Package 'SEMsens'

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An analysis based on structural equation modeling may suffer from the impact of a potential missing confounder that may change its conclusions (Harring, McNeish, & Hancock, 2017). This package is a tool to evaluate the sensitivity of structural equation models to potential missing confounders using the Ant Colony Optimization (ACO; Colorni, Dorigo, & Maniezzo, 1992; Dorigo & Stützle, 2004; Socha & Dorigo, 2008) algorithm. The reference for the current package is: 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.

The current version includes three main functions and they are

- *gen.sens.pars* function: This function generates a set of required sensitivity parameters according to the rank of object function, with which the method has been developed by Socha & Dorigo (2008).

- *sa.aco* function: This function automatically performs the search for an omitted confounder in structural equation modeling using the ACO algorithm

- *sens.table* function: This function provides five summary tables of results produced in the *sa.aco* function.

Next, we use an example to illustrate how to perform sensitivity analysis in structural equation modeling.

1. Function *sa.aco*

Given a data set (or variance covariance matrix) and an analytic model, this function searches an omitted confounder to optimize the objective function. *sa.aco* function calls *gen.sens.pars* function to perform the algorithm together.

We need the following information/arguments to perform the search

- data: The data set used for an analysis. If there is no data available, use covariance matrix instead.
- sample.cov: Covariance matrix.
- sample.nobs: Number of observations for covariance matrix.
- model: The analytic model of interest.
- sens.model: Sensitivity analysis model template for structural equation modeling with a phantom variable. This is the model of interest with a phantom variable and sensitivity parameters added. See the example provided.
- opt.fun: Customized or preset object function for optimization.
- ......

To see more arguments, please run ?sa.aco in R or RStudio.

An exmaple

The example is from: Kim, Y. S. G., & Schatschneider, C. (2017). Expanding the developmental models of writing: A direct and indirect effects model of developmental writing (DIEW). Journal of Educational psychology, 109(1), 35-50.

```r
# Load lavaan and SEMsens packages
require(lavaan)
require(SEMsens)

# STEP 1: Prepare data:
# Lower diagonal correlation matrix in the study by Kim & Schatschneider (2017)
lower = '
1.00
.40 1.00
.40 .64 1.00
.41 .66 .61 1.00
.42 .52 .53 .61 1.00
.34 .50 .46 .53 .48 1.00
.42 .47 .41 .43 .47 .55 1.00
.39 .46 .39 .30 .21 .30 .37 1.00
.24 .31 .30 .31 .26 .32 .27 .56 1.00
.33 .35 .35 .40 .31 .25 .35 .51 .42 1.00
.30 .42 .36 .32 .24 .37 .43 .44 .37 .49 1.00'

# Convert to full covariance matrix
sample.cov = getCov(lower, sds = c(5.64,14.68,6.57,6.07,3.39,10.16,6.11,4.91,15.59,0.96,0.99),
              names = c("Working_memory",
                        "Vocabulary",
                        "Grammar",
                        "Inference",
                        "ToM",
                        "TNL",
                        "Expository",
                        "Spelling",
                        "Sentence_copying",
                        "One_day",
                        "Castle"))

# STEP 2: Set up analytic model and sensitivity anaysis model
  # The original analytic model
model <-'Vocabulary~Working_memory
  Grammar~Working_memory
  Inference~Vocabulary+Grammar+Working_memory
  ToM~Vocabulary+Grammar+Working_memory
  Spelling~Working_memory
  Sentence_copying~Working_memory
  Discourse~Inference+ToM+Vocabulary+Grammar+Working_memory
  Writing~Spelling+Sentence_copying+Discourse

  Discourse=~TNL+Expository
  Writing=~One_day+Castle

  Vocabulary~~Grammar
  Grammar~~Sentence_copying
  Vocabulary~~Sentence_copying
  Grammar~~Spelling
  Vocabulary~~Spelling
  Inference~~ToM
  Discourse~~Sentence_copying
```

```
    Discourse~~Spelling
    Spelling~~Sentence_copying'

    # A sensitivity analysis model template, which additionally includes paths
    #  from a phantom variable to a set of variables (= number of sensitivity parameters)
    #   in the analytic model.
sens.model <- 'Vocabulary~Working_memory
    Grammar~Working_memory
    Inference~Vocabulary+Grammar+Working_memory
    ToM~Vocabulary+Grammar+Working_memory
    Spelling~Working_memory
    Sentence_copying~Working_memory
    Discourse~Inference+ToM+Vocabulary+Grammar+Working_memory
    Writing~Spelling+Sentence_copying+Discourse

    Discourse=~TNL+Expository
    Writing=~One_day+Castle

    Vocabulary~~Grammar
    Grammar~~Sentence_copying
    Vocabulary~~Sentence_copying
    Grammar~~Spelling
    Vocabulary~~Spelling
    Inference~~ToM
    Discourse~~Sentence_copying
    Discourse~~Spelling
    Spelling~~Sentence_copying

    Working_memory ~ phantom1*phantom
    Grammar ~ phantom2*phantom
    Vocabulary ~ phantom3*phantom
    ToM ~ phantom4*phantom
    Inference ~ phantom5*phantom
    Spelling ~ phantom6*phantom
    Sentence_copying  ~ phantom7*phantom
    Discourse ~ phantom8*phantom
    Writing ~ phantom9*phantom
    phantom =~ 0 # added for mean of zero
    phantom ~~ 1*phantom'

# STEP 3: Set up the paths of interest to be evaluated in sensitivity analysis.
    paths <- 'Vocabulary~Working_memory
    Grammar~Working_memory
    Inference~Vocabulary+Grammar+Working_memory
    ToM~Vocabulary+Grammar+Working_memory
    Spelling~Working_memory
    Sentence_copying~Working_memory
    Discourse~Inference+ToM+Vocabulary+Grammar+Working_memory
    Writing~Spelling+Sentence_copying+Discourse'

    # STEP 4: Perform sensitivity analysis.
my.sa <-sa.aco(model = model, sens.model = sens.model, sample.cov = sample.cov,
                sample.nobs = 193, k = 50, max.value= 2000, max.iter = 100,
```

```
              opt.fun = 4, ## from significant to just significant
              paths = paths, seed = 1, verbose = FALSE)
# We set up a max iteration of 100 and solution archive length of 50 for
# illustration purpose. Please specify a larger number of iteration (e.g., 1000),
#  and a larger k (e.g., 100).
```

2. Function *sens.tables*

sens.tables function can help summarize the sensitivity analysis results. Beyond this function, investigators always can summarize the results by accessing to the results in *sa.aco* function.

```
my.table <- sens.tables(my.sa)
# Table 1: Summary of the sensitivity analysis for each path
my.table[[1]]
```

```
##                                model.est model.pvalue mean.est.sens
## Discourse~Grammar              0.1003703 2.545458e-01     0.1052304
## Inference~Working_memory       0.1245455 2.600317e-02     0.1232723
## Writing~Sentence_copying       0.1719948 7.373380e-01     0.1633071
## Discourse~Working_memory       0.1888038 8.008110e-03     0.1910799
## Discourse~Inference            0.1943264 3.648517e-02     0.1920310
## ToM~Working_memory             0.2036364 1.138824e-03     0.2030261
## Sentence_copying~Working_memory 0.2399999 3.306181e-04    0.2401460
## ToM~Vocabulary                 0.2565656 1.434170e-02     0.2540932
## Discourse~ToM                  0.2610613 1.478182e-03     0.2545997
## Discourse~Vocabulary           0.2589070 4.397424e-03     0.2615377
## ToM~Grammar                    0.2843434 1.360850e-04     0.2878169
## Inference~Grammar              0.2873737 1.359032e-05     0.2894558
## Spelling~Working_memory        0.3899999 2.976219e-11     0.3883753
## Writing~Spelling               0.3759830 5.069807e-02     0.3886019
## Grammar~Working_memory         0.3999999 5.308198e-12     0.3979180
## Vocabulary~Working_memory      0.3999999 5.308198e-12     0.3996722
## Inference~Vocabulary           0.4262626 3.953415e-10     0.4261592
## Writing~Discourse              0.4504663 6.269999e-02     0.4355599
##                                min.est.sens max.est.sens
## Discourse~Grammar               0.04912704    0.1774544
## Inference~Working_memory        0.10477421    0.1485761
## Writing~Sentence_copying        0.05199882    0.2657367
## Discourse~Working_memory        0.14529692    0.2331204
## Discourse~Inference             0.15029004    0.2484007
## ToM~Working_memory              0.17420102    0.2505132
## Sentence_copying~Working_memory 0.23129571    0.2588857
## ToM~Vocabulary                  0.22454770    0.3059992
## Discourse~ToM                   0.15889535    0.3087243
## Discourse~Vocabulary            0.23408924    0.3120485
## ToM~Grammar                     0.21758721    0.3477721
## Inference~Grammar               0.23936198    0.3261455
## Spelling~Working_memory         0.36602307    0.4141131
## Writing~Spelling                0.19253896    0.6603765
## Grammar~Working_memory          0.36081953    0.4178667
## Vocabulary~Working_memory       0.38836436    0.4096268
## Inference~Vocabulary            0.40745780    0.4641450
## Writing~Discourse               0.16872738    0.5776849
```

```
# Table 2:  Summary of the sensitivity parameters
my.table[[2]]
```

```
##                            mean.phan    min.phan    max.phan
## Grammar~phantom          -0.0255901298 -0.19855864 0.14923981
## Working_memory~phantom   -0.0116100689 -0.21192127 0.16501694
## Inference~phantom        -0.0059654784 -0.15852757 0.19673890
## Vocabulary~phantom        0.0009162615 -0.07989683 0.06497973
## Sentence_copying~phantom  0.0040785197 -0.05962908 0.11357489
## Discourse~phantom         0.0302226186 -0.12647184 0.24583688
## Spelling~phantom          0.0366678782 -0.19658642 0.24672188
## ToM~phantom               0.0561965145 -0.23155307 0.49606813
## Writing~phantom           0.1132356278 -0.52889818 0.61827105
```

```
# Table 3: The sensitivity parameters lead to the minimum coefficient for each
my.table[[3]]
```

```
##                              Working_memory~phantom Grammar~phantom
## Vocabulary~Working_memory              -0.211921268     -0.18415235
## Grammar~Working_memory                 -0.211921268     -0.18415235
## Inference~Vocabulary                    0.002184957     -0.19855864
## Inference~Grammar                      -0.110365605     -0.15220596
## Inference~Working_memory               -0.167003237     -0.04988583
## ToM~Vocabulary                         -0.030085236     -0.12832087
## ToM~Grammar                            -0.110365605     -0.15220596
## ToM~Working_memory                     -0.167003237     -0.04988583
## Spelling~Working_memory                 0.152931730     -0.01137375
## Sentence_copying~Working_memory        -0.155173551      0.08682558
## Discourse~Inference                     0.044223231     -0.06027779
## Discourse~ToM                          -0.034499544     -0.13024128
## Discourse~Vocabulary                    0.051240582     -0.06690173
## Discourse~Grammar                      -0.120907356      0.14923981
## Discourse~Working_memory                0.165016936     -0.01754155
## Writing~Spelling                        0.048004382     -0.02181512
## Writing~Sentence_copying                0.072626707      0.11784237
## Writing~Discourse                       0.072626707      0.11784237
##                              Vocabulary~phantom ToM~phantom
## Vocabulary~Working_memory          -0.054220461  0.22938668
## Grammar~Working_memory             -0.054220461  0.22938668
## Inference~Vocabulary               -0.030296701  0.20987620
## Inference~Grammar                   0.051535666 -0.21725287
## Inference~Working_memory           -0.030364651 -0.22577041
## ToM~Vocabulary                      0.003831129  0.27028636
## ToM~Grammar                         0.051535666 -0.21725287
## ToM~Working_memory                 -0.030364651 -0.22577041
## Spelling~Working_memory             0.049251697 -0.11155276
## Sentence_copying~Working_memory    -0.011157983  0.28069048
## Discourse~Inference                -0.035560127 -0.08384902
## Discourse~ToM                      -0.079896827  0.49606813
## Discourse~Vocabulary                0.062516527 -0.20132409
## Discourse~Grammar                  -0.013843073 -0.18486429
## Discourse~Working_memory           -0.017716484 -0.19524466
## Writing~Spelling                   -0.064244453  0.14765876
## Writing~Sentence_copying           -0.023845171  0.27678824
## Writing~Discourse                  -0.023845171  0.27678824
```

```
##                                   Inference~phantom Spelling~phantom
## Vocabulary~Working_memory               0.11169709       0.11546808
## Grammar~Working_memory                  0.11169709       0.11546808
## Inference~Vocabulary                    0.12562746       0.15355763
## Inference~Grammar                      -0.15852757       0.18009840
## Inference~Working_memory               -0.15021823      -0.05282820
## ToM~Vocabulary                          0.06902098       0.02181626
## ToM~Grammar                            -0.15852757       0.18009840
## ToM~Working_memory                     -0.15021823      -0.05282820
## Spelling~Working_memory                -0.09672352       0.17233148
## Sentence_copying~Working_memory        -0.07186973       0.14099539
## Discourse~Inference                     0.12930466       0.19994834
## Discourse~ToM                           0.14159692       0.24672188
## Discourse~Vocabulary                   -0.02696729      -0.10090585
## Discourse~Grammar                      -0.00735754       0.01807200
## Discourse~Working_memory               -0.14682888       0.06457722
## Writing~Spelling                       -0.09555416       0.20318504
## Writing~Sentence_copying                0.16155105      -0.18908332
## Writing~Discourse                       0.16155105      -0.18908332
##                                   Sentence_copying~phantom Discourse~phantom
## Vocabulary~Working_memory                       0.08826528        0.24583688
## Grammar~Working_memory                          0.08826528        0.24583688
## Inference~Vocabulary                            0.05705421        0.10077127
## Inference~Grammar                              -0.02665071       -0.08985596
## Inference~Working_memory                       -0.02098849       -0.08802815
## ToM~Vocabulary                                 -0.03303541        0.07442881
## ToM~Grammar                                    -0.02665071       -0.08985596
## ToM~Working_memory                             -0.02098849       -0.08802815
## Spelling~Working_memory                        -0.05756797       -0.02387311
## Sentence_copying~Working_memory                -0.05369555        0.10337791
## Discourse~Inference                             0.02990099        0.13270063
## Discourse~ToM                                   0.11357489        0.17226044
## Discourse~Vocabulary                           -0.05219069        0.08786791
## Discourse~Grammar                              -0.02210510        0.13456352
## Discourse~Working_memory                        0.01005041        0.13126727
## Writing~Spelling                                0.05236181        0.05720109
## Writing~Sentence_copying                        0.05069574        0.08586779
## Writing~Discourse                               0.05069574        0.08586779
##                                   Writing~phantom
## Vocabulary~Working_memory             -0.12163204
## Grammar~Working_memory                -0.12163204
## Inference~Vocabulary                   0.08132341
## Inference~Grammar                     -0.28691915
## Inference~Working_memory               0.36057655
## ToM~Vocabulary                         0.41217884
## ToM~Grammar                           -0.28691915
## ToM~Working_memory                     0.36057655
## Spelling~Working_memory               -0.12680418
## Sentence_copying~Working_memory       -0.08211608
## Discourse~Inference                    0.11588441
## Discourse~ToM                          0.21492898
## Discourse~Vocabulary                   0.07410964
## Discourse~Grammar                      0.08140368
## Discourse~Working_memory               0.30589957
```

```
## Writing~Spelling                        0.61827105
## Writing~Sentence_copying                0.60389707
## Writing~Discourse                       0.60389707
```
```
# Table 4: The sensitivity parameters lead to the maximum coefficient for each path
my.table[[4]]
```
```
##                                Working_memory~phantom Grammar~phantom
## Vocabulary~Working_memory             -0.176061341       0.03160994
## Grammar~Working_memory                -0.120907356       0.14923981
## Inference~Vocabulary                  -0.110365605      -0.15220596
## Inference~Grammar                      0.002184957      -0.19855864
## Inference~Working_memory               0.165016936      -0.01754155
## ToM~Vocabulary                        -0.110365605      -0.15220596
## ToM~Grammar                            0.002184957      -0.19855864
## ToM~Working_memory                    -0.155173551       0.08682558
## Spelling~Working_memory               -0.176061341       0.03160994
## Sentence_copying~Working_memory       -0.211921268      -0.18415235
## Discourse~Inference                   -0.014368362      -0.02012266
## Discourse~ToM                         -0.120907356       0.14923981
## Discourse~Vocabulary                  -0.110365605      -0.15220596
## Discourse~Grammar                     -0.211921268      -0.18415235
## Discourse~Working_memory              -0.211921268      -0.18415235
## Writing~Spelling                       0.072626707       0.11784237
## Writing~Sentence_copying              -0.138008251      -0.05072568
## Writing~Discourse                     -0.167003237      -0.04988583
##                                Vocabulary~phantom ToM~phantom
## Vocabulary~Working_memory             0.055384298    0.1217345
## Grammar~Working_memory               -0.013843073   -0.1848643
## Inference~Vocabulary                  0.051535666   -0.2172529
## Inference~Grammar                    -0.030296701    0.2098762
## Inference~Working_memory             -0.017716484   -0.1952447
## ToM~Vocabulary                        0.051535666   -0.2172529
## ToM~Grammar                          -0.030296701    0.2098762
## ToM~Working_memory                   -0.011157983    0.2806905
## Spelling~Working_memory               0.055384298    0.1217345
## Sentence_copying~Working_memory      -0.054220461    0.2293867
## Discourse~Inference                   0.002323414    0.2029898
## Discourse~ToM                        -0.013843073   -0.1848643
## Discourse~Vocabulary                  0.051535666   -0.2172529
## Discourse~Grammar                    -0.054220461    0.2293867
## Discourse~Working_memory             -0.054220461    0.2293867
## Writing~Spelling                     -0.023845171    0.2767882
## Writing~Sentence_copying              0.046036288   -0.1319380
## Writing~Discourse                    -0.030364651   -0.2257704
##                                Inference~phantom Spelling~phantom
## Vocabulary~Working_memory            -0.07860246       0.14301228
## Grammar~Working_memory               -0.00735754       0.01807200
## Inference~Vocabulary                 -0.15852757       0.18009840
## Inference~Grammar                     0.12562746       0.15355763
## Inference~Working_memory             -0.14682888       0.06457722
## ToM~Vocabulary                       -0.15852757       0.18009840
## ToM~Grammar                           0.12562746       0.15355763
## ToM~Working_memory                   -0.07186973       0.14099539
## Spelling~Working_memory              -0.07860246       0.14301228
```

```
## Sentence_copying~Working_memory        0.11169709          0.11546808
## Discourse~Inference                    -0.14558684          0.02211563
## Discourse~ToM                          -0.00735754          0.01807200
## Discourse~Vocabulary                   -0.15852757          0.18009840
## Discourse~Grammar                       0.11169709          0.11546808
## Discourse~Working_memory                0.11169709          0.11546808
## Writing~Spelling                        0.16155105         -0.18908332
## Writing~Sentence_copying                0.02871137          0.13761525
## Writing~Discourse                      -0.15021823         -0.05282820
##                              Sentence_copying~phantom Discourse~phantom
## Vocabulary~Working_memory                 -0.02140238        0.02093407
## Grammar~Working_memory                    -0.02210510        0.13456352
## Inference~Vocabulary                      -0.02665071       -0.08985596
## Inference~Grammar                          0.05705421        0.10077127
## Inference~Working_memory                   0.01005041        0.13126727
## ToM~Vocabulary                            -0.02665071       -0.08985596
## ToM~Grammar                                0.05705421        0.10077127
## ToM~Working_memory                        -0.05369555        0.10337791
## Spelling~Working_memory                   -0.02140238        0.02093407
## Sentence_copying~Working_memory            0.08826528        0.24583688
## Discourse~Inference                        0.02421053        0.04225371
## Discourse~ToM                             -0.02210510        0.13456352
## Discourse~Vocabulary                      -0.02665071       -0.08985596
## Discourse~Grammar                          0.08826528        0.24583688
## Discourse~Working_memory                   0.08826528        0.24583688
## Writing~Spelling                           0.05069574        0.08586779
## Writing~Sentence_copying                  -0.05513577        0.05556959
## Writing~Discourse                         -0.02098849       -0.08802815
##                              Writing~phantom
## Vocabulary~Working_memory         -0.19619587
## Grammar~Working_memory             0.08140368
## Inference~Vocabulary              -0.28691915
## Inference~Grammar                  0.08132341
## Inference~Working_memory           0.30589957
## ToM~Vocabulary                    -0.28691915
## ToM~Grammar                        0.08132341
## ToM~Working_memory                -0.08211608
## Spelling~Working_memory           -0.19619587
## Sentence_copying~Working_memory   -0.12163204
## Discourse~Inference                0.44354405
## Discourse~ToM                      0.08140368
## Discourse~Vocabulary              -0.28691915
## Discourse~Grammar                 -0.12163204
## Discourse~Working_memory          -0.12163204
## Writing~Spelling                   0.60389707
## Writing~Sentence_copying           0.57441944
## Writing~Discourse                  0.36057655
```

```
# Table 5: The sensitivity parameters lead to change in significance for each path
my.table[[5]]
```

```
##                      p.value  p.changed Working_memory~phantom
## Discourse~Grammar  2.545458e-01 0.04368873            -0.21192127
## Writing~Discourse  6.269999e-02 0.04818198            -0.08322882
## Writing~Spelling   5.069807e-02 0.04821511            -0.15517355
```

```
## Discourse~Inference              3.648517e-02 0.05029828              0.13247035
## Inference~Working_memory         2.600317e-02 0.05155547             -0.17606134
## Vocabulary~Working_memory        5.308198e-12         NA                      NA
## Grammar~Working_memory           5.308198e-12         NA                      NA
## Inference~Vocabulary             3.953415e-10         NA                      NA
## Inference~Grammar                1.359032e-05         NA                      NA
## ToM~Vocabulary                   1.434170e-02         NA                      NA
## ToM~Grammar                      1.360850e-04         NA                      NA
## ToM~Working_memory               1.138824e-03         NA                      NA
## Spelling~Working_memory          2.976219e-11         NA                      NA
## Sentence_copying~Working_memory  3.306181e-04         NA                      NA
## Discourse~ToM                    1.478182e-03         NA                      NA
## Discourse~Vocabulary             4.397424e-03         NA                      NA
## Discourse~Working_memory         8.008110e-03         NA                      NA
## Writing~Sentence_copying         7.373380e-01         NA                      NA
##                                 Grammar~phantom Vocabulary~phantom ToM~phantom
## Discourse~Grammar                   -0.18415235       -0.054220461   0.2293867
## Writing~Discourse                   -0.03898185        0.009949832   0.2378987
## Writing~Spelling                     0.08682558       -0.011157983   0.2806905
## Discourse~Inference                  0.13901839        0.000755389   0.2517705
## Inference~Working_memory             0.03160994        0.055384298   0.1217345
## Vocabulary~Working_memory                    NA                 NA          NA
## Grammar~Working_memory                       NA                 NA          NA
## Inference~Vocabulary                         NA                 NA          NA
## Inference~Grammar                            NA                 NA          NA
## ToM~Vocabulary                               NA                 NA          NA
## ToM~Grammar                                  NA                 NA          NA
## ToM~Working_memory                           NA                 NA          NA
## Spelling~Working_memory                      NA                 NA          NA
## Sentence_copying~Working_memory              NA                 NA          NA
## Discourse~ToM                                NA                 NA          NA
## Discourse~Vocabulary                         NA                 NA          NA
## Discourse~Working_memory                     NA                 NA          NA
## Writing~Sentence_copying                     NA                 NA          NA
##                                 Inference~phantom Spelling~phantom
## Discourse~Grammar                      0.11169709        0.1154681
## Writing~Discourse                     -0.09825143        0.1615811
## Writing~Spelling                      -0.07186973        0.1409954
## Discourse~Inference                   -0.12051453       -0.1067430
## Inference~Working_memory              -0.07860246        0.1430123
## Vocabulary~Working_memory                     NA               NA
## Grammar~Working_memory                        NA               NA
## Inference~Vocabulary                          NA               NA
## Inference~Grammar                             NA               NA
## ToM~Vocabulary                                NA               NA
## ToM~Grammar                                   NA               NA
## ToM~Working_memory                            NA               NA
## Spelling~Working_memory                       NA               NA
## Sentence_copying~Working_memory               NA               NA
## Discourse~ToM                                 NA               NA
## Discourse~Vocabulary                          NA               NA
## Discourse~Working_memory                      NA               NA
## Writing~Sentence_copying                      NA               NA
##                                 Sentence_copying~phantom Discourse~phantom
```

```
## Discourse~Grammar                       0.088265280       0.245836878
## Writing~Discourse                        0.057165866       0.043155142
## Writing~Spelling                        -0.053695547       0.103377908
## Discourse~Inference                     -0.001290908      -0.007021009
## Inference~Working_memory                -0.021402377       0.020934066
## Vocabulary~Working_memory                        NA                NA
## Grammar~Working_memory                            NA                NA
## Inference~Vocabulary                              NA                NA
## Inference~Grammar                                 NA                NA
## ToM~Vocabulary                                    NA                NA
## ToM~Grammar                                       NA                NA
## ToM~Working_memory                                NA                NA
## Spelling~Working_memory                           NA                NA
## Sentence_copying~Working_memory                   NA                NA
## Discourse~ToM                                     NA                NA
## Discourse~Vocabulary                              NA                NA
## Discourse~Working_memory                          NA                NA
## Writing~Sentence_copying                          NA                NA
##                                  Writing~phantom
## Discourse~Grammar                     -0.12163204
## Writing~Discourse                      0.35336901
## Writing~Spelling                      -0.08211608
## Discourse~Inference                   -0.18978921
## Inference~Working_memory              -0.19619587
## Vocabulary~Working_memory                      NA
## Grammar~Working_memory                         NA
## Inference~Vocabulary                           NA
## Inference~Grammar                              NA
## ToM~Vocabulary                                 NA
## ToM~Grammar                                    NA
## ToM~Working_memory                             NA
## Spelling~Working_memory                        NA
## Sentence_copying~Working_memory                NA
## Discourse~ToM                                  NA
## Discourse~Vocabulary                           NA
## Discourse~Working_memory                       NA
## Writing~Sentence_copying                       NA
```