



SEM TABLES WITH THE SEMTABLE PACKAGE FOR R

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Abstract

The `semTable` package features functions for preparing report tables for estimates of structural equation models fitted with `lavaan` (Rosseel, 2012). This essay discusses the usage of the `semTable` function and provides a profuse collection of output examples.

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1 semTable

The `semTable` function is the featured offering of the `semTable` package for R (R Core Team, 2019). This function allows authors who estimate structural equation models (SEM) with the `lavaan` package for R to, more-or-less automatically, generate acceptable tabular summaries for reports and presentations. `semTable` has been offered as a part of the `kutils` package in the past, but we believe it is sufficiently well developed that it can stand on its own. As soon as `semTable` is accepted on CRAN, this function will be removed from `kutils`. The `semTable` package also includes a function called `modelComparison`, which can assemble a standard format for a “diff” test result for structural equation models. That function is considerably less elaborate than `semTable`.

2 Important Parameters

object: A fitted `lavaan` model object or a list with one or more SEM fitted `lavaan` model objects.

We suggest providing “pretty names” for inclusion in the final report, as in `list("Model A" = obj1, "Model B" = obj2)`. Results will be side-by-side. Hint: take care to adjust the `columns` parameter to make the results fit within the space allowed.

paramSets: Each fitted SEM may have many different parameter sections. This argument can include any of the following:

`c("loadings", "slopes", "intercepts", "residualvariances", "residualcovariances", "latentmeans", "latentvariances", "latentcovariances", "thresholds", "constructed", "fits")` The default is "all", and the setting applies to all of the models in the fitted object list.

paramSetLabels: This should be a named vector of “pretty-printable” labels for the parameter sets. It is not necessary to provide improved labels for all `paramSets` items, but it is allowed to do so.

columns: choose the desired columns in the output. In the default table in `lavaan` summaries, the columns are [“Estimate”, “Std. Error”, “Z”, and “p”]. In our opinion, inclusion of both the standard error and the Z is redundant and the p value may not be necessary if significance stars are used. Hence we provide alternatives to “tighten up” the result table. To specify columns, the legal parameter values may be drawn from `c("est", "se", "z", "p", "rsquare", "estse", "eststars", "estsestars")`. The four new values are the R-square for the item, a compact combined estimate and standard errors (estse: “1.2(0.02)”), with estimates with stars and no standard errors (eststars: “1.2**”) or estimates with standard errors in parentheses with “significance stars” (estsestars: “1.2(0.02)**”). Columns can differ between models, so a named list of vectors will be accepted: `list("Model A" = c("est", "se"), "Model B" = c("estse", "p"))`.

columnLabels: names list of “presentable” titles for columns that authors prefer. Provide these names by parameter, not by model, For example, any of these might be suitable: `est = "Estimate", se = "Std. Err.", z = "Z", p = "p", rsquare = "R Square", estse = "Estimate(Std.Err.)"`.

fits: selection of fit indices to include. The help page has a partial list of these, but the lavaan estimator can generate additional fit indicators for models of different types. This is the one part of the semTable output that is likely to require some hand-editing in order to be truly publication ready.

varLabels: Rather than R variable names, a truly polished table needs presentable variable names. Provide a named vector of names in the format “orig.R.name” = “new.pretty.name”. See examples below.

type: Can be “latex”, “html” or “csv”. If a table object is created with one format in mind, the object can be re-designated to a new format. See examples in “?semTable”.

LaTeX specific arguments:

table.float: is an enclosing float table object required, or should we simply make a tabular (or longtable) object.

longtable If longtable is true (probably preferred), use the LaTeX class longtable. Otherwise tabular.

caption: title for the floating table, if table.float=TRUE.

label: label to be used for internal cross-referencing.

centering: One of these `c("siunitx", "none")`.

alpha: The levels of statistical significance to be used for assigning stars (only needed if columns includes eststars or estsestars).

file: This is a convenience function to save the results in a separate file. It will add suffix “.tex”, “.html”, or “.csv”, depending on the value of type. This is the same as fitting a model with `print.results = FALSE`, then `semTable` to produce `object.tbl`, and then running `cat(object.tbl, file= "fn")` to save the result object in a file.

`print.results:` If FALSE, the results are not immediately displayed. This is advantageous if an author wants to revise the marked-up table results or control the point at which they are delivered in the documents.

3 Confirmatory Factor Analysis

```
require(lavaan)
library(semTable)
tempdir <- "tmpout"
if(!dir.exists(tempdir)) dir.create(tempdir)
```

```
## The example from lavaan's docs
HS.model <- ' visual  =~ x1 + x2 + x3
              textual =~ x4 + x5 + x6
              speed   =~ x7 + x8 + x9
              '
```

5

Because the SEM estimation can be time consuming, we will save a file with the fitted model and re-use it if it is available when the vignette is recompiled.

```
if(file.exists("fit1.rds")){
  fit1 <- readRDS("fit1.rds")
} else {
  fit1 <- cfa(HS.model, data = HolzingerSwineford1939,
    std.lv = TRUE, meanstructure = TRUE)
  saveRDS(fit1, "fit1.rds")
}
```

The “raw” output from the lavaan summary function is as follows:

```
summary(fit1)
```

lavaan 0.6-3 ended normally after 20 iterations

Optimization method	NLMINB
Number of free parameters	30
Number of observations	301
Estimator	ML
Model Fit Test Statistic	85.306
Degrees of freedom	24
P-value (Chi-square)	0.000

Parameter Estimates:

Information	Expected
Information saturated (h1) model	Structured
Standard Errors	Standard

Latent Variables:

	Estimate	Std.Err	z-value	P(> z)
visual =~				
x1	0.900	0.081	11.128	0.000
x2	0.498	0.077	6.429	0.000
x3	0.656	0.074	8.817	0.000
textual =~				
x4	0.990	0.057	17.474	0.000
x5	1.102	0.063	17.576	0.000
x6	0.917	0.054	17.082	0.000
speed =~				
x7	0.619	0.070	8.903	0.000
x8	0.731	0.066	11.090	0.000
x9	0.670	0.065	10.305	0.000

Covariances:

	Estimate	Std.Err	z-value	P(> z)
visual ~				
textual	0.459	0.064	7.189	0.000
speed	0.471	0.073	6.461	0.000
textual ~				
speed	0.283	0.069	4.117	0.000

Intercepts:

	Estimate	Std.Err	z-value	P(> z)
.x1	4.936	0.067	73.473	0.000
.x2	6.088	0.068	89.855	0.000
.x3	2.250	0.065	34.579	0.000
.x4	3.061	0.067	45.694	0.000
.x5	4.341	0.074	58.452	0.000
.x6	2.186	0.063	34.667	0.000

50	.x7	4.186	0.063	66.766	0.000
	.x8	5.527	0.058	94.854	0.000
	.x9	5.374	0.058	92.546	0.000
	visual	0.000			
	textual	0.000			
55	speed	0.000			
Variances:					
		Estimate	Std.Err	z-value	P(> z)
	.x1	0.549	0.114	4.833	0.000
60	.x2	1.134	0.102	11.146	0.000
	.x3	0.844	0.091	9.317	0.000
	.x4	0.371	0.048	7.779	0.000
	.x5	0.446	0.058	7.642	0.000
	.x6	0.356	0.043	8.277	0.000
65	.x7	0.799	0.081	9.823	0.000
	.x8	0.488	0.074	6.573	0.000
	.x9	0.566	0.071	8.003	0.000
	visual	1.000			
	textual	1.000			
70	speed	1.000			

It is not necessary to specify a set of “pretty” variable labels, but sometimes this makes for more pleasant tables. In this case, we create a vector of labels first, and then put it to use. To prevent the table from becoming too wide, we ask for two columns in the output, “`estse`” and “`p`”. The default `semTable` input would include a larger set of parameters, but we don’t need all of them. The default table includes latent intercepts and latent variances, which are restricted to 0 and 1 by the model itself, so it is not necessary to include them. Hence, we ask for a smaller selection of parameter sets:

```
vlabs <- c("x1" = "Vis 1", "x2" = "Vis 2", x3 = "Vis 3", x4 = "Txt
  1", x5 = "Txt 2", x6 = "Txt 3", x7 = "Speed 1", x8 = "Speed 2",
  x9 = "Speed 3")
fit1.t1 <- semTable(fit1, columns = c("estse", "p"), paramSets =
  c("loadings", "intercepts", "residualvariances", "
  latentcovariances"), fits = c("chisq", "rmsea"), file =
  file.path(tempdir, "fit1.t1"), varLabels = vlabs, type = "
  latex", table.float = TRUE, caption = "Holzinger Swineford CFA
  in a longtable Float", label = "tab:HS10", longtable=TRUE)
```

Table 1: Holzinger Swineford CFA in a longtable Float

		Model	
		Estimate(Std.Err.)	p
		Factor Loadings	
<u>visual</u>			
	Vis 1	0.90(0.08)	0.000
	Vis 2	0.50(0.08)	0.000
	Vis 3	0.66(0.07)	0.000
<u>textual</u>			
	Txt 1	0.99(0.06)	0.000
	Txt 2	1.10(0.06)	0.000
	Txt 3	0.92(0.05)	0.000
<u>speed</u>			

Speed 1	0.62(0.07)	0.000
Speed 2	0.73(0.07)	0.000
Speed 3	0.67(0.07)	0.000
<u>Intercepts</u>		
Vis 1	4.94(0.07)	0.000
Vis 2	6.09(0.07)	0.000
Vis 3	2.25(0.07)	0.000
Txt 1	3.06(0.07)	0.000
Txt 2	4.34(0.07)	0.000
Txt 3	2.19(0.06)	0.000
Speed 1	4.19(0.06)	0.000
Speed 2	5.53(0.06)	0.000
Speed 3	5.37(0.06)	0.000
<u>Residual Variances</u>		
Vis 1	0.55(0.11)	0.000
Vis 2	1.13(0.10)	0.000
Vis 3	0.84(0.09)	0.000
Txt 1	0.37(0.05)	0.000
Txt 2	0.45(0.06)	0.000
Txt 3	0.36(0.04)	0.000
Speed 1	0.80(0.08)	0.000
Speed 2	0.49(0.07)	0.000
Speed 3	0.57(0.07)	0.000
<u>Latent Covariances</u>		
visual w/textual	0.46(0.06)	0.000
visual w/speed	0.47(0.07)	0.000
textual w/speed	0.28(0.07)	0.000
<u>Fit Indices</u>		
$\chi^2(df)$	85.31(24)	0.000
RMSEA	0.09	

⁺Fixed parameter

Because we have `longtable` set as TRUE, a floating table is created with the indicated caption in Table 1.

In the previous example, we allowed the LaTeX markup to be printed directly into the document. There might be times when we would rather delay the output. We might instead have set “`print.results = FALSE`” to prevent code display, and then at a time of our choosing we could export the fitted model into the document with the `cat` function.

```
cat(fit1.t1)
```

Using the `cat` function, we also can export the table into a file:

```
fn <- file.path(tempdir, "fit1.t12.tex")
cat(fit1.t1, file = fn)
```

This is the same result obtained by specifying file name in the `semTable` function itself. However, this latter approach leaves the door open for the user to inspect & edit the marked-up table.

Alternative Output Formats

This function was developed primarily for LaTeX output tables. However, we have redesigned so that the output may be requested in either Web code (HTML) or comma separated variable (CSV) files. If HTML output is desired, replace `type = "latex"` with `type = "html"`.

```
fit1.t1h <- semTable(fit1, columns = c("estse", "p"), paramSets =  
  c("loadings", "intercepts", "residualvariances", "  
    latentcovariances"),  
                        fits = c("chisq", "rmsea"), file =  
                          file.path(tempdir, "fit1.t1h.html"),  
                        varLabels = vlabs, type = "html",  
                        print.results = FALSE)
```

In an interactive session, the output file can be inspected on the screen.

```
browseURL(file.path(tempdir, "fit1.t1.html"))
```

```
## Try CSV output next  
fit1.t1c <- semTable(fit1, columns = c("estse", "p"),  
                      fits = c("chisq", "rmsea"), file =  
                        file.path(tempdir, "fit1.t1c"),  
                      varLabels = vlabs, type = "csv",  
                      print.results = FALSE)
```

```
## Go inspect this file with a spread sheet program:  
attr(fit1.t1c, "file")
```

```
[1] "tmpout/fit1.t1c.csv"
```

It is possible to change the output format of an `semTable` object. This is done with the function `markupConvert`. Here we demonstrate how to re-channel a LaTeX fitted table to a csv object:

```
fit1.t1c2 <- markupConvert(attr(fit1.t1, "markedResults"), type = "  
  csv")
```

4 To Float or Not to Float?

In an academic paper, we would seldom/never have a table that prints directly into the middle of the text. Instead, all tables are presented as numbered “floating” table objects. The author has a choice to ask `semTable` to create the floating table object (with indicated caption and label), or to simply create the tabular object that would be included inside the floated table in a following setup. The quick, easy method of specifying the floating table elements in the `semTable` command itself does not allow all of the flexibility that we might want in controlling table output, so we’ll illustrate both methods.

First, we have an ordinary table (not a `longtable`) that is created as a float by the the reference label “tab:hs1939”, as seen in Table 2.

Table 2: Table Floated (not a longtable)

	Model		
	Estimate	Std. Err.	p
	<u>Factor Loadings</u>		
<u>visual</u>			
Vis 1	0.90	0.08	0.000
Vis 2	0.50	0.08	0.000
Vis 3	0.66	0.07	0.000
<u>textual</u>			
Txt 1	0.99	0.06	0.000
Txt 2	1.10	0.06	0.000
Txt 3	0.92	0.05	0.000
<u>speed</u>			
Speed 1	0.62	0.07	0.000
Speed 2	0.73	0.07	0.000
Speed 3	0.67	0.07	0.000
	<u>Fit Indices</u>		
$\chi^2(df)$	85.31(24)		0.000
RMSEA	0.09		

⁺Fixed parameter

```
## floating table
fit1.t3 <- semTable(fit1, columns = c("est", "se", "p"), paramSets
  = c("loadings"), fits = c("chisq", "rmsea"), file =
  file.path(tempdir, "fit1.t3"), varLabels =
  vlabs, longtable=FALSE, table.float = TRUE, caption = "Table
  Floated (not a longtable)", label = "tab:fit1.t3")
```

In Table 3, we have a similar table produced with the `longtable` class. We have tested some alternative settings for the columns (just to keep this interesting for the reader). Of course, the benefit of a `longtable` is that a table that needs to “break” across pages will do so, while an ordinary `tabular` will run into the bottom margin. In this case, with a loadings-only display, the table stays on the page and the `longtable` is not strictly necessary. However, the `longtable` also does not appear to be harmful even for small tables. Hence, we use `longtable = TRUE` in most of our work.

```
## floating longtable
fit1.t4 <- semTable(fit1, columns = c("est", "estsestars"),
  paramSets = c("loadings"), fits = c("chisq", "rmsea"), file =
  file.path(tempdir, "fit1.t4"), varLabels = vlabs, longtable =
  TRUE, table.float=TRUE, caption = "Table Floated (longtable)",
  label = "tab:fit1.t4")
```

Table 3: Table Floated (longtable)

Model

	Estimate	Estimate(Std.Err.)
	<u>Factor Loadings</u>	
<u>visual</u>		
Vis 1	0.90	0.90(0.08)***
Vis 2	0.50	0.50(0.08)***
Vis 3	0.66	0.66(0.07)***
<u>textual</u>		
Txt 1	0.99	0.99(0.06)***
Txt 2	1.10	1.10(0.06)***
Txt 3	0.92	0.92(0.05)***
<u>speed</u>		
Speed 1	0.62	0.62(0.07)***
Speed 2	0.73	0.73(0.07)***
Speed 3	0.67	0.67(0.07)***
	<u>Fit Indices</u>	
$\chi^2(df)$	85.31(24)	***
RMSEA	0.09	
⁺ Fixed parameter		
* p<0.05, ** p<0.01, ***p<0.001		

As an alternative, in the following code we do not request a float to be created. After creating the table in the file named “`tmpout/fit1.t5.tex`”, we use LaTeX commands to manually create the float that appears in Table 4. After creating the floating table, inside it we simply use the LaTeX code

```
\input{tmpout/fit1.t5.tex}.
```

```
##columnLabels
fit1.t5 <- semTable(fit1, fits = c("chisq", "rmsea"), paramSets =
  c("loadings"), columns = c("est", "se", "p"), columnLabels =
  c(se = "S.E."), file = file.path(tempdir, "fit1.t5"),
  print.results = FALSE)
```

5 Fine tuning titles

We’ve already emphasized the ability to customize variable labels. Now we focus on column names as well as parameter sets. The ability to adjust both the column names and parameter section names is emphasized in Table 5.

```
##columnLabels
fit1.t6 <- semTable(list("A Fancy Fitted Model" = fit1), fits =
  c("chisq", "rmsea"), paramSets = c("loadings"), paramSetLabels
  = c("loadings" = "Loading Estimates(ML robust)"), columns =
  c("estsestars"), columnLabels = c("estsestars" = "
  Estimates(Std.Errors)"), file = file.path(tempdir, "fit1.t6"),
```

Table 4: A Manually Created Floating Table

Model			
	Estimate	S.E.	p
<u>Factor Loadings</u>			
<u>visual</u>			
x1	0.90	0.08	0.000
x2	0.50	0.08	0.000
x3	0.66	0.07	0.000
<u>textual</u>			
x4	0.99	0.06	0.000
x5	1.10	0.06	0.000
x6	0.92	0.05	0.000
<u>speed</u>			
x7	0.62	0.07	0.000
x8	0.73	0.07	0.000
x9	0.67	0.07	0.000
<u>Fit Indices</u>			
$\chi^2(df)$	85.31(24)		0.000
RMSEA	0.09		

⁺Fixed parameter

```
table.float=TRUE, caption="Demonstrate Flexibility with Column
and Parameter Set Labels", label = "tab:fit1.t6")
```

The names of the latent variables will default to the names used in the lavaan model file. Those names, however, can be replaced in the variable label vector. See Table 6.

```
## Test alternative latent variable labels
vl <- c(vlabs, visual = "Seeing", textual = "Thumb Texting", speed
= "Speed")
fit1.t7 <- semTable(fit1, fits = c("chisq", "rmsea"), paramSets =
c("loadings", "intercepts"), columns = c("eststars", "p"),
columnLabels = c("eststars" = "Est(SE)"), file =
file.path(tempdir, "fit1.t7"), varLabels = vl, longtable =
TRUE, type = "latex", table.float=TRUE, caption="Variable
Labels can include parameter sections", label = "tab:fit1.t7")
```

Table 6: Variable Labels can include parameter sections

Model			
	Est(SE)	p	
<u>Factor Loadings</u>			
<u>Seeing</u>			
Vis 1	0.90***	0.000	
Vis 2	0.50***	0.000	
Vis 3	0.66***	0.000	
<u>Thumb Texting</u>			

	Txt 1	0.99***	0.000
	Txt 2	1.10***	0.000
	Txt 3	0.92***	0.000
<u>Speed</u>			
	Speed 1	0.62***	0.000
	Speed 2	0.73***	0.000
	Speed 3	0.67***	0.000
		<u>Intercepts</u>	
	Vis 1	4.94***	0.000
	Vis 2	6.09***	0.000
	Vis 3	2.25***	0.000
	Txt 1	3.06***	0.000
	Txt 2	4.34***	0.000
	Txt 3	2.19***	0.000
	Speed 1	4.19***	0.000
	Speed 2	5.53***	0.000
	Speed 3	5.37***	0.000
		<u>Fit Indices</u>	
	$\chi^2(df)$	85.31(24)***	0.000
	RMSEA	0.09	
<hr/>			
	+Fixed parameter		
	* p<0.05, ** p<0.01, ***p<0.001		

The ability to fine-tune the selection and labels for fit values is demonstrated in Table 7.

```
fit4.t2 <- semTable(fit1, paramSets = c("loadings"), fits =
  c("rmsea", "cfi", "chisq"), fitLabels = c(rmsea = "Root
  M.SQ.E.A", cfi = "CompFitIdx", chisq = "chisq"), type = "
  latex", table.float = TRUE, caption = "Customized Fits and
  Labels", label = "tab:fit1.t8")
```

6 Two/Multi Group Models

A model that estimates parameters for a two group model, using school as the grouping model, is obtained with lavaan as follows:

```
if(file.exists("fit1.g.rds")){
  fit1.g <- readRDS("fit1.g.rds")
} else {
  fit1.g <- cfa(HS.model, data = HolzingerSwineford1939, std.lv
    = TRUE, group = "school", estimator = "MLR")
  saveRDS(fit1.g, "fit1.g.rds")
}
```

A table that displays both groups can be obtained, as illustrated in Table 8. This table runs into the margins unless we specify `longtable = TRUE`. Also it is worth noting that the table does not fit

Table 5: Demonstrate Flexibility with Column and Parameter Set Labels

A Fancy Fitted Model	
Estimates(Std.Errors)	
Loading Estimates(ML robust)	
<u>visual</u>	
x1	0.90(0.08)***
x2	0.50(0.08)***
x3	0.66(0.07)***
<u>textual</u>	
x4	0.99(0.06)***
x5	1.10(0.06)***
x6	0.92(0.05)***
<u>speed</u>	
x7	0.62(0.07)***
x8	0.73(0.07)***
x9	0.67(0.07)***
<u>Fit Indices</u>	
$\chi^2(df)$	85.31(24)***
RMSEA	0.09

⁺Fixed parameter

* p<0.05, ** p<0.01, ***p<0.001

Table 7: Customized Fits and Labels
Model

		Estimate	Std. Err.	z	p
		<u>Factor Loadings</u>			
<u>visual</u>					
	x1	0.90	0.08	11.13	0.000
	x2	0.50	0.08	6.43	0.000
	x3	0.66	0.07	8.82	0.000
<u>textual</u>					
	x4	0.99	0.06	17.47	0.000
	x5	1.10	0.06	17.58	0.000
	x6	0.92	0.05	17.08	0.000
<u>speed</u>					
	x7	0.62	0.07	8.90	0.000
	x8	0.73	0.07	11.09	0.000
	x9	0.67	0.07	10.30	0.000
		<u>Fit Indices</u>			
Root M.SQ.E.A		0.09			
CompFitIdx		0.93			
$\chi^2(df)$		85.31(24)			0.000

⁺Fixed parameter

within the allowed horizontal space if we try to print the 4 standard columns individually. Hence, we use the more compact “Est(Std.Err.)” format.

```
## 2 groups table
fit1.gt1 <- semTable(fit1.g, columns = c("estsestars", "p"),
  columnLabels = c(estsestars = "Est(Std.Err.)", p = "p-value"),
  file = file.path(tempdir, "fit1.gt1"), table.float = TRUE,
  caption = "A Two Group Model", label = "tab:fit1.gt1",
  longtable=TRUE)
```

Table 8: A Two Group Model

		Pasteur		Grant-White	
		Est(Std.Err.)	p-value	Est(Std.Err.)	p-value
<u>Factor Loadings</u>					
<u>visual</u>	x1	1.05(0.18)***	0.000	0.78(0.13)***	0.000
	x2	0.41(0.16)**	0.008	0.57(0.10)***	0.000
	x3	0.60(0.13)***	0.000	0.72(0.10)***	0.000
<u>textual</u>	x4	0.95(0.08)***	0.000	0.97(0.08)***	0.000
	x5	1.12(0.07)***	0.000	0.96(0.08)***	0.000
	x6	0.83(0.08)***	0.000	0.93(0.08)***	0.000
<u>speed</u>	x7	0.59(0.12)***	0.000	0.68(0.09)***	0.000
	x8	0.67(0.10)***	0.000	0.83(0.11)***	0.000
	x9	0.55(0.11)***	0.000	0.72(0.13)***	0.000
<u>Intercepts</u>					
	x1	4.94(0.09)***	0.000	4.93(0.10)***	0.000
	x2	5.98(0.10)***	0.000	6.20(0.09)***	0.000
	x3	2.49(0.09)***	0.000	2.00(0.09)***	0.000
	x4	2.82(0.09)***	0.000	3.32(0.09)***	0.000
	x5	4.00(0.10)***	0.000	4.71(0.10)***	0.000
	x6	1.92(0.08)***	0.000	2.47(0.09)***	0.000
	x7	4.43(0.09)***	0.000	3.92(0.09)***	0.000
	x8	5.56(0.08)***	0.000	5.49(0.09)***	0.000
	x9	5.42(0.08)***	0.000	5.33(0.09)***	0.000
<u>Residual Variances</u>					
	x1	0.30(0.34)	0.378	0.71(0.18)***	0.000
	x2	1.33(0.18)***	0.000	0.90(0.14)***	0.000
	x3	0.99(0.15)***	0.000	0.56(0.12)***	0.000
	x4	0.43(0.07)***	0.000	0.32(0.07)***	0.000
	x5	0.46(0.09)***	0.000	0.42(0.07)***	0.000
	x6	0.29(0.06)***	0.000	0.41(0.08)***	0.000
	x7	0.82(0.13)***	0.000	0.60(0.10)***	0.000
	x8	0.51(0.10)***	0.000	0.40(0.16)*	0.012
	x9	0.68(0.13)***	0.000	0.53(0.14)***	0.000
<u>Latent Intercepts</u>					

visual	0.00 ⁺		0.00 ⁺	
textual	0.00 ⁺		0.00 ⁺	
speed	0.00 ⁺		0.00 ⁺	
<u>Latent Variances</u>				
visual	1.00 ⁺		1.00 ⁺	
textual	1.00 ⁺		1.00 ⁺	
speed	1.00 ⁺		1.00 ⁺	
<u>Latent Covariances</u>				
visual w/textual	0.48(0.09) ^{***}	0.000	0.54(0.10) ^{***}	0.000
visual w/speed	0.30(0.14) [*]	0.031	0.52(0.15) ^{***}	0.000
textual w/speed	0.33(0.10) ^{**}	0.001	0.34(0.14) [*]	0.019
<u>Fit Indices</u>				
$\chi^2(df)$	115.85			
CFI	0.92			
TLI	0.89			
RMSEA	0.10			
Scaled $\chi^2(df)$	121.74(48) ^{***}	0.000		

⁺Fixed parameter
^{*} p<0.05, ^{**} p<0.01, ^{***}p<0.001

It is not necessary to display all of the groups in the table. It is possible to select groups by name, as we see in Table 9.

```
## Now name particular group by name
fit1.gt2 <- semTable(fit1.g, columns = c("estsestars", "p"),
  paramSets = c("loadings", "intercepts", "residualvariances"),
  columnLabels = c(estsestars = "Est w/stars", p = "p-value"),
  file = file.path(tempdir, "fit1.gt2"), groups = "Pasteur",
  table.float = TRUE, caption = "Group 'Pasteur' Group from the 2
  Model", label = "tab:fit1.gt2")
```

It is also possible to select groups by integer numbers in the group list, rather than by name. The results for group 1 are offered in Table 10.

```
## Name particular group by number
fit1.gt3 <- semTable(fit1.g, columns = c("estsestars", "p"),
  paramSets = c("loadings"), columnLabels = c(estsestars = "Est
  w/stars", p = "p-value"), file = file.path(tempdir, "
  fit1.gt3"), groups = 2, table.float = TRUE, caption = "Group
  '2' from the 2 Model is 'Grant-White'", label = "tab:fit1.gt3")
```

7 Two Models Side-by-Side

One might wonder if the “standardized” SEM estimates are substantively different from the original estimates. With lavaan, we can refit the original CFA model and specify that we want standardized latent and observed variables, along with estimates of a mean structure.

Table 9: Group 'Pasteur' Group from the 2 Model
Pasteur

		Est w/stars	p-value
		<u>Factor Loadings</u>	
<u>visual</u>			
	x1	1.05(0.18)***	0.000
	x2	0.41(0.16)**	0.008
	x3	0.60(0.13)***	0.000
<u>textual</u>			
	x4	0.95(0.08)***	0.000
	x5	1.12(0.07)***	0.000
	x6	0.83(0.08)***	0.000
<u>speed</u>			
	x7	0.59(0.12)***	0.000
	x8	0.67(0.10)***	0.000
	x9	0.55(0.11)***	0.000
		<u>Intercepts</u>	
	x1	4.94(0.09)***	0.000
	x2	5.98(0.10)***	0.000
	x3	2.49(0.09)***	0.000
	x4	2.82(0.09)***	0.000
	x5	4.00(0.10)***	0.000
	x6	1.92(0.08)***	0.000
	x7	4.43(0.09)***	0.000
	x8	5.56(0.08)***	0.000
	x9	5.42(0.08)***	0.000
		<u>Residual Variances</u>	
	x1	0.30(0.34)	0.378
	x2	1.33(0.18)***	0.000
	x3	0.99(0.15)***	0.000
	x4	0.43(0.07)***	0.000
	x5	0.46(0.09)***	0.000
	x6	0.29(0.06)***	0.000
	x7	0.82(0.13)***	0.000
	x8	0.51(0.10)***	0.000
	x9	0.68(0.13)***	0.000
		<u>Fit Indices</u>	
	$\chi^2(df)$	115.85	
	CFI	0.92	
	TLI	0.89	
	RMSEA	0.10	
	Scaled $\chi^2(df)$	121.74(48)***	0.000

⁺Fixed parameter

* p<0.05, ** p<0.01, ***p<0.001

Table 10: Group '2' from the 2 Model is 'Grant-White'

Grant-White			
		Est w/stars	p-value
<u>Factor Loadings</u>			
<u>visual</u>			
	x1	0.78(0.13)***	0.000
	x2	0.57(0.10)***	0.000
	x3	0.72(0.10)***	0.000
<u>textual</u>			
	x4	0.97(0.08)***	0.000
	x5	0.96(0.08)***	0.000
	x6	0.93(0.08)***	0.000
<u>speed</u>			
	x7	0.68(0.09)***	0.000
	x8	0.83(0.11)***	0.000
	x9	0.72(0.13)***	0.000
<u>Fit Indices</u>			
	$\chi^2(df)$	115.85	
	CFI	0.92	
	TLI	0.89	
	RMSEA	0.10	
	Scaled $\chi^2(df)$	121.74(48)***	0.000

⁺Fixed parameter

* p<0.05, ** p<0.01, ***p<0.001


```

if(file.exists("fit1.std.rds")){
  fit1.std <- readRDS("fit1.std.rds")
} else {
  fit1.std <- update(fit1, std.lv = TRUE, std.ov = TRUE,
    meanstructure = TRUE)
  saveRDS(fit1.std, "fit1.std.rds")
}

```

The two models are presented in Table 11. We combine the estimates and standard errors into one column in order to improve the chances that the table stays within the margins. Nevertheless, the right side is well into the margin.

```

# include 2 models in table request
fit1.t2 <- semTable(list("Ordinary" = fit1, "Standardized" =
  fit1.std), columns=c("estse", "z", "p"), file =
  file.path(tempdir, "fit1.2.1"), table.float = TRUE, longtable =
  TRUE, caption = "Ordinary and Standardized CFA Estimates",
  label = "tab:fit1.t2")

```

Table 11: Ordinary and Standardized CFA Estimates

		Ordinary			Standardized		
		Estimate(Std.Err.)	z	p	Estimate(Std.Err.)	z	p
<u>Factor Loadings</u>							
<u>visual</u>	x1	0.90(0.08)	11.13	0.000	0.77(0.07)	11.13	0.000
	x2	0.50(0.08)	6.43	0.000	0.42(0.07)	6.43	0.000
	x3	0.66(0.07)	8.82	0.000	0.58(0.07)	8.82	0.000
<u>textual</u>	x4	0.99(0.06)	17.47	0.000	0.85(0.05)	17.47	0.000
	x5	1.10(0.06)	17.58	0.000	0.85(0.05)	17.58	0.000
	x6	0.92(0.05)	17.08	0.000	0.84(0.05)	17.08	0.000
<u>speed</u>	x7	0.62(0.07)	8.90	0.000	0.57(0.06)	8.90	0.000
	x8	0.73(0.07)	11.09	0.000	0.72(0.07)	11.09	0.000
	x9	0.67(0.07)	10.30	0.000	0.66(0.06)	10.30	0.000
<u>Intercepts</u>							
	x1	4.94(0.07)	73.47	0.000	0.00(0.06)	0.00	1.000
	x2	6.09(0.07)	89.85	0.000	0.00(0.06)	0.00	1.000
	x3	2.25(0.07)	34.58	0.000	0.00(0.06)	0.00	1.000
	x4	3.06(0.07)	45.69	0.000	0.00(0.06)	0.00	1.000
	x5	4.34(0.07)	58.45	0.000	0.00(0.06)	0.00	1.000
	x6	2.19(0.06)	34.67	0.000	0.00(0.06)	0.00	1.000
	x7	4.19(0.06)	66.77	0.000	0.00(0.06)	0.00	1.000
	x8	5.53(0.06)	94.85	0.000	0.00(0.06)	0.00	1.000
	x9	5.37(0.06)	92.55	0.000	0.00(0.06)	0.00	1.000
<u>Residual Variances</u>							

x1	0.55(0.11)	4.83	0.000	0.40(0.08)	4.83	0.000
x2	1.13(0.10)	11.15	0.000	0.82(0.07)	11.15	0.000
x3	0.84(0.09)	9.32	0.000	0.66(0.07)	9.32	0.000
x4	0.37(0.05)	7.78	0.000	0.27(0.04)	7.78	0.000
x5	0.45(0.06)	7.64	0.000	0.27(0.04)	7.64	0.000
x6	0.36(0.04)	8.28	0.000	0.30(0.04)	8.28	0.000
x7	0.80(0.08)	9.82	0.000	0.67(0.07)	9.82	0.000
x8	0.49(0.07)	6.57	0.000	0.48(0.07)	6.57	0.000
x9	0.57(0.07)	8.00	0.000	0.56(0.07)	8.00	0.000
<u>Latent Intercepts</u>						
visual	0.00 ⁺			0.00 ⁺		
textual	0.00 ⁺			0.00 ⁺		
speed	0.00 ⁺			0.00 ⁺		
<u>Latent Variances</u>						
visual	1.00 ⁺			1.00 ⁺		
textual	1.00 ⁺			1.00 ⁺		
speed	1.00 ⁺			1.00 ⁺		
<u>Latent Covariances</u>						
visual w/textual	0.46(0.06)	7.19	0.000	0.46(0.06)	7.19	0.000
visual w/speed	0.47(0.07)	6.46	0.000	0.47(0.07)	6.46	0.000
textual w/speed	0.28(0.07)	4.12	0.000	0.28(0.07)	4.12	0.000
<u>Fit Indices</u>						
$\chi^2(df)$	85.31(24)		0.000	85.31(24)		0.000
CFI	0.93			0.93		
TLI	0.90			0.90		
RMSEA	0.09			0.09		

⁺Fixed parameter

In the present case, it is perhaps not needed to display p values on the standardized model estimates, so we might economize on horizontal space by keeping just the estimates from the standardized model. To demonstrate the fact that it is possible to select different columns for the two models, we offer Table 12.

```
fit1.t2.2 <- semTable(list("Ordinary" = fit1, "Standardized" =
  fit1.std), columns = list("Ordinary" = c("estse", "z", "p"), "
  Standardized" = c("estse")), columnLabels = c(estse = "
  Est(S.E.)", z = "Z", se = "SE"), file = file.path(tempdir, "
  fit1.t2.2"), table.float = TRUE, longtable = TRUE, caption = "
  Customizing Column Selections by Model", label = "
  tab:fit1.t2.2" )
```

Table 12: Customizing Column Selections by Model

	Ordinary		Standardized
	Est(S.E.)	Z	Est(S.E.)
	<u>Factor Loadings</u>		
<u>visual</u>			

	x1	0.90(0.08)	11.13	0.000	0.77(0.07)
	x2	0.50(0.08)	6.43	0.000	0.42(0.07)
<u>textual</u>	x3	0.66(0.07)	8.82	0.000	0.58(0.07)
	x4	0.99(0.06)	17.47	0.000	0.85(0.05)
	x5	1.10(0.06)	17.58	0.000	0.85(0.05)
<u>speed</u>	x6	0.92(0.05)	17.08	0.000	0.84(0.05)
	x7	0.62(0.07)	8.90	0.000	0.57(0.06)
	x8	0.73(0.07)	11.09	0.000	0.72(0.07)
	x9	0.67(0.07)	10.30	0.000	0.66(0.06)
			<u>Intercepts</u>		
	x1	4.94(0.07)	73.47	0.000	0.00(0.06)
	x2	6.09(0.07)	89.85	0.000	0.00(0.06)
	x3	2.25(0.07)	34.58	0.000	0.00(0.06)
	x4	3.06(0.07)	45.69	0.000	0.00(0.06)
	x5	4.34(0.07)	58.45	0.000	0.00(0.06)
	x6	2.19(0.06)	34.67	0.000	0.00(0.06)
	x7	4.19(0.06)	66.77	0.000	0.00(0.06)
	x8	5.53(0.06)	94.85	0.000	0.00(0.06)
	x9	5.37(0.06)	92.55	0.000	0.00(0.06)
			<u>Residual Variances</u>		
	x1	0.55(0.11)	4.83	0.000	0.40(0.08)
	x2	1.13(0.10)	11.15	0.000	0.82(0.07)
	x3	0.84(0.09)	9.32	0.000	0.66(0.07)
	x4	0.37(0.05)	7.78	0.000	0.27(0.04)
	x5	0.45(0.06)	7.64	0.000	0.27(0.04)
	x6	0.36(0.04)	8.28	0.000	0.30(0.04)
	x7	0.80(0.08)	9.82	0.000	0.67(0.07)
	x8	0.49(0.07)	6.57	0.000	0.48(0.07)
	x9	0.57(0.07)	8.00	0.000	0.56(0.07)
			<u>Latent Intercepts</u>		
	visual	0.00 ⁺			0.00 ⁺
	textual	0.00 ⁺			0.00 ⁺
	speed	0.00 ⁺			0.00 ⁺
			<u>Latent Variances</u>		
	visual	1.00 ⁺			1.00 ⁺
	textual	1.00 ⁺			1.00 ⁺
	speed	1.00 ⁺			1.00 ⁺
			<u>Latent Covariances</u>		
	visual w/textual	0.46(0.06)	7.19	0.000	0.46(0.06)
	visual w/speed	0.47(0.07)	6.46	0.000	0.47(0.07)
	textual w/speed	0.28(0.07)	4.12	0.000	0.28(0.07)
			<u>Fit Indices</u>		
	$\chi^2(df)$	85.31(24)		0.000	85.31(24)
	CFI	0.93			0.93
	TLI	0.90			0.90

RMSEA	0.09	0.09
⁺ Fixed parameter		

8 Larger Models

The structural equation model (SEM) introduces a regression relationship between the latent variables. In `lavaan`, the regression relationships are introduced by the same notation as regression in linear models.

```
regmodel1 <- 'visual  =~ x1 + x2 + x3
              textual =~ x4 + x5 + x6
              speed   =~ x7 + x8 + x9
              visual  ~ textual + speed
'
```

```
if(file.exists("fit2.rds")){
  fit2 <- readRDS("fit2.rds")
} else {
  fit2 <- sem(regmodel1, data = HolzingerSwineford1939, std.lv
    = FALSE, meanstructure = TRUE)
  saveRDS(fit2, "fit2.rds")
}
```

```
if(file.exists("fit2.std.rds")){
  fit2.std <- readRDS("fit2.std.rds")
} else {
  fit2.std <- update(fit2, std.lv = TRUE, std.ov = TRUE,
    meanstructure = TRUE)
  saveRDS(fit2.std, "fit2.std.rds")
}
```

A table comparing the standardized with the non-standardized models is offered in Table 13.

```
fit2.t <- semTable(list("Ordinary" = fit2, "Standardized" =
  fit2.std), fits = "rmsea", columns = list("Ordinary" = c("est",
  "se", "p"), "Standardized" = c("estsestars")), columnLabels =
  c("est" = "Est", "se" = "Std.Err.", "p" = "p", "estsestars" = "
  Standardized Est."), paramSets = c("loadings", "intercepts", "
  slopes", "latentcovariances"), file = file.path(tempdir, "
  fit2.t1"), type = "latex", table.float = TRUE, longtable =
  TRUE, caption = "SEM, Standardized or Not", label = "
  tab:fit2.t")
```

Table 13: SEM, Standardized or Not

	Ordinary		Standardized
Est	Std.Err.	p	Standardized Est.

<u>Factor Loadings</u>					
<u>visual</u>	x1	1.00 ⁺			1.00 ⁺
	x2	0.55	0.10	0.000	0.25(0.05)***
	x3	0.73	0.11	0.000	0.39(0.05)***
<u>textual</u>	x4	1.00 ⁺			1.00 ⁺
	x5	1.11	0.07	0.000	0.94(0.04)***
	x6	0.93	0.06	0.000	0.92(0.04)***
<u>speed</u>	x7	1.00 ⁺			1.00 ⁺
	x8	1.18	0.16	0.000	0.83(0.06)***
	x9	1.08	0.15	0.000	0.68(0.06)***
<u>Regression Slopes</u>					
<u>visual</u>	textual	0.32	0.07	0.000	0.38(0.06)***
	speed	0.54	0.13	0.000	0.22(0.07)**
<u>Intercepts</u>					
	x1	4.94	0.07	0.000	0.00(0.06)
	x2	6.09	0.07	0.000	0.00(0.06)
	x3	2.25	0.07	0.000	0.00(0.06)
	x4	3.06	0.07	0.000	0.00(0.06)
	x5	4.34	0.07	0.000	0.00(0.06)
	x6	2.19	0.06	0.000	0.00(0.06)
	x7	4.19	0.06	0.000	0.00(0.07)
	x8	5.53	0.06	0.000	0.00(0.06)
	x9	5.37	0.06	0.000	0.00(0.06)
<u>Latent Covariances</u>					
textual w/speed	0.17	0.05	0.000		0.35(0.06)***
<u>Fit Indices</u>					
RMSEA	0.09				0.12

⁺Fixed parameter

* p<0.05, ** p<0.01, ***p<0.001

```
# Change output format to csv
cat(markupConvert(attr(fit2.t, "markedResults"), type = "csv"),
    file = file.path(tempdir, "fit2.t.converted.csv"))
cat(markupConvert(attr(fit2.t, "markedResults"), type = "html"),
    file = file.path(tempdir, "fit2.t.converted.html"))
```

It is not necessary to have all of the same relationships estimated in every model. To demonstrate that, we estimate a second structural equation with some indicators removed and also we have a different regression relationship.

```
regmodel2 <- 'visual =~ x1 + x2 + x3
              textual =~ x4 + x6
              speed =~ x8 + x9
              visual ~ speed'
```

```

5      textual ~ speed
      ,

if(file.exists("fit3.rds")){
  fit3 <- readRDS("fit3.rds")
} else {
  fit3 <- sem(regmodel2, data = HolzingerSwineford1939, std.lv
    = TRUE, meanstructure = TRUE)
5    saveRDS(fit3, "fit3.rds")
  }
if(file.exists("fit3.std.rds")){
  fit3.std <- readRDS("fit3.std.rds")
} else {
10   fit3.std <- update(fit3, std.lv = TRUE, std.ov = TRUE)
  saveRDS(fit3.std, "fit3.std.rds")
}

```

See Table 14 for output from the following, which combines four model columns. Note that the result table handles the problem that some estimates are not included in each model.

```

fit3.std.t1 <- semTable(list("Mod 1" = fit2, "Mod 1 std" =
  fit2.std, "Mod 2" = fit3, "Mod 3 std" = fit3.std), paramSets =
  c("loadings", "slopes", "intercepts", "residualvariances", "
  latentvariances", "latentcovariances"), columns =
  c("estsestars"), type = "latex", file = file.path(tempdir, "
  fit3.std.t1"), table.float = TRUE, longtable = TRUE, caption = "
  Several SEMs with Differing Parameters", label = "
  tab:fit3.std.t1")

```

Table 14: Several SEMs with Differing Parameters

		Mod 1	Mod 1 std	Mod 2	Mod 3 std
		Estimate(Std.Err.)	Estimate(Std.Err.)	Estimate(Std.Err.)	Estimate(Std.Err.)
<u>Factor Loadings</u>					
<u>visual</u>					
	x1	1.00 ⁺	1.00 ⁺	0.72(0.08)***	0.61(0.07)***
	x2	0.55(0.10)***	0.25(0.05)***	0.41(0.07)***	0.35(0.06)***
	x3	0.73(0.11)***	0.39(0.05)***	0.54(0.07)***	0.48(0.06)***
<u>textual</u>					
	x4	1.00 ⁺	1.00 ⁺	0.92(0.08)***	0.79(0.06)***
	x5	1.11(0.07)***	0.94(0.04)***		
	x6	0.93(0.06)***	0.92(0.04)***	0.90(0.07)***	0.82(0.07)***
<u>speed</u>					
	x7	1.00 ⁺	1.00 ⁺		
	x8	1.18(0.16)***	0.83(0.06)***	0.51(0.07)***	0.50(0.07)***
	x9	1.08(0.15)***	0.68(0.06)***	0.90(0.10)***	0.89(0.10)***
<u>Regression Slopes</u>					
<u>visual</u>					

	textual	0.32(0.07)***	0.38(0.06)***		
	speed	0.54(0.13)***	0.22(0.07)**	0.72(0.14)***	0.72(0.14)***
<u>textual</u>					
	speed			0.30(0.08)***	0.30(0.08)***
			<u>Intercepts</u>		
	x1	4.94(0.07)***	0.00(0.06)	4.94(0.07)***	0.00(0.06)
	x2	6.09(0.07)***	0.00(0.06)	6.09(0.07)***	0.00(0.06)
	x3	2.25(0.07)***	0.00(0.06)	2.25(0.07)***	0.00(0.06)
	x4	3.06(0.07)***	0.00(0.06)	3.06(0.07)***	0.00(0.06)
	x5	4.34(0.07)***	0.00(0.06)		
	x6	2.19(0.06)***	0.00(0.06)	2.19(0.06)***	0.00(0.06)
	x7	4.19(0.06)***	0.00(0.07)		
	x8	5.53(0.06)***	0.00(0.06)	5.53(0.06)***	0.00(0.06)
	x9	5.37(0.06)***	0.00(0.06)	5.37(0.06)***	0.00(0.06)
			<u>Residual Variances</u>		
	x1	0.55(0.11)***	-0.12(0.07)	0.58(0.10)***	0.42(0.07)***
	x2	1.13(0.10)***	0.93(0.07)***	1.12(0.10)***	0.81(0.07)***
	x3	0.84(0.09)***	0.83(0.07)***	0.83(0.09)***	0.65(0.07)***
	x4	0.37(0.05)***	0.25(0.03)***	0.43(0.11)***	0.32(0.08)***
	x5	0.45(0.06)***	0.27(0.03)***		
	x6	0.36(0.04)***	0.31(0.04)***	0.32(0.10)**	0.27(0.09)**
	x7	0.80(0.08)***	0.53(0.08)***		
	x8	0.49(0.07)***	0.49(0.06)***	0.76(0.08)***	0.74(0.08)***
	x9	0.57(0.07)***	0.66(0.07)***	0.21(0.16)	0.20(0.15)
			<u>Latent Variances</u>		
	visual	0.54(0.12)***	1.00 ⁺	1.00 ⁺	1.00 ⁺
	textual	0.98(0.11)***	1.00 ⁺	1.00 ⁺	1.00 ⁺
	speed	0.38(0.09)***	1.00 ⁺	1.00 ⁺	1.00 ⁺
			<u>Latent Covariances</u>		
	textual w/speed	0.17(0.05)***	0.35(0.06)***		
	visual w/textual			0.44(0.08)***	0.44(0.08)***
			<u>Fit Indices</u>		
	$\chi^2(df)$	85.31(24)***	145.49(27)***	14.46(11)	14.46(11)
	CFI	0.93	0.87	0.99	0.99
	TLI	0.90	0.82	0.99	0.99
	RMSEA	0.09	0.12	0.03	0.03

⁺Fixed parameter

* p<0.05, ** p<0.01, ***p<0.001

SEM estimates can also be obtained for the two group model, as illustrated in Table 15:

```

if(file.exists("fit3.g2.rds")){
  fit3.g2 <- readRDS("fit3.g2.rds")
} else {
  fit3.g2 <- sem(regmodel1, data = HolzingerSwineford1939,
    group = "school")
  saveRDS(fit3.g2, "fit3.g2.rds")
}

```

#

```
fit3.g2.2 <- semTable(fit3.g2, paramSets = c("loadings", "slopes",
  "intercepts"), columns = c("estsestars"), fits = c("chisq", "
  rmsea", "cfi"), type = "latex", file = file.path(tempdir, "
  fit3.g2"), table.float=TRUE, longtable=TRUE, caption = "SEM
  with Two Groups", label = "tab:fit3.g2")
```

Table 15: SEM with Two Groups

	Pasteur	Grant-White
	Estimate(Std.Err.)	Estimate(Std.Err.)
	<u>Factor Loadings</u>	
<u>visual</u>		
x1	1.00 ⁺	1.00 ⁺
x2	0.39(0.12)**	0.74(0.15)***
x3	0.57(0.14)***	0.92(0.17)***
<u>textual</u>		
x4	1.00 ⁺	1.00 ⁺
x5	1.18(0.10)***	0.99(0.09)***
x6	0.87(0.08)***	0.96(0.08)***
<u>speed</u>		
x7	1.00 ⁺	1.00 ⁺
x8	1.12(0.28)***	1.23(0.19)***
x9	0.92(0.22)***	1.06(0.16)***
	<u>Regression Slopes</u>	
<u>visual</u>		
textual	0.48(0.11)***	0.33(0.09)***
speed	0.28(0.20)	0.44(0.14)**
	<u>Intercepts</u>	
x1	4.94(0.09)***	4.93(0.10)***
x2	5.98(0.10)***	6.20(0.09)***
x3	2.49(0.09)***	2.00(0.09)***
x4	2.82(0.09)***	3.32(0.09)***
x5	4.00(0.10)***	4.71(0.10)***
x6	1.92(0.08)***	2.47(0.09)***
x7	4.43(0.09)***	3.92(0.09)***
x8	5.56(0.08)***	5.49(0.09)***
x9	5.42(0.08)***	5.33(0.09)***
	<u>Fit Indices</u>	
$\chi^2(df)$	115.85(48)***	
RMSEA	0.10	
CFI	0.92	

⁺Fixed parameter

* p<0.05, ** p<0.01, ***p<0.001

Mediation Model

There seems to be an unwritten rule in SEM that all tutorials must use, for at least one model, Bollen's famous data set about industrialization and democracy. We'll use that data for a model with mediation. We'll make this interesting by calculating one set of ML estimates for the standard errors and one bootstrapped set.

```
## Model 5 - Mediation model with equality constraints
model5 <-
  '
    # latent variable definitions
    ind60 =~ x1 + x2 + x3
    dem60 =~ y1 + e*y2 + d*y3 + y4
    dem65 =~ y5 + e*y6 + d*y7 + y8
    # regressions
    dem60 ~ a*ind60
    dem65 ~ c*ind60 + b*dem60
    # residual correlations
    y1 ~~ y5
    y2 ~~ y4 + y6
    y3 ~~ y7
    y4 ~~ y8
    y6 ~~ y8

    # indirect effect (a*b)
    ## := operator defines new parameters
    ab := a*b

    ## total effect
    total := c + (a*b)
  '
```

Because this model can take a while to estimate, we use the saved copies if they are available.

```
if(file.exists("fit5.rds")){
  fit5 <- readRDS("fit5.rds")
} else {
  fit5 <- sem(model5, data=PoliticalDemocracy)
  saveRDS(fit5, "fit5.rds")
}
if(file.exists("fit5boot.rds")){
  fit5boot <- readRDS("fit5boot.rds")
} else {
  fit5boot <- sem(model5, data=PoliticalDemocracy, se = "
    bootstrap", bootstrap = 500)
  saveRDS(fit5boot, "fit5boot.rds")
}
```

The ML and bootstrapped estimates are compared in Table 16.

```
fit5.t2 <- semTable(list("ML estimates" = fit5, "Bootstrapped SE"
  = fit5boot), columns = c("estsestars", "rsquare"), file =
  file.path(tempdir, "fit5.2"), type = "latex", longtable = TRUE,
  table.float = TRUE, caption = "Comparing ML and Bootstrapped
  Estimates", label = "tab:fit5t2")
```

Table 16: Comparing ML and Bootstrapped Estimates

	ML estimates		Bootstrapped SE	
	Estimate(Std.Err.)	R Square	Estimate(Std.Err.)	R Square
<u>Factor Loadings</u>				
<u>ind60</u>				
x1	1.00 ⁺	0.85	1.00 ⁺	0.85
x2	2.18(0.14) ^{***}	0.95	2.18(0.15) ^{***}	0.95
x3	1.82(0.15) ^{***}	0.76	1.82(0.15) ^{***}	0.76
<u>dem60</u>				
y1	1.00 ⁺	0.72	1.00 ⁺	0.72
y2	1.19(0.14) ^{***}	0.47	1.19(0.15) ^{***}	0.47
y3	1.17(0.12) ^{***}	0.57	1.17(0.12) ^{***}	0.57
y4	1.26(0.13) ^{***}	0.70	1.26(0.15) ^{***}	0.70
<u>dem65</u>				
y5	1.00 ⁺	0.67	1.00 ⁺	0.67
y6	1.19(0.14) ^{***}	0.57	1.19(0.15) ^{***}	0.57
y7	1.17(0.12) ^{***}	0.64	1.17(0.12) ^{***}	0.64
y8	1.25(0.14) ^{***}	0.69	1.25(0.16) ^{***}	0.69
<u>Regression Slopes</u>				
<u>dem60</u>				
ind60	1.47(0.39) ^{***}		1.47(0.38) ^{***}	
<u>dem65</u>				
ind60	0.60(0.23) ^{**}		0.60(0.25) [*]	
dem60	0.87(0.08) ^{***}		0.87(0.08) ^{***}	
<u>Residual Variances</u>				
x1	0.08(0.02) ^{***}		0.08(0.02) ^{***}	
x2	0.12(0.07)		0.12(0.08)	
x3	0.47(0.09) ^{***}		0.47(0.08) ^{***}	
y1	1.86(0.43) ^{***}		1.86(0.45) ^{***}	
y2	7.59(1.37) ^{***}		7.59(1.25) ^{***}	
y3	4.96(0.96) ^{***}		4.96(1.08) ^{***}	
y4	3.22(0.73) ^{***}		3.22(0.80) ^{***}	
y5	2.31(0.48) ^{***}		2.31(0.58) ^{***}	
y6	4.97(0.92) ^{***}		4.97(0.94) ^{***}	
y7	3.56(0.71) ^{***}		3.56(0.62) ^{***}	
y8	3.31(0.71) ^{***}		3.31(0.92) ^{***}	
<u>Residual Covariances</u>				
y1 w/y5	0.58(0.36)		0.58(0.46)	
y2 w/y4	1.44(0.69) [*]		1.44(0.72) [*]	
y2 w/y6	2.18(0.74) ^{**}		2.18(0.83) ^{**}	

y3 w/y7	0.71(0.61)		0.71(0.59)	
y4 w/y8	0.36(0.44)		0.36(0.45)	
y6 w/y8	1.37(0.58)*		1.37(0.78)	
		<u>Latent Variances</u>		
ind60	0.45(0.09)***		0.45(0.07)***	
dem60	3.87(0.87)***	0.20	3.87(0.81)***	0.20
dem65	0.16(0.23)	0.96	0.16(0.26)	0.96
		<u>Constructed</u>		
ab	1.27(0.36)***		1.27(0.35)***	
total	1.88(0.37)***		1.88(0.38)***	
		<u>Fit Indices</u>		
$\chi^2(df)$	40.18(37)		40.18(37)	
CFI	1.00		1.00	
TLI	0.99		0.99	
RMSEA	0.03		0.03	

⁺Fixed parameter
* p<0.05, ** p<0.01, ***p<0.001

Now we remove some indicators from the model and re-fit. The results are presented in Table 17.

```
## '
## Model 5b - Revision of Model 5s
model5b <-
  '
5   # Cut some indicators from the measurement model
  ind60 =~ x1 + x2
  dem60 =~ y1 + e*y2 + d*y3 + y4
  dem65 =~ y5 + e*y6 + d*y7
  # regressions
10  dem60 ~ a*ind60
  dem65 ~ c*ind60 + b*dem60
  # cut out the residual correlations
  # indirect effect (a*b)
  ## := operator defines new parameters
15  ab := a*b
  ## total effect
  total := c + (a*b)
  '
```

Again, we use the saved fits, or if they are unavailable, we re-calculate.

```
if(file.exists("fit5b.rds")){
  fit5b <- readRDS("fit5.rds")
} else {
  fit5b <- sem(model5b, data=PoliticalDemocracy, se = "
    bootstrap", bootstrap = 500)
5  saveRDS(fit5b, "fit5b.rds")
}
```

```
fit5.5b <- semTable(list("Model 5" = fit5boot, "Model 5b" =
  fit5b), columns = c("estsestars", "rsquare"), file =
  file.path(tempdir, "fit5.5"), type = "latex", longtable = TRUE,
  table.float = TRUE, caption = "Models 5 and 5b", label = "
  tab:fit5.5b")
```

Table 17: Models 5 and 5b

	Model 5		Model 5b	
	Estimate(Std.Err.)	R Square	Estimate(Std.Err.)	R Square
	<u>Factor Loadings</u>			
<u>ind60</u>				
x1	1.00 ⁺	0.85	1.00 ⁺	0.85
x2	2.18(0.15) ^{***}	0.95	2.18(0.14) ^{***}	0.95
x3	1.82(0.15) ^{***}	0.76	1.82(0.15) ^{***}	0.76
<u>dem60</u>				
y1	1.00 ⁺	0.72	1.00 ⁺	0.72
y2	1.19(0.15) ^{***}	0.47	1.19(0.14) ^{***}	0.47
y3	1.17(0.12) ^{***}	0.57	1.17(0.12) ^{***}	0.57
y4	1.26(0.15) ^{***}	0.70	1.26(0.13) ^{***}	0.70
<u>dem65</u>				
y5	1.00 ⁺	0.67	1.00 ⁺	0.67
y6	1.19(0.15) ^{***}	0.57	1.19(0.14) ^{***}	0.57
y7	1.17(0.12) ^{***}	0.64	1.17(0.12) ^{***}	0.64
y8	1.25(0.16) ^{***}	0.69	1.25(0.14) ^{***}	0.69
	<u>Regression Slopes</u>			
<u>dem60</u>				
ind60	1.47(0.38) ^{***}		1.47(0.39) ^{***}	
<u>dem65</u>				
ind60	0.60(0.25) [*]		0.60(0.23) ^{**}	
dem60	0.87(0.08) ^{***}		0.87(0.08) ^{***}	
	<u>Residual Variances</u>			
x1	0.08(0.02) ^{***}		0.08(0.02) ^{***}	
x2	0.12(0.08)		0.12(0.07)	
x3	0.47(0.08) ^{***}		0.47(0.09) ^{***}	
y1	1.86(0.45) ^{***}		1.86(0.43) ^{***}	
y2	7.59(1.25) ^{***}		7.59(1.37) ^{***}	
y3	4.96(1.08) ^{***}		4.96(0.96) ^{***}	
y4	3.22(0.80) ^{***}		3.22(0.73) ^{***}	
y5	2.31(0.58) ^{***}		2.31(0.48) ^{***}	
y6	4.97(0.94) ^{***}		4.97(0.92) ^{***}	
y7	3.56(0.62) ^{***}		3.56(0.71) ^{***}	
y8	3.31(0.92) ^{***}		3.31(0.71) ^{***}	
	<u>Residual Covariances</u>			
y1 w/y5	0.58(0.46)		0.58(0.36)	
y2 w/y4	1.44(0.72) [*]		1.44(0.69) [*]	
y2 w/y6	2.18(0.83) ^{**}		2.18(0.74) ^{**}	

y3 w/y7	0.71(0.59)		0.71(0.61)	
y4 w/y8	0.36(0.45)		0.36(0.44)	
y6 w/y8	1.37(0.78)		1.37(0.58)*	
		<u>Latent Variances</u>		
ind60	0.45(0.07)***		0.45(0.09)***	
dem60	3.87(0.81)***	0.20	3.87(0.87)***	0.20
dem65	0.16(0.26)	0.96	0.16(0.23)	0.96
		<u>Constructed</u>		
ab	1.27(0.35)***		1.27(0.36)***	
total	1.88(0.38)***		1.88(0.37)***	
		<u>Fit Indices</u>		
$\chi^2(df)$	40.18(37)		40.18(37)	
CFI	1.00		1.00	
TLI	0.99		0.99	
RMSEA	0.03		0.03	

⁺Fixed parameter
* p<0.05, ** p<0.01, ***p<0.001

9 Conclusion

The `semTable` function is, to our knowledge, the first effort successful effort to create a flexible function to present various kinds of `lavaan` estimates of confirmatory factor analyses and structural equation models. This version includes the ability of authors to select parameter sets, output columns, fit indices, as well as to customize many of the labels.

This document is not intended as a lesson in structural equation modeling. Instead, we offer it as evidence that the `semTable` function does work, as promised, for a wide variety of contexts.

References

- R Core Team (2019). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria: R Foundation for Statistical Computing.
- Rosseel, Y. (2012). `lavaan`: An R package for structural equation modeling. *Journal of Statistical Software*, 48(2), 1–36.

Replication Information

Please leave this next code chunk if you are producing a guide document.

```
R version 3.6.0 (2019-04-26)
Platform: x86_64-pc-linux-gnu (64-bit)
Running under: Ubuntu 19.04

Matrix products: default
BLAS: /usr/lib/x86_64-linux-gnu/atlas/libblas.so.3.10.3
LAPACK: /usr/lib/x86_64-linux-gnu/atlas/liblapack.so.3.10.3
```

```

10 locale:
  [1] LC_CTYPE=en_US.UTF-8      LC_NUMERIC=C
  [3] LC_TIME=en_US.UTF-8      LC_COLLATE=C
  [5] LC_MONETARY=en_US.UTF-8  LC_MESSAGES=en_US.UTF-8
  [7] LC_PAPER=en_US.UTF-8     LC_NAME=C
  [9] LC_ADDRESS=C             LC_TELEPHONE=C
15 [11] LC_MEASUREMENT=en_US.UTF-8 LC_IDENTIFICATION=C

  attached base packages:
  [1] stats      graphics  grDevices  utils      datasets  methods    base

20 other attached packages:
  [1] semTable_1.6      lavaan_0.6-3      stationery_0.98.6

  loaded via a namespace (and not attached):
25 [1] Rcpp_1.0.1      digest_0.6.18    plyr_1.8.4      xtable_1.8-4
  [5] stats4_3.6.0    evaluate_0.13    zip_2.0.2      pbivnorm_0.6.0
  [9] openxlsx_4.1.0  rmarkdown_1.12  tools_3.6.0    foreign_0.8-71
 [13] kutils_1.69     xfun_0.7         compiler_3.6.0  mnormt_1.5-5
 [17] htmltools_0.3.6 knitr_1.22

```