

A sensitivity analysis of predicting continued use of online teacher professional development and the influence of social presence and sociability by Jo A. Smith and Stephen A. Sivo

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#####Original Paper: Smith,J.A.,& Sivo,S.A.(2012). Predicting continued use of online teacher professional development and the influence of social presence and sociability. *British Journal of Educational Technology*, 43(6), 871-882. doi:10.1111/j.1467-8535.2011.01223.x

SENSITIVITY ANALYSIS USING SEMsens

This document provides a simple example analysis of a path analysis dataset, a survey of teachers enrolled in a statewide online reading course. The study examines how a Technology Acceptance Model (TAM) could predict teachers' intentions to continue using e-learning for professional development based on perceived ease of use and usefulness, as well as examine mediating influences of social presence and sociability in e-learning professional development.

The dataset has six manifest variables: Perceived Usefulness (PU), Perceived Ease of Use (PEU), Teachers' Reading Knowledge Assessment gains (Gains), Social Presence (SP), Sociability (SOC), and Continuance Intention (CI).

In addition to the **SEMsens** package, this vignette also makes use of **lavaan**.

```
#Load the packages
require(SEMsens)
require(lavaan)
set.seed(1)
```

Step 1: Original Path Model & Estimation

Here, we reproduce the the correlation matrix found in the article. First we create the lower diagonal and then convert to a covariance matrix and label the variables with `getCov()` from **lavaan**.

```
#Set a correlation matrix
lower = '
1.00
0.68 1.00
0.54 0.55 1.00
0.65 0.63 0.67 1.00
0.33 0.37 0.68 0.54 1.00
-0.01 0.00 0.03 -0.04 0.07 1.00'
```

```
#convert to full covariance matrix, using function from lavaan
full = getCov(lower, sds= c(4.61,5.37,7.25,3.44,8.91,8.80),
names = c("PU", "PEU", "SP", "CI","SOC","Gains"))
```

We next set up the path model from the article, using `lavaan` model syntax with `sem` function. Through this code, we can get the result of (standardized) path coefficients and model fit indices. Standardized coefficient and model fit of this test almost exactly reproduces the results of the original paper (Smith & Sivo,2012). Slight differences are a result of using different statistical software (R or LISREL).

```
# Original model
lav_model <- 'SP~SOC
Gains~SP
PU~SP+PEU
PEU~SP
CI~SP+PU+PEU+SOC
Gains ~~ 0*CI
'

# Fit the original model with sem function
modelFit <- sem(lav_model, sample.nobs=517, sample.cov=full, fixed.x=TRUE, std.lv=TRUE)
summary(modelFit, standardized = TRUE) #look at Std.all
```

```
## lavaan 0.6-9 ended normally after 24 iterations
##
##      Estimator                      ML
##      Optimization method          NLMINB
##      Number of model parameters      14
##
##      Number of observations          517
##
## Model Test User Model:
##
##      Test statistic                  9.567
##      Degrees of freedom              6
##      P-value (Chi-square)            0.144
##
## Parameter Estimates:
##
##      Standard errors                Standard
##      Information                    Expected
##      Information saturated (h1) model Structured
##
## Regressions:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
##      SP ~
##      SOC      0.553   0.026  21.087   0.000   0.553   0.680
##      Gains ~
##      SP      0.036   0.053   0.682   0.495   0.036   0.030
##      PU ~
##      SP      0.151   0.024   6.404   0.000   0.151   0.238
##      PEU     0.471   0.032  14.775   0.000   0.471   0.549
##      PEU ~
##      SP      0.407   0.027  14.974   0.000   0.407   0.550
```

```
## CI ~
## SP          0.128    0.020    6.283    0.000    0.128    0.268
## PU          0.226    0.029    7.746    0.000    0.226    0.302
## PEU         0.134    0.025    5.318    0.000    0.134    0.209
## SOC         0.069    0.015    4.769    0.000    0.069    0.179
##
## Covariances:
##          Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .Gains ~~
## .CI          0.000          0.000    0.000
##
## Variances:
##          Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .SP          28.203    1.754   16.078    0.000   28.203    0.538
## .Gains       77.221    4.803   16.078    0.000   77.221    0.999
## .PU          10.565    0.657   16.078    0.000   10.565    0.498
## .PEU         20.075    1.249   16.078    0.000   20.075    0.697
## .CI          4.651    0.289   16.078    0.000    4.651    0.392
```

```
fitMeasures(modelFit)
```

```
##          npar          fmin          chisq          df
##          14.000          0.009          9.567          6.000
##          pvalue    baseline.chisq    baseline.df    baseline.pvalue
##          0.144          1359.242          15.000          0.000
##          cfi          tli          nnfi          rfi
##          0.997          0.993          0.993          0.982
##          nfi          pnfi          ifi          rni
##          0.993          0.397          0.997          0.997
##          logl    unrestricted.logl          aic          bic
##          -7436.961          -7432.177          14901.922          14961.394
##          ntotal          bic2          rmsea    rmsea.ci.lower
##          517.000          14916.955          0.034          0.000
##          rmsea.ci.upper    rmsea.pvalue          rmr          rmr_nomean
##          0.072          0.711          1.038          1.038
##          srmr          srmr_bentler    srmr_bentler_nomean          crmr
##          0.020          0.020          0.020          0.024
##          crmr_nomean          srmr_mplus    srmr_mplus_nomean          cn_05
##          0.024          0.020          0.020          681.482
##          cn_01          gfi          agfi          pgfi
##          909.558          0.994          0.978          0.284
##          mfi          ecvi
##          0.997          0.073
```

We can get same results by using `lavannify`, `lavaan` and the `standardizedsolution` functions. These are all in the `lavaan` package and present more focused results for standardized path coefficients and their standard error and p-values. Depending on users' research questions, it is possible to select results for individual pathways in the model.

```
smith_original <- lavaan::lavaanify(model = lav_model, auto = TRUE, model.type = "sem", fixed.x = TRUE)
smith_original <- lavaan::lavaan(model = smith_original, sample.cov = full, sample.nobs = 517)
smith_original_par <- lavaan::standardizedSolution(smith_original, type = "std.all")
smith_original_par #4th row and 7th column of table : smith_original_par[1:4,1:7]
```

##	lhs	op	rhs	est	std	se	z	pvalue	ci.lower	ci.upper
## 1	SP	~	SOC	0.680	0.021	32.801	0.000	0.639	0.721	
## 2	Gains	~	SP	0.030	0.044	0.683	0.495	-0.056	0.116	
## 3	PU	~	SP	0.238	0.037	6.492	0.000	0.166	0.310	
## 4	PU	~	PEU	0.549	0.033	16.453	0.000	0.484	0.615	
## 5	PEU	~	SP	0.550	0.030	18.226	0.000	0.491	0.609	
## 6	CI	~	SP	0.268	0.042	6.343	0.000	0.186	0.351	
## 7	CI	~	PU	0.302	0.038	7.852	0.000	0.227	0.378	
## 8	CI	~	PEU	0.209	0.039	5.347	0.000	0.132	0.286	
## 9	CI	~	SOC	0.179	0.037	4.804	0.000	0.106	0.252	
## 10	Gains	~~	CI	0.000	0.000	NA	NA	0.000	0.000	
## 11	SP	~~	SP	0.538	0.028	19.068	0.000	0.482	0.593	
## 12	Gains	~~	Gains	0.999	0.003	378.978	0.000	0.994	1.004	
## 13	PU	~~	PU	0.498	0.031	16.195	0.000	0.438	0.558	
## 14	PEU	~~	PEU	0.697	0.033	21.013	0.000	0.632	0.763	
## 15	CI	~~	CI	0.392	0.026	15.201	0.000	0.342	0.443	
## 16	SOC	~~	SOC	1.000	0.000	NA	NA	1.000	1.000	

Step 2: Construct the Sensitivity Model

After checking the original path model, we then create the sensitivity model using a **Phantom Variable**. A phantom variable is modeled with paths to all other variables to see the trajectory of estimates in the original model affected by specification of the Phantom variable. As shown in the code below, the phantom variable follows the normal distribution which has mean of zero and variance of one.

```
# Sensitivity model, with sensitivity parameters for all variables
sens_model <- 'SP~SOC
  Gains ~ SP
  PU ~ SP+PEU
  PEU ~ SP
  CI ~ SP+PU+PEU+SOC
  Gains ~~ 0*CI
  SP ~ phantom1*phantom
  Gains ~ phantom2*phantom
  PU ~ phantom3*phantom
  PEU ~ phantom4*phantom
  CI ~ phantom5*phantom
  SOC ~ phantom6*phantom
  phantom =~ 0 #mean of zero
  phantom ~~ 1*phantom # variance of one'
```

Step 3: Conducting Sensitivity Analysis

Based on the specified `sens_model`, we can run the sensitivity analysis through `sa.aco()` function in `SEMsens` package. Note that we run with the parameters `k = 5` and `max.iter = 20` for a simple illustration. The default values for these parameters are `k = 50` and `max.iter = 1000`. For the other options, see the paper or vignette of `SEMsens` package (<https://cran.r-project.org/web/packages/SEMsens/index.html>).

```
smith_example <- sa.aco(
  sample.cov = full,
  sample.nobs = 517,
  model = lav_model,
```

```
sens.model = sens_model,
opt.fun = 1,
paths = c(1:9),
max.iter = 20,
k = 5)
```

```
## Number of tried evaluations is 1.
## Number of converged evaluations is 1.
## Number of tried evaluations is 2.
## Number of converged evaluations is 2.
## Number of tried evaluations is 3.
## Number of converged evaluations is 3.
## Number of tried evaluations is 4.
## Number of converged evaluations is 4.
## Number of tried evaluations is 5.
## Number of converged evaluations is 5.
```

Step 4: Sensitivity Analysis Results

We can get the sensitivity analysis results after 5 iterations. The **sens.tables** function helps us to summarize of sensitivity analysis. In the smith_tables results, the **sens.summary** table contains estimates and p-values for each path in the original model information suggested in Step 1. It also provides the minimum, mean and maximum path estimates during sensitivity analysis.

```
smith_tables <- sens.tables(smith_example)
smith_tables$sens.summary
```

##	model.est	model.pvalue	mean.est.sens	min.est.sens	max.est.sens
## Gains~SP	0.03000005	4.947475e-01	0.03078806	0.02735571	0.03562662
## CI~SOC	0.17912707	1.553400e-06	0.17525972	0.14255763	0.20699081
## CI~PEU	0.20913951	8.949231e-08	0.20793924	0.16071079	0.24031659
## PU~SP	0.23799284	8.462697e-11	0.23152339	0.22321878	0.24179787
## CI~SP	0.26848140	2.255842e-10	0.27010031	0.22550080	0.32256848
## CI~PU	0.30228504	3.996803e-15	0.31350603	0.26999750	0.39231625
## PEU~SP	0.55000002	0.000000e+00	0.54972379	0.54023885	0.56146020
## PU~PEU	0.54910394	0.000000e+00	0.55356443	0.53608380	0.57792956
## SP~SOC	0.68000001	0.000000e+00	0.68091945	0.67523652	0.68849064

The result of **phan.paths** suggests the minimum, mean and maximum value of sensitivity parameters which were formed in the relationship between phantom variable and each variables in the path model during the iteration of Ant Colony Optimization (ACO).

```
smith_tables$phan.paths
```

##	mean.phan	min.phan	max.phan
## PEU~phantom	-0.032628286	-0.16322067	0.1521077
## SOC~phantom	0.001431526	-0.08418588	0.1103978
## SP~phantom	0.002450675	-0.06472979	0.1227683
## Gains~phantom	0.003651090	-0.02906461	0.0630220
## CI~phantom	0.017121906	-0.17295276	0.2147725
## PU~phantom	0.036459926	-0.21132376	0.1887766

The table of **phan.min** indicates the sensitivity parameters for each path that led to smallest size of path estimates during the iteration process of ACO.

smith_tables\$phan.min

##	SP~phantom	Gains~phantom	PU~phantom	PEU~phantom	CI~phantom
## SP~SOC	0.05161516	-0.02637793	0.11714527	-0.0008575855	0.12632124
## Gains~SP	0.12276830	0.03659312	0.05607790	-0.1632206676	-0.17060386
## PU~SP	0.05161516	-0.02637793	0.11714527	-0.0008575855	0.12632124
## PU~PEU	-0.06426463	-0.02591714	-0.21132376	-0.0438425624	0.21477253
## PEU~SP	-0.03313566	0.06302200	0.18877664	-0.1073283518	0.08807237
## CI~SP	-0.06472979	-0.02906461	0.03162358	0.1521077372	-0.17295276
## CI~PU	-0.03313566	0.06302200	0.18877664	-0.1073283518	0.08807237
## CI~PEU	0.12276830	0.03659312	0.05607790	-0.1632206676	-0.17060386
## CI~SOC	0.12276830	0.03659312	0.05607790	-0.1632206676	-0.17060386
##	SOC~phantom				
## SP~SOC	0.11039776				
## Gains~SP	-0.07264936				
## PU~SP	0.11039776				
## PU~PEU	-0.03585607				
## PEU~SP	-0.08418588				
## CI~SP	0.08945118				
## CI~PU	-0.08418588				
## CI~PEU	-0.07264936				
## CI~SOC	-0.07264936				

Similar to phan.min case, **phan.max** table provides the sensitivity parameters for each path that resulted in the largest size of path estimates during the process of ACO.

smith_tables\$phan.max

##	SP~phantom	Gains~phantom	PU~phantom	PEU~phantom	CI~phantom
## SP~SOC	0.12276830	0.03659312	0.05607790	-0.16322067	-0.17060386
## Gains~SP	-0.03313566	0.06302200	0.18877664	-0.10732835	0.08807237
## PU~SP	-0.06472979	-0.02906461	0.03162358	0.15210774	-0.17295276
## PU~PEU	-0.03313566	0.06302200	0.18877664	-0.10732835	0.08807237
## PEU~SP	0.12276830	0.03659312	0.05607790	-0.16322067	-0.17060386
## CI~SP	0.12276830	0.03659312	0.05607790	-0.16322067	-0.17060386
## CI~PU	-0.06426463	-0.02591714	-0.21132376	-0.04384256	0.21477253
## CI~PEU	-0.03313566	0.06302200	0.18877664	-0.10732835	0.08807237
## CI~SOC	-0.06472979	-0.02906461	0.03162358	0.15210774	-0.17295276
##	SOC~phantom				
## SP~SOC	-0.07264936				
## Gains~SP	-0.08418588				
## PU~SP	0.08945118				
## PU~PEU	-0.08418588				
## PEU~SP	-0.07264936				
## CI~SP	-0.07264936				
## CI~PU	-0.03585607				
## CI~PEU	-0.08418588				
## CI~SOC	0.08945118				

The final **p.paths** table covers not only the p-values of original model's path estimates at the first column (default significance level: 0.05) but the final p-value of each path estimates that reverse the null-hypothesis

decision of original path estimates. From the third column of table, sensitivity parameters are suggested that leads to the change of p-value. An **NA** result in the table occurs if there is no change in p-value and meaningful sensitivity parameters that changed p-value in the `sa.aco` function.

```
smith_tables$p.paths
```

##		p.value	p.changed	SP~phantom	Gains~phantom	PU~phantom	PEU~phantom
##	SP~SOC	0.000000e+00	NA	NA	NA	NA	NA
##	Gains~SP	4.947475e-01	NA	NA	NA	NA	NA
##	PU~SP	8.462697e-11	NA	NA	NA	NA	NA
##	PU~PEU	0.000000e+00	NA	NA	NA	NA	NA
##	PEU~SP	0.000000e+00	NA	NA	NA	NA	NA
##	CI~SP	2.255842e-10	NA	NA	NA	NA	NA
##	CI~PU	3.996803e-15	NA	NA	NA	NA	NA
##	CI~PEU	8.949231e-08	NA	NA	NA	NA	NA
##	CI~SOC	1.553400e-06	NA	NA	NA	NA	NA
##		CI~phantom	SOC~phantom				
##	SP~SOC	NA	NA				
##	Gains~SP	NA	NA				
##	PU~SP	NA	NA				
##	PU~PEU	NA	NA				
##	PEU~SP	NA	NA				
##	CI~SP	NA	NA				
##	CI~PU	NA	NA				
##	CI~PEU	NA	NA				
##	CI~SOC	NA	NA				

References

Leite, W., Shen, Z., Marcoulides, K., Fish, C., & Harring, J. (in press). Using ant colony optimization for sensitivity analysis in structural equation modeling. *Structural Equation Modeling: A Multidisciplinary Journal*.