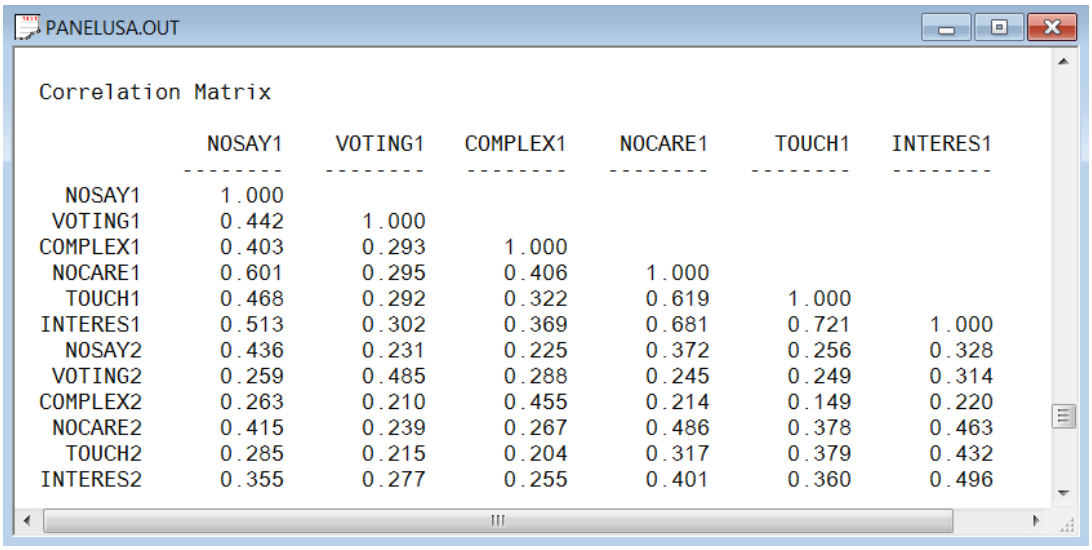


	NOSAY1	VOTING1	COMPLEX1	NOCARE1	TOUCH1	INTERES1	NOSAY2
1	2.00	2.00	1.00	1.00	1.00	1.00	-9.00
2	2.00	3.00	3.00	3.00	2.00	3.00	2.00
3	3.00	2.00	2.00	3.00	3.00	3.00	3.00
4	2.00	2.00	1.00	1.00	2.00	1.00	2.00
5	3.00	2.00	2.00	3.00	3.00	3.00	3.00

Select **Output Options** from the **Statistics** menu to obtain the **Output** dialog box. The **Output Options** dialog box allows the user to save various matrices as well as the raw data as files. Select **Correlations** (to be saved as a LISREL System File (also referred to as a LISREL summary data file) with extension *.**dsf**) from the **Moment Matrix** drop-down list box. Check the LISREL **System Data** check box. Also check the **Save to File** check box below **Asymptotic Covariance Matrix** and enter the name **panelusa.acm** in the string field. With the required selections made, click **OK** to run PRELIS. Note that PRELIS computes polychoric correlations for all variables that are defined as ordinal, provided that the number of distinct values of the variables is less than 15.



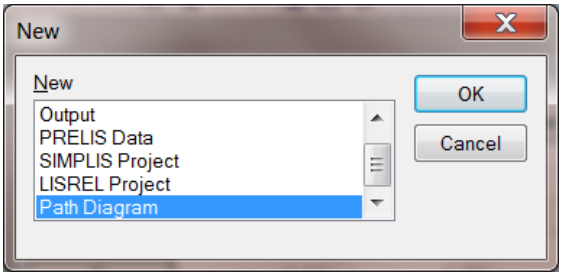
A portion of the PRELIS output is given below:



4.2 Drawing a Path Diagram

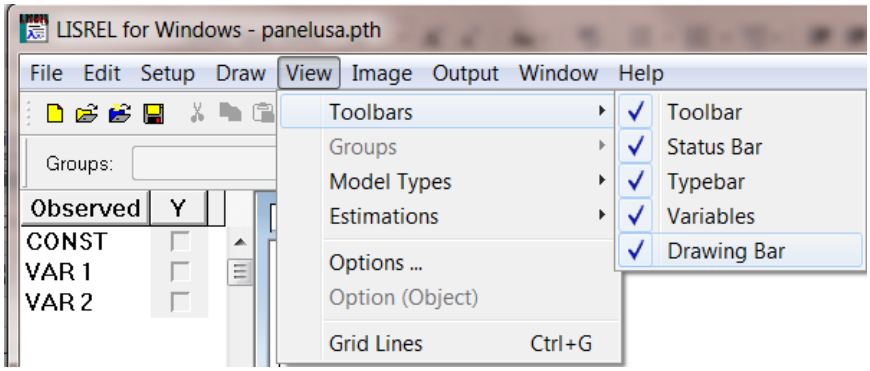
In this example we use PRELIS to compute the polychoric correlation matrix and corresponding asymptotic covariance matrix of these correlations. The next step is to create a path diagram from which the LISREL or SIMPLIS syntax may be built.

Select the **New** option from the **File** menu to obtain the **New** dialog box. From the **New** dialog box, select **Path Diagram** and click **OK** when done.

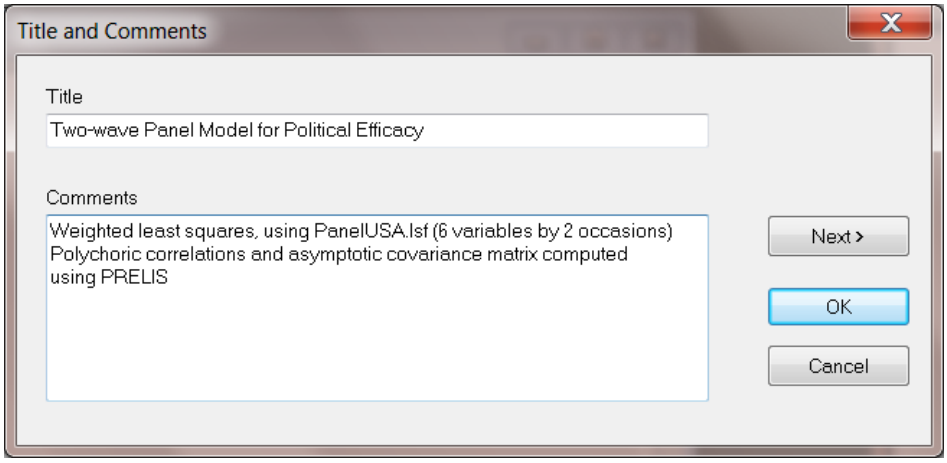


The **Save As** dialog box will appear. Save the new path diagram as **panelusa.pth**.

Before proceeding to the next step, ensure that the **Toolbar**, **Status Bar**, **Type Bar**, **Variables** and **Drawing Bar** options are selected, see below.



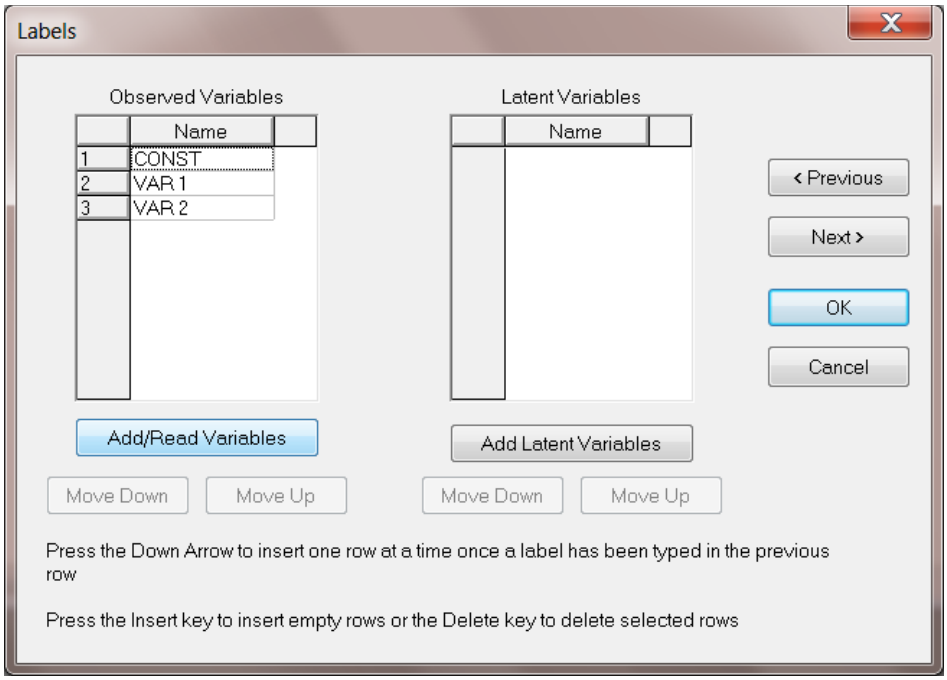
Select the **Title and Comments** option from the **Setup** menu to obtain the **Title and Comments** dialog box. Use the **Title and Comments** dialog box to enter a title and to add additional comments as shown in the example below:



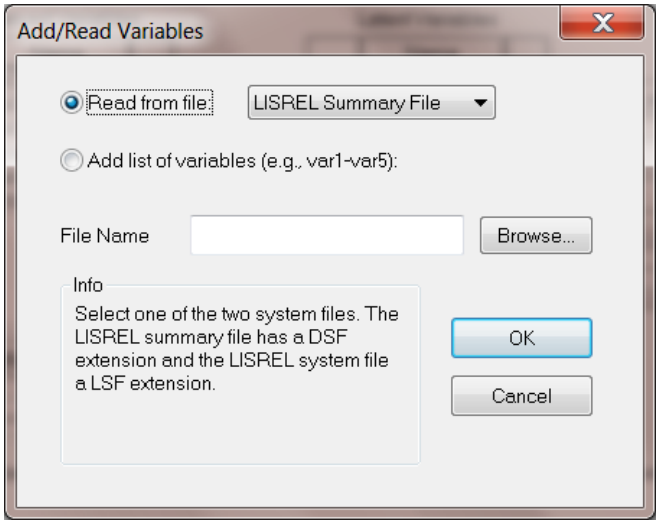
Click **Next** to go to the **Group Names** dialog box. Since the present example is based on the analysis of a single group, we can leave this dialog box blank and go to the variable names (**Labels**) dialog box by clicking **Next**.

4.3 Reading Variable Names from the DSF File

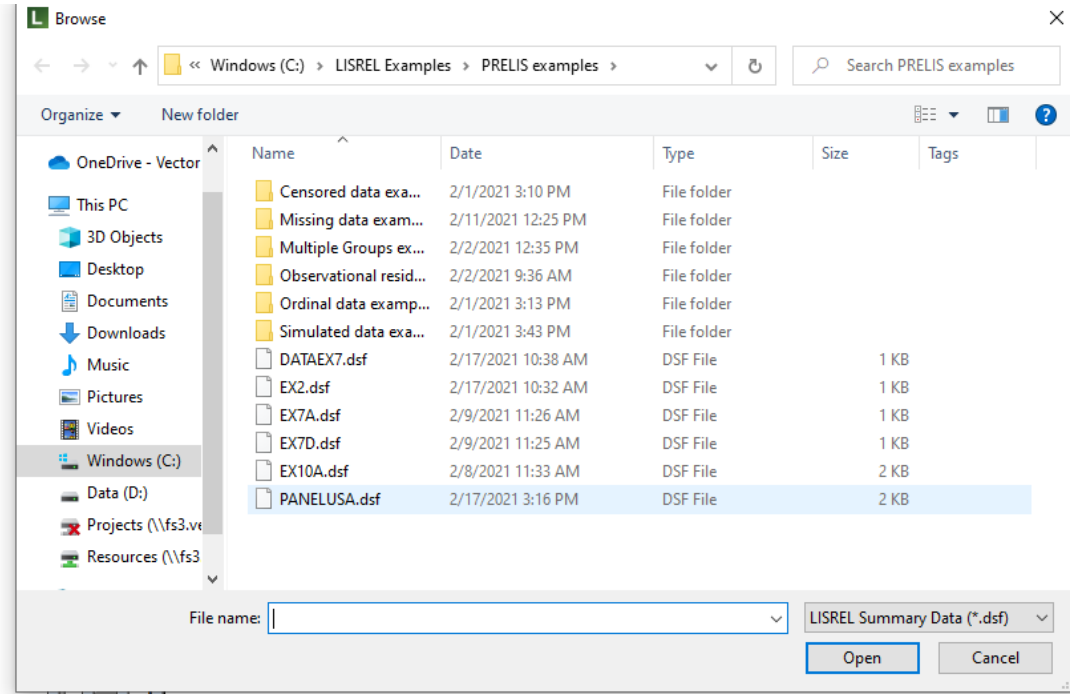
The data system file **panelusa.dsf**, which was created during the PRELIS analysis, contains the variable names, the location of the asymptotic covariance matrix, and the matrix of polychoric correlation coefficients. The variable names can be read in by clicking **Add/Read Variables** on the **Labels** dialog box.



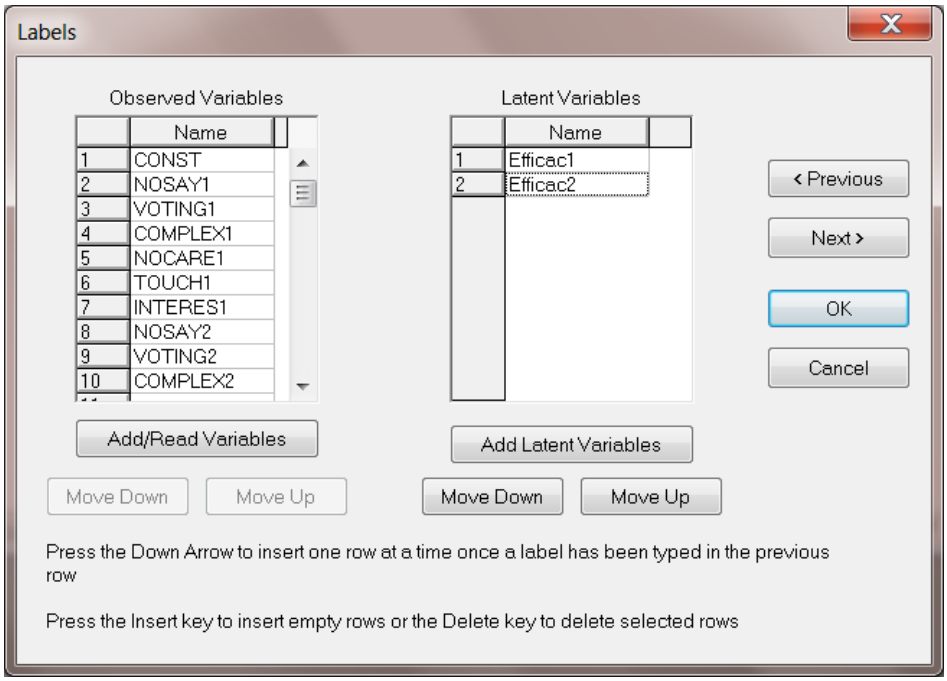
In doing so, the **Add/Read Variables** dialog box is activated and on this dialog box click the **Read from File: LISREL Summary File** radio button.



Click **Browse** to select the file **panelusa.dsf**. Click **Open** to return to the **Add/Read Variables** dialog box.



Click **OK** to obtain the list of twelve names shown in the **Labels** dialog box below. To complete the information in this dialog box, add the names of the two latent variables Efficac1 and Efficac2 in the **Latent Variables** window. See the notes at the bottom of the **Labels** window. To start typing a name, click anywhere within the **Latent Variables** window and type in the name. Alternatively, use the **Add Latent Variables** button.

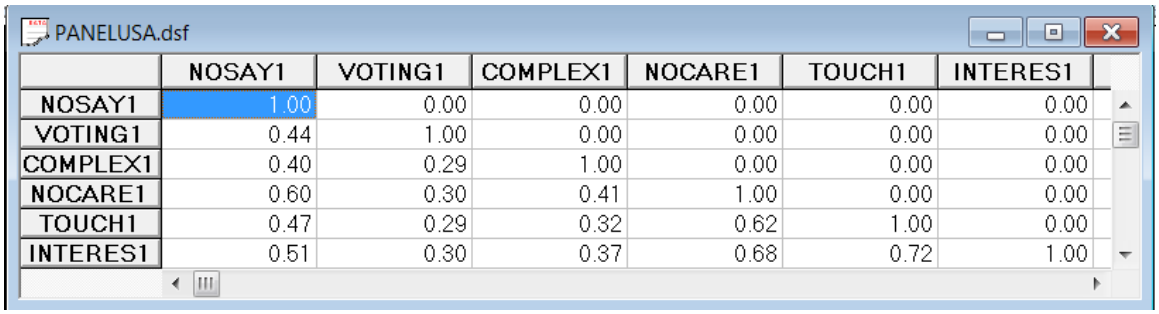


Once names for the observed and latent variables are entered, click **Next** to go to the **Data** dialog box. Select **Correlations** from the **Statistics from** drop-down list box.

Note:

Since the location of the asymptotic covariance matrix is stored in the ***.dsf** file, it is not necessary to enter the weight matrix details on the **Data** dialog box.

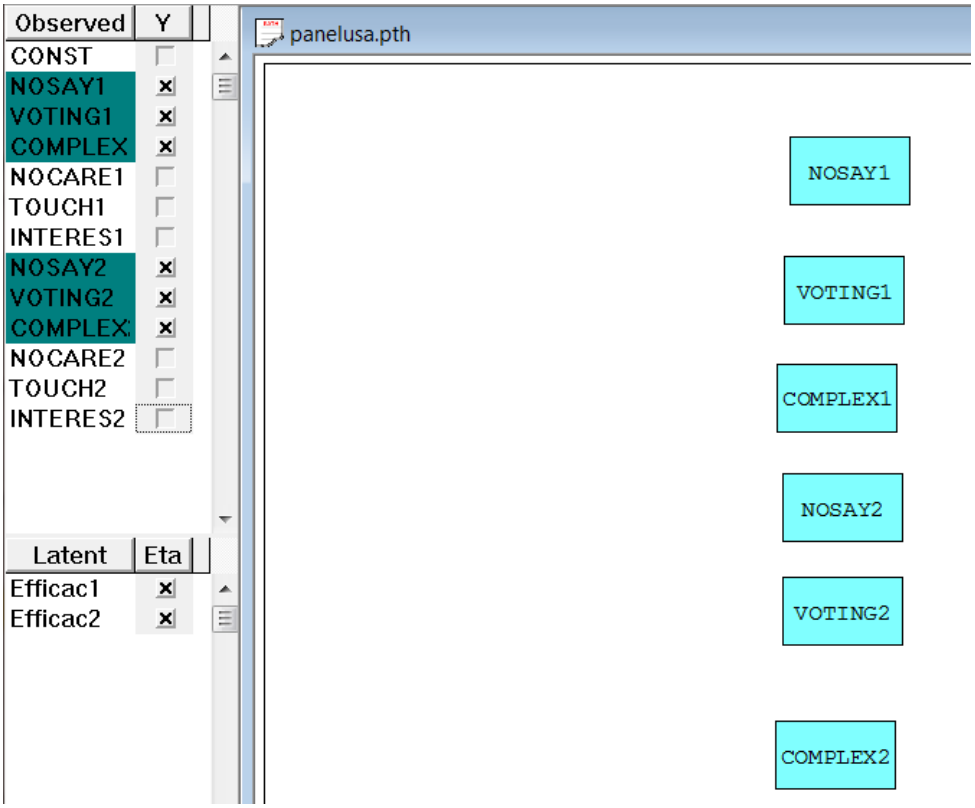
At this point, one may view the contents of the **panelusa.dsf** file by clicking the **Edit** button. A portion of the correlation matrix is shown below. Note that only the lower triangular halve contains correlation values.



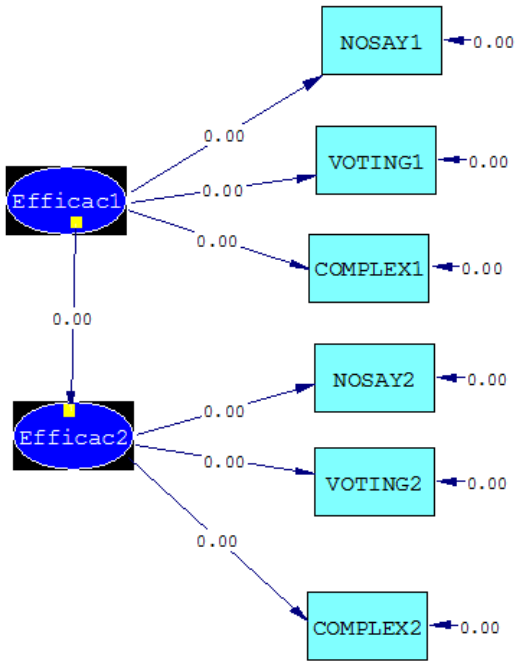
	NOSAY1	VOTING1	COMPLEX1	NOCARE1	TOUCH1	INTERES1
NOSAY1	1.00	0.00	0.00	0.00	0.00	0.00
VOTING1	0.44	1.00	0.00	0.00	0.00	0.00
COMPLEX1	0.40	0.29	1.00	0.00	0.00	0.00
NOCARE1	0.60	0.30	0.41	1.00	0.00	0.00
TOUCH1	0.47	0.29	0.32	0.62	1.00	0.00
INTERES1	0.51	0.30	0.37	0.68	0.72	1.00

Close the spreadsheet to return to the path diagram environment. The list of variable names will appear on the left side on the computer screen. Define the variables NOSAY1, VOTING1, COMPLEX1, NOSAY2, VOTING2 and COMPLEX2 as Y-variables by checking the appropriate boxes under the heading **Y**. Also check the **Eta-variable** boxes to define Efficac1 and Efficac2 as Eta latent variables.

The observed values to be used in the drawing of the path diagram can be dragged to the path diagram area by clicking on a variable name (mouse left button). By holding this button down, a variable can be dragged to a desired position.

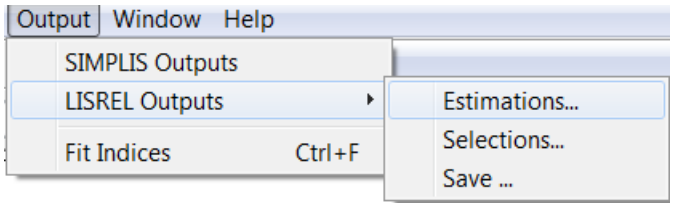


Drag the two latent variables to the path diagram window. To create paths between variables we proceed as follows: Click on the single headed arrow icon button on the **Draw** toolbar as shown. Move the mouse cursor to the middle of the Efficac1 ellipse, and then click the left mouse button. Hold the button down while dragging the arrow to within the NOSAY1 rectangle. The colors of both objects should change. Repeat the procedure to add the remaining paths as illustrated:

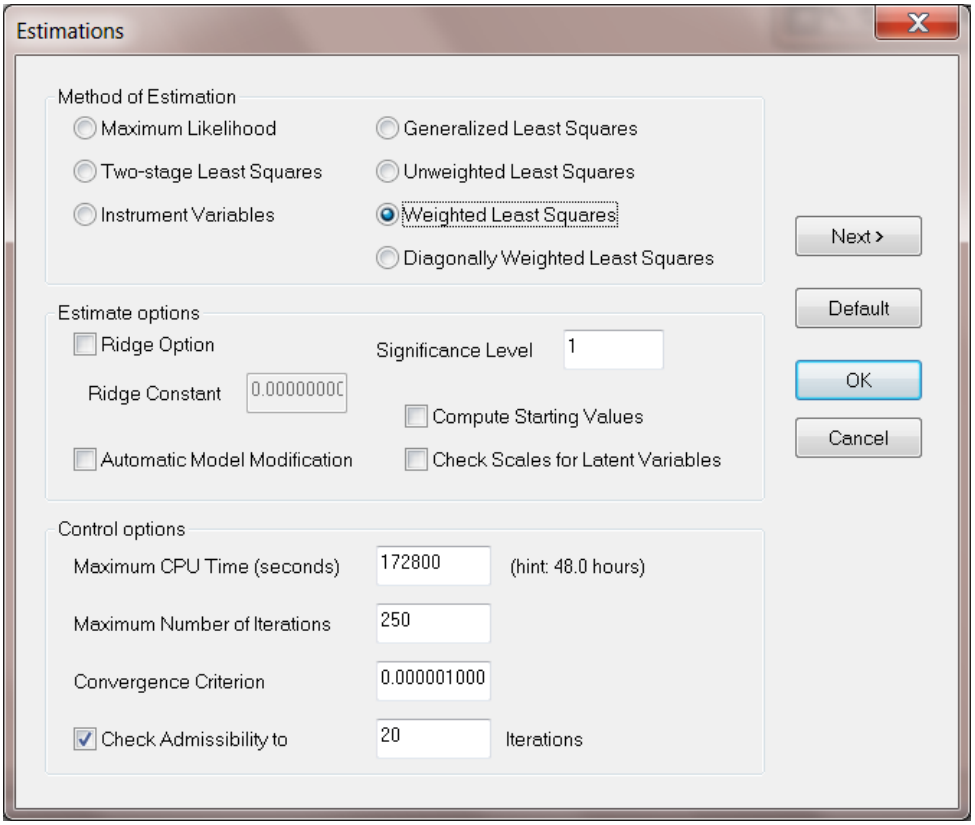


4.4 Creating LISREL and/or SIMPLIS Syntax from the Path Diagram

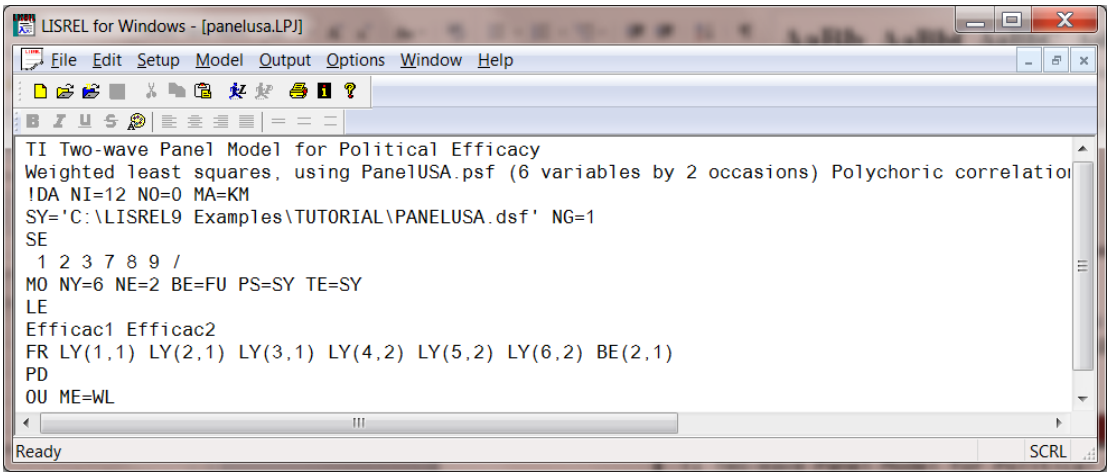
Prior to building the SIMPLIS or LISREL syntax, we adjust the default number of decimals from 2 to 4. This is accomplished by selecting the **Output, LISREL outputs**, **Estimations…** option.



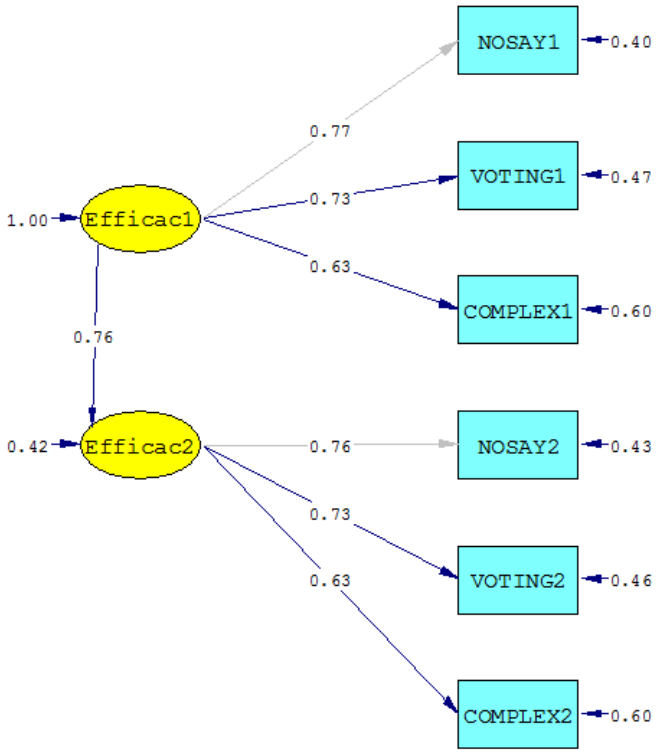
The method of estimation is also changed from **Maximum Likelihood** to **Weighted Least Squares** by selecting the **Output**, **LISREL output**, **Estimations** option.



Select **Build LISREL Syntax** from the **Setup** menu to obtain the following LISREL project window that displays the contents of the LISREL syntax file **panelusa.lpj**.

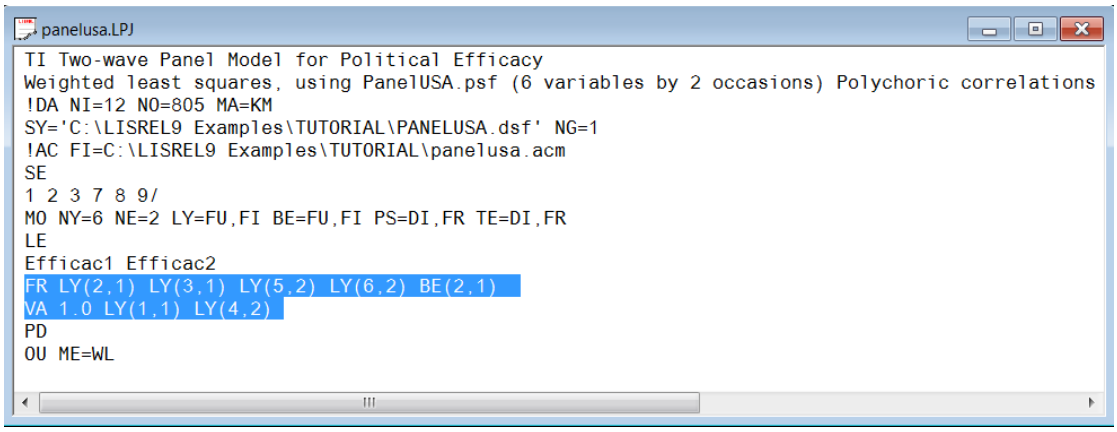


Click the **Run LISREL** icon button to start the analysis. The path diagram shows the estimated parameter values and χ^2-value.



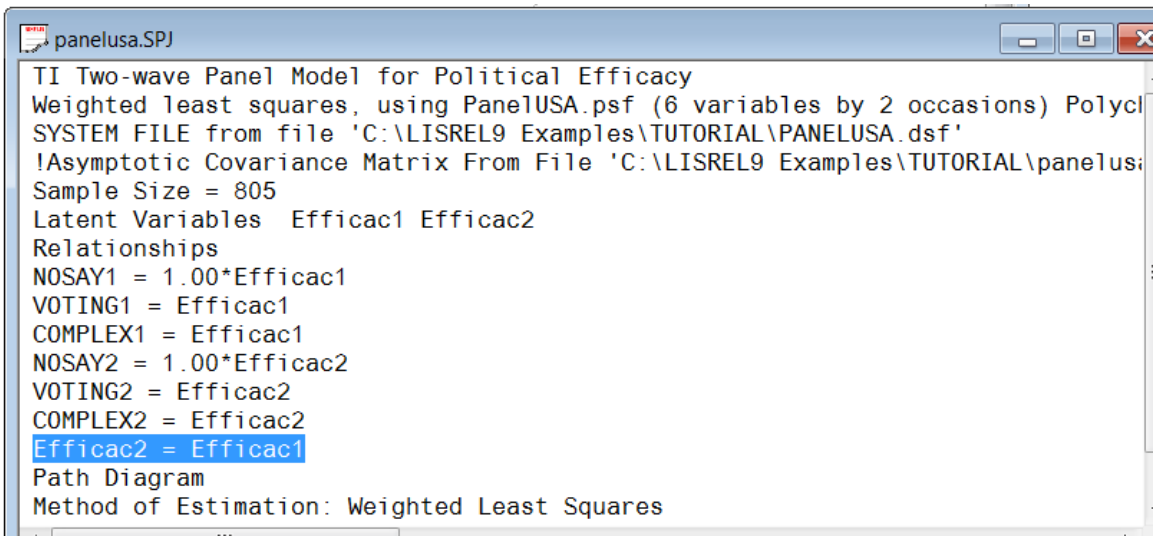
Chi-Square=118.38, df=8, P-value=0.00000, RMSEA=0.131

Often researchers prefer to set one factor loading each set that are indicators of a specific latent variable (factor) equal to one. This can be accomplished by editing the contents of the .**lpj** file or by right clicking on a factor loading, and then fixing its value to one. The resultant .**lpj** file is shown below.

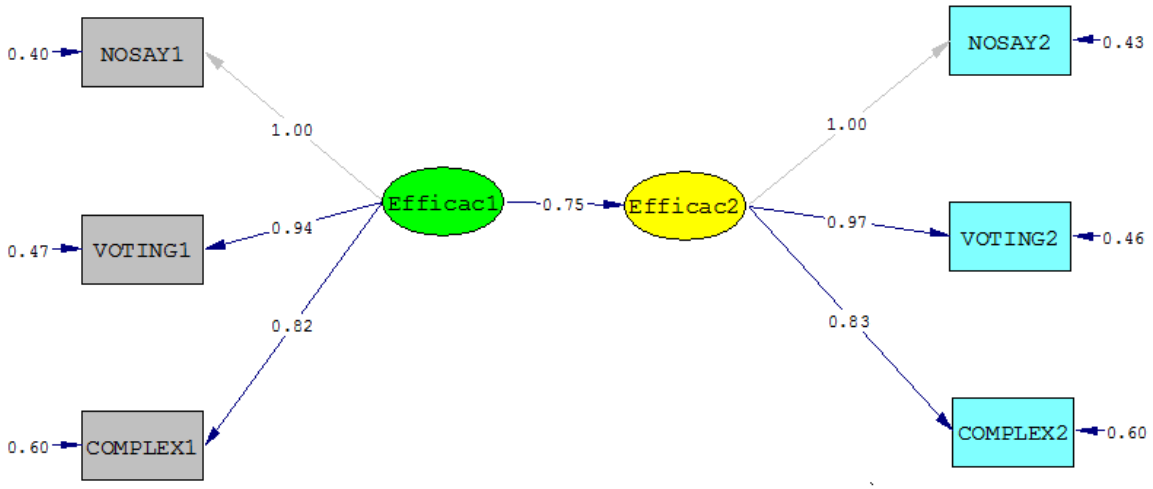


The corresponding SIMPLIS input syntax can be built from the path diagram obtained by running LISREL. This is accomplished by selecting the **Build SIMPLIS Syntax** option from the **Setup** menu.

A selection of the SIMPLIS syntax (**panelusa.spj**) is displayed in the SIMPLIS project window as shown in the next image.



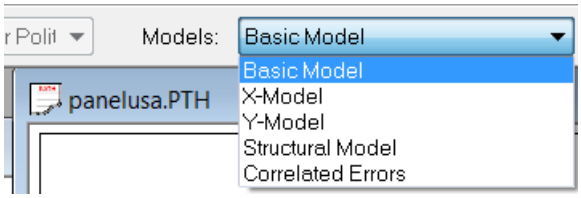
This syntax produces a model that consists of X-variables and Y-variables, a KSI latent variable and an Eta latent variable. Click the **Run LISREL** icon button to run the analysis. It is interesting to note that the Y-only model and the model shown below are equivalent.



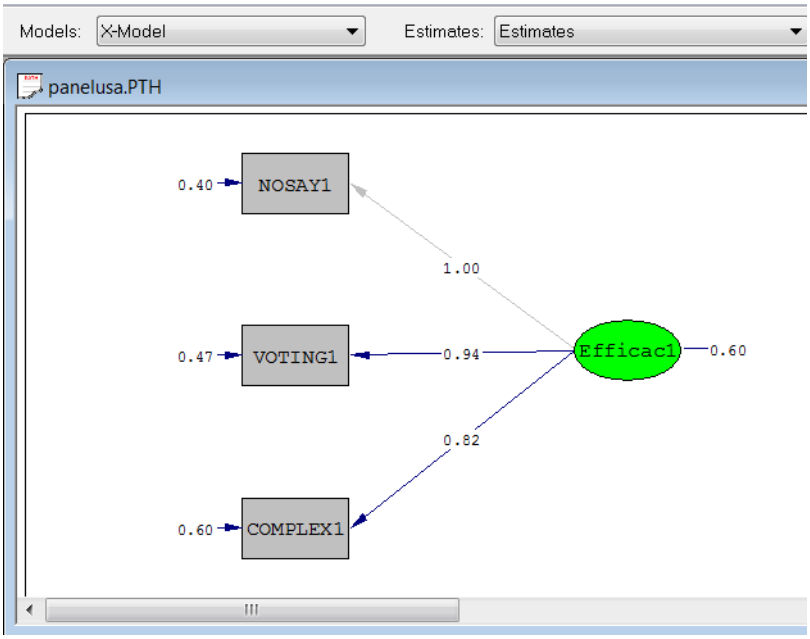
Chi-Square=118.38, df=8, P-value=0.00000, RMSEA=0.131

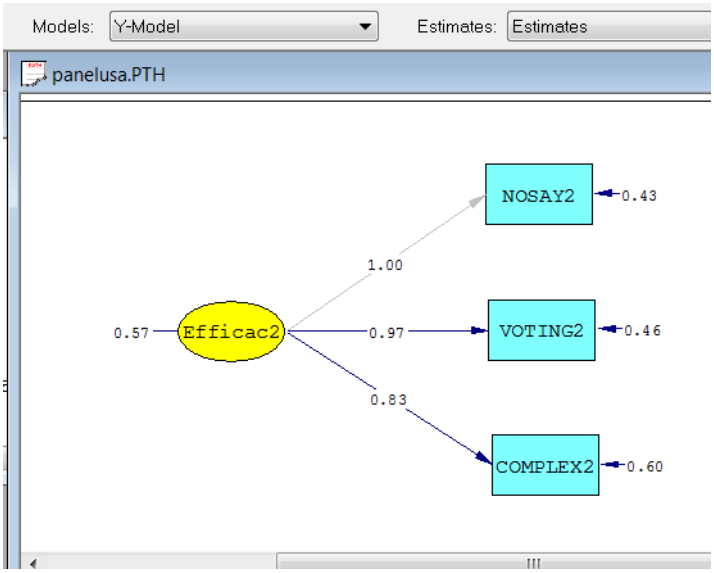
4.5 The Basic Model and its Components

The model shown above is called the **Basic Model**, which can be divided into the **X-Model**, the **Y-Model** and the **Structural Model**. Each of these models may be viewed separately by clicking on the **Basic Model** drop-down list box to obtain the list of models.

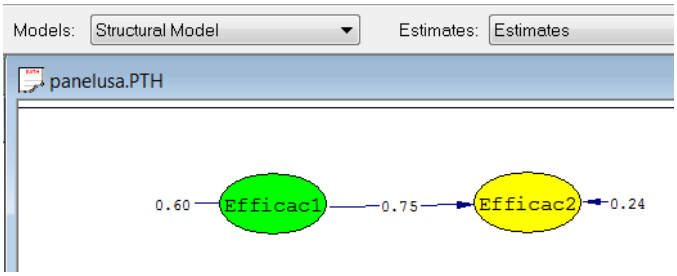


By selecting the **X-Model** model type, this portion of the path diagram is displayed. The **X-Model** selection and **Y-Model** selection are shown below.

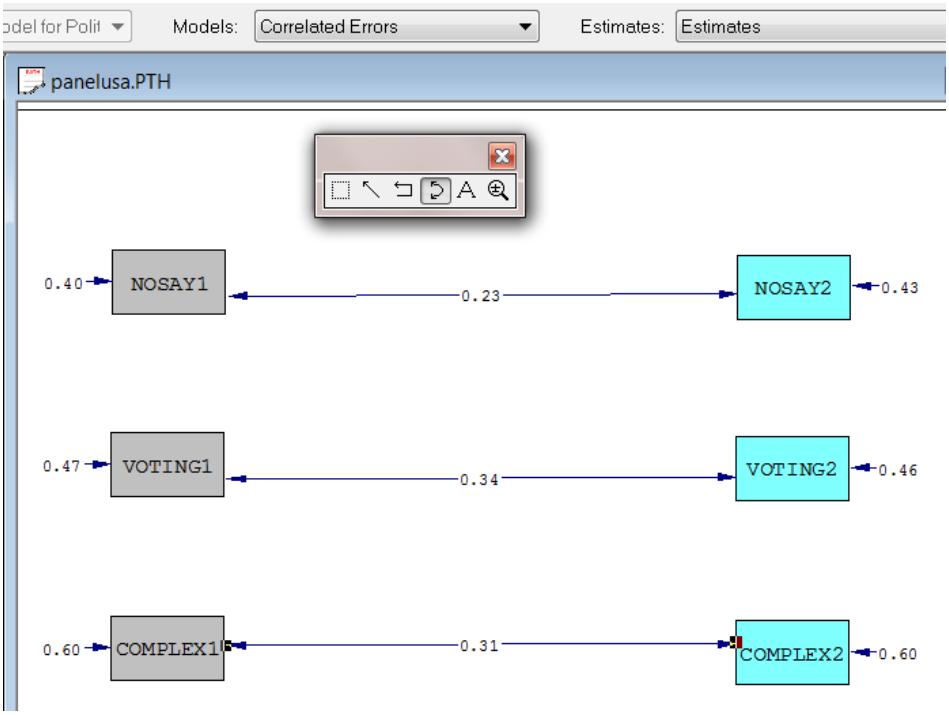




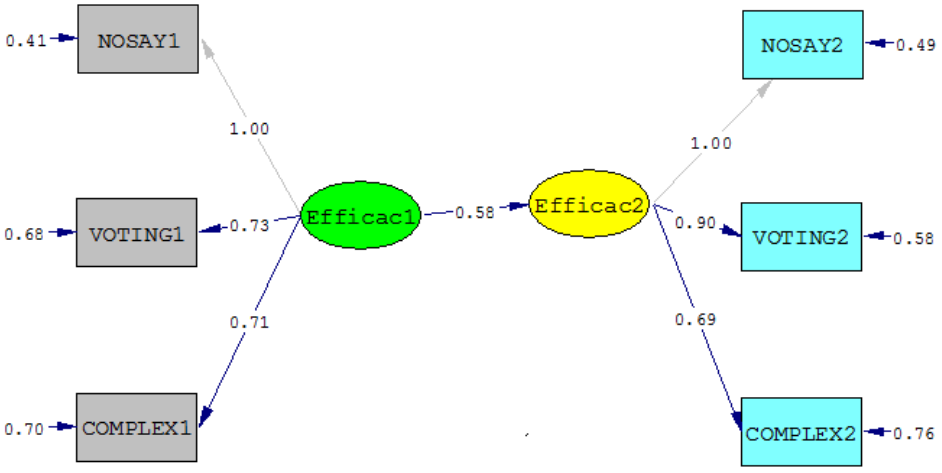
The selection of the **Structural Model** option produces that part of the path diagram:



Finally, the selection of the **correlated errors** option produces the following diagram. Note that use was made of the two-headed arrow to add the error covariance paths to the diagram.



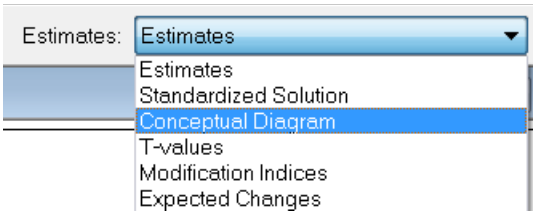
When the **Run LISREL** icon button is clicked, the following path diagram is obtained. From this display, it is seen that the χ^2-value has significantly decreased as a result of the addition of the error covariances.



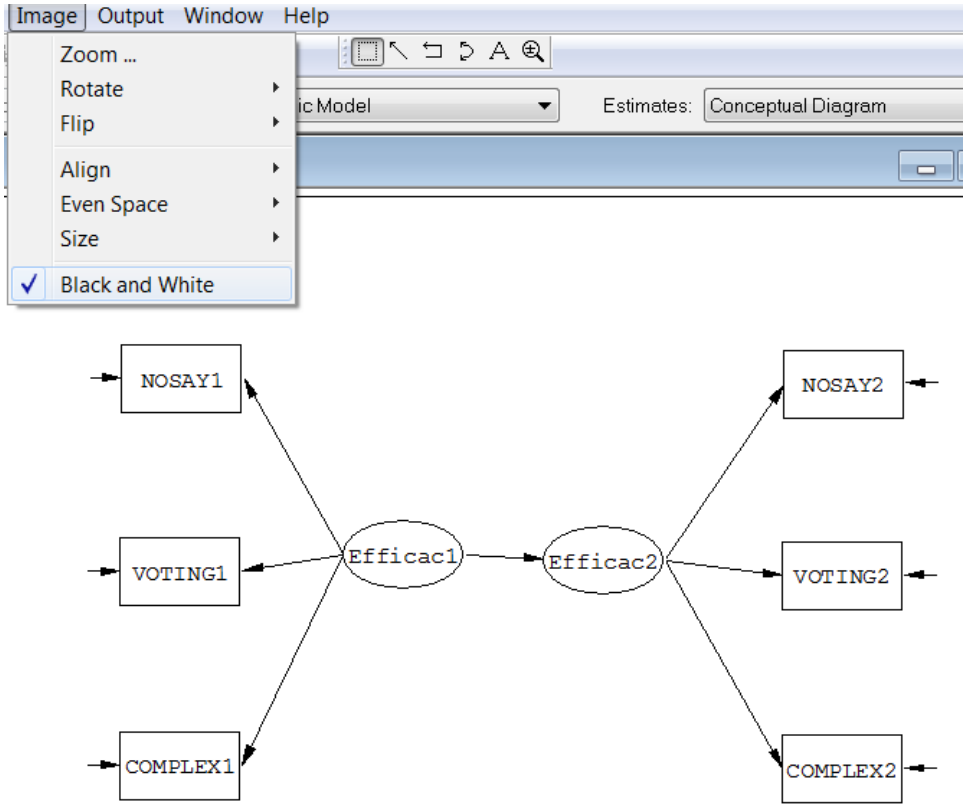
Chi-Square=12.05, df=5, P-value=0.03416, RMSEA=0.042

4.6 Estimation Types and the Conceptual Path Diagram

LISREL also allows the user to view the parameter **Estimates**, **Completely Standardized Solution**, **Conceptual Diagram**, **T-values**, etc. by clicking on **View** (main menu bar) or by clicking on the **Estimates** drop-down list box as shown below:



The selection of the **Conceptual Diagram** option produces a path diagram that contains only variable names and paths between variables. A black and white display of the path diagram can be obtained by selecting the **Black and White** option from the **Image** menu.



4.7 Saving the Path Diagram in Graphics Format

The conceptual path diagram, or one with an alternative selection from the **Estimations** bar, can be saved as a Windows Metafile (*.**emf**) file, which may be included as a graphic in, for example, Microsoft Word or Powerpoint. To save as a *.**emf** file, select the **Export as Metafile** option from the **File** menu.

5 Empty Path Diagrams

5.1 Motivation

Empty path diagrams can be used in teaching to discuss various types of models. The commands for creating empty path diagram are explained here. After the empty path diagram has been produced, user can start drawing the paths (arrows).

5.2 Examples

Example 1

If no relationships are specified, LISREL treats all observed variables as x-variables and all latent variables as Ksi-variables.

```
Raw Data from File NPV.LSF
Latent Variables: Visual Verbal Speed
Path Diagram
End of Problem
```

The LISREL model is (omitting intercepts)

$$\mathbf{x} = \boldsymbol{\Lambda}_x \boldsymbol{\xi} + \boldsymbol{\delta}$$

Example 2

This example illustrates a model with only x- and y-variables.

```
Observed Variables: Y1 - Y3 X1 X2
Covariance matrix:
14.610
-5.250 11.017
-8.057 11.087 31.971
-0.482 0.677 1.559 1.021
-18.857 17.861 28.250 7.139 215.662
Sample Size 173
Y-Variables Y1-Y3
Path Diagram
End of problem
```

The LISREL model is (omitting intercepts)

$$\mathbf{y} = \mathbf{B}\mathbf{y} + \boldsymbol{\Gamma}\mathbf{x} + \boldsymbol{\zeta}$$

Example 3

The next example illustrates a model with y-, Eta- and Ksi-variables (but no x-variables and omitting intercepts)

```
Raw Data from File NPV.LSF
Latent Variables: Visual Verbal Speed Ksi
Y-Variables 'VIS PERC' - SCCAPS
```

Eta-Variables Visual - Speed
Path Diagram
End of Problem

The LISREL model is

$$\mathbf{y} = \boldsymbol{\Lambda}_y \boldsymbol{\eta} + \boldsymbol{\varepsilon}$$
$$\boldsymbol{\eta} = \boldsymbol{\Gamma}\boldsymbol{\xi} + \boldsymbol{\zeta}$$

Example 4

The last example illustrates a model with only y- and Eta-variables (omitting intercepts)

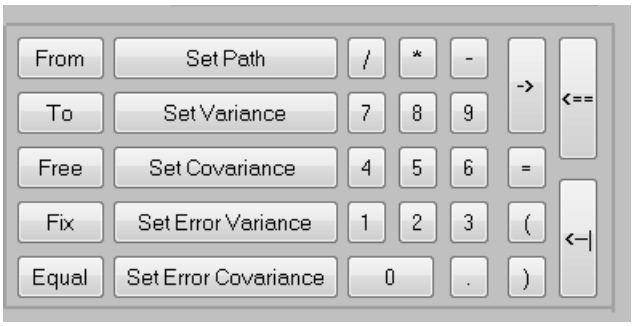
Observed Variables: Y1-Y7
Correlation Matrix
(20F4.3) Symmetric
1000
5561000
456 4901000
439 445 5621000
415 418 496 5121000
399 383 456 469 5511000
387 364 445 442 500 5441000
Sample Size 1600
Latent Variables Eta1-Eta7
Y-Variables Y1-Y7
Eta-Variables Eta1-Eta7
Path Diagram
End of Problem

The LISREL model is

$$\mathbf{y} = \boldsymbol{\Lambda}_y \boldsymbol{\eta} + \boldsymbol{\varepsilon}$$
$$\boldsymbol{\eta} = \mathbf{B}\boldsymbol{\eta} + \boldsymbol{\zeta}$$

6 Using SIMPLIS Project Files

LISREL allows the user to create SIMPLIS syntax by making use of a dialog box keypad. This keypad, see illustration below, is operated by clicking (left mouse button) on the appropriate symbol. Note that the **<==** symbol represents the **backspace** key while the symbol **<--|** denotes the **enter** key. The path diagram produced by running the program can subsequently be modified to change the model specifications.



As an illustration, we consider path analysis for latent variables, which, in its most general form, is a structural equation system for a set of latent variables classified as dependent or independent. In the application described below, the system is recursive (see the LISREL 8: SIMPLIS command language guide.)

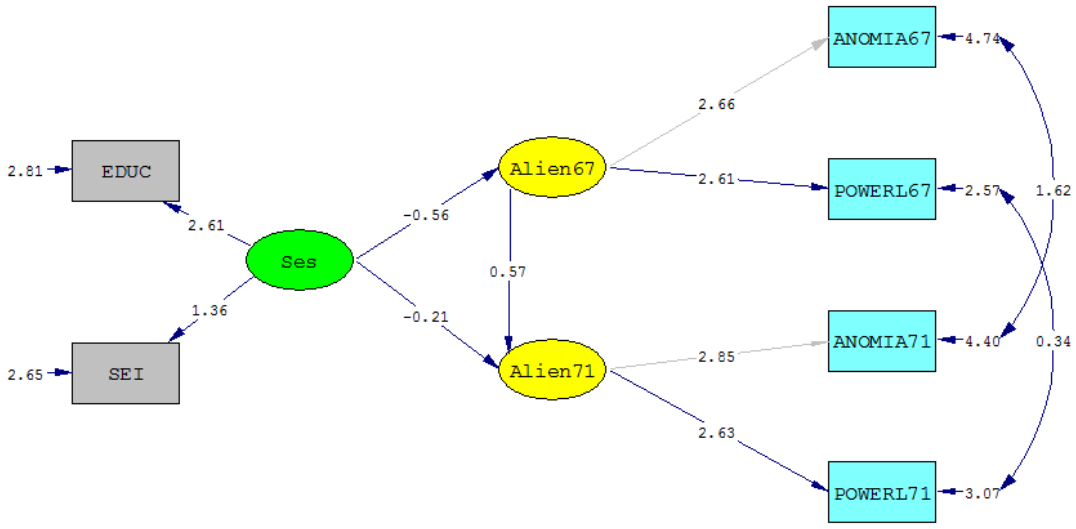
Recursive models are particularly useful for analyzing data from longitudinal studies in psychology, education and sociology. The characteristic feature of a longitudinal research design is that the same measurements are used on the same people at two or more occasions. Wheaton, et al. (1977) reported on a study concerned with the stability over time of attitudes such as alienation, and the relation to background variables such as education and occupation. Data on attitude scales were collected from 932 persons in two rural regions in Illinois at three points in time: 1966, 1967, and 1971. The variables used for the present example are the Anomia subscale and the Powerlessness subscale, taken to be indicators of Alienation. This example uses data from 1967 and 1971 only.

The background variables are the respondent's education (years of schooling completed) and Duncan's Socio-economic Index (SEI). These are taken to be indicators of the respondent's socio-economic status (Ses). The sample covariance matrix of the six observed variables is given below:

	y1	y2	y3	y4	x1	x2
ANOMIA67	11.834					
POWERL67	6.947	9.364				
ANOMIA71	6.819	5.091	12.532			
POWERL71	4.783	5.028	7.495	9.986		
EDUC	-3.839	-3.889	-3.841	-3.625	9.610	
SEI*	-2.190	-1.883	-2.175	-1.878	3.552	4.503

*The variable SEI has been scaled down by a factor of 10.

The path diagram for this model is shown below:



Notes:

- The error terms of ANOMIA and POWERL are specified to be correlated over time.
- The four one-way arrows to the right of the diagram represent the measurement errors in ANOMIA67, POWERL67, ANOMIA71 and POWERL71 respectively.
- The two-way arrows on the right indicate that some of the measurement errors are correlated. The covariance between the two error terms for each variable can be interpreted as a specific error variance. For other models for the same data, see Jöreskog & Sörbom (1989, pp. 213-223).

To set up this model for SIMPLIS is straightforward as shown in the following syntax file:

```
Stability of Alienation
Observed Variables
ANOMIA67 POWERL67 ANOMIA71 POWERL71 EDUC SEI
Covariance matrix
 11.834
  6.947      9.364
  6.819      5.091     12.532
  4.783      5.028      7.495      9.986
 -3.839     -3.889     -3.841     -3.625      9.610
 -2.190     -1.883     -2.175     -1.878      3.552      4.503
Sample Size 932
Latent Variables Alien67 Alien71 Ses
Relationships
ANOMIA67 POWERL67 = Alien67
ANOMIA71 POWERL71 = Alien71
EDUC SEI = Ses
Alien67 = Ses
Alien71 = Alien67 Ses
Set Error Covariance of ANOMIA67 and ANOMIA71 Free
Set Error Covariance of POWERL67 and POWERL71 Free
Path Diagram
End of Problem
```

Notes:

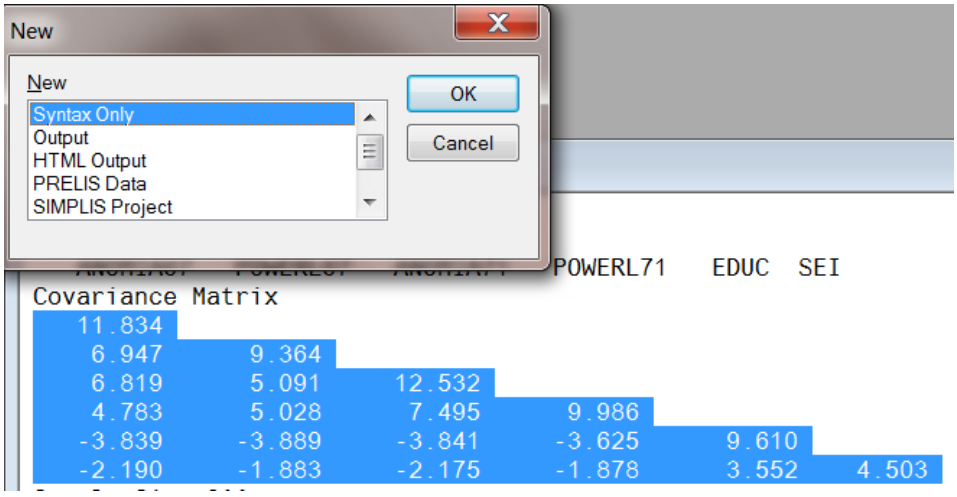
- The model is specified in terms of relationships. The first three lines under `Relationships` specify the relationships between the observed and the latent variables. For example, ANOMIA71 POWERL71 = Alien71 means that the observed variables ANOMIA71 and POWERL71 depend on the latent variable Alien71.
- The Line Alien71 = Alien67 Ses means that the latent variable Alien71 depends on the two latent variables Alien67 and Ses. This is one of the structural relationships.

6.2 Building the SIMPLIS Syntax

The files **ex6a.spl** and **ex6b.spl** in the **SIMPLIS examples** folder both contain the numeric values of the covariance matrix of the observed variables.

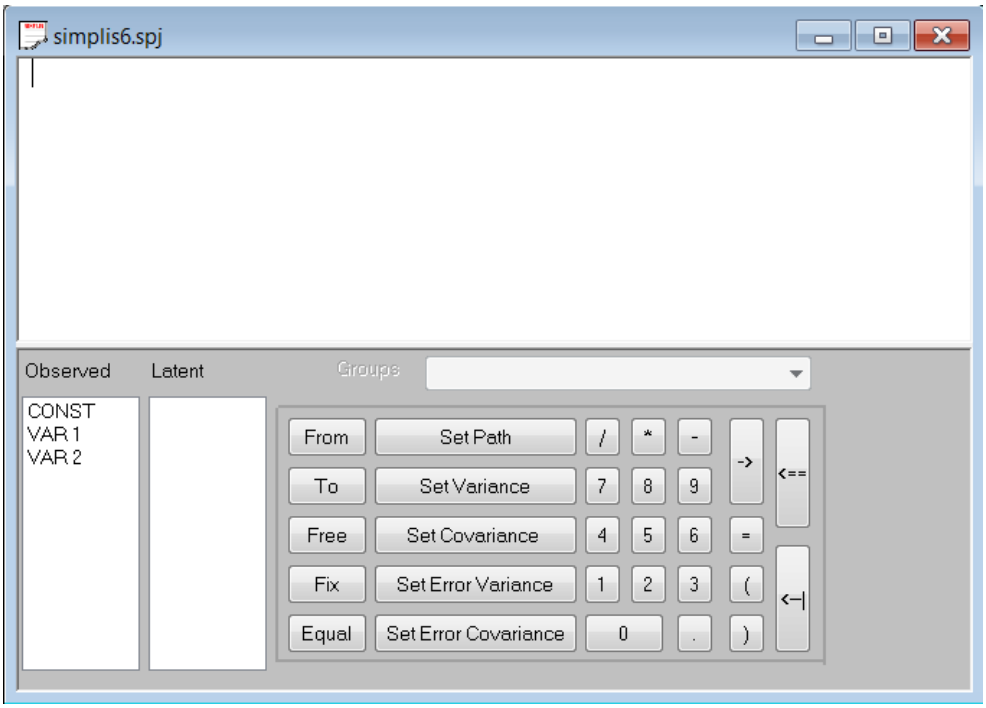
From the **File** menu, select **Open** and locate **ex6a.spl**. Use the mouse cursor (left button down) to mark the covariances as shown below. Use the **Edit** menu and click **Copy** or, alternatively, press the **Ctrl** - **C** keys on the keyboard.

From **File**, **New** select **Syntax Only** and click **OK**. Use the **Edit**, **Paste** function to copy the contents of the clipboard to the syntax window or, alternatively, use the **Ctrl** - **V** keys on the keyboard. Use the **File**, **Save As** option to save the covariances to the file **wheaton.cov**.



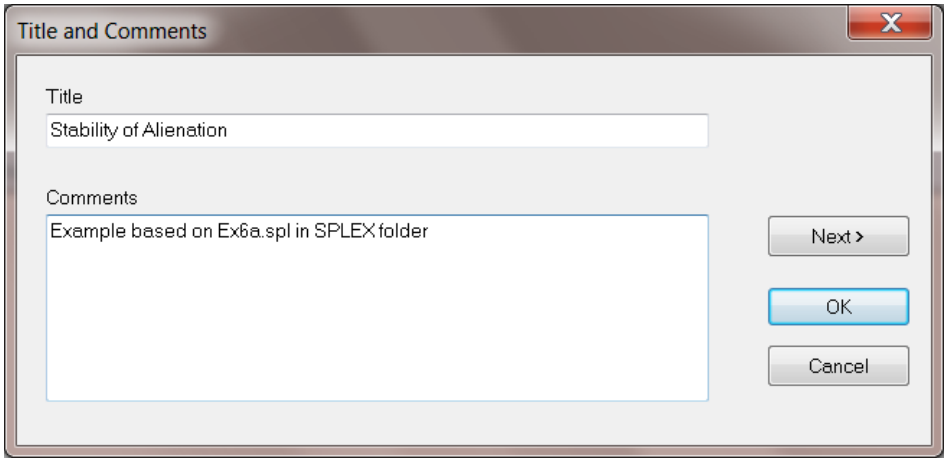
Select the **New** option from the **File** menu and select **SIMPLIS Project** in the **New** dialog box. Click **OK** to open the **Save As** dialog box.

Select a filename and a folder in which the SIMPLIS project should be saved. For the present example the filename selected is SIMPLIS**6.spj**. When done, click **Save** to go to the SIMPLIS project (SPJ) window.



Before generating syntax, you may optionally select **SIMPLIS Outputs** from the **Output** menu. Customize this dialog box according to your preferences; for example, change the **Number of Decimals in the Output** option to 4. When done, click **OK**.

The following step is to provide information regarding **Title and Comments, Groups, Variables**, and **Data**. Select the **Titles and Comments** option from the **Setup** menu. The first item on the **Title and Comments** dialog box is the title for the problem. After typing in the title and (optionally) the comments, click on **Next** to go on with the setup.

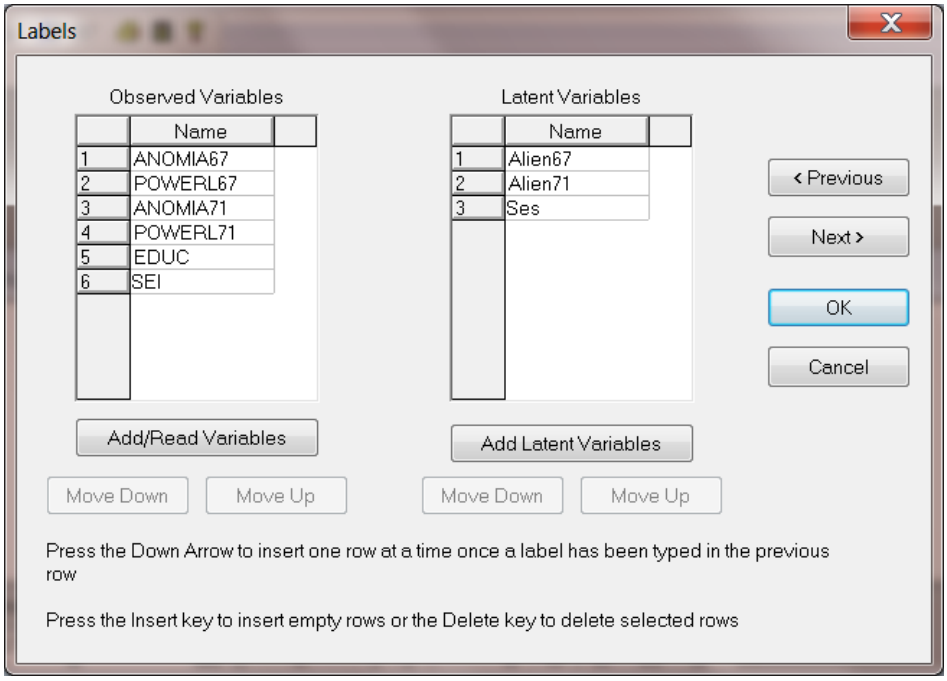


Since the present example is based o n the one group only, nothing is entered in the space allowed for **Group Labels**, and **Next** is clicked to go to the **Labels** dialog box.

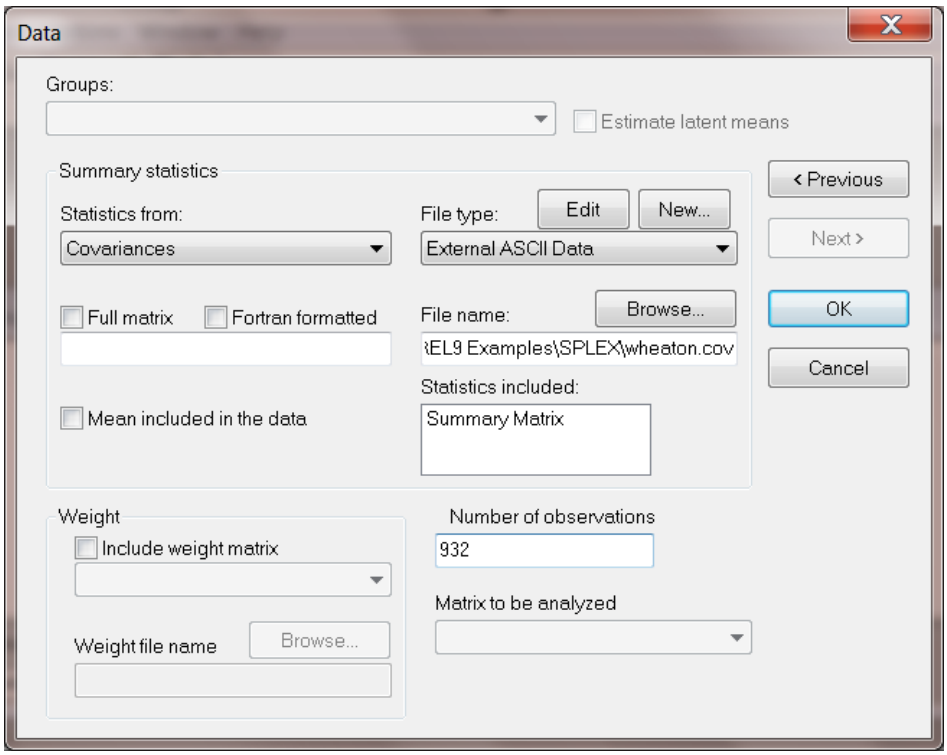
The default number of variables shown on the **Labels** dialog box is 3, these being CONST, VAR 1 and VAR 2. Click in the CONST textbox and change the name to ANOMIA67. Enter the label POWERL67 in the VAR 1 textbox

and ANOMIA71 in the VAR 2 text box. Move the mouse cursor into the ANOMIA71 textbox and use the down arrow to create a fourth text box. Type in POWERL71 and repeat the procedure for EDUC and SEI.

In a similar manner, use the down arrow key to create text boxes in the **Latent Variables** column and enter the names Alien67, Alien71 and Ses. Note that a label name, which may include blanks, may not exceed 8 characters.



On the **Data** dialog box select **Covariances** from the **Statistics from:** drop-down list box. Type 932 in the **Number of Observations** string field. For **File type**, select **External ASCII data** and use the **Browse** button to select **wheaton.cov**.



6.3 Building and Completing the SIMPLIS Syntax

Select **Build SIMPLIS Syntax** from the **Setup** menu to create the basic SIMPLIS syntax. The **Build SIMPLIS Syntax** option on the **Setup** menu provides the user with a skeleton of SIMPLIS commands. There are a few commands that must be included to complete the SIMPLIS syntax. The first of these commands is:

ANOMIA67 POWERL67=Alien67

To add a line in the syntax window, move the mouse cursor to the end of the keyword Relationships and click once. Now move the cursor to the Enter key (**<--|**) on the keypad and click to insert a blank line below the Relationships line.

To enter the line

ANOMIA67 POWERL67 = Alien67

proceed as follows:

- Click on the observed variable ANOMIA67 (First variable under the heading **Observed**) and with the mouse button held down drag the variable name to the syntax window.
- Repeat by dragging the variable name POWERL67 next to ANOMIA67. To continue, click on the "=" key and then drag the latent variable name Alien67 (first variable under the heading **Latent**).

To complete, move the mouse cursor to the end of the line

ANOMIA67 POWERL67 = Alien67

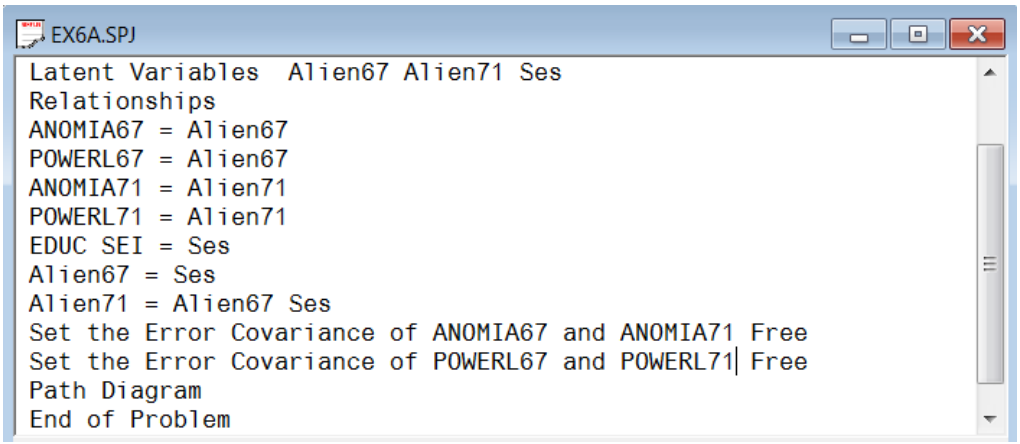
and click. Then click on the **enter** key and repeat the steps outlined above to insert the lines:

ANOMIA71 POWERL71 = Alien71
EDUC SEI = Ses
Alien67 = Ses
Alien71 = Alien67 Ses
Finally, enter the commands:

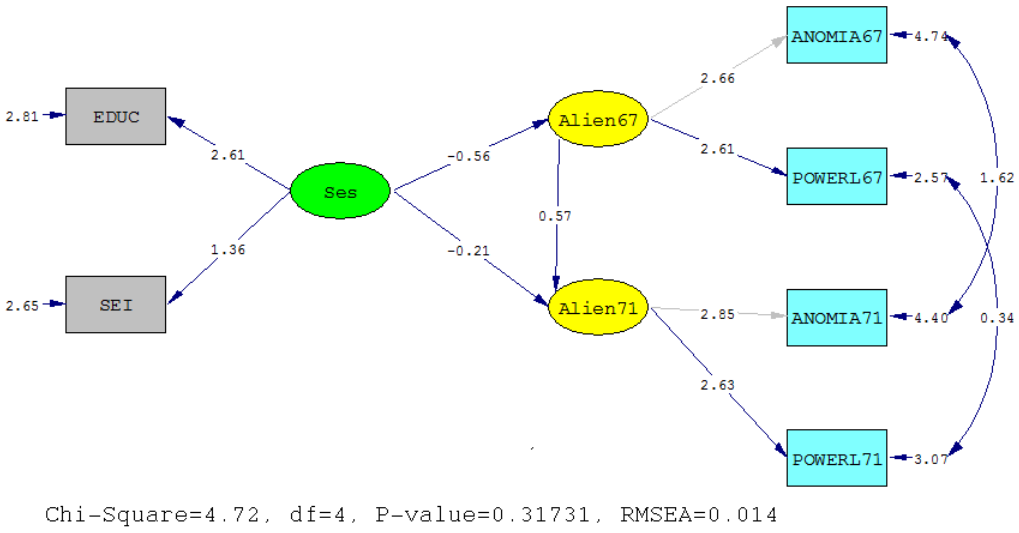
Set Error Covariance of ANOMIA67 ANOMIA71 free
and

Set Error Covariance of POWERL67 POWERL71 free

by using the keypad and by dragging the variable names to the appropriate positions. The completed syntax should correspond to the lines shown in the SPJ window below:



To run SIMPLIS, click the **Run LISREL** icon button on the main menu bar. A path diagram as shown below is produced, as well as the usual output file.



7 Using LISREL Project Files

LISREL allows the user to create LISREL syntax interactively by making use of a set of menus. As an illustration, we consider a second-order factor analysis model.

Second-order factor analysis

The following equation

$$\mathbf{y} = \boldsymbol{\Lambda}_y \boldsymbol{\eta} + \boldsymbol{\varepsilon}$$

is in the form of a factor analysis model for $\mathbf{y}$ with first order factors $\boldsymbol{\eta}$ and measurement errors $\boldsymbol{\varepsilon}$. Now suppose that the variables $\boldsymbol{\eta}$ in turn can be accounted for by a set of so called second-order factors $\boldsymbol{\xi}$, so that

$$\eta = \Gamma\xi + \varsigma$$

where Γ is a matrix of second-order factor loadings and ς is a vector of unique components for η.

To illustrate the model, we use data on some cognitive ability tests. The standard deviations and correlations of two forms of each of five tests are given in the table below. The sample size (N) is 267.

Table 2: Correlations and Standard Deviations for Some Cognitive Tests

GESCOM-A	2.42	1								
GESCOM-B	2.80	0.74	1							
CONWORD-A	3.40	0.33	0.42	1						
CONWORD-B	3.19	0.34	0.39	0.65	1					
HIDPAT-A	1.94	0.26	0.21	0.15	0.18	1				
HIDPAT-B	1.79	0.23	0.24	0.22	0.21	0.77	1			
THIROUND	5.63	0.15	0.12	0.14	0.11	0.17	0.20	1		
THIBLUE	3.10	0.14	0.14	0.14	0.15	0.06	0.09	0.42	1	
VOCABU_A	3.05	-.04	0.03	0.09	0.16	0.06	0.09	0.19	0.21	1
VOCABU_B	2.25	0.02	0.02	0.10	0.23	0.024	0.07	0.09	0.21	0.72 1

We shall examine the hypothesis that the two forms of each test are tau-equivalent, except for the two-word fluency tests Things Round and Things Blue that are only assumed to be congeneric. The five true scores are postulated to depend on two factors, the first, Speed Closure, being measured by the first three tests and the second, Vocabulary, being measured by the last two tests. The model specification is:

$$\Lambda_y = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & * & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}, \quad \Gamma = \begin{pmatrix} * & 0 \\ * & 0 \\ * & 0 \\ 0 & * \\ 0 & * \end{pmatrix}, \quad \Phi = \begin{pmatrix} 1 & \\ * & 1 \end{pmatrix}$$

Here * denotes parameters to be estimated and "0" and "1" are fixed parameters. The LISREL syntax file for this model is as follows:

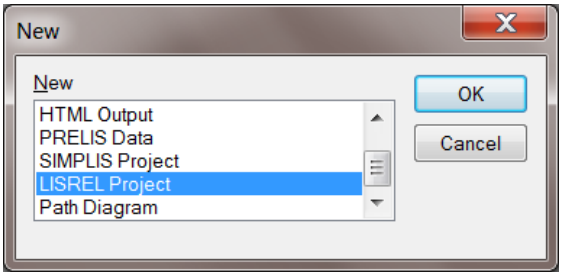
```
Second order factor analysis
DA NI=10 NO=267
LA FI=EX62.DAT
KM FI=EX62.DAT
SD FI=EX62.DAT
MO NY=10 NE=5 NK=2 GA=FI PH=ST PS=DI
LE
```

```
GESCOM CONWOR HIDPAT THINGS VOCABU
LK
SPEEDCLO VOCABUL
VA 1 LY 1 1 LY 2 1 LY 3 2 LY 4 2 LY 5 3 LY 6 3 LY 7 4 LY 9 5 LY 10 5
FR LY 8 4 GA 1 1 GA 2 1 GA 3 1 GA 4 2 GA 5 2
ST 1 ALL
OU SE TV SS NS
```

The goodness-of-fit statistic χ^2 is 53.06 with 33 degrees of freedom.

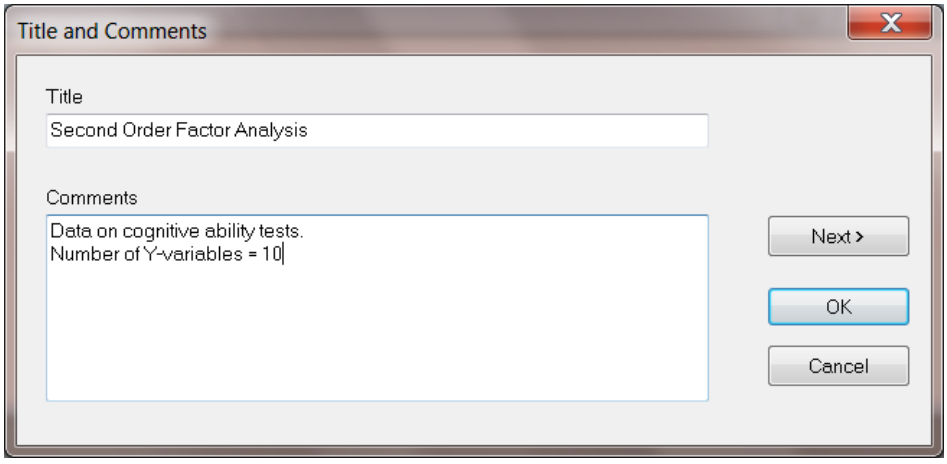
7.1 Building the LISREL Syntax

From the **File** menu, select **New** to obtain the **New** dialog box. Select **LISREL Project** and click **OK** to obtain the **Save As** dialog box.



Select the filename **sofa.lpj**. When done, click **Save**.

The following step is to provide information regarding the title, additional comments to be included in the syntax file, the data file and the variables in it. This is accomplished by selecting the **Title and Comments** option from the **Setup** menu. The **Title and Comments** dialog box appears. Enter a title and (optional) comments in the **Title** string field and the **Comments** text box.



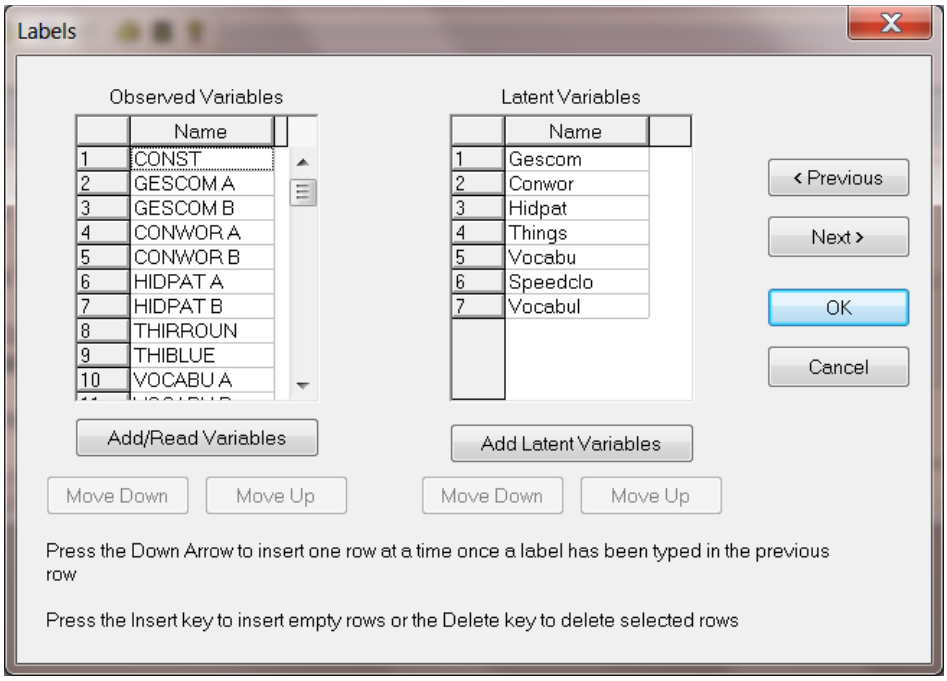
Since the present example is based on the analysis of a single group, nothing is entered in the space allowed for **Group Labels**, and **Next** is clicked to go to the **Labels** dialog box.

The default number of variables on the **Labels** dialog box is 2, these being VAR 1 and VAR 2. Since the present analysis calls for 10 variables, the mouse cursor is moved to the **Observed Variables** box. By pressing the **Insert** key on the computer keyboard eight times, provision is made for eight additional observed variables, and

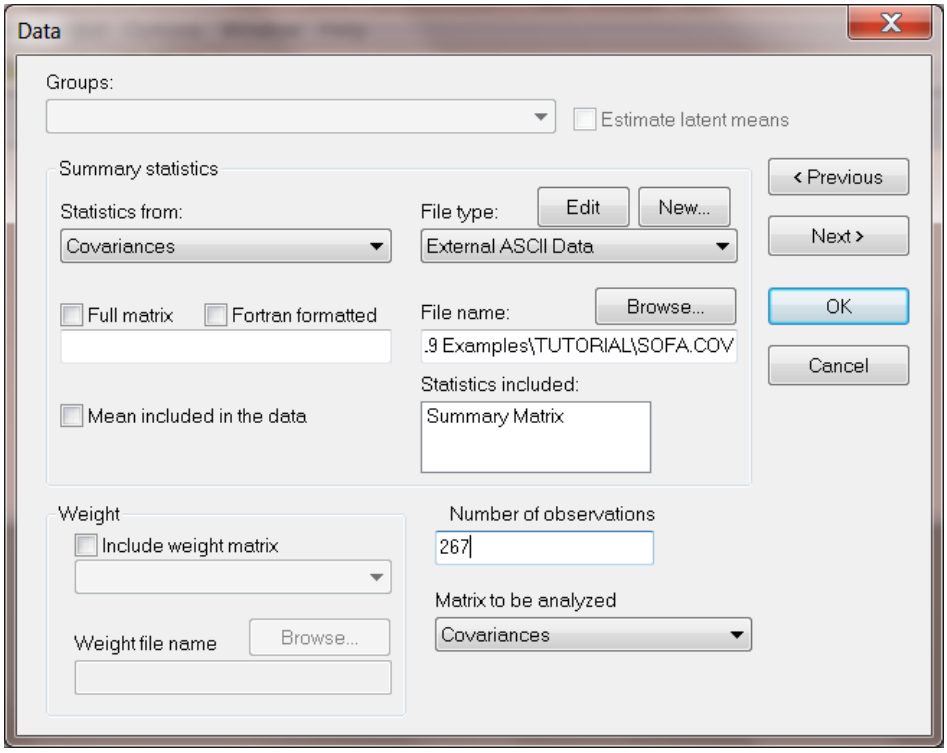
therefore the total number becomes ten. Alternatively, the **Add List** option may be used and var3-var10 entered (or, for example, X3-X10). If the **Add List** option was used, click **OK** to return to the **Labels** dialog box. Variable labels can alternatively be read in from an existing ***.lsf** or ***.dsf** file. See the section on LISREL system files for more information on this option.

A label may be assigned to each of the 10 variables by clicking on the corresponding button (numbered 1,2,3, …, under the **Observed Variables** column). The background color of the space allowed for entering the variable name will change and one can go ahead and type the appropriate label. For the present example, the labels are GESCOM A, GESCOM B, CONWOR A, CONWOR B, HIDPAT A, HIDPAT B, THIROUND, THIBLUE, VOCABU A and VOCABU B respectively. Note that a label name, which may include blanks, may not exceed 8 characters. Note also that the labels for the variables may instead be entered by, for example, clicking on VAR 1. Type in GESCOM A and use the down arrow on the keyboard to create the next space. Type GESCOM B and continue in a similar fashion until all the labels are typed in.

Since we have 7 latent variables, Gescom, Conwor, Hidpat, Things, Vocabu, Speedclo and Vocabu1, the procedure outlined above for the observed variables is repeated by selecting **Add List** on the **Latent Variables** portion of the **Labels** dialog box. Add var1-var7 and click on **OK** (alternatively the keyboard down arrow may be used). Assign labels to these latent variables by clicking on the number of each variable. Finally, click **Next** to go to the **Data** dialog box.

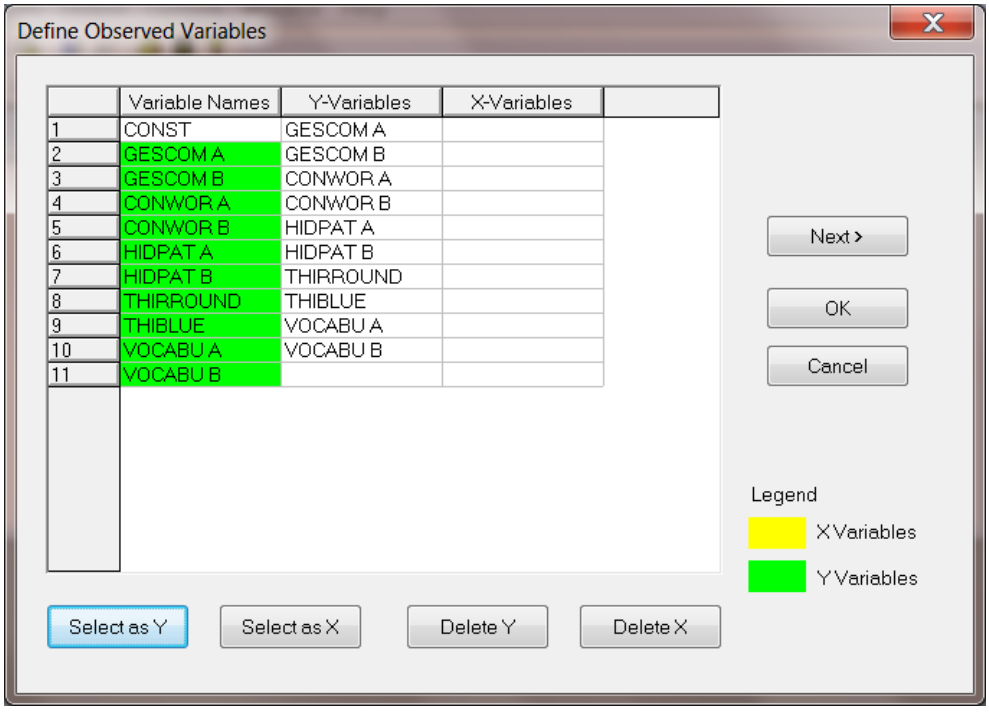


From the **Data** dialog box, select **Covariances** from the **Statistics from:** drop-down list box and also **Covariances** from the **Matrix to be analyzed** drop-down list box. Type 267 in the **Number of Observations** string field. For **File type**, select **External ASCII Data** and then click **Browse** to go to the **Browse** dialog box.



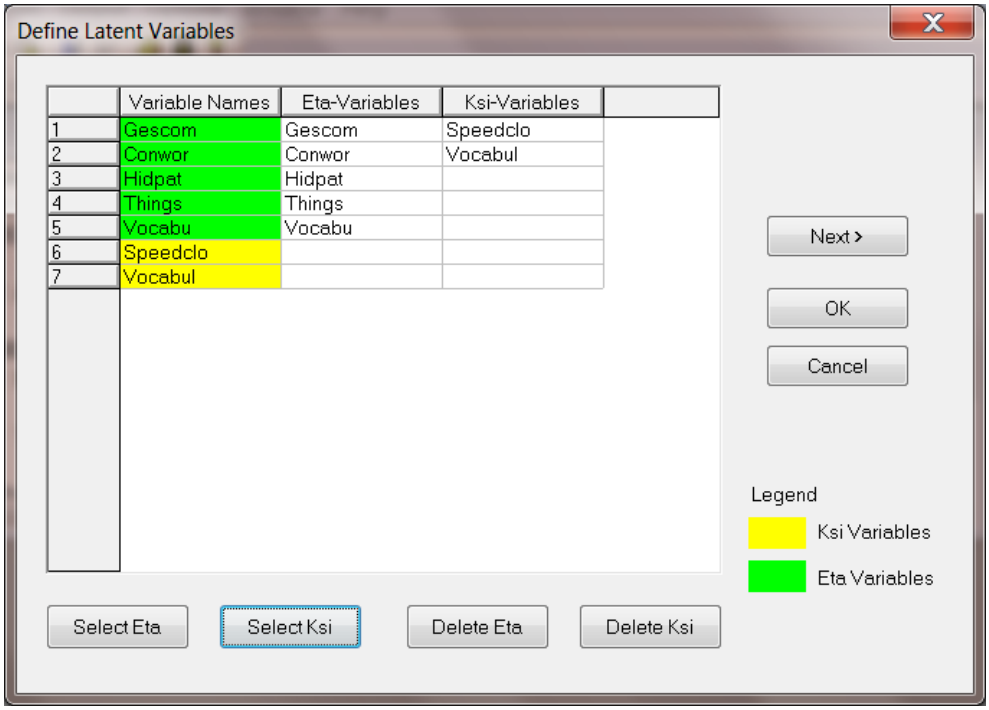
Select the ASCII file **sofa.cov**. Click **Open** to return to the **Data** dialog box, and then select **Next** to go to the **Define Observed Variables** dialog box.

The program will now produce the **Define Observed Variables** dialog box, on which the user may select **Y-variables** and **X-variables** from the list of **Variable Names**. Since the present application calls for Y-variables only, all of the variable names are selected as Y-variables. This is achieved by sequentially clicking on each variable number box and then on the **Select as Y** option. Alternatively, with the left mouse button down, drag from variable number 1 to number 10, release the mouse button and click on the **Select as Y** button.



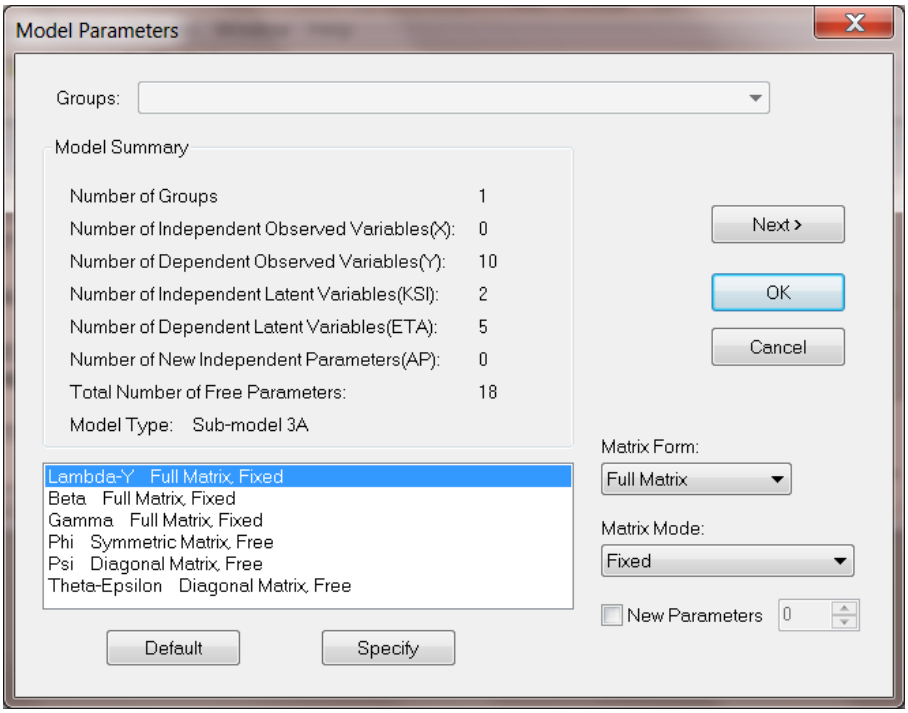
Click **Next** to go to the **Define Latent Variables** dialog box.

The latent variables consist of 5 Eta-variables and 2 Ksi-variables. Click on the appropriate square under **Variable Names** and then choose **Select Eta** for the Eta-variables (the first 5) or **Select Ksi** for the Ksi-variables (the last 2 variables). Once this is done, click **Next** to go to the **Model Parameters** dialog box.

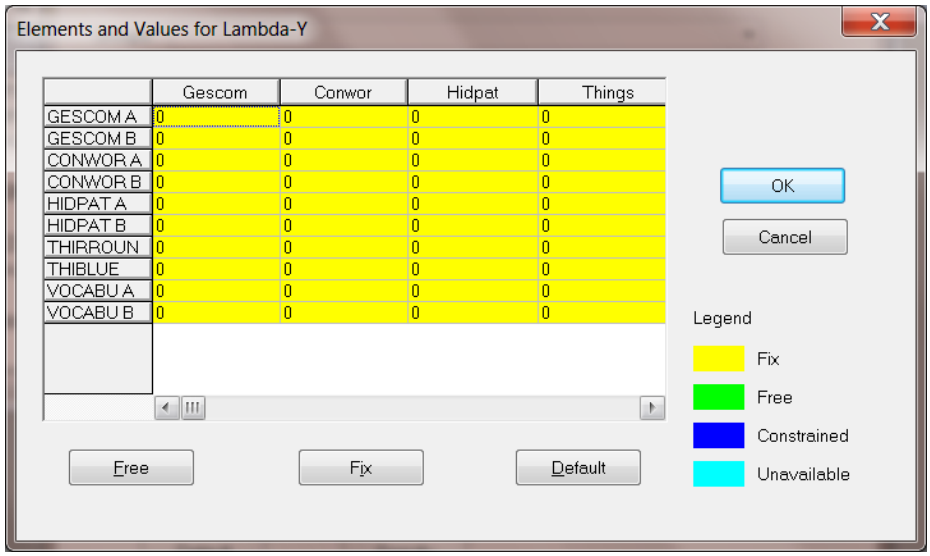


The **Model Parameters** dialog box shown below allows the user to:

- specify the form and mode of the matrices listed,
- specify which elements are fixed and which are free, and
- assign values to the elements of each of the matrices.



Since some changes need to be made to the default specifications for the Lambda-Y matrix, highlight the **Lambda-Y Full Matrix, Fixed** option by clicking on it. This action will cause the words Full Matrix and Fixed to appear in the **Matrix From** and **Matrix Mode** fields respectively. Proceed by clicking **Specify** to obtain the dialog shown below.



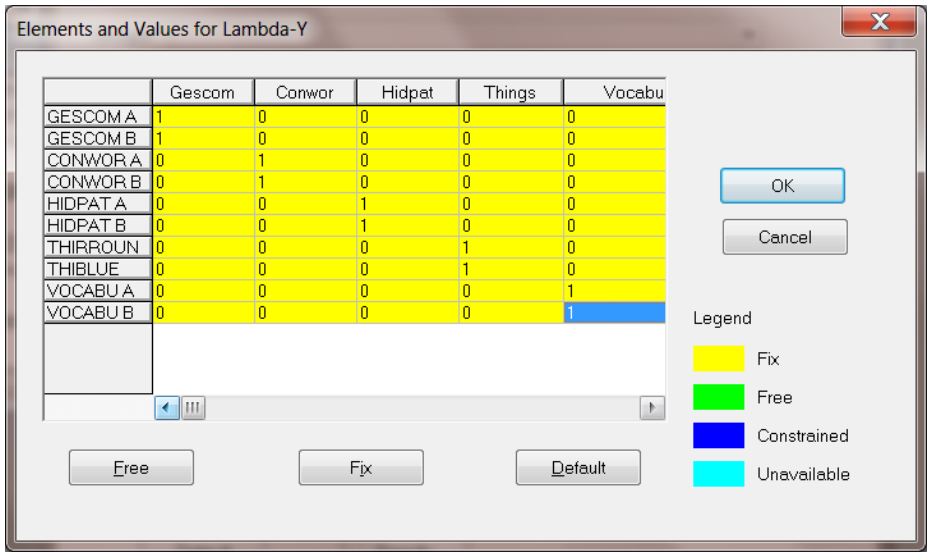
The initial dialog box will indicate that all the elements of Lambda-Y are fixed and equal to zero. The steps required to obtain the pattern shown in the dialog box below corresponding to the statements is given next.

```
VA 1.0 LY(1,1) LY(2,1) LY(3,2) LY(4,2) LY(5,2) LY(6,3) LY(7,4) LY(9,5) LY(10,5)
FR LY(8,4),
```

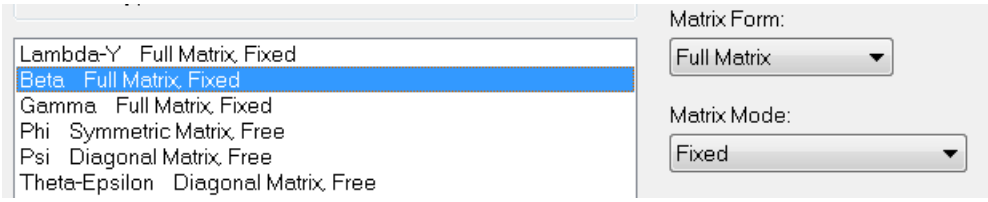
- Click on the first rectangle next to the variable description button (that is under the heading Gescom) and use the computer keyboard to type in the value of 1, then press the keyboard Enter button.
- Proceed in a similar fashion to enter 1 in the second row, and finally a 1 in the rectangle corresponding to the row VOCABU B and column Vocabu.

- By clicking on the rectangle in the row THIBLUE and column Things and then on the **Free** button, the color of the rectangle will change to indicate that LY(8,4) is free.

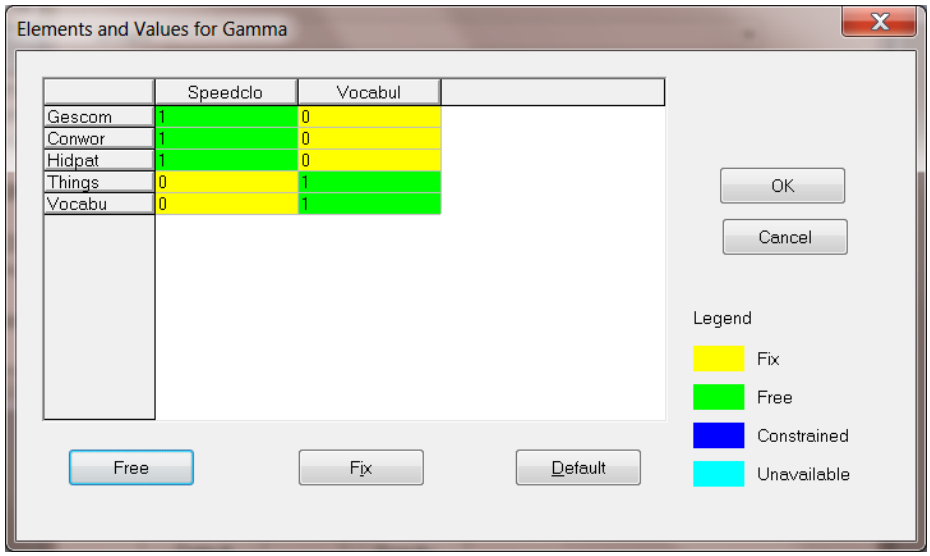
Note that one may move the mouse pointer to a vertical divider line on the dialog box below. Column widths can subsequently be adjusted by clicking the left button and dragging the vertical line to the left or the right of its present position.



The input specifications require BETA to be a full matrix with all elements fixed at a value of 0. Since this is the default, one can proceed to specify the pattern and values for the GAMMA matrix.



Highlight the **Gamma Full Matrix, Fixed** option and click on **Specify**.

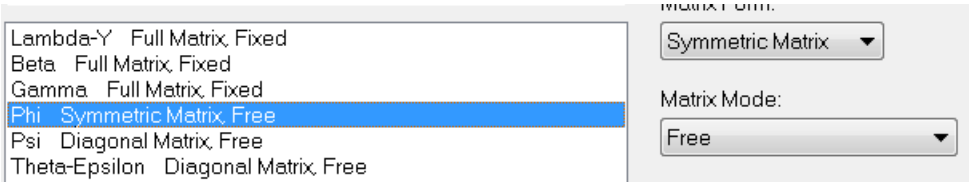


Use the dialog box shown above to specify the following statements

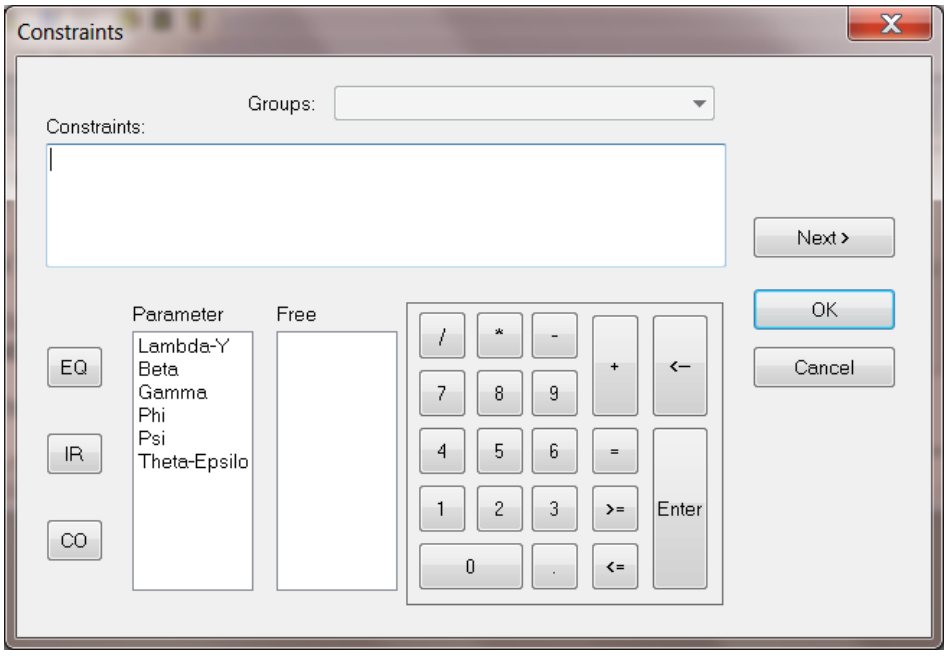
FR GA(1,1) GA(2,1) GA(3,1) GA(4,2) GA(5,2)
VA 1.0 GA(1,1) GA(2,1) GA(3,1) GA(4,2) GA(5,2)

This is accomplished by clicking on the rectangle that corresponds to the Eta-variable Gescom and the Ksi-variable Speedclo. Use the computer keyboard to type in 1 and click again to activate this rectangle. Then select the **Free** button to change the status of the GA(1,1) parameter to free. Continue in a similar fashion to obtain the pattern shown above.

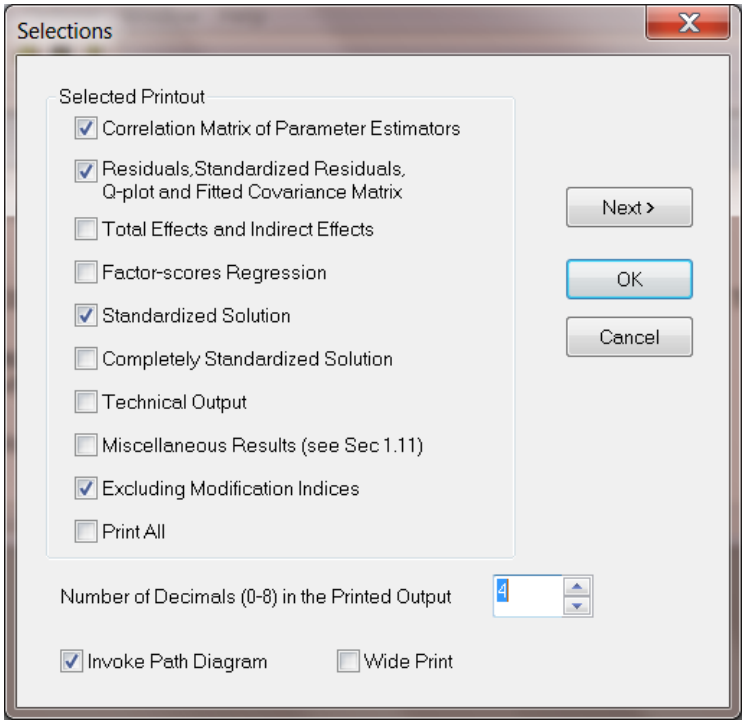
Since the default settings for the parameter matrices Psi and Theta-Epsilon are correctly set at the default values (see dialog box below), click on **Next** to go to the **Constraints** dialog box.



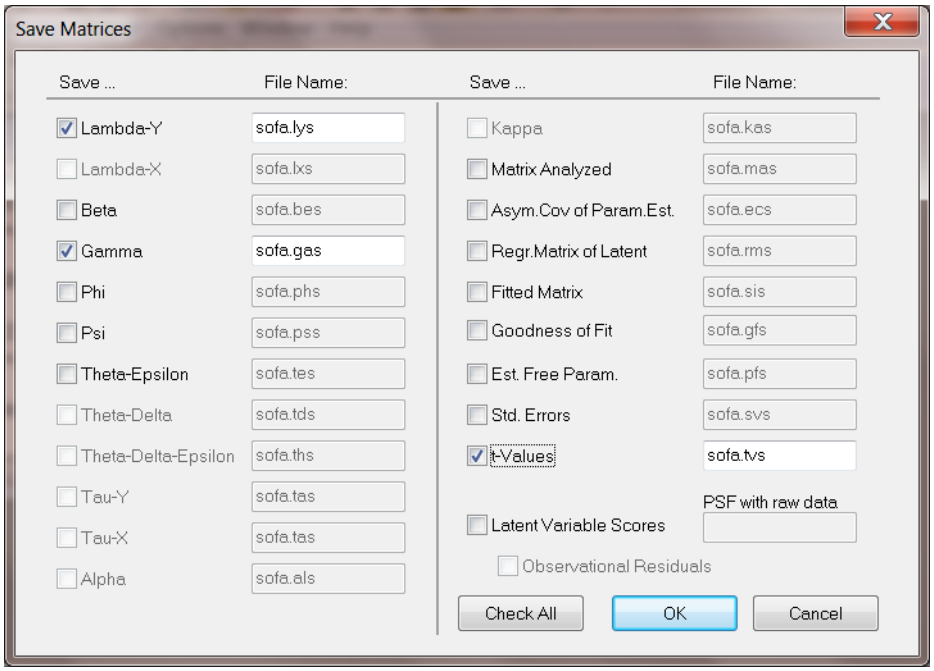
In the present example, no constraints are imposed on the elements of the parameter matrices and therefore the **Next** button is clicked to go to the **Output Selections** dialog box.



The **Output Selections** dialog box enables the user to create an output file that contains selected parts of the LISREL printout. Make the appropriate selections by clicking on the boxes at the left of the different options. Once this is done, click **Next** to go to the final dialog box, which is the **Save Matrices** dialog box.



Any of the matrices or statistics shown on the dialog box illustration below may be selected by clicking on the boxes.



As an example, we selected **Lambda-Y**, **Gamma** and **t-values**. These files will have the same filename as the LISREL project file but with different file extensions, these being *.**lys**, *.**gas**, and *.**tvs** respectively.

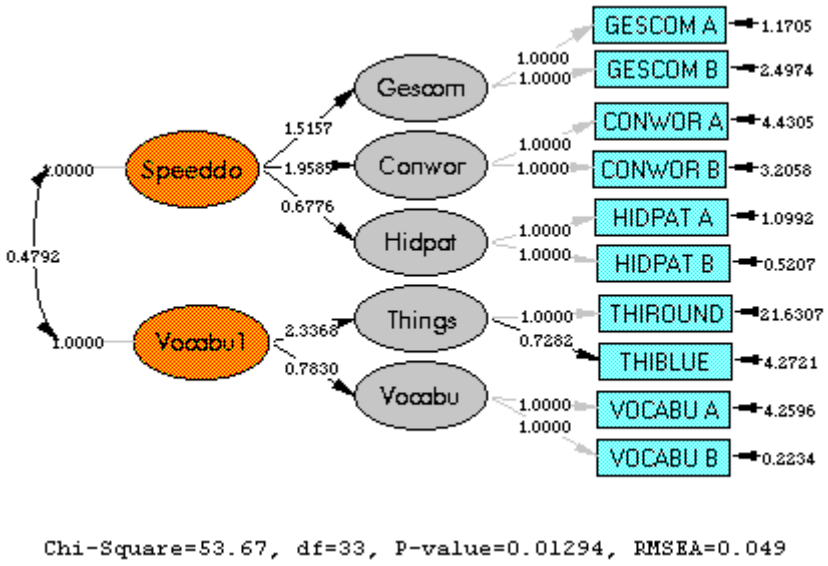
Click **OK** to return to the LISREL project (LPJ) window. The LISREL syntax, saved in the file **sofa.lpj**, is shown below:

sofa.lpj

```
TI Second Order Factor Analysis
!Data on cognitive ability tests. Number of Y-variables = 10
DA NI=10 NO=267 MA=CM
LA
CONST 'GESCOM A' 'GESCOM B' 'CONWOR A' 'CONWOR B' 'HIDPAT A' 'HIDPAT B' THIRROUN THIBLUE 'VOCABU A' 'VOCABU B'
CM FI='C:\LISREL9 Examples\TUTORIAL\SOFA.COV' SY
MO NY=10 NK=2 NE=5 BE=FU GA=FI PS=SY TE=SY
LE
Gescom Conwor Hidpat Things Vocabu
LK
Speedclo Vocabul
FR LY(8,4) GA(1,1) GA(2,1) GA(3,1) GA(4,2) GA(5,2)
VA 1 LY(1,1)
VA 1 LY(2,1)
VA 1 LY(3,2)
VA 1 LY(4,2)
VA 1 LY(5,3)
VA 1 LY(6,3)
VA 1 LY(7,4)
VA 1 LY(8,4)
VA 1 LY(9,5)
VA 1 LY(10,5)
PD
OU PC RS SS XM ND=4  LY=sofa.lys GA=sofa.gas TV=sofa.tvs
```

Click the **Run LISREL** icon button on the main menu bar to run the problem.

The path diagram for this example is shown below and the output is saved to the file **sofa.out**.



One may modify the path diagram by deleting, fixing or adding paths.

8 Analysis with Missing Data

8.1 Single-Group Analysis with Missing Data

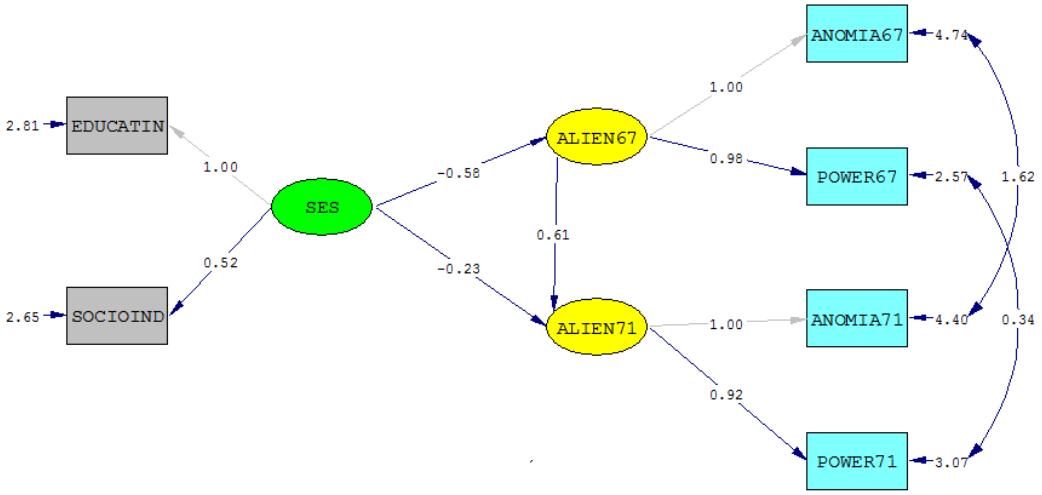
Data on attitude scales were collected from 932 persons in two rural regions in Illinois at three points in time: 1966, 1967 and 1971. The variables used for the present example are the Anomia subscale and the Powerlessness subscale, taken to be indicators of Alienation. This example uses data from 1967 and 1971 only.

The background variables are the respondent's education (years of schooling completed) and Duncan's Socioeconomic Index (SEI). These are taken to be indicators of the respondent's socioeconomic status (SES).

Observed Variables: Anomia 67, Powerlessness 67, Anomia 71, Powerlessness 71, Education, SEI

Latent Variables: SES, Alienation 67, Alienation 71

The model shown in the path diagram below was fitted by running **ex64d.lis** (in the **LISREL examples** folder).

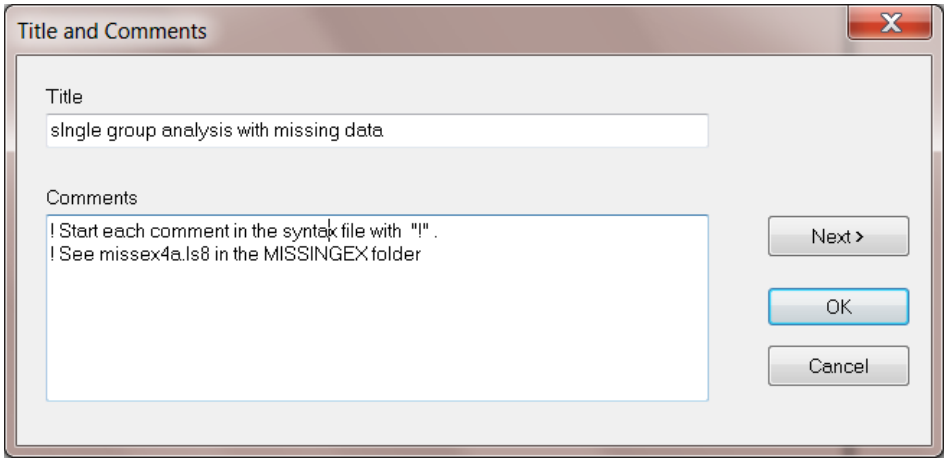


Chi-Square=4.72, df=4, P-value=0.31731, RMSEA=0.014

By adding SI=filename to the OU line of the syntax file, the fitted covariance matrix may be saved to an external file.

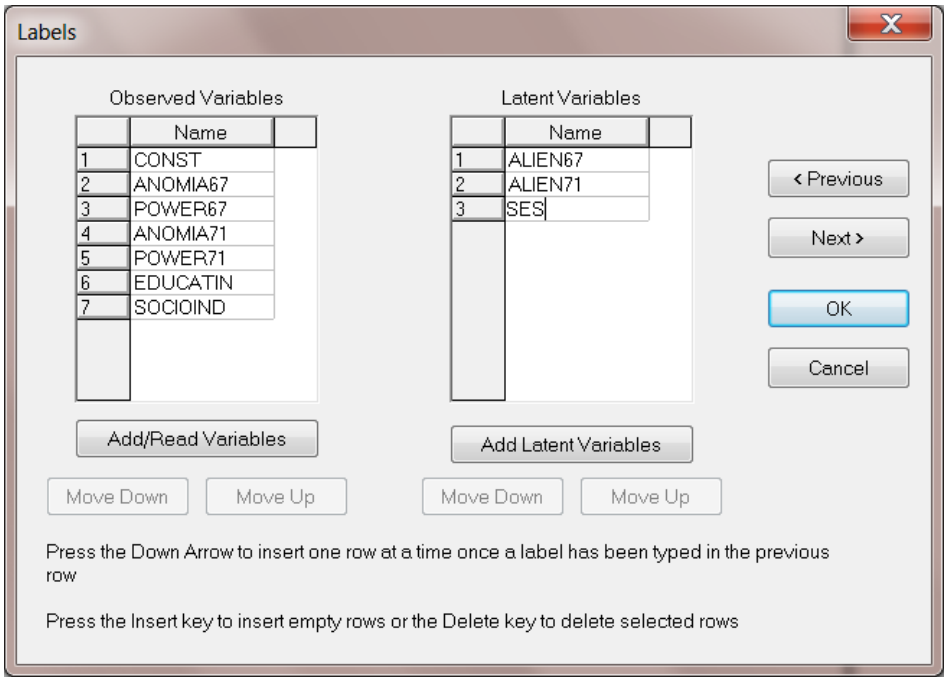
Subsequently, a data set of size 1500, with 15% of the values missing at random, was simulated by regarding the fitted covariance matrix as the true population covariance matrix. This data set is stored as the text file **wmas.dat**. A corresponding ***.lsf** file, containing the variable names, missing value code, number of records and the data is stored as **wmas.lsf**. Select **File, New, Path Diagram** and save the path. In the dialog box below, we used the name **sgroup.pth**.

Click **Save** when done and select the **Title and Options** option from the **Setup** menu. Enter a title and optional comments. Click **Next** to proceed to the **Group Names** dialog box and again click **Next** to proceed to the **Labels** dialog box.



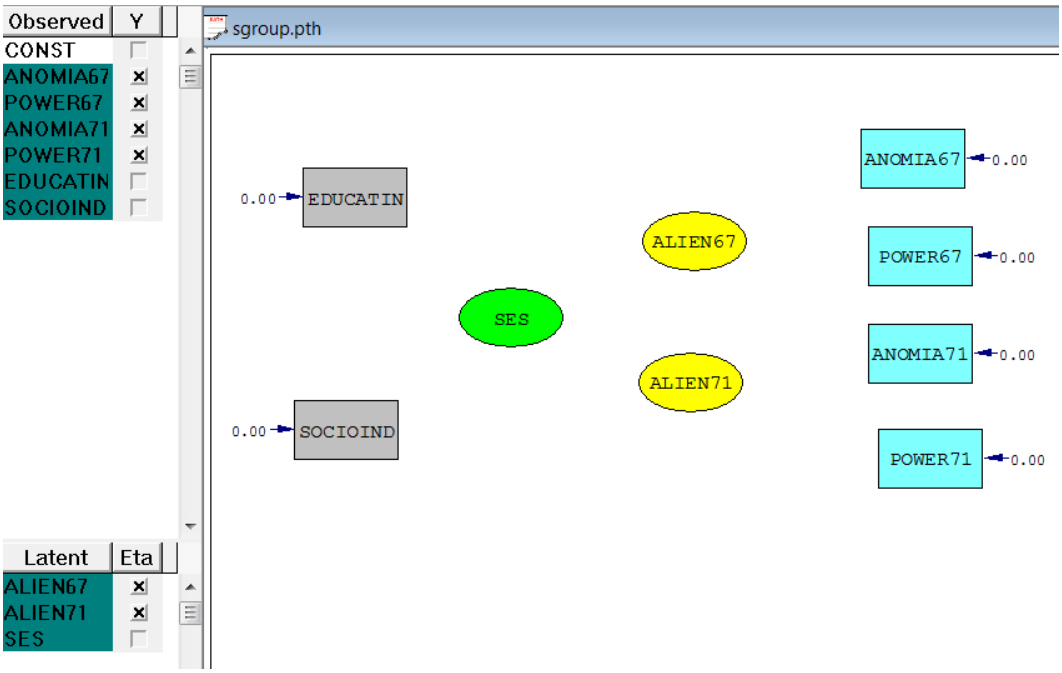
Click the **Add/Read Variables** button and on the **Add/Read Variables** dialog box select LISREL System data file from the **Read from file** drop-down list. Use the **Browse** button to locate **wmas.lsf**.

Click **OK** when done and add the latent variable names as shown below. By default, LISREL uses the file selected for reading in variable names as the data file. It is therefore not necessary to proceed to the **Data** menu. Click **OK** to return to the path diagram window.



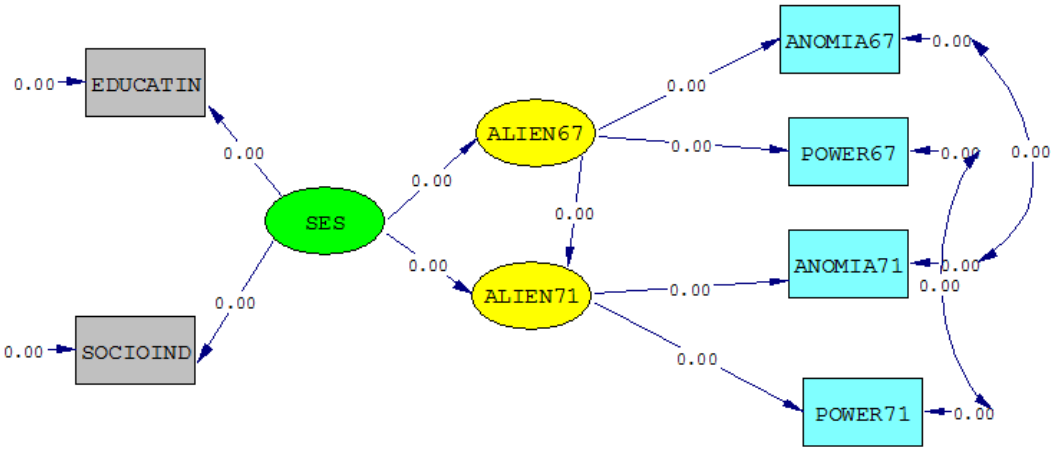
Mark the first four variables as Y-variables and the first two latent variables as Eta-variables. (Left) click on each variable name, and with the mouse button down, drag the variable to the path diagram (PTH) window.

Start with the Y-variables first, then continue with the Eta-variables, then the Ksi-variables and finally the X-variables. In other words, start with ANOMIA67 and end with SOCIOIND.

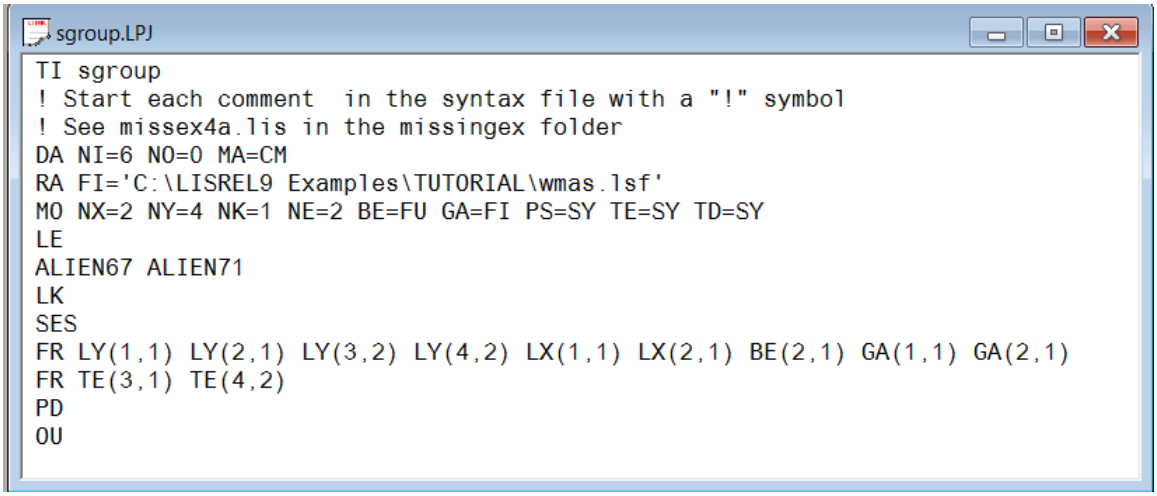


Click on the draw tool (single-headed arrow) and add all the paths as shown below. Start by moving the mouse cursor to the center of ALIEN67, and, with the mouse button down, drag the arrow to the center of ANOMIA67 and release the button.

Once all the single paths have been drawn, click on the double-headed arrow. Move the cursor to the center of the error variance arrow of ANOMIA67, then, with the left mouse button held down, drag to the center of the error variance arrow of ANOMIA71. Repeat this procedure to allow for a covariance between POWER67 and POWER71.



Select **Build** LISREL **syntax** from the **Setup** menu to produce the **sgroup.lpj** file. This file is displayed in the LISREL project (LPJ) window shown below.



The syntax files **missex4a.lis** and **missex4b.spl** in the **missing data examples** subfolders of **LISREL examples** and **SIMPLIS examples** contain the corresponding LISREL and SIMPLIS syntax for fitting the model. Missing values for this analysis are indicated by a value of -9. A FIML analysis is carried out if the DA line in the LISREL syntax contains the keyword MI=<value>. This is required if the data file is not a LSF file:

```
DA NI=6 NO=1500 MI=-9
LA
ANOMIA67 POWER67 ANOMIA71 POWER71 EDUCATIN SOCIOIND
RA FI=WMAS.DAT
MO NY=4 NX=2 NE=2 NK=1 BE=SD PS=DI TE=SY
LE
ALIEN67 ALIEN71
LK
SES
FR LY(2,1) LY(4,2) LX(2,1) TE(3,1) TE(4,2)
VA 1 LY(1,1) LY(3,2) LX(1,1)
PD
OU SE TV MI ND=3 PT
```

Click the **Run** LISREL icon button to obtain a path diagram and output file. Once the data are read, estimates are obtained of the means and covariances and a $-2\ln L$ value is printed. This value is the $-2\ln L$ value for the unrestricted model.

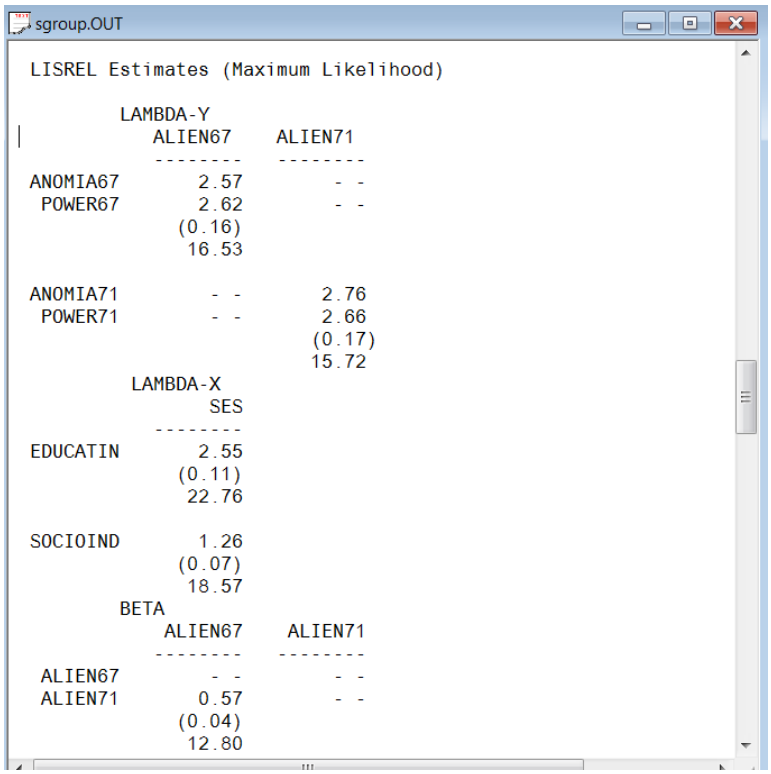
Portions of the output file are shown below:

(i) –2*Log(likelihood) and percentage cases missing

The EM-algorithm is used to obtain estimates of the population means and covariances. LISREL uses these values to obtain starting values for the maximum likelihood procedure. Convergence is attained in 8 iterations, and at convergence $-2\ln L$ equals 35822.65. This value is also referred to as the $-2\ln L$ value for the saturated model.

sgroup.OUT

```
               ---------------------------------
                EM Algorithm for missing Data:
               ---------------------------------

          Number of different missing-value patterns=       47
          Effective sample size:     1500

          Convergence of EM-algorithm in     6 iterations
          -2 Ln(L) =    35822.64699
          Percentage missing values=  15.32

     Note:
       The Covariances and/or Means to be analyzed are estimated
       by the EM procedure and are only used to obtain starting
       values for the FIML procedure


        Covariance Matrix

            ANOMIA67    POWER67   ANOMIA71    POWER71   EDUCATIN   SOCIOIND
            --------    --------  --------    --------  --------   --------
ANOMIA67      11.84
 POWER67       6.75       9.51
ANOMIA71       6.57       4.94      11.99
 POWER71       4.37       5.07       7.29      10.05
EDUCATIN      -3.79      -3.74      -3.40      -3.47       8.96
SOCIOIND      -2.02      -1.83      -1.59      -1.66       3.21       4.20
```



(iv) Global Goodness of Fit Statistics, Missing Data Case

-2ln(L) for the saturated model = 35822.647
-2ln(L) for the fitted model = 35828.671
Degrees of Freedom = 4
Full Information ML Chi-Square = 6.02 (P = 0.20)
Root Mean Square Error of Approximation (RMSEA) = 0.018

8.2 Multiple-groups with Missing Data

Sörbom (1981) reanalyzed some data from the Head Start summer program previously analyzed by Magidson (1977). Sörbom used data on 303 white children consisting of a Head Start sample (N = 148) and a matched Control sample (N = 155). The children were matched on gender and kindergarten attendance, but no attempt had been made to match on social status variables.

The variables used in Sörbom's re-analysis were:

X_1 = Mother's education (MOTHEDUC)
X_2 = Father's education (FATHEDUC)
X_3 = Father's occupation (FATHOCCU)
X_4 = Family income (FAMILINC)
Y_1 = Score on the Metropolitan Readiness Test (MRT)
Y_2 = Score on the Illinois Test of Psycholinguistic Abilities (ITPA)

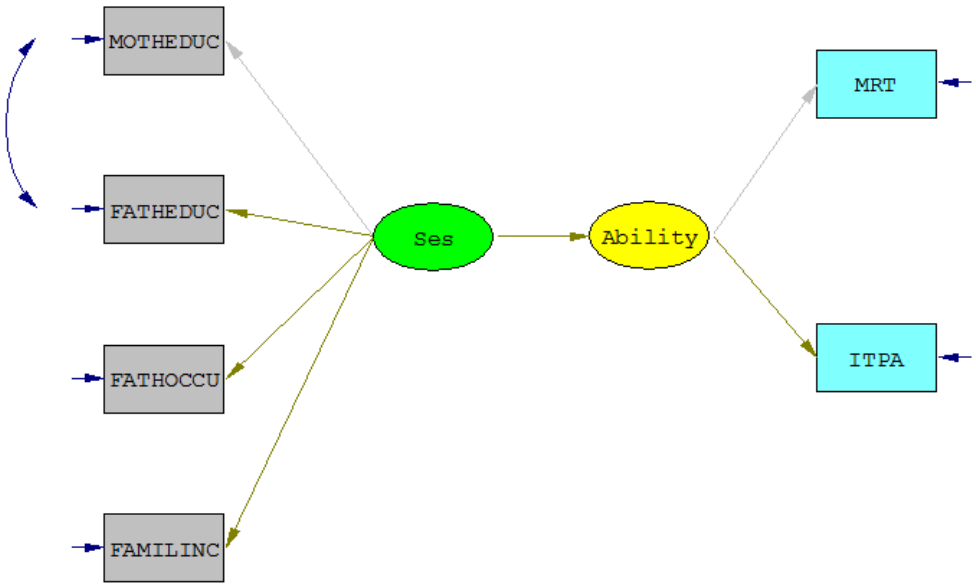
The following issues were examined:

- Test whether X_1, X_2, X_3 and X_4 can be regarded as indicators of a single construct Ses (socioeconomic status) for both groups. Is the measurement model the same for both groups? Is there a difference in the mean of Ses between groups?
- Assuming that Y_1 and Y_2 can be used as indicators of another construct Ability (cognitive ability), test whether the same measurement model applies to both groups. Test the hypothesis of no difference in the mean of Ability between groups.
- Estimate the structural equation:

$$Ability = \alpha + \gamma Ses + z$$

- Is γ the same for the two groups? Test the hypothesis $\alpha = 0$ and interpret the results.

A conceptual path diagram for the model fitted to the data is shown below.



The fitted covariance matrices obtained from **ex16d.spl** (in the **SIMPLIS examples** folder) were used to simulate a control group data set (sample size 550 and percentage missing 15%) and to simulate a Head Start data set (sample size of 600 and percentage missing 10%).

Note:

To invoke the FIML procedure for the analysis of missing data, the following three statements must be given in the SIMPLIS syntax in the order shown below.

```
Missing Value Code <value>
Sample Size: <nsize>
Raw data from file <filename>
```

The complete SIMPLIS syntax file is shown below.

```
FIML: Example 1: SIMPLIS syntax
Group = Control
```

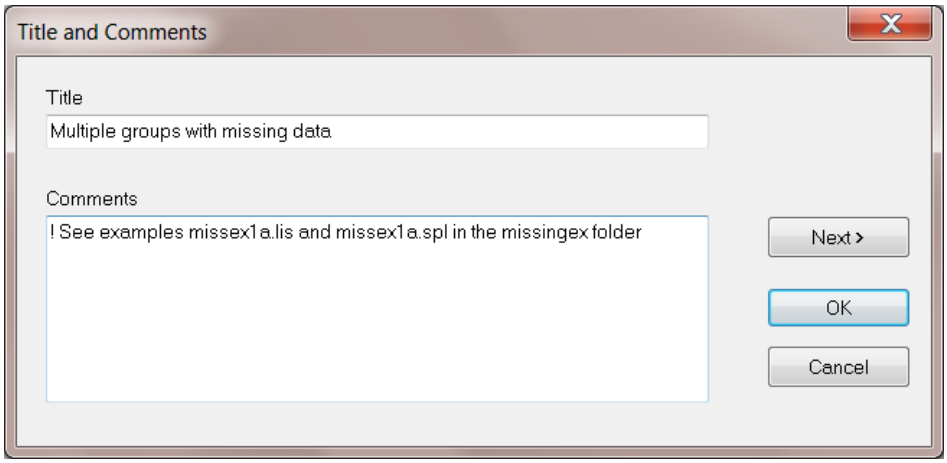
```
Observed Variables: MOTHEDUC FATHEDUC FATHOCCU FAMILINC MRT ITPA
Missing Value Code –9
Sample Size: 550
Raw Data from File CONTROL.DAT
Latent Variables: Ses Ability
Relationships:
  MOTHEDUC          = CONST + 1*Ses
  FATHEDUC - FAMILINC = CONST +   Ses
  MRT               = CONST + 1*Ability
  ITPA              = CONST +   Ability
  Ability = Ses
Let the Errors of MOTHEDUC and FATHEDUC correlate
Group = Head Start
Missing Value Code –9
Sample Size: 600
Raw Data from File EXPERIM.DAT

Relationships:
  Ses     = CONST
  Ability = CONST + Ses
Set the Error Variances of MOTHEDUC - ITPA free
Set the Variance of Ses free
Set the Error Variance of Ability free
Let the Errors of MOTHEDUC and FATHEDUC correlate
LISREL Output: ND=3
Path Diagram
End of Problem
```

If the data are stored in a LISREL system file (*.**lsf**), the Observed Variables, Missing Value Code, Sample Size and Raw data from file control.dat can be replaced with the statement

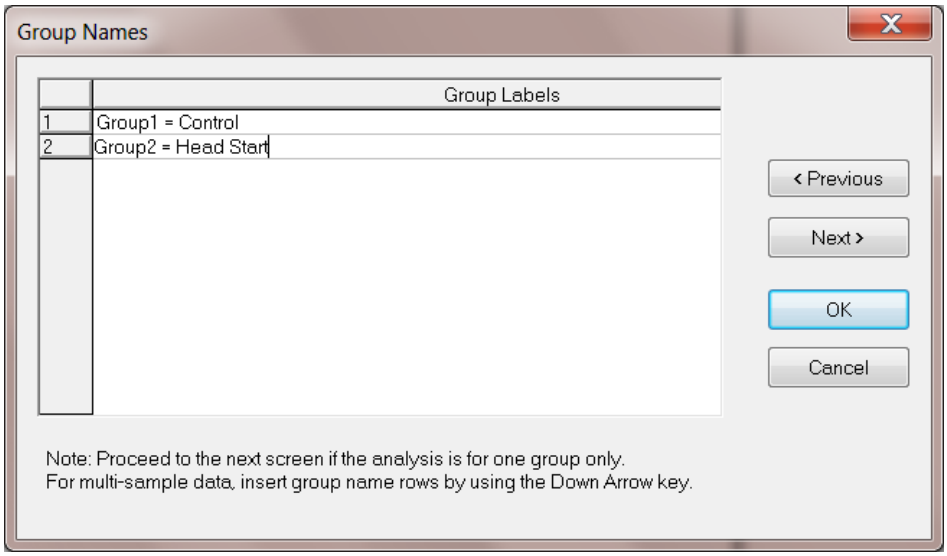
```
Raw data from file control.lsf
```

If a *.**lsf** file contains missing data, the user should ensure that a global missing value code is assigned. This can be done by using the **Data**, **Define Variables** option. Subsequently, we illustrate how to build the SIMPLIS (or LISREL) syntax by drawing a path diagram.

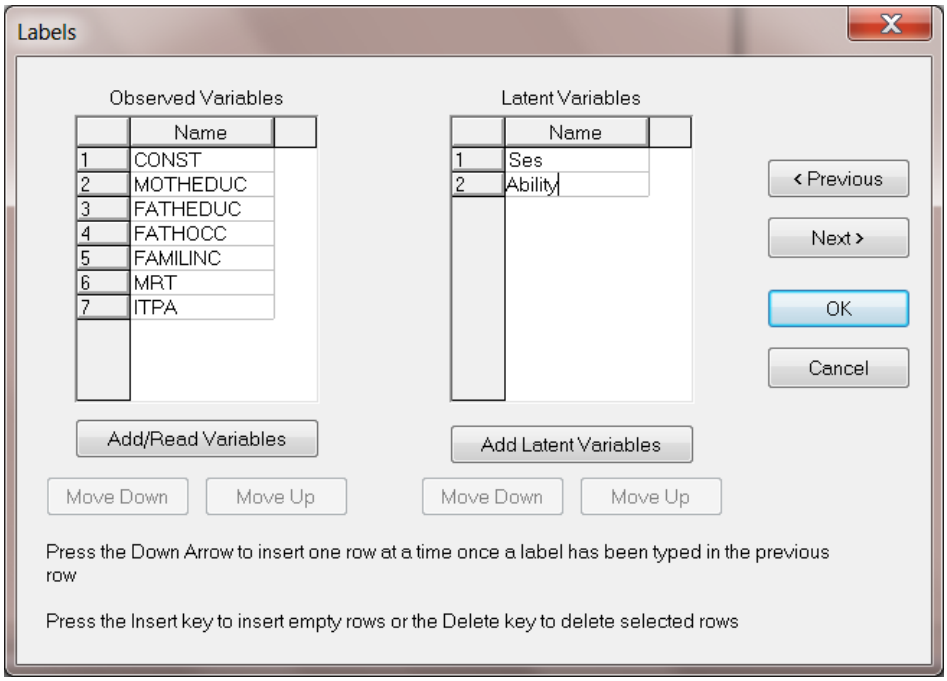
Select the **New** option from the **File** menu. On the **New** dialog box, select **Path Diagram** and save the path diagram as **mgroup.pth**. These steps are described in detail in earlier sections of this guide. From the **Setup** menu, select **Title and Comments** and provide a title and any optional comments. When done, click **Next** to go to the **Group Names** dialog box.



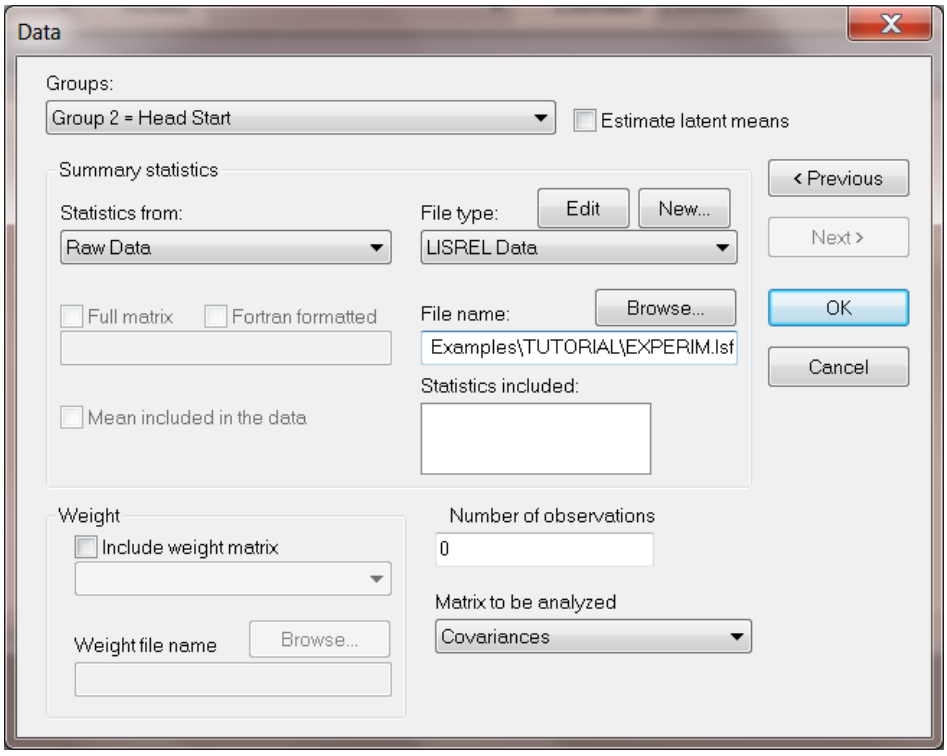
Use the instructions on the bottom of the **Group Names** dialog box to enter group names, then click **Next** to go to the **Labels** dialog box.



The files **control.lsf** and **experim.lsf** contain the Group1 and Group2 data respectively. Click the **Add/Read Variables** button, select LISREL **System File** from the **Add/Read Variables** dialog box and use the **Browse** button to locate the file **control.lsf**. Click **OK** when done to return to the **Labels** dialog box. Use the **Add Latent Variables** button to insert the names Ses and Ability.

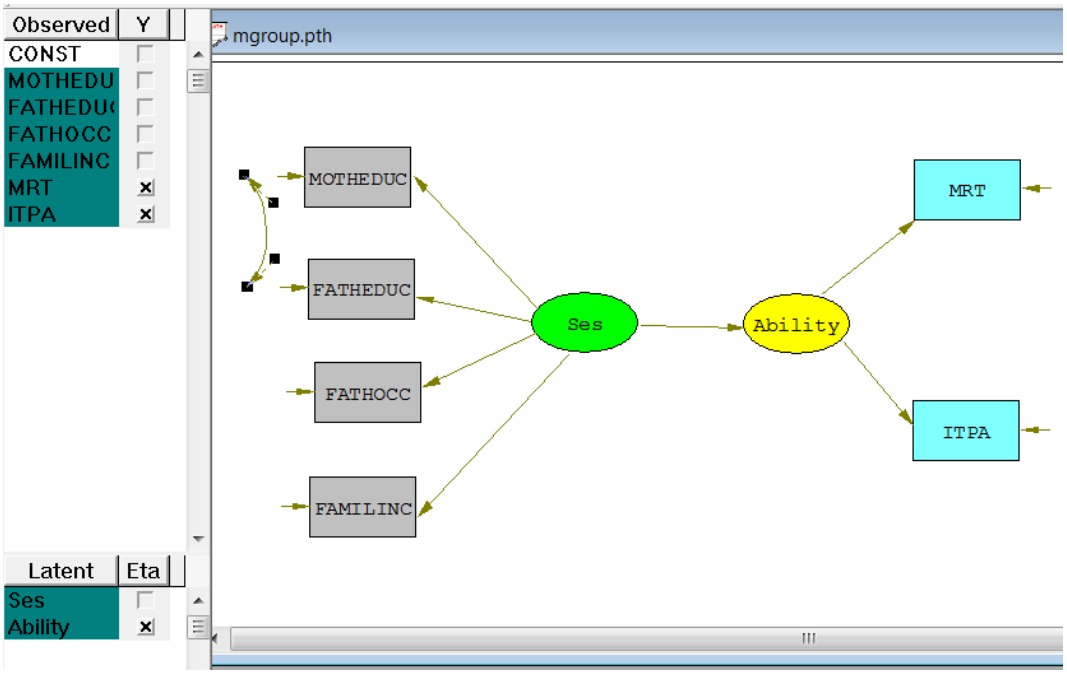


Click the **Next** button to go to the **Data** dialog box. Since a ***.lsf** file was selected in the previous step, the **Data** dialog box shows the **File type:** as LISREL System Data File and the filename as **control.lsf**. Use the **Groups:** drop-down list box to select Group2=Head Start. Once this is done, use the **Browse** button to locate the file **experim.lsf**. Click **Open** to return to the **Data** dialog box.

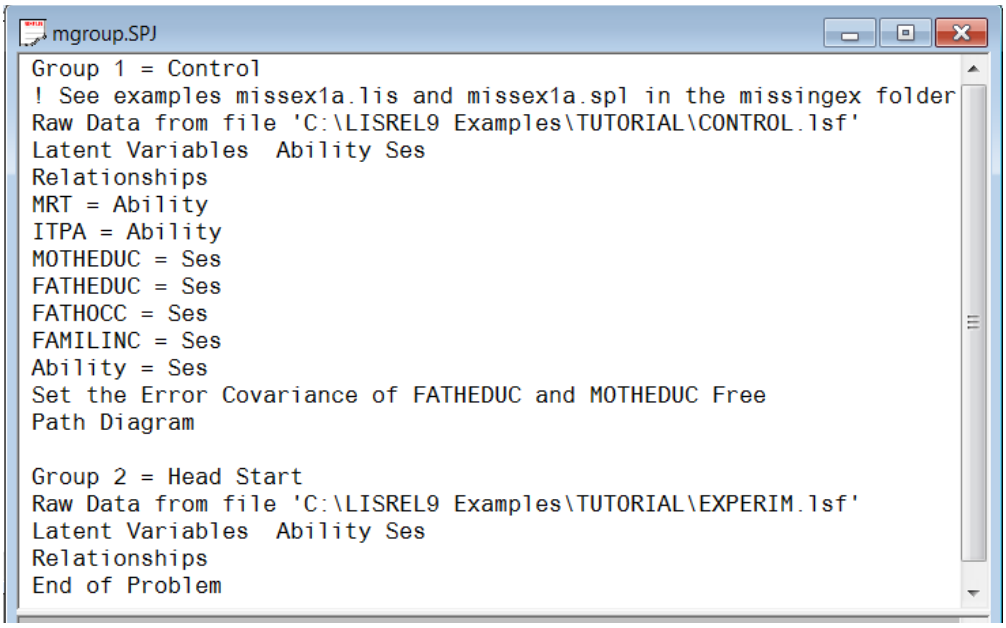


Click **OK** when done. Select the variables MRT and ITPA as Y-variables and Ability as an Eta-variable. Drag variable names to the path diagram screen in the order MRT, ITPA, Ability, Ses, MOTHEDUC, FATHEDUC, FATHOCC, and FAMILINC. Use the draw toolbar to draw the paths as shown below.

A more detailed description of this process is given in preceding sections of this guide.

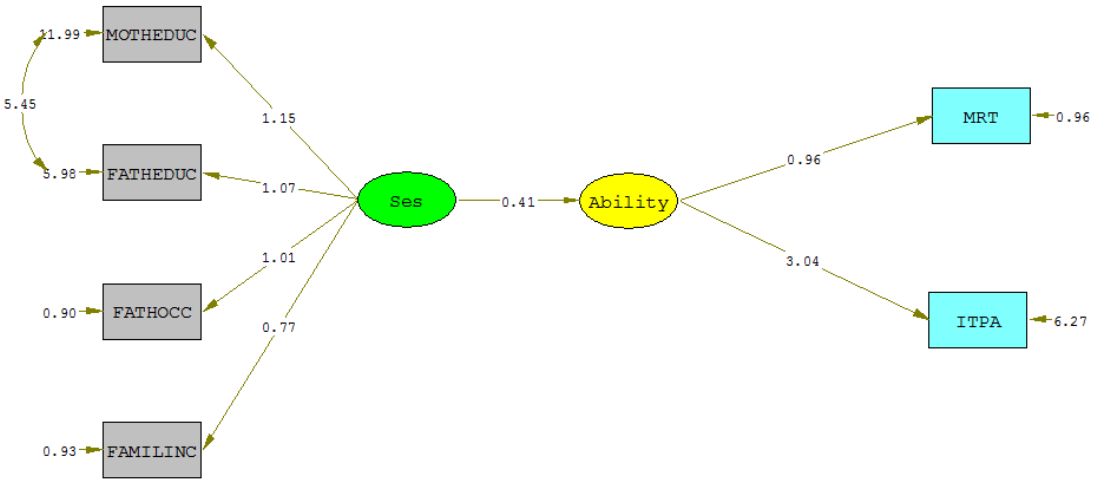


When the path diagram is completed, use the **Build SIMPLIS syntax** option from the **Setup** menu to create the SIMPLIS syntax file which is displayed in the SIMPLIS project window, as shown below.



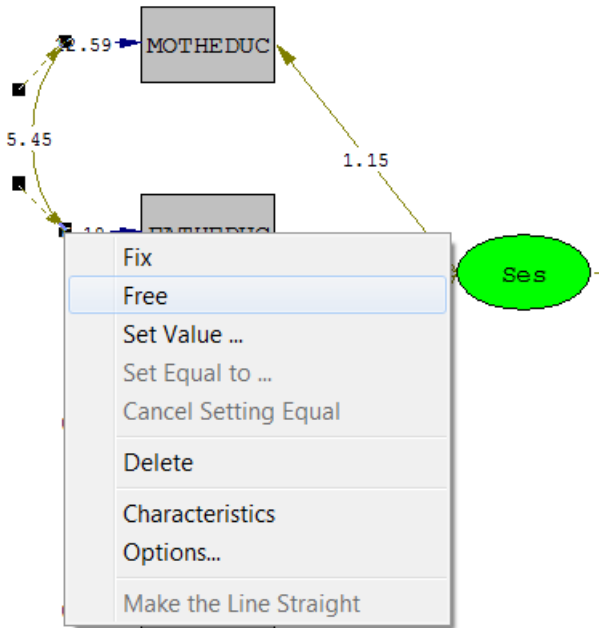
Note that no relationships are given for Group2 under the Relationships keyword. This implies that all parameters are constrained to be equal across groups.

Click the **Run LISREL** icon to create an output file and the path diagram shown below.



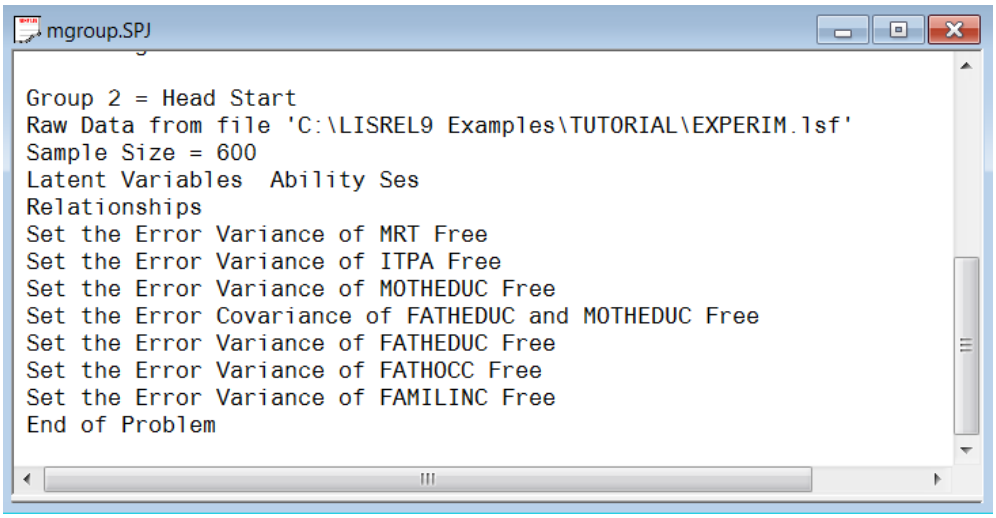
Chi-Square=72.69, df=27, P-value=0.00000, RMSEA=0.054

Since it is not realistic to assume equal error variances across groups, we can set each error variance free by moving the mouse to the appropriate arrow (e.g. MRT ← 0.96). Right click to obtain the menu below and select the **Free** option. Proceed in a similar way to free the error variances of ITPA, MOTHEDUC, FATHEDUC, FATHOCC and FAMILINC as well as the covariance (5.45) between MOTHEDUC and FATHEDUC.

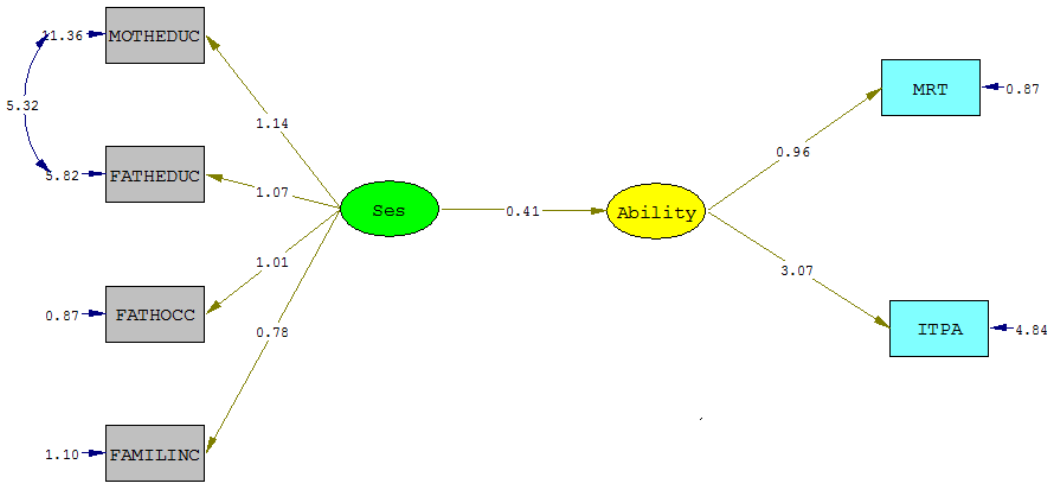


Also right click on the arrow between Ses and Ability to free that path. When this is done, rebuild the SIMPLIS syntax using the **Build SIMPLIS syntax** option on the **File** menu.

A portion of the SIMPLIS project file showing the resultant relationships for group 2 is shown below.



Click the **Run LISREL** icon button to produce the path diagram shown below.



Chi-Square=31.87, df=20, P-value=0.04468, RMSEA=0.032

When the missing value code, sample size and raw data file information are read in, the EM algorithm for estimating the means and covariances under the unrestricted model is started. From this portion of the output a percentage of 14.61% missing cases are reported for group 1 and 9.92% for group 2.

Note that the estimated means and covariances are used to obtain starting values for the FIML procedure. In addition, a $-2\ln L$ value is reported for each group. This value is minus two times the log likelihood value obtained when no restrictions are imposed on means and covariance matrices. From the output it follows that the sum of the $-2\ln L$ values for the groups equals 11358.595 + 12716.065 = 24074.660.

The FIML procedure converged in 6 iterations. Portions of the output file are given below.

(i) LISREL Estimates (Maximum Likelihood) for the control group

Number of Iterations = 6

Measurement Equations

MRT = 0.86*Ability, Errorvar.= 1.06 , R**2 = 0.20
(0.11) (0.084)
7.78 12.58

ITPA = 2.74*Ability, Errorvar.= 7.89 , R**2 = 0.26
(0.69)
11.41

MOTHEDUC = 1.14*Ses, Errorvar.= 12.70, R**2 = 0.093
(0.14) (0.85)
8.42 14.92

FATHEDUC = 1.07*Ses, Errorvar.= 6.15 , R**2 = 0.16
(0.098) (0.43)
10.90 14.26

FATHOCC = 1.01*Ses, Errorvar.= 0.96 , R**2 = 0.51
(0.055) (0.11)
18.35 8.39

FAMILINC = 0.78*Ses, Errorvar.= 0.74 , R**2 = 0.45
(0.047) (0.076)
16.65 9.81

(ii) Global Goodness of Fit Statistics, Missing Data Case

-2ln(L) for the saturated model = 24074.660
-2ln(L) for the fitted model = 24106.532
Degrees of Freedom = 20
Full Information ML Chi-Square = 31.872 (P = 0.0447)
Root Mean Square Error of Approximation (RMSEA) = 0.032

The FIML χ^2 is obtained as the difference between -2 ln L (24105.18) for the fitted model and -2 ln L for the unrestricted model and equals 31.872.

9 Latent Variable Scores

9.1 Calculation of Latent Variable Scores

To obtain scores for the latent variables of a structural equation model, the following three steps are required.

Step 1

If the data are not available as a LISREL system data file (*.**lsf**) yet, use the **Import Data in Free Format** or **Import External Data in Other Formats** options from the **File** menu to create a *.**lsf** file.

Step 2

Use this *.**lsf** file to compute the desired sample covariance or correlation matrix to which the structural equation model should be fitted. This may be done by running the appropriate PRELIS syntax file or by using

the **Output Options** option from the **Statistics** menu. Either action will result in the creation a LISREL data summary file (*.**dsf**). A *.**dsf** file contains all the data information that LISREL requires to fit the structural equation model to the data.

Step 3

In SIMPLIS syntax, use the line

System File from file <filename>.DSF

to specify the data to be analyzed and insert the command line

LSFfile <filename>.LSF

after the Relationships paragraph where <filename> denotes the path and name of the *.**lsf** file. The System File command replaces the Observed Variables paragraph and the Sample Size line.

In LISREL syntax, use the command line

SY = <filename>.DSF

to specify the *.**dsf** file and the

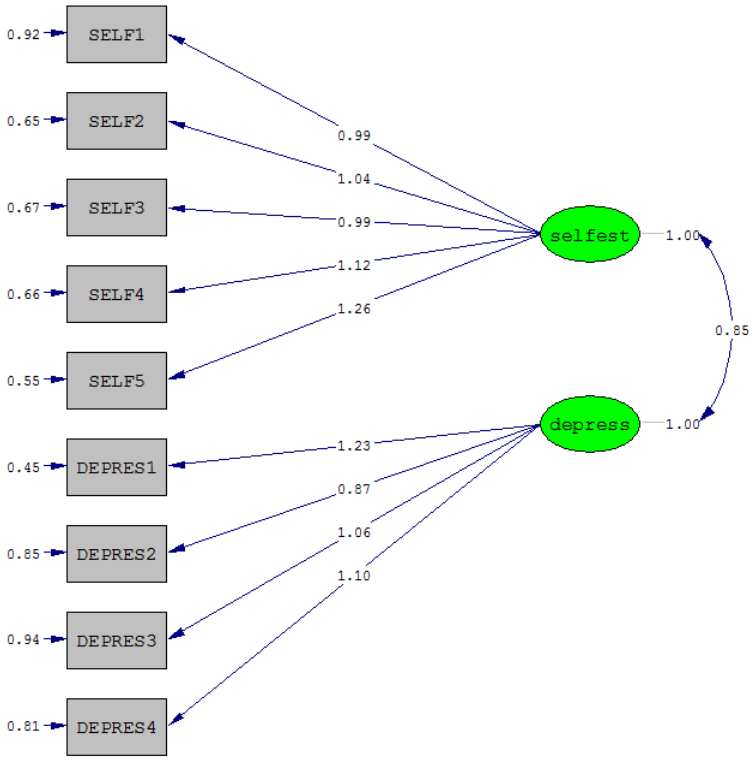
LS = <filename>.LSF

command line to specify the *.**lsf** file. The SY command replaces the LA and the DA commands.

When done, run the syntax file by clicking the **Run LISREL** icon button. When the output file is displayed, open the relevant *.**lsf** file using the **Open** option from the **File** menu. The latent variable scores appear as the last set of columns of this file.

9.2 An Illustrative Example

Chow (2000) used five indicators of self esteem (Selfest) and four indicators of depression (Depress) to formulate a measurement model for the latent variables Self Esteem and Depression. A path diagram of this measurement model is shown below.

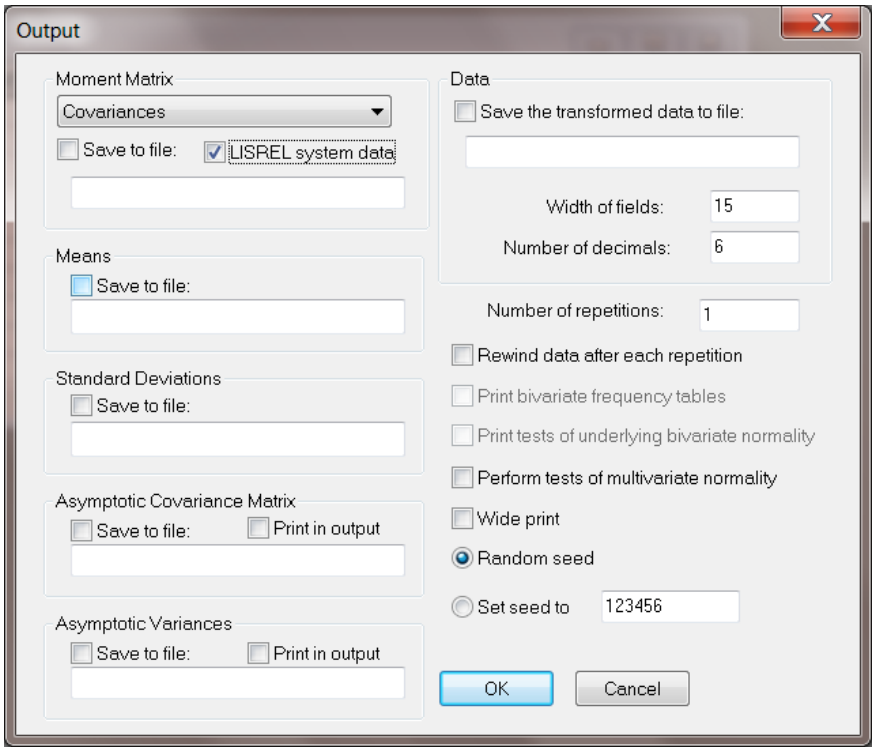


The nine indicators were observed for a random sample size of 230 college graduates. The resulting raw data are listed in the PRELIS System File **depression.lsf**. A portion of the spreadsheet is shown below.

Depression.lsf

	SELF1	SELF2	SELF3	SELF4	SELF5	DEPRES1	DEPRES2
1	3.00	2.00	3.00	4.00	4.00	4.00	2.00
2	2.00	1.00	2.00	3.00	2.00	3.00	0.00
3	2.00	1.00	4.00	2.00	2.00	2.00	0.00
4	1.00	1.00	2.00	2.00	4.00	4.00	3.00
5	2.00	0.00	1.00	2.00	3.00	2.00	1.00
6	4.00	3.00	3.00	2.00	4.00	2.00	1.00
7	0.00	0.00	1.00	2.00	1.00	2.00	0.00
8	4.00	2.00	2.00	2.00	2.00	2.00	0.00
9	3.00	3.00	2.00	2.00	3.00	4.00	2.00
10	0.00	3.00	3.00	3.00	1.00	3.00	1.00

The PRELIS syntax file **depression.prl** contains the required syntax to compute the sample covariance and to create the desired LISREL Data Summary File **depression.dsf**. This file is generated by selecting the **Output Options** option from the **Statistics** menu. The **Output** dialog box is shown below. Select **Covariances** and check the **LISREL system data** box. Click **OK** to run PRELIS.



The contents of **depression.prl** are listed below.

```
SY= Depress.lsf
OU MA=CM XM XB XT
```

The SIMPLIS syntax file **depress.spl** is used to compute the latent variable scores for the latent variables Self Esteem and Depression. The contents of this file are listed below.

If LISREL is executed, a LISREL system data file **depressionnew.lsf** is created with the latent variable scores as shown below.

DEPRESSIONnew.lsf

	SELF5	DEPRES1	DEPRES2	DEPRES3	DEPRES4	selfest	depress
1	4.00	4.00	2.00	0.00	4.00	1.14	0.97
2	2.00	3.00	0.00	0.00	1.00	-0.01	-0.25
3	2.00	2.00	0.00	4.00	4.00	0.20	0.47
4	4.00	4.00	3.00	4.00	4.00	0.39	1.50
5	3.00	2.00	1.00	4.00	4.00	-0.14	0.53
6	4.00	2.00	1.00	3.00	4.00	1.02	0.58
7	1.00	2.00	0.00	2.00	1.00	-0.91	-0.44
8	2.00	2.00	0.00	4.00	4.00	0.28	0.48
9	3.00	4.00	2.00	4.00	4.00	0.66	1.42
10	1.00	3.00	1.00	4.00	4.00	0.16	0.90

The LISREL syntax file corresponding to the SIMPLIS syntax file **depress.spl** is shown below.

Depress.lis

```
TI Latent variable scores
SY='C:\LISREL9 Examples\TUTORIAL\DEPRESSION.DSF'
MO NX=9 NK=2 TD=SY
LK
selfest depress
FR LX(1,1) LX(2,1) LX(3,1) LX(4,1) LX(5,1) LX(6,2) LX(7,2) LX(8,2) LX(9,
LS Depression.lsf
PD
OU
```

10 Multilevel Confirmatory Factor Analysis

The next example illustrates

- importing of external data such as SPSS ***.sav** files
- drawing a multiple-group path diagram
- building SIMPLIS/LISREL syntax from a path diagram
- fitting a multilevel structural equations model to the data

The data set used in this example forms part of the data library of the Multilevel Project at the University of London, and comes from the Junior School Project (Mortimore et al, 1988). Mathematics and language tests were administered in three consecutive years to more than 1000 students from 50 primary schools, which were randomly selected from primary schools maintained by the Inner London Education Authority. The data set is stored as an SPSS for Windows file named **jsp2.sav**.

It is convenient to work with LISREL system data files (***.lsf**) since LISREL can read the variable names, the number of variables, the number of records and other relevant information directly from these files. It is therefore advantageous to convert files from other software packages to the ***.lsf** format.

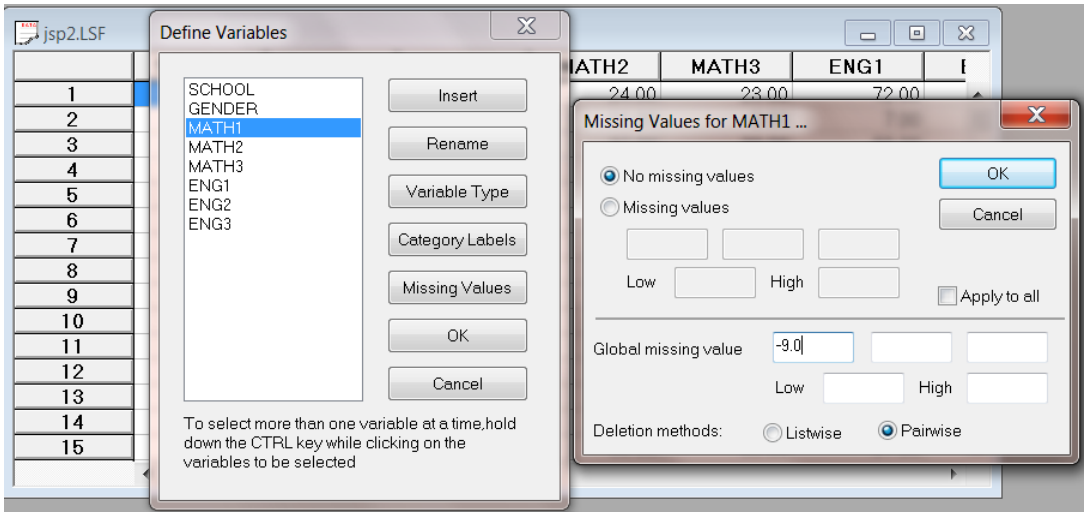
10.1 Import of External Data

Use the **Import External Data in Other Formats** option from the **File** menu to obtain the **Input Database** dialog box. Select SPSS for Windows (***.sav**) from the **Files of type** drop-down menu list and select **jsp2.sav**. Click **Open** to obtain the **Save As** dialog box.

Enter the name **jsp2.lsf** in the **File name** string field. By clicking the **Save** button a LISREL system data file is created and displayed in the form of a data spreadsheet.

Although no missing value codes were assigned in **jsp2.sav**, data values of -9 indicate missing values and can be defined as such by selecting the **Define Variables** option from the **Data** menu.

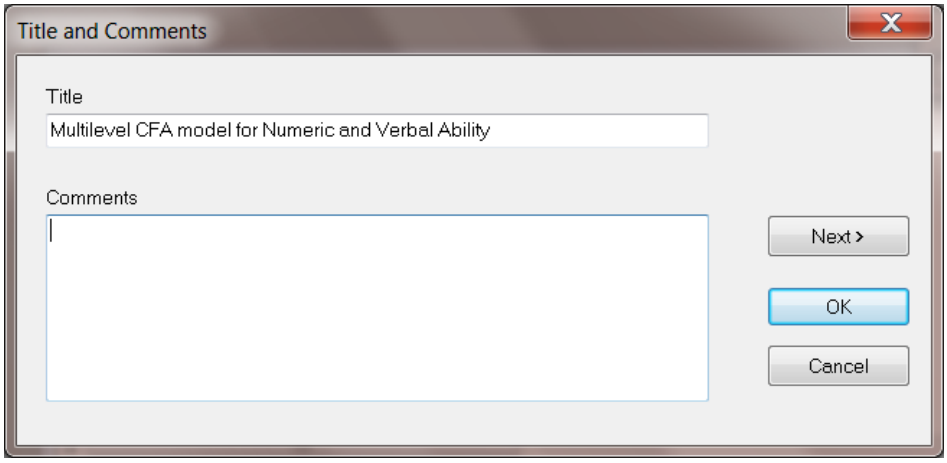
Click on MATH1 (or any other variable) to select it. Click **Missing Values** to obtain the **Missing Values** dialog box. Enter the value -9.0 in the **Global Missing Value** edit box and change the method of deletion from listwise to pairwise. The pairwise option ensures that recoding and computing of variables do not change the number of cases.



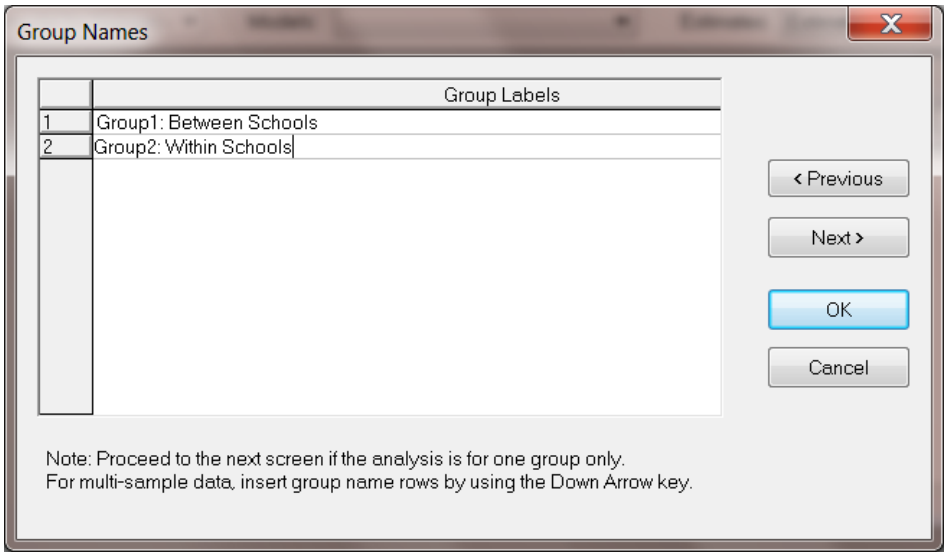
10.2 Draw the Path Diagram

Click the **OK** buttons of the **Missing Values** and **Define Variables** dialog boxes to return to the main window. Use the **Save** option from the **File** menu to save the changes to **jsp2.lsf**. Use the **New** option from the **File** menu to open the **New** dialog box and select the **Path Diagram** option from the **New** dialog box and assign a file name, for example, **msemex.pth**. By clicking the **Save** button, the path diagram window appears.

Select the **Title and Comments** option from the **Setup** menu to open the **Title and Comments** dialog box. Enter the title Multilevel CFA model for Numeric and Verbal Ability in the **Title** string field to produce the following **Title and Comments** dialog box.

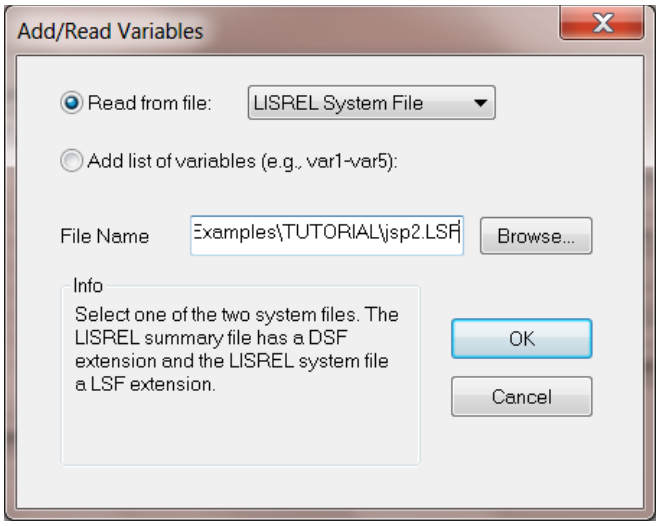


Click **Next** to open the **Groups** dialog box. Enter the label Group1: Between Schools in the first string field. Use the down arrow key to create a string field for the second group. Enter the label Group2: Within Schools in the second string field to produce the following **Groups** dialog box.

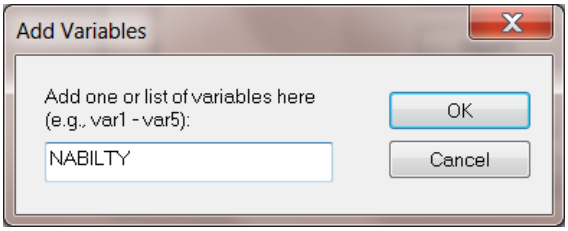


Click **Next** to proceed to the **Labels** dialog box. Since the observed variables are stored in the file **jsp2.lsf**, it is convenient to read the variable names from this file. Click **Add/Read Variables** to open the **Add/Read Variables** dialog box. Select the **LISREL System File** option from the **Read from file** drop-down list box.

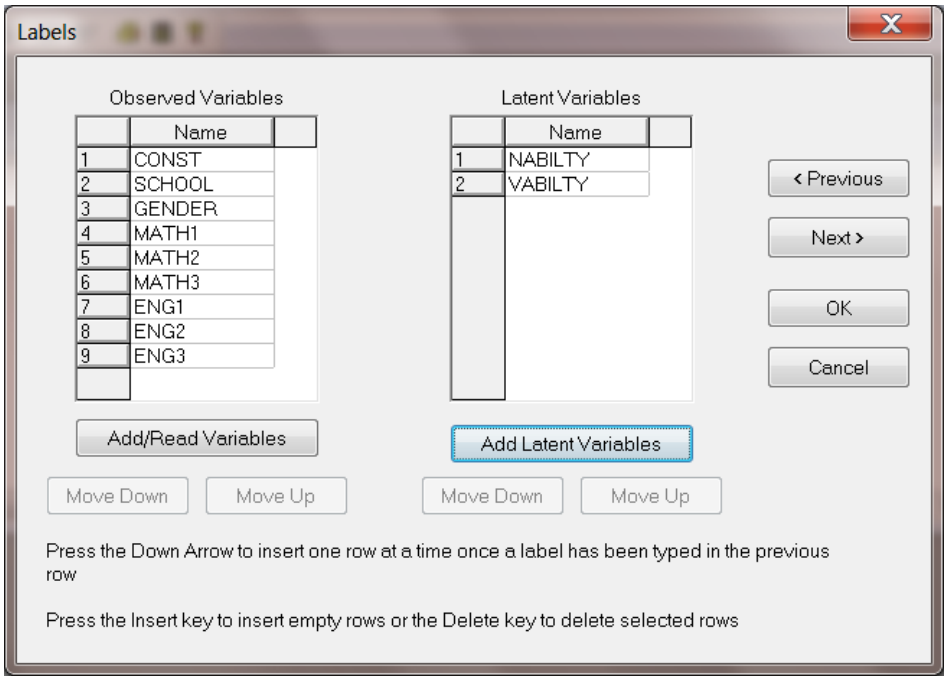
Use the **Browse** button to select the file **jsp2.lsf** to produce the following **Add/Read Variables** dialog box. Click **OK** to return to the **Labels** dialog box.



Click **Add Latent Variables** to open the **Latent Variables** dialog box. Enter the label NABILITY for Numeric Ability to produce the following dialog box.



Click **OK**. Repeat the process to enter the label VABILITY for Verbal Ability. Click **OK** to produce the following **Labels** dialog box.

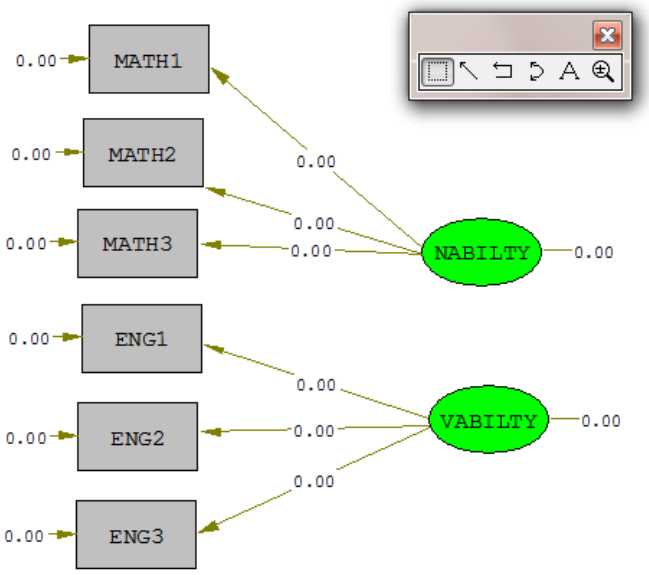


Click **OK** to return to the path diagram window. Click and drag the observed variables MATH1, MATH2, MATH3, ENG1, ENG2 and ENG3 one by one into the path diagram window. Also click and drag the latent variables NABILITY and VABILITY one by one into the path diagram window to produce the following display.

Use the one-directional arrow on the **Draw** toolbar to insert paths from NABILITY to MATH1, MATH2 and MATH3 and also to insert paths from VABILITY to ENG1, ENG2 and ENG3 as shown below.

Note:

Once this arrow is selected, move the mouse to within an ellipse representing a latent variable. With the left mouse button down, drag the arrow to an observed variable. Release the mouse button when the arrow is in the rectangle representing the observed variable.



10.3 Build SIMPLIS/LISREL Syntax

Select the **Build SIMPLIS Syntax** option from the **Setup** menu to produce the text editor window shown overleaf. Insert the command line $CLUSTER SCHOOL after the Raw Data from File command:

msemex.SPJ

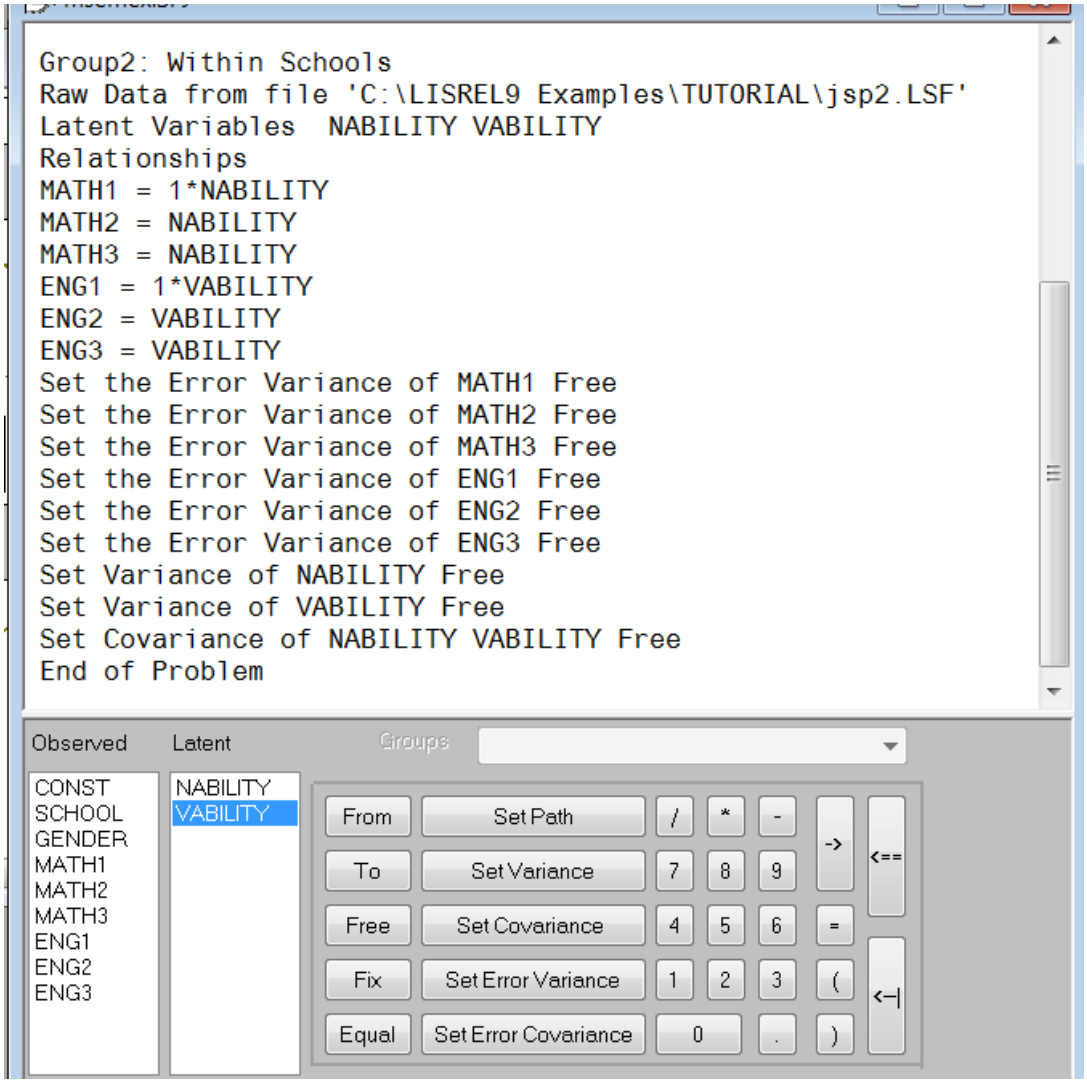
```
Group1: Between Schools
Raw Data from file 'C:\LISREL9 Examples\TUTORIAL\jsp2.LSF'
$CLUSTER SCHOOL
Latent Variables  NABILITY VABILITY
Relationships
MATH1 = NABILITY
MATH2 = NABILITY
MATH3 = NABILITY
ENG1 = VABILITY
ENG2 = VABILITY
ENG3 = VABILITY
Path Diagram

Group2: Within Schools
Raw Data from file 'C:\LISREL9 Examples\TUTORIAL\jsp2.LSF'
Latent Variables  NABILITY VABILITY
Relationships
Set the Error Variance of MATH1 Free
Set the Error Variance of MATH2 Free
Set the Error Variance of MATH3 Free
Set the Error Variance of ENG1 Free
Set the Error Variance of ENG2 Free
Set the Error Variance of ENG3 Free
End of Problem
```

Change the command line MATH1=NABILITY to MATH1=1*NABILITY to set the scale of NABILITY. Change the command line ENG1=VABILITY to ENG1=1*VABILITY to set the scale of VABILITY. Copy and paste the relationships of the Between Schools group to the Relationships paragraph of the Within Schools group.

In the Relationships paragraph of the Within Schools group, insert the following SIMPLIS commands

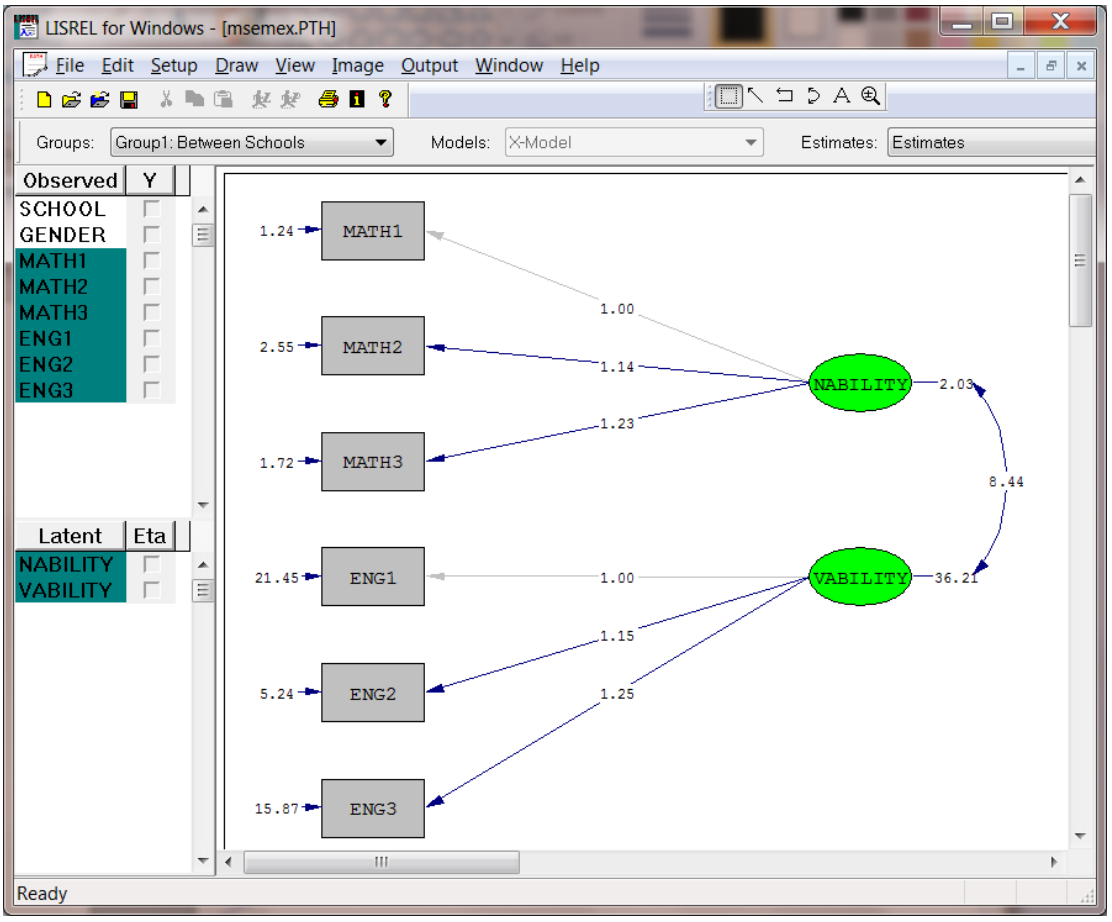
Set Variance of NABILITY Free
Set Variance of VABILITY Free

Set Covariance NABILITY VABILITY Free



10.4 Fit the Model to the Data

Click the **Run LISREL** icon button on the main toolbar to produce the path diagram for the between schools group shown below:



LISREL produces an output file, **msemex.out** which contains the results of the analysis. See the **Additional Topics Guide** for more information on multilevel structural equation models.