A Sensitivity Analysis of Toward a Greater Understanding of How Dissatisfaction Drives Employee Turnover by Peter W. Hom and Angelo J. Kinicki

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SENSITIVITY ANALYSIS USING SEMsens

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This example sensitivity analysis uses the published data and model from Hom and Kinicki (2001). We create a covariance matrix from their data, set up lavaan models for their original model and the sensitivity model, run the analysis, and view the results.

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

Step 1: Enter the data

Hom and Kinicki (2001) published correlations and standard deviations for all indicator variables, so we use those to create a covariance matrix `covmat`.

```
# Correlation matrix from published data
cormat <- diag(1,29) # start with the diagonal
cormat[lower.tri(cormat)] <- c( # add lower triangle data
  .46,.22,.30,-.20,-.30,-.20,-.22,-.33,-.19,-.25,-.63,-.60,-.48,-.17,-.42,-.09,-.36,.09,
  .04,-.12,0,-.20,-.20,-.43,-.33,-.49,-.18,-.03,.21,.30,-.15,-.25,-.10,-.20,-.31,-.15,
  -.24,-.40,-.37,-.32,-.08,-.24,-.02,-.27,.06,.07,-.08,0,-.10,-.16,-.25,-.18,-.35,-.06,
  -.05,.04,-.05,-.09,-.12,-.10,-.01,.03,.02,-.18,-.14,-.09,-.02,-.12,-.05,-.08,.03,.07,
  -.08,-.06,-.10,-.07,-.10,-.03,-.11,.04,.03,-.07,-.24,0,-.12,-.50,-.32,-.45,-.38,-.29,
  -.31,-.16,-.24,-.16,-.37,.12,.05,-.28,-.13,-.06,-.03,-.16,-.12,-.23,-.08,.06,.29,.31,
  .10,.08,-.02,.07,.21,.24,.25,.06,.09,.04,.14,-.02,-.01,.10,.04,.04,.13,.19,.03,.18,
  .14,-.04,.38,.41,.23,.13,.22,.36,.35,.35,.09,.14,.11,.14,-.09,-.04,.11,.04,.11,.15,
  .30,.17,.33,.12,-.02,.31,.05,.03,.15,.22,.20,.21,-.05,.10,-.05,.03,-.04,-.06,.03,.05,
  .03,.07,.24,.19,.23,.13,-.08,.17,.15,.19,.28,.23,.23,.04,.18,.08,.10,-.09,-.06,.07,
  .01,.11,.08,.21,.20,.28,.06,-.03,.43,.56,.35,.32,.26,.16,.27,.13,.45,-.04,-.04,.16,
```

```r
  .07,.14,.15,.23,.12,.29,.09,-.07,.67,.24,.26,.27,.15,.21,.13,.25,-.10,-.02,.12,0,.12,
  .10,.18,.21,.27,.17,-.06,.36,.32,.31,.11,.29,.16,.40,-.10,-.05,.22,.10,.17,.15,.27,
  .23,.33,.17,-.08,.78,.77,.11,.49,.09,.40,-.23,-.14,.19,-.07,.29,.27,.57,.40,.68,.27,0,
  .82,.10,.57,.08,.42,-.29,-.10,.13,-.12,.33,.31,.66,.46,.75,.32,.02,.10,.49,.08,.38,
  -.31,-.11,.18,-.06,.33,.34,.54,.38,.67,.31,-.08,.14,.52,.20,.22,.31,.42,.39,.01,.01,
  .07,.06,.13,-.03,.06,.14,.42,-.29,-.12,.24,-.06,.25,.25,.38,.28,.48,.18,-.01,.16,.16,
  .28,.68,.48,.06,.10,.01,.12,.15,-.05,.04,.02,.03,.24,.11,.14,.16,.31,.22,.32,.09,-.01,
  .37,.12,.18,-.20,-.15,-.22,-.08,-.23,-.11,.07,.13,.18,-.07,0,-.10,.04,-.06,-.03,.15,
  .54,.11,.12,.07,.10,.16,-.01,-.02,-.06,-.01,-.09,-.05,-.10,-.14,.06,.57,.28,.17,.36,
  .27,-.05,.32,.21,.36,.18,.05,.42,.68,.26,-.05,.55,.23,.04,.28,-.03,-.07
)
cormat[upper.tri(cormat)] <- t(cormat)[upper.tri(cormat)] # mirror lower to upper

# Standard deviations from published data
sds <- diag(c(1,.38,.73,.65,.58,.78,.75,.55,.59,.54,.45,.74,.85,.80,.57,
              .74,.69,.42,.57,.63,.62,.70,1.01,.94,.65,.37,.73,.40,1))

# Create covariance matrix covmat with row and column names
covmat <- sds %*% cormat %*% sds
rownames(covmat) <- colnames(covmat) <- c(
  "FACES","Duty","Team","Hours","Absent","Effort","Sick","Quality","Family",
  "Community","Personal","Thoughts","SI","QI","Stress","Jobs","Costs",
  "Benefits","Joblessness","Moving","Impact","Interference","V1","V2",
  "Prepare","Look","Intensity","Resign","Unemployed"
)
```

Step 2: Define the models

The SEMsens package requires both an original model and a sensitivity model that adds the phantom variables. These models are defined SEMsens using the lavaan model syntax.

We first define the original model:

```r
# Original model from Hom and Kinicki (2001)
model <- "JSat =~ FACES + Duty + Team
  IC =~ Family + Personal + Community
  JAvoid =~ Quality + Absent + Effort + Sick
  WC =~ QI + Thoughts + SI
  WEU =~ Stress + Benefits + Impact + Jobs
  JSearch =~ Prepare + Look + Intensity
  CA =~ V1 + V2
  Turnover =~ Resign
  Resign ~~ 0*Resign
  UR =~ Unemployed
  Unemployed ~~ 0*Unemployed

  JSat ~ IC
  JAvoid ~ JSat
  WC ~ JAvoid + JSat + IC
  WEU ~ WC + JSat + UR
  JSearch ~ WEU
  CA ~ JSearch
  Turnover ~ CA + WC + UR"
```

For the sensitivity model, we use the same model definition as the original model but add one phantom variable with paths phantom1, phantom2, etc. to each of the latent variables in the original model.

```
# Sensitivity model
sens.model <- "JSat =~ FACES + Duty + Team
  IC =~ Family + Personal + Community
  JAvoid =~ Quality + Absent + Effort + Sick
  WC =~ QI + Thoughts + SI
  WEU =~ Stress + Benefits + Impact + Jobs
  JSearch =~ Prepare + Look + Intensity
  CA =~ V1 + V2
  Turnover =~ Resign
  Resign ~~ 0*Resign
  UR =~ Unemployed
  Unemployed ~~ 0*Unemployed

  JSat ~ IC
  JAvoid ~ JSat
  WC ~ JAvoid + JSat + IC
  WEU ~ WC + JSat + UR
  JSearch ~ WEU
  CA ~ JSearch
  Turnover ~ CA + WC + UR

  IC ~ phantom1*phantom
  UR ~ phantom2*phantom
  JSat ~ phantom3*phantom
  JAvoid ~ phantom4*phantom
  WC ~ phantom5*phantom
  WEU ~ phantom6*phantom
  JSearch ~ phantom7*phantom
  CA ~ phantom8*phantom
  Turnover ~ phantom9*phantom

  phantom =~ 0
  phantom ~~ 1*phantom"
```

Step 3: Identify paths of interest

Before running the analysis, we need to identify the rows in a lavaan parameter table that include the paths we are interested in looking at in the analysis. To save space, only the most relevant section of the parameter table is displayed below.

```
ptab = lavaanify(model = model, auto = TRUE, model.type="sem")
ptab[26:40,1:4]
```

```
##    id        lhs op        rhs
## 26 26 Unemployed ~~ Unemployed
## 27 27       JSat  ~         IC
## 28 28     JAvoid  ~       JSat
## 29 29         WC  ~     JAvoid
## 30 30         WC  ~       JSat
```

```
## 31 31          WC  ~          IC
## 32 32         WEU  ~          WC
## 33 33         WEU  ~        JSat
## 34 34         WEU  ~          UR
## 35 35     JSearch  ~         WEU
## 36 36          CA  ~     JSearch
## 37 37    Turnover  ~          CA
## 38 38    Turnover  ~          WC
## 39 39    Turnover  ~          UR
## 40 40       FACES ~~       FACES
```

For this example, we are interested in all the paths between latent variables. These are located on rows 27 to 39 in the parameter table for this model. That information will be used in the next step for the analysis.

Step 4: Sensitivity analysis

The `sa.aco` function is used to run the sensitivity analysis.

```
my.sa <- sa.aco(model = model, sens.model = sens.model, sample.cov = covmat,
                sample.nobs = 410, opt.fun = 3, paths = 27:39,
                seed = 1, k = 5, max.iter = 20)
```

We specified the original model (`model`), the sensitivity model (`sens.model`), the covariance matrix (`sample.cov`), the number of observations in the sample (`sample.nobs`), the number of sensitivity parameters included (`n.of.sens.pars`), a preset optimization function (`opt.fun`), the paths from the previous step (`paths`), and a seed for reproducibility (`seed`).

Note: We only used `k = 5` and `max.iter = 20` so the analysis would run quickly for illustration purposes. For actual analyses, please specify these parameters as larger numbers (e.g., the default values are `k = 50` and `max.iter = 1000`).

Step 5: Results

The `sens.tables` function helps summarize the results of a sensitivity analysis. We specify `path = TRUE` to only obtain results for the structural paths.

```
my.sa.results = sens.tables(my.sa, path=TRUE) # get results
my.sa.results = lapply(my.sa.results, round, digits = 3) # round results (optional)
```

The tables contain several categories of results. Each is displayed below.

The `sens.summary` table contains the estimates and p values for each path in the original model as well as the mean, minimum, and maximum values for the paths that were estimated during the sensitivity analysis.

```
my.sa.results$sens.summary
```

```
##              model.est model.pvalue mean.est.sens min.est.sens max.est.sens
## JSat~IC         -0.401        0.000        -0.579       -1.023       -0.336
## JAvoid~JSat     -0.529        0.000        -0.499       -0.660       -0.129
## WC~JSat         -0.637        0.000        -0.484       -0.645       -0.270
## Turnover~UR     -0.065        0.155        -0.075       -0.256        0.129
## WEU~UR          -0.018        0.575        -0.039       -0.225        0.028
```

```
## WC~JAvoid       0.139        0.034         0.080        -0.046         0.141
## WEU~JSat       -0.093        0.202         0.112        -1.309         2.226
## WC~IC           0.144        0.004         0.154        -0.066         0.551
## Turnover~CA     0.190        0.002         0.211         0.129         0.304
## Turnover~WC     0.245        0.000         0.414        -0.660         1.628
## JSearch~WEU     0.883        0.000         0.588         0.032         2.124
## CA~JSearch      0.520        0.000         0.669         0.167         1.004
## WEU~WC          0.903        0.000         1.208        -2.875         6.782
```

The phan.paths table contains the mean, minimum, and maximum of the sensitivity parameters from the analysis

```
my.sa.results$phan.paths
```

```
##                   mean.phan min.phan max.phan
## WEU~phantom          -2.310   -4.965   -0.670
## JSat~phantom         -0.458   -0.837   -0.047
## UR~phantom           -0.305   -0.686    0.285
## CA~phantom           -0.230   -0.481    0.280
## IC~phantom           -0.180   -0.965    0.813
## WC~phantom            0.115   -1.103    0.694
## JAvoid~phantom        0.277   -0.148    0.805
## JSearch~phantom       0.332   -0.894    1.499
## Turnover~phantom      0.553   -1.105    1.795
```

The phan.min table provides the set of tested sensitivity parameter values for each path that resulted in the smallest coefficient value for the path.

```
my.sa.results$phan.min
```

```
##              IC~phantom UR~phantom JSat~phantom JAvoid~phantom WC~phantom
## JSat~IC          -0.965     -0.595       -0.384          0.123      0.409
## JAvoid~JSat      -0.514      0.285       -0.837         -0.148      0.694
## WC~JAvoid        -0.514      0.285       -0.837         -0.148      0.694
## WC~JSat          -0.965     -0.595       -0.384          0.123      0.409
## WC~IC            -0.295      0.001       -0.497          0.151     -1.103
## WEU~WC           -0.295      0.001       -0.497          0.151     -1.103
## WEU~JSat         -0.295      0.001       -0.497          0.151     -1.103
## WEU~UR            0.060     -0.531       -0.524          0.453      0.169
## JSearch~WEU      -0.295      0.001       -0.497          0.151     -1.103
## CA~JSearch       -0.295      0.001       -0.497          0.151     -1.103
## Turnover~CA      -0.514      0.285       -0.837         -0.148      0.694
## Turnover~WC      -0.514      0.285       -0.837         -0.148      0.694
## Turnover~UR       0.813     -0.686       -0.047          0.805      0.408
##              WEU~phantom JSearch~phantom CA~phantom Turnover~phantom
## JSat~IC           -0.714           1.499     -0.423           -0.194
## JAvoid~JSat       -4.965           0.935     -0.389            1.254
## WC~JAvoid         -4.965           0.935     -0.389            1.254
## WC~JSat           -0.714           1.499     -0.423           -0.194
## WC~IC             -3.900          -0.894     -0.481            1.795
## WEU~WC            -3.900          -0.894     -0.481            1.795
## WEU~JSat          -3.900          -0.894     -0.481            1.795
```

```
## WEU~UR          -1.301          -0.675     0.280            1.014
## JSearch~WEU     -3.900          -0.894    -0.481            1.795
## CA~JSearch      -3.900          -0.894    -0.481            1.795
## Turnover~CA     -4.965           0.935    -0.389            1.254
## Turnover~WC     -4.965           0.935    -0.389            1.254
## Turnover~UR     -0.670           0.794    -0.135           -1.105
```

Likewise, the `phan.max` table provides the set of tested sensitivity parameter values for each path that resulted in the *largest* coefficient value for the path.

```
my.sa.results$phan.max
```

```
##             IC~phantom UR~phantom JSat~phantom JAvoid~phantom WC~phantom
## JSat~IC          0.060     -0.531       -0.524          0.453      0.169
## JAvoid~JSat      0.813     -0.686       -0.047          0.805      0.408
## WC~JAvoid        0.060     -0.531       -0.524          0.453      0.169
## WC~JSat         -0.295      0.001       -0.497          0.151     -1.103
## WC~IC           -0.965     -0.595       -0.384          0.123      0.409
## WEU~WC          -0.514      0.285       -0.837         -0.148      0.694
## WEU~JSat        -0.514      0.285       -0.837         -0.148      0.694
## WEU~UR           0.813     -0.686       -0.047          0.805      0.408
## JSearch~WEU     -0.965     -0.595       -0.384          0.123      0.409
## CA~JSearch       0.060     -0.531       -0.524          0.453      0.169
## Turnover~CA      0.813     -0.686       -0.047          0.805      0.408
## Turnover~WC     -0.295      0.001       -0.497          0.151     -1.103
## Turnover~UR      0.060     -0.531       -0.524          0.453      0.169
##             WEU~phantom JSearch~phantom CA~phantom Turnover~phantom
## JSat~IC          -1.301          -0.675      0.280            1.014
## JAvoid~JSat      -0.670           0.794     -0.135           -1.105
## WC~JAvoid        -1.301          -0.675      0.280            1.014
## WC~JSat          -3.900          -0.894     -0.481            1.795
## WC~IC            -0.714           1.499     -0.423           -0.194
## WEU~WC           -4.965           0.935     -0.389            1.254
## WEU~JSat         -4.965           0.935     -0.389            1.254
## WEU~UR           -0.670           0.794     -0.135           -1.105
## JSearch~WEU      -0.714           1.499     -0.423           -0.194
## CA~JSearch       -1.301          -0.675      0.280            1.014
## Turnover~CA      -0.670           0.794     -0.135           -1.105
## Turnover~WC      -3.900          -0.894     -0.481            1.795
## Turnover~UR      -1.301          -0.675      0.280            1.014
```

The final table `p.paths` provides the sensitivity parameters that lead to a change in significance for each path according to the significance level specified in the `sens.tables` function. We used the default significance level of .05 for that. The first column contains the original p values and the second contains the changed p values that are obtained with the listed phantom variable path coefficients. The NAs occur when there is no change in p value for any of the tested phantom variable path coefficients.

```
my.sa.results$p.paths
```

```
##             p.value p.changed IC~phantom UR~phantom JSat~phantom JAvoid~phantom
## WEU~UR        0.575     0.000      0.060     -0.531       -0.524          0.453
## WEU~JSat      0.202     0.032      0.813     -0.686       -0.047          0.805
```

```
## Turnover~UR   0.155      0.048      -0.965      -0.595        -0.384            0.123
## WC~IC         0.004      0.053       0.813      -0.686        -0.047            0.805
## JSearch~WEU   0.000      0.430      -0.295       0.001        -0.497            0.151
## JSat~IC       0.000         NA          NA          NA            NA               NA
## JAvoid~JSat   0.000         NA          NA          NA            NA               NA
## WC~JAvoid     0.034         NA          NA          NA            NA               NA
## WC~JSat       0.000         NA          NA          NA            NA               NA
## WEU~WC        0.000         NA          NA          NA            NA               NA
## CA~JSearch    0.000         NA          NA          NA            NA               NA
## Turnover~CA   0.002         NA          NA          NA            NA               NA
## Turnover~WC   0.000         NA          NA          NA            NA               NA
##             WC~phantom WEU~phantom JSearch~phantom CA~phantom Turnover~phantom
## WEU~UR           0.169      -1.301          -0.675      0.280            1.014
## WEU~JSat         0.408      -0.670           0.794     -0.135           -1.105
## Turnover~UR      0.409      -0.714           1.499     -0.423           -0.194
## WC~IC            0.408      -0.670           0.794     -0.135           -1.105
## JSearch~WEU     -1.103      -3.900          -0.894     -0.481            1.795
## JSat~IC             NA          NA              NA         NA               NA
## JAvoid~JSat         NA          NA              NA         NA               NA
## WC~JAvoid           NA          NA              NA         NA               NA
## WC~JSat             NA          NA              NA         NA               NA
## WEU~WC              NA          NA              NA         NA               NA
## CA~JSearch          NA          NA              NA         NA               NA
## Turnover~CA         NA          NA              NA         NA               NA
## Turnover~WC         NA          NA              NA         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.