

# Package ‘SEMsens’

Walter Leite (University of Florida) & Zuchao Shen (University of Florida)

2022-04-29

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.

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

# 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	2.544519e-01	0.1052304
## Inference~Working_memory	0.1245455	2.598216e-02	0.1232723
## Writing~Sentence_copying	0.1719948	4.222710e-02	0.1633071
## Discourse~Working_memory	0.1888038	7.941219e-03	0.1910799
## Discourse~Inference	0.1943264	3.608645e-02	0.1920310
## ToM~Working_memory	0.2036364	1.096483e-03	0.2030261
## Sentence_copying~Working_memory	0.2399999	3.306180e-04	0.2401460
## ToM~Vocabulary	0.2565656	6.016058e-04	0.2540932
## Discourse~ToM	0.2610613	1.360093e-03	0.2545997
## Discourse~Vocabulary	0.2589070	4.345386e-03	0.2615377
## ToM~Grammar	0.2843434	1.345400e-04	0.2878169
## Inference~Grammar	0.2873737	1.336915e-05	0.2894558
## Spelling~Working_memory	0.3899999	2.976197e-11	0.3883753
## Writing~Spelling	0.3759830	3.442786e-05	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	3.005818e-11	0.4261592
## Writing~Discourse	0.4504663	3.396553e-07	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	2.544519e-01	0.04361667	-0.21192127
## Writing~Sentence_copying	4.222710e-02	0.05085436	-0.08329305
## Discourse~Inference	3.608645e-02	0.05138185	-0.05379439
## Inference~Working_memory	2.598216e-02	0.05154444	-0.17606134
## Writing~Discourse	3.396553e-07	0.06126915	0.07262671
## Vocabulary~Working_memory	5.308198e-12	NA	NA
## Grammar~Working_memory	5.308198e-12	NA	NA
## Inference~Vocabulary	3.005818e-11	NA	NA
## Inference~Grammar	1.336915e-05	NA	NA
## ToM~Vocabulary	6.016058e-04	NA	NA
## ToM~Grammar	1.345400e-04	NA	NA
## ToM~Working_memory	1.096483e-03	NA	NA
## Spelling~Working_memory	2.976197e-11	NA	NA
## Sentence_copying~Working_memory	3.306180e-04	NA	NA
## Discourse~ToM	1.360093e-03	NA	NA
## Discourse~Vocabulary	4.345386e-03	NA	NA
## Discourse~Working_memory	7.941219e-03	NA	NA
## Writing~Spelling	3.442786e-05	NA	NA
##	Grammar~phantom	Vocabulary~phantom	ToM~phantom
## Discourse~Grammar	-0.184152355	-0.05422046	0.22938668
## Writing~Sentence_copying	0.009402667	0.02524991	-0.06890207
## Discourse~Inference	-0.113046928	-0.01528202	0.25107119
## Inference~Working_memory	0.031609938	0.05538430	0.12173446
## Writing~Discourse	0.117842375	-0.02384517	0.27678824
## 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~Spelling	NA	NA	NA
##	Inference~phantom	Spelling~phantom	
## Discourse~Grammar	0.11169709	0.1154681	
## Writing~Sentence_copying	0.15064797	-0.1555506	
## Discourse~Inference	0.10060722	0.1050860	
## Inference~Working_memory	-0.07860246	0.1430123	
## Writing~Discourse	0.16155105	-0.1890833	
## 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~Spelling	NA	NA
##	Sentence_copying~phantom	Discourse~phantom
## Discourse~Grammar	0.08826528	0.245836878
## Writing~Sentence_copying	-0.05921337	0.001210933
## Discourse~Inference	0.05885676	0.132617696
## Inference~Working_memory	-0.02140238	0.020934066
## Writing~Discourse	0.05069574	0.085867787
## 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~Spelling	NA	NA
##	Writing~phantom	
## Discourse~Grammar	-0.1216320	
## Writing~Sentence_copying	0.2289633	
## Discourse~Inference	0.2951056	
## Inference~Working_memory	-0.1961959	
## Writing~Discourse	0.6038971	
## 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~Spelling	NA	