

18 Drawing Path Diagrams

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Structural equation modeling (SEM) is a statistical technique that can be used to evaluate relations among observed and latent variables (Hoyle, 1995). A SEM model typically consists of observed and latent variables where an observed variable can be measured directly but a latent variable has to be assessed using observed variables. The relations between two variables can be non-directional as correlation relationship or directional as regression relationship (Hoyle, 1995; Kline, 2011). SEM generalizes many commonly used statistical models such as confirmatory factor models, path models, latent regression models, and growth curve models (Kline, 2011). Over the past few decades, the use of SEM has been rapidly growing in many disciplines (Kline, 2011; Nachtigall et al., 2003; Westland, 2015), especially in education (Khine, 2013), psychology (MacCallum & Austin, 2000), management (Shook et al., 2004), and marketing (Babin et al., 2008), benefiting from the fact that a SEM can be represented graphically as a path diagram.

18.1 Traditional path diagrams

Figure 18.1 shows a typical path diagram for a SEM. A SEM path diagram consists of two types of graphical components: variables and paths. The variables are also called vertices/nodes and the paths are also called edges in graph theory.

18.1.1 Variables

Three types of variables are allowed in a regular SEM path diagram: observed, latent and constant variables. An observed variable is represented by a rectangle, a latent variable is represented by an ellipse node, and a constant variable is represented by a triangle. The constant variable is a special variable with value 1. It is used to represent a mean or an intercept.

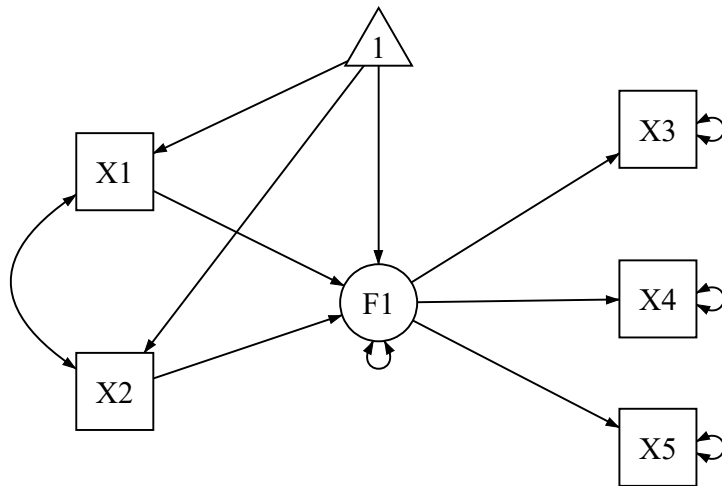


Figure 18.1: A typical SEM path diagram example

18.1.2 Paths

Two types of paths, a directed one and an undirected one, are allowed to define the relationship of the variables in a model or diagram. A directed path, represented by a single-headed arrow, is used to indicate that one variable can predict another variable. In statistical language, it means a regression relationship. A directed path points from the predicting variable toward the outcome variable. More specifically in SEM, a directed path from an ellipse (a latent variable) to a rectangle (an observed variable) represents a factor loading, otherwise it represents a regression coefficient.

An undirected path is represented by a double-headed arrow. If an undirected path connects two variables, it is the covariance between the two variables. An undirected path can start from one variable and end on the same variable. Such a path can represent either a variance or a residual variance in a structural equation model. For a variable with such a path, if there is no directed path pointing to it, the path represents a variance, otherwise, a residual variance.

Both variables and paths can be labeled or named. The labels can be as meaningful as possible. For paths, numbers can be used to denote the values of coefficients in a model.

18.1.3 Basic rules for drawing SEM path diagram

To ensure consistency and improve usability, the following rules are imposed in constructing path diagrams. First, no more than one triangle variable can be created in one diagram. Second, if existing, a directed path can only be drawn starting from the triangle variable. Third, either a directed or an undirected path can be drawn between two observed

and latent variables. Fourth, an undirected path (double headed arrow) is automatically created for a variable that is predicted by one or more variables. The path is also automatically removed when the involved variable loses its predicting variables. Finally, when a variable is removed, all paths connecting to it will be removed automatically.

18.2 Path diagram in WebPower

WebPower can conduct statistical power analysis by drawing a path diagram directly online. The path diagram application is developed using JavaScript with the the library d3js (Myatt & Johnson, 2011) and the library jQuery (Resig et al., 2009). The path diagrams can be saved in the scalable vector graphics (SVG) format (Ferraiolo et al., 2000). In addition to the variables and paths used in the regular path diagrams, we also provide the support of non-normal data and missing data representation as we will discuss later.

18.2.1 Interface and buttons

The overall path diagram interface is shown in Figure 18.1. Intuitively, a path diagram is constructed using the buttons on the left panel.

WebPower
Statistical power analysis online

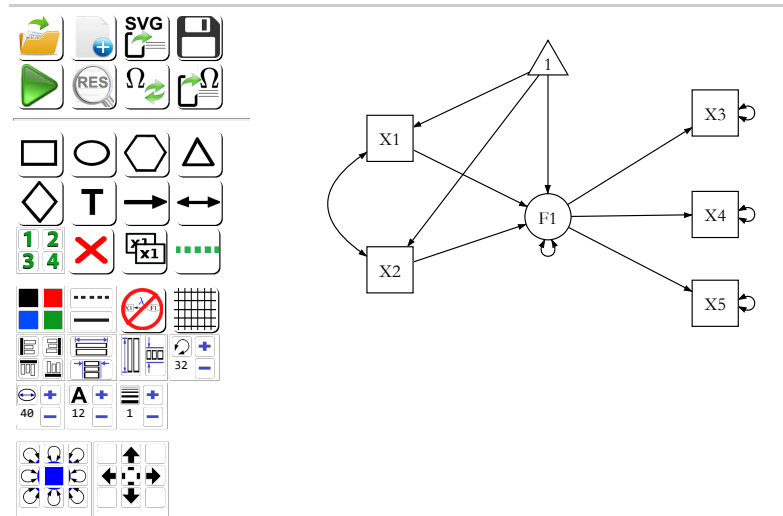


Figure 18.1: WebPower path diagram interface

Table show the buttons in the diagram and their functionalities.

Button	Functionalities
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Open an existing path diagram



Start a new diagram



Save a diagram as a SVG image



Save a diagram



Run power analysis based on a diagram



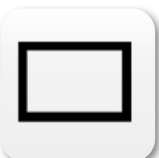
View the power analysis results



Process LaTeX equations



Save a diagram with LaTeX equations



Add a square to the canvas, representing an observed variable.



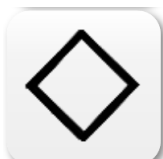
Add a circle to the canvas, representing a latent variable.



Add a hexagon to the canvas. It should have the same name as an observed variable since it is used to specify how data in the variable are missing.



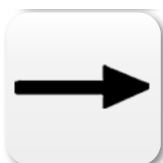
Add a triangle to the canvas, representing either a mean or an intercept.



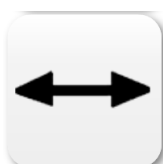
Add a diamond to the canvas. It is used to specify the non-normality of data. On the path, the skewness and kurtosis for a variable can be specified.



Add any text to the canvas.



Draw a single-headed arrow between two shapes using one of the two ways. Firstly, one can start by clicking the line button, then drag from the start node to the end node. Secondly, one can first select the start node, then click the line button, and finally click the end node.



Draw a double-headed arrow between two shapes using one of the two ways. Firstly, one can start by clicking the line button, then drag from the start node to the end node. Secondly, one can first select the start node, then click the line button, and finally click the end node.



Set the level of variables. Each number can be clicked as a separated button to set a variable to be a 1st, 2nd, 3rd or 4th level variable.



Delete a selected shape from the canvas.



Copy selected shape(s). To select multiple shapes, drag the mouse while holding the right button around the shapes.



Add a line to the canvas.



Change the color of the selected shapes.



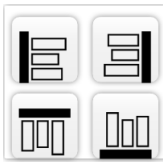
Change the lines or shapes from solid to dashed or vice versa.



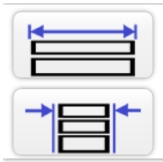
Hide or show the labels on the paths.



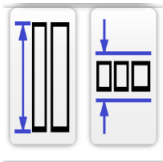
Hide or show the grid lines on the canvas.



Align selected shapes according to the side.



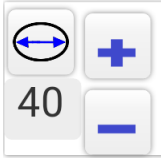
Resize the selected shapes to have the same width.



Resize the selected shapes to have the same height.



Change the size of the double headed arrow on a variable. Clicking "+" to increase and "-" to decrease the size. The font size as a number is shown on the bottom right corner.



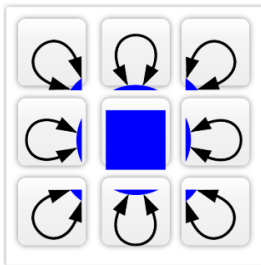
Change the size of the selected shapes. Clicking "+" to increase and "-" to decrease the size. The font size as a number is shown on the bottom right corner.



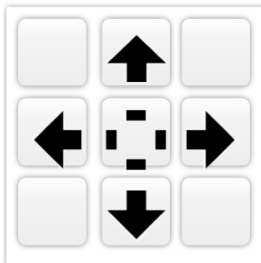
Change the size of the text. Clicking "+" to increase and "-" to decrease the size. The font size as a number is shown on the bottom right corner.



Change the size of the paths. Clicking "+" to increase and "-" to decrease the size. The font size as a number is shown on the bottom right corner.







Position the double-headed arrow on a variable. Eight different positions are allowed.










Move shapes on a canvas around. The four arrows tell the direction to move.

18.2.2 How to draw a path diagram














Using the buttons on the interface, one can draw a new and edit an existing path diagram interactively.


- To create a new diagram, click the button () and to edit an existing diagram, click the button () to open it.
- A rectangle/square variable () or an ellipse/circle variable ()

can be created by clicking their corresponding buttons in the interface. A hexagon () can also be created in the same way.

- A new path can be drawn in two ways. Firstly, one can start by clicking the path button, then drag from the start variable to the end variable. Secondly, one can first select the start variable, then click the path button, and finally click the end variable. Both the single-headed () and double-headed () lines can be drawn in this way. For the double-headed arrow on a variable itself, the start variable and the end variable are the same. The position of the double-headed arrow on a variable itself can be changed by dragging it around or use this button () .
- A line can be changed between solid line and dotted line using the button () .
- To create a triangle shape () , one needs to first select a rectangle, ellipse, or a hexagon shape and then click on the triangle button. A single-headed path will also be added automatically from the triangle shape to the shape selected.
- Both shapes and paths can be duplicated easily. To duplicate one shape, simply select it by clicking it and then click the copy button () . To copy and paste multiple shapes, one can select all of them together first.
- **Select multiple items on the canvas.** There are two ways to do it. First, one can hold the “Ctrl” button on the keyboard and then click the items to be selected. Second, one can hold the left button of the mouse and drag a square on the canvas to include all the items to be selected.
- Both shapes and paths can be named. To name a shape or path, first double-click it and then change or add a name in the pop-up dialog window as shown below.



- To add text to the canvas, click the button () and then type the text in the pop-up dialog window.
- To draw a line anywhere on the canvas, click the button To add text to the canvas, click the button ().
- Everything within a path diagram can be moved freely by one of the two ways. Firstly, one can simply drag it around. Secondly, one can first select a shape and then use the buttons () on the left-hand panel to move it around. To move multiple shapes, one can select all of them and then drag them to a desired location.
- The properties of a selected shape or path can be modified by clicking the properties buttons such as color () font size () and stroke width (). Clicking "+" to increase and "-" to decrease the size. The font size as a number is shown on the bottom right corner.
- To delete a shape or path, simply select it and then click the delete button ().
- One can align multiple selected shapes on their four sides by using the button ().
- To set the selected shapes to have the same width using () and same height using ().
- **LaTeX equation.** Math formulas can be put anywhere on the canvas through LaTeX notation. First, type the equation as you would do in LaTeX, e.g., α , $\alpha^2 + \beta^2$. The click the button () to show the equations. Note that when clicking the canvas, the equation will go back to text. To save the diagram with the math equations, click the button (). The path diagram will be saved into a HTML file that can be viewed in a web browser.
- To save the path diagram on the server to use in the future, click the button (). The save diagram can be opened for edits in the future.

- The diagram can also be saved to local storage by clicking the button . This saves the diagram into a SVG figure that can be used in publication or converted to other format such as PDF, JPEG, or PNG.

Several videos have been created to show how to draw path diagrams using WebPower. This can be viewed using the following links.