Synthesizing Indirect Effects in Mediation Models with Meta-Analytic Methods: Supplementary Materials 2

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June 01, 2021

Contents

Data preparation

```
library(metaSEM)

## Get the data from the local file
source("Hagger18.R")

## Check whether the correlation matrices are positive definite
```

```r
which(is.pd(Hagger18$data)==FALSE)
```

```
## 21
## 21
```

```r
## Drop the 21th study as the correlation matrix is not positive definite.
Hagger18 <- lapply(Hagger18, function(x) x[-21])
```

Illustration 1 with one mediator

```r
## Use df1 as the data file in illustration 1
df1 <- Hagger18

## Select Beh, Int, and PB for the illustration
obs.vars1 <- c("Beh", "Int", "PB")
df1$data <- lapply(df1$data, function(x) x[obs.vars1, obs.vars1])

## NA is not allowed in computing the indirect and direct effects.
## Studies with NA are excluded first.
index1 <- sapply(df1$data, function(x) any(is.na(vechs(x))) )
df1 <- lapply(df1, function(x) x[!index1])

## Show the first few studies
head(df1)
```

```
## $data
## $data$`3`
##       Beh  Int    PB
## Beh 1.000 0.65 0.709
## Int 0.650 1.00 0.650
## PB  0.709 0.65 1.000
##
## $data$`19`
##      Beh  Int   PB
## Beh 1.00 0.84 0.87
## Int 0.84 1.00 0.94
## PB  0.87 0.94 1.00
##
## $data$`20`
##       Beh   Int    PB
## Beh 1.000 0.534 0.768
## Int 0.534 1.000 0.540
## PB  0.768 0.540 1.000
##
## $data$`22`
##      Beh  Int   PB
## Beh 1.00 0.55 0.54
## Int 0.55 1.00 0.32
## PB  0.54 0.32 1.00
##
## $data$`25`
##      Beh  Int   PB
## Beh 1.00 0.53 0.52
```

```
## Int 0.53 1.00 0.78
## PB  0.52 0.78 1.00
##
## $data$`26`
##      Beh  Int   PB
## Beh 1.00 0.53 0.54
## Int 0.53 1.00 0.54
## PB  0.54 0.54 1.00
##
## $data$`29`
##      Beh  Int   PB
## Beh 1.00 0.64 0.63
## Int 0.64 1.00 0.70
## PB  0.63 0.70 1.00
##
## $data$`30`
##       Beh   Int    PB
## Beh 1.000 0.589 0.651
## Int 0.589 1.000 0.539
## PB  0.651 0.539 1.000
##
## $data$`33`
##       Beh   Int    PB
## Beh 1.000 0.742 0.756
## Int 0.742 1.000 0.798
## PB  0.756 0.798 1.000
##
## $data$`34`
##       Beh   Int    PB
## Beh 1.000 0.732 0.780
## Int 0.732 1.000 0.752
## PB  0.780 0.752 1.000
##
## $data$`35`
##      Beh  Int   PB
## Beh 1.00 0.02 0.01
## Int 0.02 1.00 0.22
## PB  0.01 0.22 1.00
##
## $data$`36`
##      Beh Int   PB
## Beh 1.00 0.3 0.09
## Int 0.30 1.0 0.20
## PB  0.09 0.2 1.00
##
## $data$`37`
##       Beh   Int    PB
## Beh 1.000 0.451 0.746
## Int 0.451 1.000 0.477
## PB  0.746 0.477 1.000
##
## $data$`44`
##      Beh  Int   PB
## Beh 1.00 0.27 0.53
```

```
## Int 0.27 1.00 0.34
## PB  0.53 0.34 1.00
##
## $data$`48`
##       Beh   Int    PB
## Beh 1.000 0.378 0.545
## Int 0.378 1.000 0.485
## PB  0.545 0.485 1.000
##
## $data$`49`
##      Beh  Int   PB
## Beh 1.00 0.22 0.36
## Int 0.22 1.00 0.49
## PB  0.36 0.49 1.00
##
## $data$`51`
##      Beh  Int  PB
## Beh 1.00 0.59 0.6
## Int 0.59 1.00 0.7
## PB  0.60 0.70 1.0
##
## $data$`52`
##      Beh  Int   PB
## Beh 1.00 0.40 0.61
## Int 0.40 1.00 0.41
## PB  0.61 0.41 1.00
##
## $data$`53`
##      Beh  Int   PB
## Beh 1.00 0.42 0.42
## Int 0.42 1.00 0.63
## PB  0.42 0.63 1.00
##
## $data$`54`
##      Beh  Int   PB
## Beh 1.00 0.72 0.46
## Int 0.72 1.00 0.47
## PB  0.46 0.47 1.00
##
## $data$`61`
##      Beh  Int   PB
## Beh 1.00 0.42 0.47
## Int 0.42 1.00 0.34
## PB  0.47 0.34 1.00
##
## $data$`67`
##      Beh  Int   PB
## Beh 1.00 0.44 0.55
## Int 0.44 1.00 0.59
## PB  0.55 0.59 1.00
##
## $data$`73`
##      Beh  Int   PB
## Beh 1.00 0.11 0.05
```

```
## Int 0.11 1.00 0.49
## PB  0.05 0.49 1.00
##
## $data$`74`
##      Beh  Int   PB
## Beh 1.00 0.57 0.71
## Int 0.57 1.00 0.61
## PB  0.71 0.61 1.00
##
## $data$`76`
##       Beh   Int    PB
## Beh 1.000 0.149 0.199
## Int 0.149 1.000 0.224
## PB  0.199 0.224 1.000
##
## $data$`77`
##       Beh   Int    PB
## Beh 1.000 0.261 0.517
## Int 0.261 1.000 0.315
## PB  0.517 0.315 1.000
##
## $data$`78`
##      Beh  Int   PB
## Beh 1.00 0.61 0.37
## Int 0.61 1.00 0.59
## PB  0.37 0.59 1.00
##
## $data$`80`
##      Beh  Int   PB
## Beh 1.00 0.64 0.81
## Int 0.64 1.00 0.78
## PB  0.81 0.78 1.00
##
## $data$`81`
##      Beh  Int   PB
## Beh 1.00 0.52 0.45
## Int 0.52 1.00 0.64
## PB  0.45 0.64 1.00
##
##
## $n
##  [1]  413  118   41  146  192  413 1403  133  523  596  174  272   85  365  620
## [16]  743  109   79  273   95  236  153  103  225  139  146   54  225   62
##
## $beh_freq_high
##  [1] 1 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 0 1 1 1 1 1 1 1 1 1
```

```
## Show the no. of studies per correlation
pattern.na(df1$data, show.na = FALSE)
```

```
##     Beh Int PB
## Beh  29  29 29
## Int  29  29 29
## PB   29  29 29
```

```
## Show the total sample sizes per correlation
pattern.n(df1$data, df1$n)
```

```
##      Beh  Int   PB
## Beh 8136 8136 8136
## Int 8136 8136 8136
## PB  8136 8136 8136
```

Meta-analyzing the indirect and direct effects

Caculation of indirect and direct effects

```
## Calculate the indirect and direct effects and their sampling covariance matrices
## The variables are arranged as outcome, mediator, and predictor.
IE.df1 <- indirectEffect(df1$data, df1$n)

## Add behavior frequency to the data
IE.df1 <- data.frame(IE.df1, beh_freq_high=df1$beh_freq_high)

## Show the first few studies
head(IE.df1)
```

```
##       ind_eff   dir_eff      ind_var   ind_dir_cov     dir_var beh_freq_high
## 3  0.23971461 0.5585981 0.0012158465 -0.0010127721 0.001890922             1
## 19 0.20669102 0.7963369 0.0256034746 -0.0126145194 0.007139375             0
## 20 0.09709888 0.7230498 0.0054607198 -0.0033732871 0.007436056             1
## 22 0.14246754 0.4296310 0.0016172775 -0.0006532121 0.004438969             1
## 25 0.26640325 0.2926724 0.0064450809 -0.0065081243 0.010790892             1
## 26 0.19485689 0.3841558 0.0009136998 -0.0007736947 0.002370634             1
```

Meta-analysis of indirect and direct effects

```
## Random-effects model
IE0 <- meta(y=cbind(ind_eff, dir_eff),
            v=cbind(ind_var, ind_dir_cov, dir_var),
            data=IE.df1,
            model.name = "Random")
summary(IE0)
```

```
##
## Call:
## meta(y = cbind(ind_eff, dir_eff), v = cbind(ind_var, ind_dir_cov,
##     dir_var), data = IE.df1, model.name = "Random")
##
## 95% confidence intervals: z statistic approximation (robust=FALSE)
## Coefficients:
##              Estimate  Std.Error     lbound     ubound z value  Pr(>|z|)
## Intercept1  0.1453716  0.0203468  0.1054926  0.1852507  7.1447 9.019e-13 ***
## Intercept2  0.4275448  0.0409088  0.3473651  0.5077246 10.4512 < 2.2e-16 ***
## Tau2_1_1    0.0095735  0.0030380  0.0036191  0.0155278  3.1513 0.0016257 **
## Tau2_2_1    0.0027014  0.0046064 -0.0063269  0.0117297  0.5865 0.5575692
## Tau2_2_2    0.0432142  0.0128722  0.0179851  0.0684433  3.3572 0.0007875 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Q statistic on the homogeneity of effect sizes: 1031.864
## Degrees of freedom of the Q statistic: 56
## P value of the Q statistic: 0
##
## Heterogeneity indices (based on the estimated Tau2):
##                               Estimate
## Intercept1: I2 (Q statistic)   0.9044
## Intercept2: I2 (Q statistic)   0.9349
##
## Number of studies (or clusters): 29
## Number of observed statistics: 58
## Number of estimated parameters: 5
## Degrees of freedom: 53
## -2 log likelihood: -50.01425
## OpenMx status1: 0 ("0" or "1": The optimization is considered fine.
## Other values may indicate problems.)
```

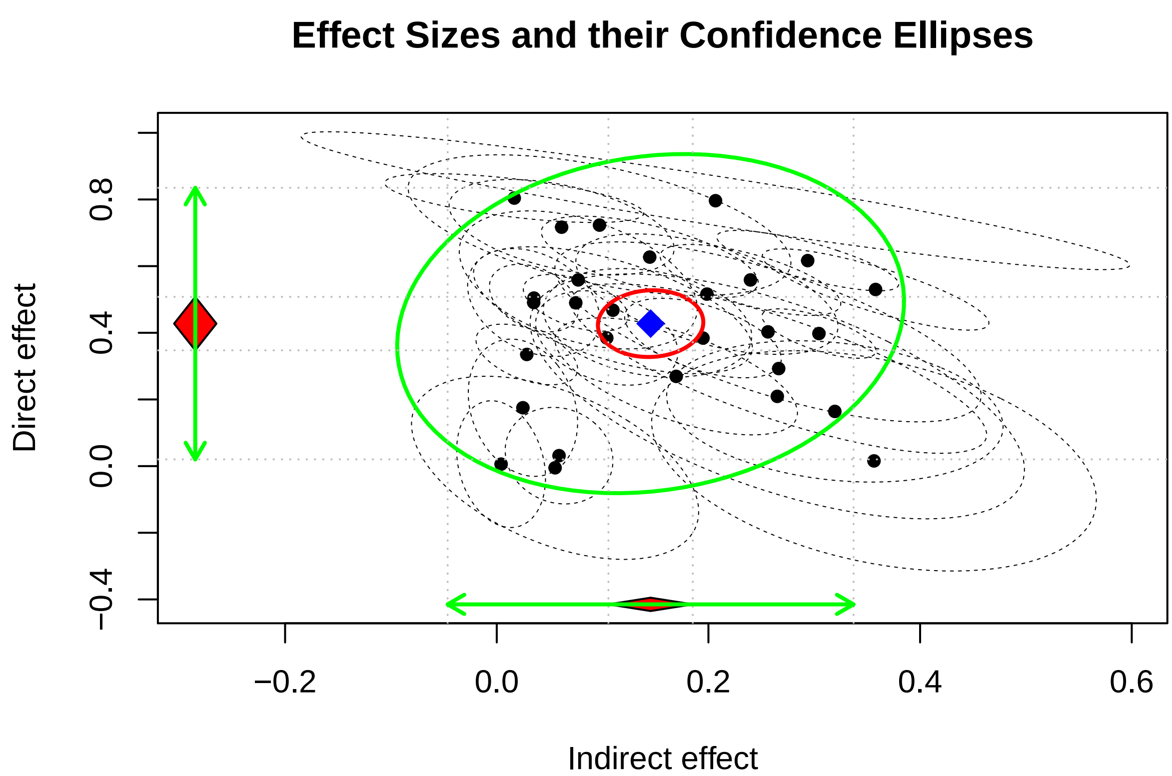
```
## Variance-covariance matrix of the random effects
VarCorr(IE0)
```

```
##             [,1]        [,2]
## [1,] 0.009573474 0.002701423
## [2,] 0.002701423 0.043214170
```

```
## Correlation matrix of the random effects
cov2cor(VarCorr(IE0))
```

```
##           [,1]      [,2]
## [1,] 1.0000000 0.1328143
## [2,] 0.1328143 1.0000000
```

```
## Plot the effect sizes
plot(IE0, axis.labels = c("Indirect effect", "Direct effect"))
```




```r
## Mixed-effects model with behavior frequency as a moderator
IE1 <- meta(y=cbind(ind_eff, dir_eff),
            v=cbind(ind_var, ind_dir_cov, dir_var),
            x=beh_freq_high,
            data=IE.df1,
            model.name = "Mixed")
summary(IE1)
```

```
##
## Call:
## meta(y = cbind(ind_eff, dir_eff), v = cbind(ind_var, ind_dir_cov,
##     dir_var), x = beh_freq_high, data = IE.df1, model.name = "Mixed")
##
## 95% confidence intervals: z statistic approximation (robust=FALSE)
## Coefficients:
##               Estimate  Std.Error     lbound     ubound z value  Pr(>|z|)
## Intercept1   0.1406059  0.0577021  0.0275118  0.2537000  2.4368 0.0148197 *
## Intercept2   0.4604307  0.1076665  0.2494083  0.6714532  4.2765 1.899e-05 ***
## Slope1_1     0.0053929  0.0614966 -0.1151382  0.1259240  0.0877 0.9301194
## Slope2_1    -0.0383525  0.1163142 -0.2663242  0.1896192 -0.3297 0.7416028
## Tau2_1_1     0.0095301  0.0030421  0.0035678  0.0154925  3.1328 0.0017315 **
## Tau2_2_1     0.0026812  0.0045911 -0.0063172  0.0116795  0.5840 0.5592234
## Tau2_2_2     0.0431205  0.0128488  0.0179373  0.0683038  3.3560 0.0007908 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Q statistic on the homogeneity of effect sizes: 1031.864
## Degrees of freedom of the Q statistic: 56
## P value of the Q statistic: 0
##
```

```
## Explained variances (R2):
##                                y1     y2
## Tau2 (no predictor)    0.0095735 0.0432
## Tau2 (with predictors) 0.0095301 0.0431
## R2                     0.0045263 0.0022
##
## Number of studies (or clusters): 29
## Number of observed statistics: 58
## Number of estimated parameters: 7
## Degrees of freedom: 51
## -2 log likelihood: -50.13325
## OpenMx status1: 0 ("0" or "1": The optimization is considered fine.
## Other values may indicate problems.)
```

```
## Test the statistical significance between the models
anova(IE1, IE0)
```

```
##    base comparison ep  minus2LL df       AIC    diffLL diffdf        p
## 1 Mixed       <NA>  7 -50.13325 51 -36.13325        NA     NA       NA
## 2 Mixed     Random  5 -50.01425 53 -40.01425 0.1189926      2 0.942239
```

TSSEM

Stage 1 analysis

```
## Random-effects model
random1 <- tssem1(df1$data, df1$n, method="REM")
summary(random1)
```

```
##
## Call:
## meta(y = ES, v = acovR, RE.constraints = Diag(paste0(RE.startvalues,
##     "*Tau2_", 1:no.es, "_", 1:no.es)), RE.lbound = RE.lbound,
##     I2 = I2, model.name = model.name, suppressWarnings = TRUE,
##     silent = silent, run = run)
##
## 95% confidence intervals: z statistic approximation (robust=FALSE)
## Coefficients:
##             Estimate Std.Error    lbound    ubound z value  Pr(>|z|)
## Intercept1 0.4766330 0.0354367 0.4071784 0.5460876 13.4503 < 2.2e-16 ***
## Intercept2 0.5264034 0.0392050 0.4495630 0.6032437 13.4270 < 2.2e-16 ***
## Intercept3 0.5371427 0.0338542 0.4707897 0.6034956 15.8664 < 2.2e-16 ***
## Tau2_1_1   0.0327619 0.0094370 0.0142658 0.0512580  3.4717 0.0005173 ***
## Tau2_2_2   0.0414127 0.0116982 0.0184846 0.0643407  3.5401 0.0004000 ***
## Tau2_3_3   0.0302936 0.0085934 0.0134508 0.0471364  3.5252 0.0004231 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Q statistic on the homogeneity of effect sizes: 1199.938
## Degrees of freedom of the Q statistic: 84
## P value of the Q statistic: 0
##
## Heterogeneity indices (based on the estimated Tau2):
##                               Estimate
## Intercept1: I2 (Q statistic)   0.9403
```

```
## Intercept2: I2 (Q statistic)   0.9590
## Intercept3: I2 (Q statistic)   0.9480
##
## Number of studies (or clusters): 29
## Number of observed statistics: 87
## Number of estimated parameters: 6
## Degrees of freedom: 81
## -2 log likelihood: -35.1454
## OpenMx status1: 0 ("0" or "1": The optimization is considered fine.
## Other values may indicate problems.)
```

```
## Average correlation matrix under a random-effects model
averageR <- vec2symMat(coef(random1, select="fixed"), diag = FALSE)
dimnames(averageR) <- list(obs.vars1, obs.vars1)
averageR
```

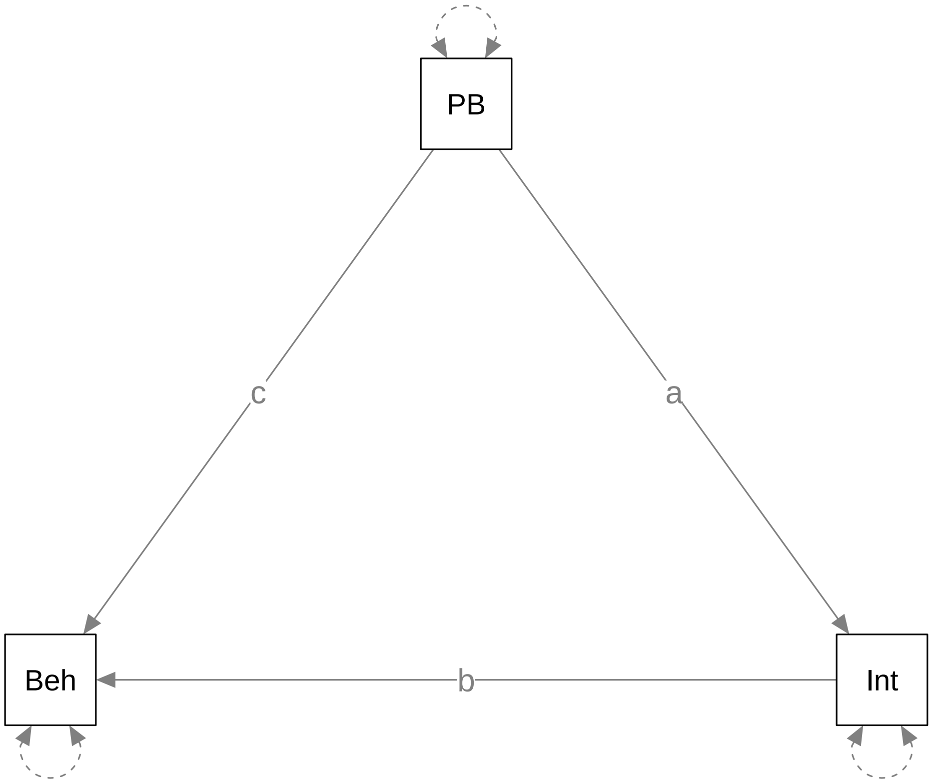
```
##           Beh       Int        PB
## Beh 1.0000000 0.4766330 0.5264034
## Int 0.4766330 1.0000000 0.5371427
## PB  0.5264034 0.5371427 1.0000000
```

```
## Heterogeneity variances of the random-effects
coef(random1, select="random")
```

```
##   Tau2_1_1   Tau2_2_2   Tau2_3_3
## 0.03276187 0.04141266 0.03029364
```

Stage 2 analysis

```
## Proposed model in lavaan syntax
model1 <- "Beh ~ c*PB + b*Int
           Int ~ a*PB
           PB ~~ 1*PB"
plot(model1)
```




```r
## Convert the lavaan syntax to RAM specification used in metaSEM
RAM1 <- lavaan2RAM(model1, obs.variables=obs.vars1)
RAM1
```

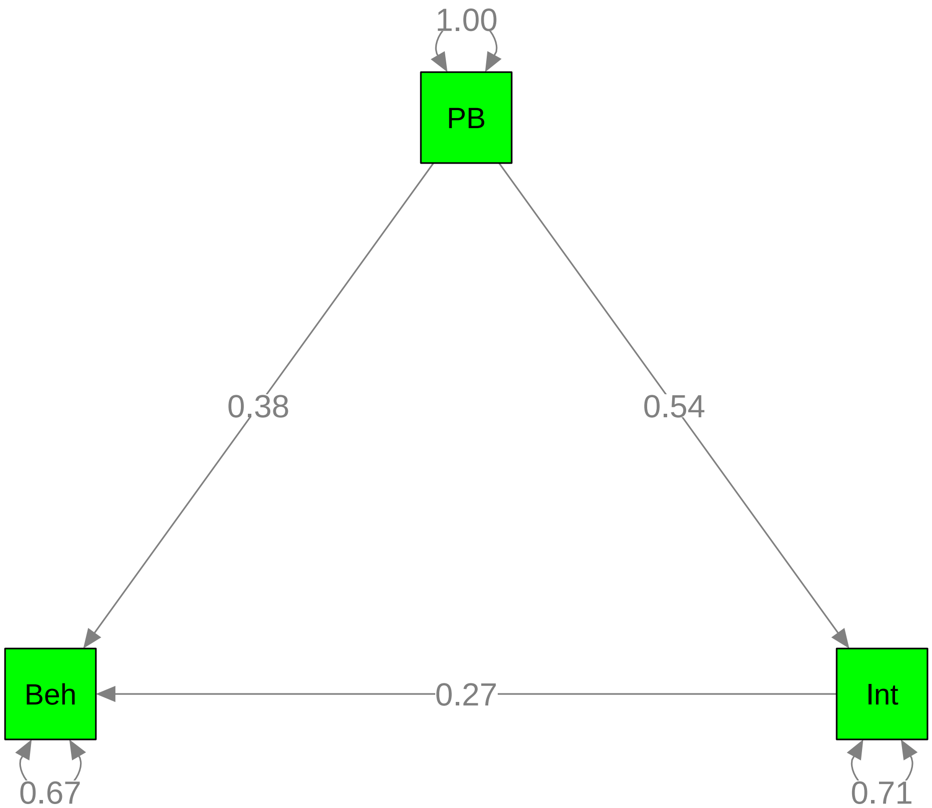
```
## $A
##     Beh Int   PB
## Beh "0" "0*b" "0*c"
## Int "0" "0"   "0*a"
## PB  "0" "0"   "0"
##
## $S
##     Beh             Int            PB
## Beh "0*BehWITHBeh" "0"             "0"
## Int "0"             "0*IntWITHInt" "0"
## PB  "0"             "0"            "1"
##
## $F
##     Beh Int PB
## Beh   1   0  0
## Int   0   1  0
## PB    0   0  1
##
## $M
##   Beh Int PB
## 1   0   0  0
```

```r
## Request the likelihood-based confidence interval
## Indirect effect: ind = a*b
## Direct effect: dir = c
tssem.fit <- tssem2(random1, RAM=RAM1, intervals.type = "LB",
```

```r
                    mx.algebras = list(ind=mxAlgebra(a*b, name="ind"),
                                       dir=mxAlgebra(c, name="dir")))
summary(tssem.fit)
```

```
##
## Call:
## wls(Cov = pooledS, aCov = aCov, n = tssem1.obj$total.n, RAM = RAM,
##     Amatrix = Amatrix, Smatrix = Smatrix, Fmatrix = Fmatrix,
##     diag.constraints = diag.constraints, cor.analysis = cor.analysis,
##     intervals.type = intervals.type, mx.algebras = mx.algebras,
##     model.name = model.name, suppressWarnings = suppressWarnings,
##     silent = silent, run = run)
##
## 95% confidence intervals: Likelihood-based statistic
## Coefficients:
##   Estimate Std.Error  lbound  ubound z value Pr(>|z|)
## b  0.27250        NA 0.15558 0.38445      NA       NA
## c  0.38003        NA 0.25953 0.49870      NA       NA
## a  0.53714        NA 0.47062 0.60350      NA       NA
##
## mxAlgebras objects (and their 95% likelihood-based CIs):
##             lbound  Estimate    ubound
## ind[1,1] 0.08579442 0.1463726 0.2103437
## dir[1,1] 0.25952818 0.3800308 0.4987001
##
## Goodness-of-fit indices:
##                                             Value
## Sample size                               8136.00
## Chi-square of target model                   0.00
## DF of target model                           0.00
## p value of target model                      0.00
## Number of constraints imposed on "Smatrix"   0.00
## DF manually adjusted                         0.00
## Chi-square of independence model           574.38
## DF of independence model                     3.00
## RMSEA                                        0.00
## RMSEA lower 95% CI                           0.00
## RMSEA upper 95% CI                           0.00
## SRMR                                         0.00
## TLI                                          -Inf
## CFI                                          1.00
## AIC                                          0.00
## BIC                                          0.00
## OpenMx status1: 0 ("0" or "1": The optimization is considered fine.
## Other values indicate problems.)
```

```r
plot(tssem.fit, color="green")
```



OSMASEM

Model without any moderator

```
## Convert the data format from TSSEM to OSMASEM
osmasem.df1 <- Cor2DataFrame(df1)

## Show the first few studies
head(osmasem.df1)
```

```
## $data
##    Int_Beh PB_Beh PB_Int C(Int_Beh Int_Beh) C(PB_Beh Int_Beh) C(PB_Int Int_Beh)
## 3    0.650  0.709  0.650       0.0013638683      0.0005774474      0.0005261464
## 19   0.840  0.870  0.940       0.0047735402      0.0020210668      0.0018415128
## 20   0.534  0.768  0.540       0.0137384846      0.0058167330      0.0052999690
## 22   0.550  0.540  0.320       0.0038580645      0.0016334631      0.0014883446
## 25   0.530  0.520  0.780       0.0029337400      0.0012421162      0.0011317654
## 26   0.530  0.540  0.540       0.0013638688      0.0005774479      0.0005261470
## 29   0.640  0.630  0.700       0.0004014809      0.0001699828      0.0001548814
## 30   0.589  0.651  0.539       0.0042351721      0.0017931284      0.0016338249
## 33   0.742  0.756  0.798       0.0010770127      0.0004559959      0.0004154847
## 34   0.732  0.780  0.752       0.0009450970      0.0004001442      0.0003645950
## 35   0.020  0.010  0.220       0.0032372287      0.0013706089      0.0012488424
## 36   0.300  0.090  0.200       0.0020708740      0.0008767865      0.0007988918
## 37   0.451  0.746  0.477       0.0066267998      0.0028057203      0.0025564575
## 44   0.270  0.530  0.340       0.0015432269      0.0006533862      0.0005953388
## 48   0.378  0.545  0.485       0.0009085126      0.0003846547      0.0003504817
## 49   0.220  0.360  0.490       0.0007581126      0.0003209769      0.0002924610
```

```
## 51   0.590  0.600  0.700       0.0051676873      0.0021879461      0.0019935670
## 52   0.400  0.610  0.410       0.0071300975      0.0030188081      0.0027506151
## 53   0.420  0.420  0.630       0.0020632884      0.0008735748      0.0007959654
## 54   0.720  0.460  0.470       0.0059292404      0.0025103790      0.0022873542
## 61   0.420  0.470  0.340       0.0023867712      0.0010105346      0.0009207580
## 67   0.440  0.550  0.590       0.0036815526      0.0015587299      0.0014202510
## 73   0.110  0.050  0.490       0.0054687177      0.0023153993      0.0021096965
## 74   0.570  0.710  0.610       0.0025034564      0.0010599368      0.0009657710
## 76   0.149  0.199  0.224       0.0040523571      0.0017157250      0.0015632984
## 77   0.261  0.517  0.315       0.0038580657      0.0016334638      0.0014883451
## 78   0.610  0.370  0.590       0.0104310676      0.0044164033      0.0040240458
## 80   0.640  0.810  0.780       0.0025034575      0.0010599384      0.0009657726
## 81   0.520  0.450  0.640       0.0090851278      0.0038465496      0.0035048192
##    C(PB_Beh PB_Beh) C(PB_Int PB_Beh) C(PB_Int PB_Int) beh_freq_high
## 3      0.0011604998     0.0003951000     0.0010885798             1
## 19     0.0040617500     0.0013828506     0.0038100295             0
## 20     0.0116899176     0.0039799152     0.0109654550             1
## 22     0.0032827827     0.0011176451     0.0030793381             1
## 25     0.0024962857     0.0008498793     0.0023415823             1
## 26     0.0011605003     0.0003951007     0.0010885803             1
## 29     0.0003416155     0.0001163053     0.0003204444             1
## 30     0.0036036592     0.0012268918     0.0033803281             1
## 33     0.0009164178     0.0003120007     0.0008596242             1
## 34     0.0008041721     0.0002737861     0.0007543349             1
## 35     0.0027545205     0.0009377955     0.0025838134             1
## 36     0.0017620828     0.0005999134     0.0016528806             1
## 37     0.0056386677     0.0019197265     0.0052892209             1
## 44     0.0013131140     0.0004470589     0.0012317359             1
## 48     0.0007730429     0.0002631879     0.0007251349             0
## 49     0.0006450693     0.0002196183     0.0006050922             0
## 51     0.0043971255     0.0014970332     0.0041246207             1
## 52     0.0060669176     0.0020655239     0.0056909310             1
## 53     0.0017556284     0.0005977158     0.0016468262             1
## 54     0.0050451224     0.0017176477     0.0047324591             0
## 61     0.0020308760     0.0006914268     0.0019050158             1
## 67     0.0031325908     0.0010665114     0.0029384537             1
## 73     0.0046532691     0.0015842388     0.0043648901             1
## 74     0.0021301621     0.0007252280     0.0019981489             1
## 76     0.0034481042     0.0011739305     0.0032344135             1
## 77     0.0032827835     0.0011176454     0.0030793385             1
## 78     0.0088756754     0.0030217841     0.0083256206             1
## 80     0.0021301632     0.0007252296     0.0019981500             1
## 81     0.0077304298     0.0026318810     0.0072513498             1
##
## $n
##  [1]  413  118   41  146  192  413 1403  133  523  596  174  272   85  365  620
## [16]  743  109   79  273   95  236  153  103  225  139  146   54  225   62
##
## $obslabels
## [1] "Beh" "Int" "PB"
##
## $ylabels
## [1] "Int_Beh" "PB_Beh"  "PB_Int"
##
```

```
## $vlabels
## [1] "C(Int_Beh Int_Beh)" "C(PB_Beh Int_Beh)"  "C(PB_Int Int_Beh)"
## [4] "C(PB_Beh PB_Beh)"   "C(PB_Int PB_Beh)"   "C(PB_Int PB_Int)"
```

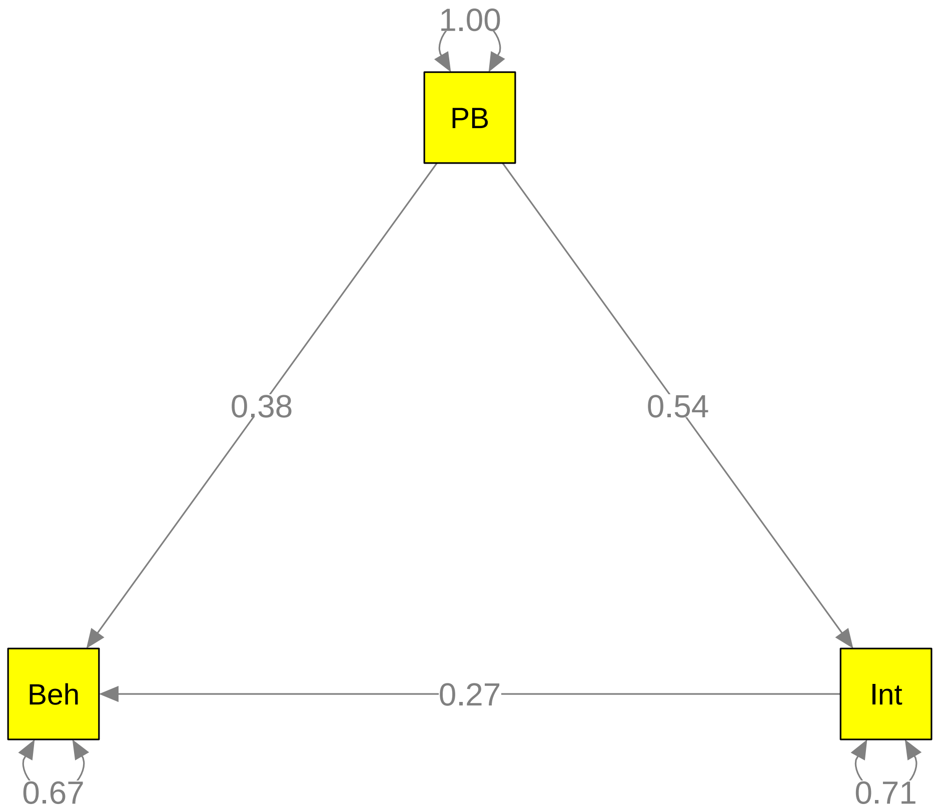
```r
## Fit a model without any moderator
osmasem.fit0 <- osmasem(model.name="No moderator", RAM=RAM1, data=osmasem.df1)
summary(osmasem.fit0)
```

```
## Summary of No moderator
##
## free parameters:
##      name  matrix row col   Estimate  Std.Error A    z value     Pr(>|z|)
## 1       b      A0 Beh Int  0.2725023 0.05783959     4.711345 2.460875e-06
## 2       c      A0 Beh  PB  0.3800308 0.06042092     6.289722 3.180347e-10
## 3       a      A0 Int  PB  0.5371427 0.03385418    15.866362 0.000000e+00
## 4 Tau1_1 vecTau1   1   1 -1.7092450 0.14402352   -11.867818 0.000000e+00
## 5 Tau1_2 vecTau1   2   1 -1.5920843 0.14123961   -11.272223 0.000000e+00
## 6 Tau1_3 vecTau1   3   1 -1.7484087 0.14183548   -12.327019 0.000000e+00
##
## Model Statistics:
##                |  Parameters  |  Degrees of Freedom  |  Fit (-2lnL units)
##        Model:              6                     81              -35.1454
##    Saturated:              9                     78                    NA
## Independence:              6                     81                    NA
## Number of observations/statistics: 8136/87
##
## Information Criteria:
##       |  df Penalty  |  Parameters Penalty  |  Sample-Size Adjusted
## AIC:      -197.1454              -23.14540              -23.1350668
## BIC:      -764.4738               18.87892               -0.1879248
## To get additional fit indices, see help(mxRefModels)
## timestamp: 2021-06-01 10:28:06
## Wall clock time: 0.05576515 secs
## optimizer:  SLSQP
## OpenMx version number: 2.19.5
## Need help?  See help(mxSummary)
```

```r
## Get the heterogeneity of variances
VarCorr(osmasem.fit0)
```

```
##            Tau2_1     Tau2_2     Tau2_3
## Tau2_1 0.03276187 0.00000000 0.00000000
## Tau2_2 0.00000000 0.04141266 0.00000000
## Tau2_3 0.00000000 0.00000000 0.03029364
```

```r
## Plot the fitted model
plot(osmasem.fit0, color="yellow")
```



Model with a moderator

```
## Create A1 to represent the moderator on the A matrix
A1 <- create.modMatrix(RAM1, output="A", "beh_freq_high")
A1
```

```
##     Beh Int                    PB
## Beh "0" "0*data.beh_freq_high" "0*data.beh_freq_high"
## Int "0" "0"                    "0*data.beh_freq_high"
## PB  "0" "0"                    "0"
```

```
## Fit a model with behavior frequency as a moderator
osmasem.fit1 <- osmasem(model.name="Behavior frequency as a moderator",
                        RAM=RAM1, Ax=A1, data=osmasem.df1)
summary(osmasem.fit1)
```

```
## Summary of Behavior frequency as a moderator
##
## free parameters:
##     name  matrix row col    Estimate  Std.Error A      z value     Pr(>|z|)
## 1      b      A0 Beh Int  0.30516661 0.17061585     1.78861817 7.367633e-02
## 2      c      A0 Beh  PB  0.36918343 0.17839173     2.06950982 3.849827e-02
## 3      a      A0 Int  PB  0.58544894 0.09000499     6.50462737 7.788614e-11
## 4    b_1      A1 Beh Int -0.03769750 0.18135146    -0.20786983 8.353306e-01
## 5    c_1      A1 Beh  PB  0.01207899 0.18958931     0.06371135 9.492001e-01
## 6    a_1      A1 Int  PB -0.05626573 0.09708942    -0.57952482 5.622351e-01
## 7 Tau1_1 vecTau1   1   1 -1.70930736 0.14338787   -11.92086436 0.000000e+00
## 8 Tau1_2 vecTau1   2   1 -1.59196770 0.14115508   -11.27814649 0.000000e+00
## 9 Tau1_3 vecTau1   3   1 -1.75242336 0.14159263   -12.37651522 0.000000e+00
```

```
##
## Model Statistics:
##                |  Parameters  |  Degrees of Freedom  |  Fit (-2lnL units)
##        Model:              9                     78             -35.76057
##    Saturated:              9                     78                    NA
## Independence:              6                     81                    NA
## Number of observations/statistics: 8136/87
##
## Information Criteria:
##       |  df Penalty  |  Parameters Penalty  |  Sample-Size Adjusted
## AIC:      -191.7606             -17.76057                 -17.73841
## BIC:      -738.0768              45.27592                  16.67565
## CFI: NA
## TLI: 1   (also known as NNFI)
## RMSEA:  0  [95% CI (NA, NA)]
## Prob(RMSEA <= 0.05): NA
## To get additional fit indices, see help(mxRefModels)
## timestamp: 2021-06-01 10:28:06
## Wall clock time: 0.09925485 secs
## optimizer:  SLSQP
## OpenMx version number: 2.19.5
## Need help?  See help(mxSummary)
```

```
## Test the statistical significance between the models
anova(osmasem.fit1, osmasem.fit0)
```

```
##                                  base   comparison ep  minus2LL df       AIC
## 1 Behavior frequency as a moderator         <NA>  9 -35.76057 78 -17.76057
## 2 Behavior frequency as a moderator No moderator  6 -35.14540 81 -23.14540
##      diffLL diffdf        p
## 1        NA     NA       NA
## 2 0.6151654      3 0.892952
```

```
## Get the R2 on the correlation coefficients
osmasemR2(osmasem.fit0, osmasem.fit1)
```

```
## $Tau2.0
##   Tau2_1_1   Tau2_2_2   Tau2_3_3
## 0.03275778 0.04142232 0.03005138
##
## $Tau2.1
##   Tau2_1_1   Tau2_2_2   Tau2_3_3
## 0.03276187 0.04141266 0.03029364
##
## $R2
##     Tau2_1_1     Tau2_2_2     Tau2_3_3
## 0.0000000000 0.0002331202 0.0000000000
```

Illustration 2 with two parallel mediators (Aut and Cap)

```
## Use new.df2 as the data file in illustration 2
df2 <- Hagger18

## Select Aut, Cap, Beh, and PB for the illustration
obs.vars2 <- c("Aut", "Cap", "Beh", "PB")
```

```r
df2$data <- lapply(df2$data, function(x) x[obs.vars2, obs.vars2])

## Drop studies do not include all correlation in c("Aut", "Cap", "Beh", "PB")
index2 <- sapply(df2$data, function(x) any(is.na(vechs(x))))
df2 <- lapply(df2, function(x) x[!index2])

## Show the first few studies
head(df2)
```

```
## $data
## $data$`3`
##       Aut   Cap   Beh    PB
## Aut 1.000 0.380 0.264 0.264
## Cap 0.380 1.000 0.591 0.591
## Beh 0.264 0.591 1.000 0.709
## PB  0.264 0.591 0.709 1.000
##
## $data$`20`
##        Aut    Cap    Beh     PB
## Aut  1.000  0.513 -0.138 -0.244
## Cap  0.513  1.000 -0.249  0.057
## Beh -0.138 -0.249  1.000  0.768
## PB  -0.244  0.057  0.768  1.000
##
## $data$`29`
##      Aut  Cap  Beh   PB
## Aut 1.00 0.42 0.28 0.25
## Cap 0.42 1.00 0.55 0.51
## Beh 0.28 0.55 1.00 0.63
## PB  0.25 0.51 0.63 1.00
##
## $data$`33`
##       Aut   Cap   Beh    PB
## Aut 1.000 0.697 0.266 0.297
## Cap 0.697 1.000 0.274 0.284
## Beh 0.266 0.274 1.000 0.756
## PB  0.297 0.284 0.756 1.000
##
## $data$`34`
##       Aut   Cap   Beh    PB
## Aut 1.000 0.797 0.527 0.562
## Cap 0.797 1.000 0.570 0.608
## Beh 0.527 0.570 1.000 0.780
## PB  0.562 0.608 0.780 1.000
##
## $data$`37`
##       Aut   Cap   Beh    PB
## Aut 1.000 0.241 0.114 0.101
## Cap 0.241 1.000 0.326 0.335
## Beh 0.114 0.326 1.000 0.746
## PB  0.101 0.335 0.746 1.000
##
## $data$`51`
##       Aut  Cap   Beh   PB
```

```
## Aut  1.00 0.18 -0.05 0.15
## Cap  0.18 1.00  0.37 0.44
## Beh -0.05 0.37  1.00 0.60
## PB   0.15 0.44  0.60 1.00
##
## $data$`52`
##       Aut  Cap   Beh   PB
## Aut  1.00 0.20 -0.19 0.03
## Cap  0.20 1.00  0.26 0.24
## Beh -0.19 0.26  1.00 0.61
## PB   0.03 0.24  0.61 1.00
##
## $data$`53`
##       Aut   Cap   Beh    PB
## Aut  1.00 -0.11 -0.12 -0.27
## Cap -0.11  1.00  0.42  0.46
## Beh -0.12  0.42  1.00  0.42
## PB  -0.27  0.46  0.42  1.00
##
## $data$`54`
##      Aut  Cap  Beh   PB
## Aut 1.00 0.32 0.17 0.07
## Cap 0.32 1.00 0.51 0.32
## Beh 0.17 0.51 1.00 0.46
## PB  0.07 0.32 0.46 1.00
##
## $data$`78`
##       Aut  Cap   Beh   PB
## Aut  1.00 0.55 -0.13 0.22
## Cap  0.55 1.00  0.40 0.43
## Beh -0.13 0.40  1.00 0.37
## PB   0.22 0.43  0.37 1.00
##
## $data$`80`
##      Aut  Cap  Beh   PB
## Aut 1.00 0.21 0.35 0.35
## Cap 0.21 1.00 0.53 0.64
## Beh 0.35 0.53 1.00 0.81
## PB  0.35 0.64 0.81 1.00
##
## $data$`81`
##       Aut  Cap   Beh   PB
## Aut  1.00 0.01 -0.30 0.51
## Cap  0.01 1.00  0.20 0.27
## Beh -0.30 0.20  1.00 0.45
## PB   0.51 0.27  0.45 1.00
##
##
## $n
##  [1]  413   41 1403  523  596   85  109   79  273   95   54  225   62
##
## $beh_freq_high
##  [1] 1 1 1 1 1 1 1 1 1 0 1 1 1
```

```r
## Show the no. of studies per correlation
pattern.na(df2$data, show.na = FALSE)
```

```
##     Aut Cap Beh PB
## Aut  13  13  13 13
## Cap  13  13  13 13
## Beh  13  13  13 13
## PB   13  13  13 13
```

```r
## Show the total sample sizes per correlation
pattern.n(df2$data, df2$n)
```

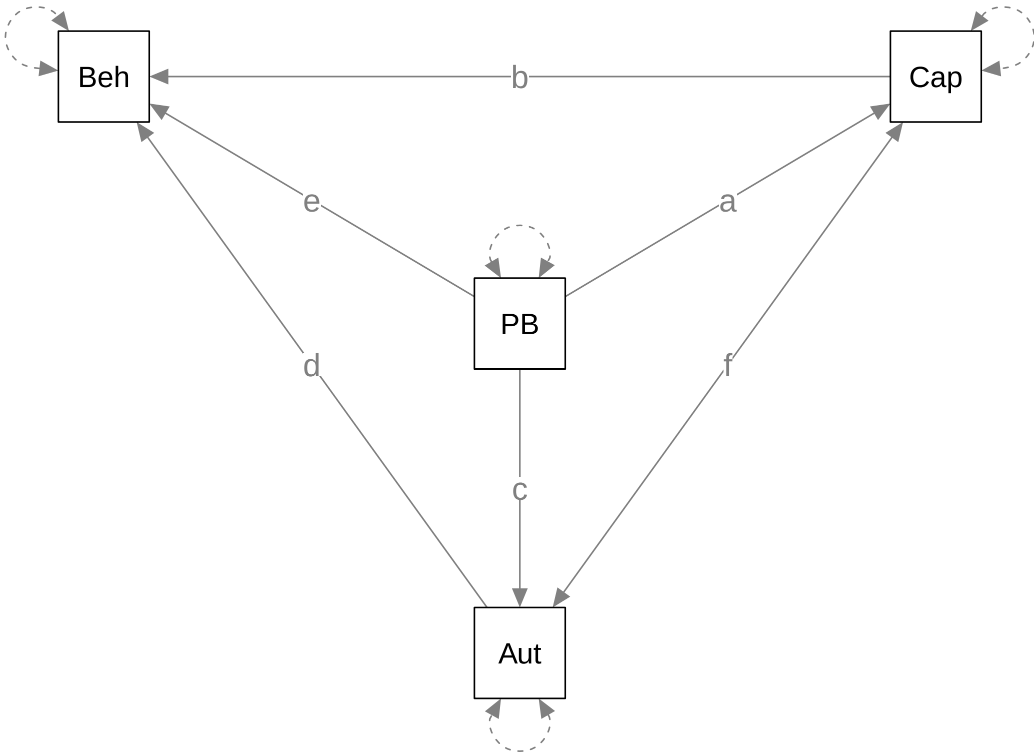
```
##      Aut  Cap  Beh   PB
## Aut 3958 3958 3958 3958
## Cap 3958 3958 3958 3958
## Beh 3958 3958 3958 3958
## PB  3958 3958 3958 3958
```

Meta-analyzing the indirect and direct effects

Caculation of indirect and direct effects

```r
## Calculate indirect and direct effects as effect sizes in each study
## PB -> Cap -> Beh
## PB -> Aut -> Beh
model2 <- "Cap ~ a*PB
           Aut ~ c*PB
           Beh ~ b*Cap + d*Aut + e*PB
           Cap ~~ f*Aut
           PB ~~ 1*PB
           ## Define indirect and direct effects
           Ind_Cap := a*b
           Ind_Aut := c*d
           Dir_PB := f"

## Display the proposed model
plot(model2, layout="circle")
```




```
## Estimate the indirect and direct effects
IE.df2 <- mapply(function(x, y) {calEffSizes(model=model2, n=y, Cov=x)},
                                  df2$data, df2$n, SIMPLIFY = FALSE)

head(IE.df2)
```

```
## $`3`
## $`3`$ES
##     Ind_Cap     Ind_Aut      Dir_PB
## 0.151994676 0.005454605 0.223975994
##
## $`3`$VCOV
##               Ind_Cap       Ind_Aut       Dir_PB
## Ind_Cap  7.440345e-04 -6.592824e-05 1.694948e-19
## Ind_Aut -6.592824e-05  9.026331e-05 2.263434e-19
## Dir_PB   2.515114e-19  2.454108e-19 1.587244e-03
##
##
## $`20`
## $`20`$ES
##     Ind_Cap     Ind_Aut      Dir_PB
## -0.02603626 -0.07525792  0.52690799
##
## $`20`$VCOV
##               Ind_Cap       Ind_Aut        Dir_PB
## Ind_Cap  5.101867e-03 -1.739814e-03 -3.599878e-17
## Ind_Aut -1.739814e-03  2.755167e-03  8.966078e-18
## Dir_PB  -3.154713e-17  7.401104e-18  2.963513e-02
##
##
```

```
## $`29`
## $`29`$ES
##     Ind_Cap     Ind_Aut      Dir_PB
## 0.149766899 0.009761141 0.292499971
##
## $`29`$VCOV
##               Ind_Cap       Ind_Aut        Dir_PB
## Ind_Cap  1.972890e-04 -2.082765e-05  1.404948e-19
## Ind_Aut -2.082765e-05  2.980877e-05 -1.487306e-20
## Dir_PB   1.833588e-19 -3.031061e-21  5.553902e-04
##
##
## $`33`
## $`33`$ES
##     Ind_Cap     Ind_Aut      Dir_PB
## 0.017583378 0.001152015 0.612652009
##
## $`33`$VCOV
##               Ind_Cap       Ind_Aut       Dir_PB
## Ind_Cap  1.357261e-04 -9.035574e-05 3.194362e-19
## Ind_Aut -9.035574e-05  1.422618e-04 4.153252e-20
## Dir_PB   2.896467e-19  6.576327e-20 2.320444e-03
##
##
## $`34`
## $`34`$ES
##    Ind_Cap    Ind_Aut     Dir_PB
## 0.06829862 0.03079963 0.45530400
##
## $`34`$VCOV
##               Ind_Cap       Ind_Aut       Dir_PB
## Ind_Cap  7.257764e-04 -4.335468e-04 5.637706e-19
## Ind_Aut -4.335468e-04  5.642697e-04 3.303910e-19
## Dir_PB   5.141592e-19  1.587066e-19 1.071392e-03
##
##
## $`37`
## $`37`$ES
##     Ind_Cap     Ind_Aut      Dir_PB
## 0.026977135 0.002241968 0.207164996
##
## $`37`$VCOV
##               Ind_Cap       Ind_Aut       Dir_PB
## Ind_Cap  7.502225e-04 -3.871017e-05 8.330654e-19
## Ind_Aut -3.871017e-05  6.138024e-05 3.590069e-19
## Dir_PB   7.567297e-19  2.890898e-19 1.084278e-02
```

```r
## Rename the variances and covariances of the effect sizes from Cov1 to Cov6 for ease of reference
IE.df2 <- t(sapply(IE.df2,
                   function(x) { acov <- vech(x$VCOV)
                                 names(acov) <- paste0("Cov", 1:6)
                                 c(x$ES, acov)} ))

## Show the first few studies
```

```r
head(IE.df2)
```

```
##        Ind_Cap      Ind_Aut   Dir_PB         Cov1          Cov2          Cov3
## 3   0.15199468  0.005454605 0.223976 0.0007440345 -6.592824e-05  2.515114e-19
## 20 -0.02603626 -0.075257923 0.526908 0.0051018674 -1.739814e-03 -3.154713e-17
## 29  0.14976690  0.009761141 0.292500 0.0001972890 -2.082765e-05  1.833588e-19
## 33  0.01758338  0.001152015 0.612652 0.0001357261 -9.035574e-05  2.896467e-19
## 34  0.06829862  0.030799631 0.455304 0.0007257764 -4.335468e-04  5.141592e-19
## 37  0.02697713  0.002241968 0.207165 0.0007502225 -3.871017e-05  7.567297e-19
##            Cov4          Cov5         Cov6
## 3  9.026331e-05  2.454108e-19 0.0015872439
## 20 2.755167e-03  7.401104e-18 0.0296351332
## 29 2.980877e-05 -3.031061e-21 0.0005553902
## 33 1.422618e-04  6.576327e-20 0.0023204437
## 34 5.642697e-04  1.587066e-19 0.0010713924
## 37 6.138024e-05  2.890898e-19 0.0108427780
```

Meta-analysis of indirect and direct effects

```r
## Random-effects model with independent random effects
## Tau2_2_2 is close to negative. It is fixed at 0.
IE2 <- meta(y=IE.df2[, c("Ind_Cap", "Ind_Aut", "Dir_PB")],
           v=IE.df2[, paste0("Cov", 1:6)],
           RE.constraints = Diag(c("0.01*Tau2_1_1", "0", "0.01*Tau2_3_3")))
summary(IE2)
```

```
##
## Call:
## meta(y = IE.df2[, c("Ind_Cap", "Ind_Aut", "Dir_PB")], v = IE.df2[,
##     paste0("Cov", 1:6)], RE.constraints = Diag(c("0.01*Tau2_1_1",
##     "0", "0.01*Tau2_3_3")))
##
## 95% confidence intervals: z statistic approximation (robust=FALSE)
## Coefficients:
##               Estimate   Std.Error      lbound      ubound z value  Pr(>|z|)
## Intercept1  6.9096e-02  1.7891e-02  3.4030e-02  1.0416e-01  3.8620 0.0001125
## Intercept2  4.6650e-03  3.0421e-03 -1.2975e-03  1.0627e-02  1.5335 0.1251644
## Intercept3  2.4447e-01  5.9063e-02  1.2871e-01  3.6023e-01  4.1391 3.487e-05
## Tau2_1_1    3.0429e-03  1.5942e-03 -8.1685e-05  6.1674e-03  1.9087 0.0562976
## Tau2_3_3    3.8025e-02  1.7341e-02  4.0376e-03  7.2012e-02  2.1928 0.0283215
##
## Intercept1 ***
## Intercept2
## Intercept3 ***
## Tau2_1_1    .
## Tau2_3_3    *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Q statistic on the homogeneity of effect sizes: 305.2991
## Degrees of freedom of the Q statistic: 36
## P value of the Q statistic: 0
##
## Heterogeneity indices (based on the estimated Tau2):
```

```
##                               Estimate
## Intercept1: I2 (Q statistic)   0.8273
## Intercept2: I2 (Q statistic)   0.0000
## Intercept3: I2 (Q statistic)   0.9302
##
## Number of studies (or clusters): 13
## Number of observed statistics: 39
## Number of estimated parameters: 5
## Degrees of freedom: 34
## -2 log likelihood: -88.50845
## OpenMx status1: 0 ("0" or "1": The optimization is considered fine.
## Other values may indicate problems.)
```

TSSEM

Stage 1 analysis

```
## Random-effects model
random1 <- tssem1(df2$data, df2$n)
summary(random1)
```

```
##
## Call:
## meta(y = ES, v = acovR, RE.constraints = Diag(paste0(RE.startvalues,
##     "*Tau2_", 1:no.es, "_", 1:no.es)), RE.lbound = RE.lbound,
##     I2 = I2, model.name = model.name, suppressWarnings = TRUE,
##     silent = silent, run = run)
##
## 95% confidence intervals: z statistic approximation (robust=FALSE)
## Coefficients:
##               Estimate   Std.Error      lbound      ubound z value  Pr(>|z|)
## Intercept1  0.35451122  0.07004355  0.21722839  0.49179406  5.0613 4.164e-07
## Intercept2  0.11727547  0.06190971 -0.00406533  0.23861627  1.8943 0.0581854
## Intercept3  0.20814645  0.06281682  0.08502774  0.33126516  3.3135 0.0009212
## Intercept4  0.40319814  0.04605582  0.31293039  0.49346589  8.7546 < 2.2e-16
## Intercept5  0.43477749  0.03722533  0.36181719  0.50773780 11.6796 < 2.2e-16
## Intercept6  0.63769893  0.04056596  0.55819110  0.71720675 15.7200 < 2.2e-16
## Tau2_1_1    0.05827989  0.02439389  0.01046874  0.10609104  2.3891 0.0168889
## Tau2_2_2    0.04228559  0.01895275  0.00513888  0.07943229  2.2311 0.0256741
## Tau2_3_3    0.04418460  0.01972984  0.00551482  0.08285437  2.2395 0.0251247
## Tau2_4_4    0.02232387  0.01159256 -0.00039713  0.04504487  1.9257 0.0541410
## Tau2_5_5    0.01309635  0.00660328  0.00015415  0.02603855  1.9833 0.0473330
## Tau2_6_6    0.01879291  0.00857040  0.00199524  0.03559059  2.1928 0.0283240
##
## Intercept1 ***
## Intercept2 .
## Intercept3 ***
## Intercept4 ***
## Intercept5 ***
## Intercept6 ***
## Tau2_1_1   *
## Tau2_2_2   *
## Tau2_3_3   *
## Tau2_4_4   .
```

```
## Tau2_5_5   *
## Tau2_6_6   *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Q statistic on the homogeneity of effect sizes: 889.6956
## Degrees of freedom of the Q statistic: 72
## P value of the Q statistic: 0
##
## Heterogeneity indices (based on the estimated Tau2):
##                              Estimate
## Intercept1: I2 (Q statistic)   0.9600
## Intercept2: I2 (Q statistic)   0.9278
## Intercept3: I2 (Q statistic)   0.9315
## Intercept4: I2 (Q statistic)   0.9096
## Intercept5: I2 (Q statistic)   0.8563
## Intercept6: I2 (Q statistic)   0.9420
##
## Number of studies (or clusters): 13
## Number of observed statistics: 78
## Number of estimated parameters: 12
## Degrees of freedom: 66
## -2 log likelihood: -34.37846
## OpenMx status1: 0 ("0" or "1": The optimization is considered fine.
## Other values may indicate problems.)
```

```
## Average correlation matrix under a random-effects model
averageR <- vec2symMat(coef(random1, select="fixed"), diag = FALSE)
dimnames(averageR) <- list(obs.vars2, obs.vars2)
averageR
```

```
##           Aut       Cap       Beh        PB
## Aut 1.0000000 0.3545112 0.1172755 0.2081464
## Cap 0.3545112 1.0000000 0.4031981 0.4347775
## Beh 0.1172755 0.4031981 1.0000000 0.6376989
## PB  0.2081464 0.4347775 0.6376989 1.0000000
```

```
## Heterogeneity variances of the random-effects
coef(random1, select="random")
```

```
##   Tau2_1_1   Tau2_2_2   Tau2_3_3   Tau2_4_4   Tau2_5_5   Tau2_6_6
## 0.05827989 0.04228559 0.04418460 0.02232387 0.01309635 0.01879291
```

Stage 2 analysis

```
RAM2 <- lavaan2RAM(model2, obs.variables=obs.vars2)
RAM2
```

```
## $A
##     Aut   Cap   Beh PB
## Aut "0"   "0"   "0" "0*c"
## Cap "0"   "0"   "0" "0*a"
## Beh "0*d" "0*b" "0" "0*e"
## PB  "0"   "0"   "0" "0"
##
## $S
```

```
##     Aut             Cap           Beh           PB
## Aut "0*AutWITHAut" "0*f"         "0"           "0"
## Cap "0*f"          "0*CapWITHCap" "0"          "0"
## Beh "0"            "0"           "0*BehWITHBeh" "0"
## PB  "0"            "0"           "0"           "1"
##
## $F
##     Aut Cap Beh PB
## Aut   1   0   0  0
## Cap   0   1   0  0
## Beh   0   0   1  0
## PB    0   0   0  1
##
## $M
##   Aut Cap Beh PB
## 1   0   0   0  0
```

```
tssem.fit <- tssem2(random1, RAM=RAM2, intervals.type = "LB",
                    mx.algebras = list(Ind_Cap=mxAlgebra(a*b, name="Ind_Cap"),
                                       Ind_Aut=mxAlgebra(c*d, name="Ind_Aut"),
                                       Dir_PB=mxAlgebra(f, name="Dir_PB")))
summary(tssem.fit)
```

```
##
## Call:
## wls(Cov = pooledS, aCov = aCov, n = tssem1.obj$total.n, RAM = RAM,
##     Amatrix = Amatrix, Smatrix = Smatrix, Fmatrix = Fmatrix,
##     diag.constraints = diag.constraints, cor.analysis = cor.analysis,
##     intervals.type = intervals.type, mx.algebras = mx.algebras,
##     model.name = model.name, suppressWarnings = suppressWarnings,
##     silent = silent, run = run)
##
## 95% confidence intervals: Likelihood-based statistic
## Coefficients:
##    Estimate Std.Error    lbound    ubound z value Pr(>|z|)
## c  0.208146        NA  0.084443  0.331279      NA       NA
## d -0.064842        NA -0.232987  0.093024      NA       NA
## b  0.176407        NA  0.032781  0.319098      NA       NA
## e  0.574498        NA  0.466060  0.684971      NA       NA
## a  0.434777        NA  0.361650  0.507827      NA       NA
## f  0.264014        NA  0.117350  0.409750      NA       NA
##
## mxAlgebras objects (and their 95% likelihood-based CIs):
##                    lbound    Estimate    ubound
## Ind_Cap[1,1]  0.01493819  0.07669767 0.1386230
## Ind_Aut[1,1] -0.06649823 -0.01349672 0.0164421
## Dir_PB[1,1]   0.11734983  0.26401383 0.4097504
##
## Goodness-of-fit indices:
##                                                Value
## Sample size                                  3958.00
## Chi-square of target model                      0.00
## DF of target model                              0.00
## p value of target model                         0.00
## Number of constraints imposed on "Smatrix"      0.00
```

```
## DF manually adjusted                                0.00
## Chi-square of independence model                  433.99
## DF of independence model                            6.00
## RMSEA                                               0.00
## RMSEA lower 95% CI                                  0.00
## RMSEA upper 95% CI                                  0.00
## SRMR                                                0.00
## TLI                                                 -Inf
## CFI                                                 1.00
## AIC                                                 0.00
## BIC                                                 0.00
## OpenMx status1: 0 ("0" or "1": The optimization is considered fine.
## Other values indicate problems.)
```

```r
plot(tssem.fit, layout="circle", color="green")
```

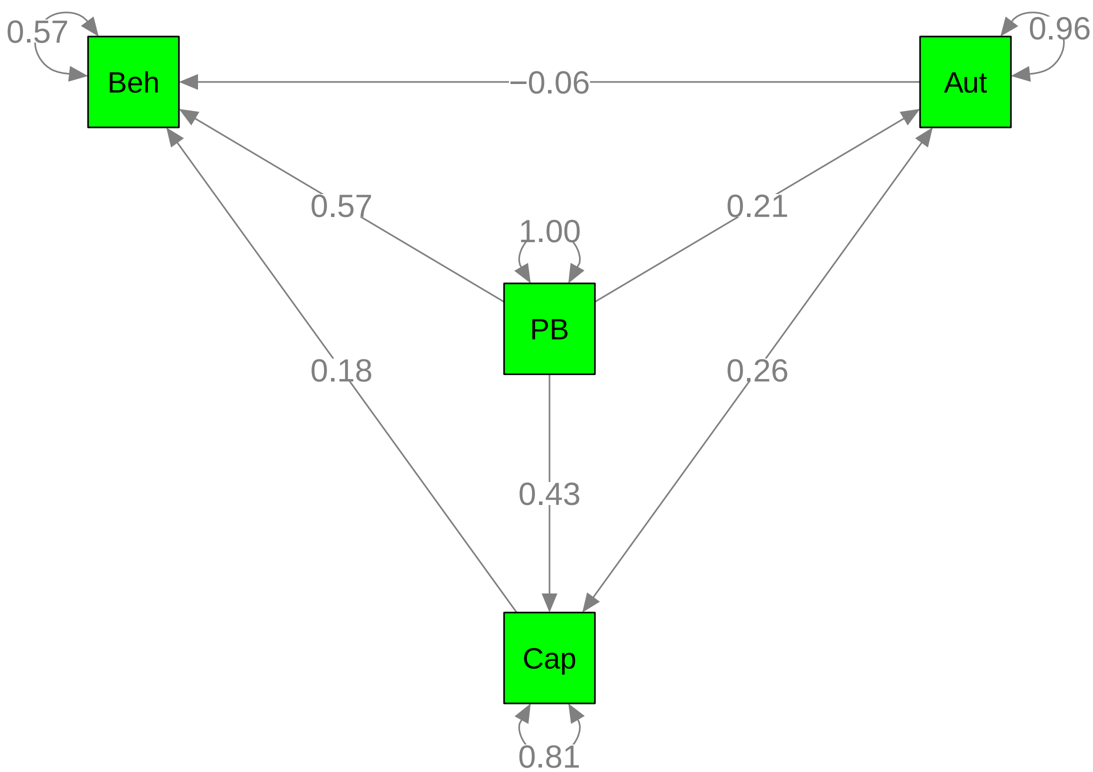


Illustration 3 with two serial mediators (Aut and Cap)

```r
## Use df3 as the data file in illustration 3
df3 <- Hagger18

## Select Cap, Int, Beh, and PB for the illustration
obs.vars3 <- c("Cap", "Int", "Beh", "PB")
df3$data <- lapply(df3$data, function(x) x[obs.vars3, obs.vars3])

## Drop studies do not include all correlations in c("Cap", "Int", "Beh", "PB")
index3 <- sapply(df3$data, function(x) any(is.na(vechs(x))))
df3 <- lapply(df3, function(x) x[!index3])
```

```r
## Show the first few studies
head(df3)
```

```
## $data
## $data$`3`
##       Cap   Int   Beh    PB
## Cap 1.000 0.702 0.591 0.591
## Int 0.702 1.000 0.650 0.650
## Beh 0.591 0.650 1.000 0.709
## PB  0.591 0.650 0.709 1.000
##
## $data$`20`
##        Cap   Int    Beh    PB
## Cap  1.000 0.376 -0.249 0.057
## Int  0.376 1.000  0.534 0.540
## Beh -0.249 0.534  1.000 0.768
## PB   0.057 0.540  0.768 1.000
##
## $data$`29`
##      Cap  Int  Beh   PB
## Cap 1.00 0.59 0.55 0.51
## Int 0.59 1.00 0.64 0.70
## Beh 0.55 0.64 1.00 0.63
## PB  0.51 0.70 0.63 1.00
##
## $data$`30`
##       Cap   Int   Beh    PB
## Cap 1.000 0.483 0.299 0.310
## Int 0.483 1.000 0.589 0.539
## Beh 0.299 0.589 1.000 0.651
## PB  0.310 0.539 0.651 1.000
##
## $data$`33`
##       Cap   Int   Beh    PB
## Cap 1.000 0.386 0.274 0.284
## Int 0.386 1.000 0.742 0.798
## Beh 0.274 0.742 1.000 0.756
## PB  0.284 0.798 0.756 1.000
##
## $data$`34`
##       Cap   Int   Beh    PB
## Cap 1.000 0.742 0.570 0.608
## Int 0.742 1.000 0.732 0.752
## Beh 0.570 0.732 1.000 0.780
## PB  0.608 0.752 0.780 1.000
##
## $data$`37`
##       Cap   Int   Beh    PB
## Cap 1.000 0.446 0.326 0.335
## Int 0.446 1.000 0.451 0.477
## Beh 0.326 0.451 1.000 0.746
## PB  0.335 0.477 0.746 1.000
##
## $data$`44`
```

```
##      Cap  Int  Beh   PB
## Cap 1.00 0.55 0.25 0.31
## Int 0.55 1.00 0.27 0.34
## Beh 0.25 0.27 1.00 0.53
## PB  0.31 0.34 0.53 1.00
##
## $data$`48`
##       Cap   Int   Beh    PB
## Cap 1.000 0.644 0.486 0.590
## Int 0.644 1.000 0.378 0.485
## Beh 0.486 0.378 1.000 0.545
## PB  0.590 0.485 0.545 1.000
##
## $data$`49`
##      Cap  Int  Beh   PB
## Cap 1.00 0.52 0.17 0.49
## Int 0.52 1.00 0.22 0.49
## Beh 0.17 0.22 1.00 0.36
## PB  0.49 0.49 0.36 1.00
##
## $data$`51`
##      Cap  Int  Beh   PB
## Cap 1.00 0.64 0.37 0.44
## Int 0.64 1.00 0.59 0.70
## Beh 0.37 0.59 1.00 0.60
## PB  0.44 0.70 0.60 1.00
##
## $data$`52`
##      Cap  Int  Beh   PB
## Cap 1.00 0.29 0.26 0.24
## Int 0.29 1.00 0.40 0.41
## Beh 0.26 0.40 1.00 0.61
## PB  0.24 0.41 0.61 1.00
##
## $data$`53`
##      Cap  Int  Beh   PB
## Cap 1.00 0.70 0.42 0.46
## Int 0.70 1.00 0.42 0.63
## Beh 0.42 0.42 1.00 0.42
## PB  0.46 0.63 0.42 1.00
##
## $data$`54`
##      Cap  Int  Beh   PB
## Cap 1.00 0.80 0.51 0.32
## Int 0.80 1.00 0.72 0.47
## Beh 0.51 0.72 1.00 0.46
## PB  0.32 0.47 0.46 1.00
##
## $data$`73`
##       Cap  Int  Beh    PB
## Cap  1.00 0.15 0.53 -0.13
## Int  0.15 1.00 0.11  0.49
## Beh  0.53 0.11 1.00  0.05
## PB  -0.13 0.49 0.05  1.00
```

```
##
## $data$`76`
##       Cap   Int   Beh    PB
## Cap 1.000 0.567 0.145 0.187
## Int 0.567 1.000 0.149 0.224
## Beh 0.145 0.149 1.000 0.199
## PB  0.187 0.224 0.199 1.000
##
## $data$`77`
##       Cap   Int   Beh    PB
## Cap 1.000 0.667 0.227 0.277
## Int 0.667 1.000 0.261 0.315
## Beh 0.227 0.261 1.000 0.517
## PB  0.277 0.315 0.517 1.000
##
## $data$`78`
##      Cap  Int  Beh   PB
## Cap 1.00 0.49 0.40 0.43
## Int 0.49 1.00 0.61 0.59
## Beh 0.40 0.61 1.00 0.37
## PB  0.43 0.59 0.37 1.00
##
## $data$`80`
##      Cap  Int  Beh   PB
## Cap 1.00 0.57 0.53 0.64
## Int 0.57 1.00 0.64 0.78
## Beh 0.53 0.64 1.00 0.81
## PB  0.64 0.78 0.81 1.00
##
## $data$`81`
##      Cap  Int  Beh   PB
## Cap 1.00 0.35 0.20 0.27
## Int 0.35 1.00 0.52 0.64
## Beh 0.20 0.52 1.00 0.45
## PB  0.27 0.64 0.45 1.00
##
##
## $n
##  [1]  413   41 1403  133  523  596   85  365  620  743  109   79  273   95  103
## [16]  139  146   54  225   62
##
## $beh_freq_high
##  [1] 1 1 1 1 1 1 1 1 0 0 1 1 1 0 1 1 1 1 1 1
```

```r
## Show the no. of studies per correlation
pattern.na(df3$data, show.na = FALSE)
```

```
##     Cap Int Beh PB
## Cap  20  20  20 20
## Int  20  20  20 20
## Beh  20  20  20 20
## PB   20  20  20 20
```

```r
## Show the total sample sizes per correlation
pattern.n(df3$data, df3$n)
```

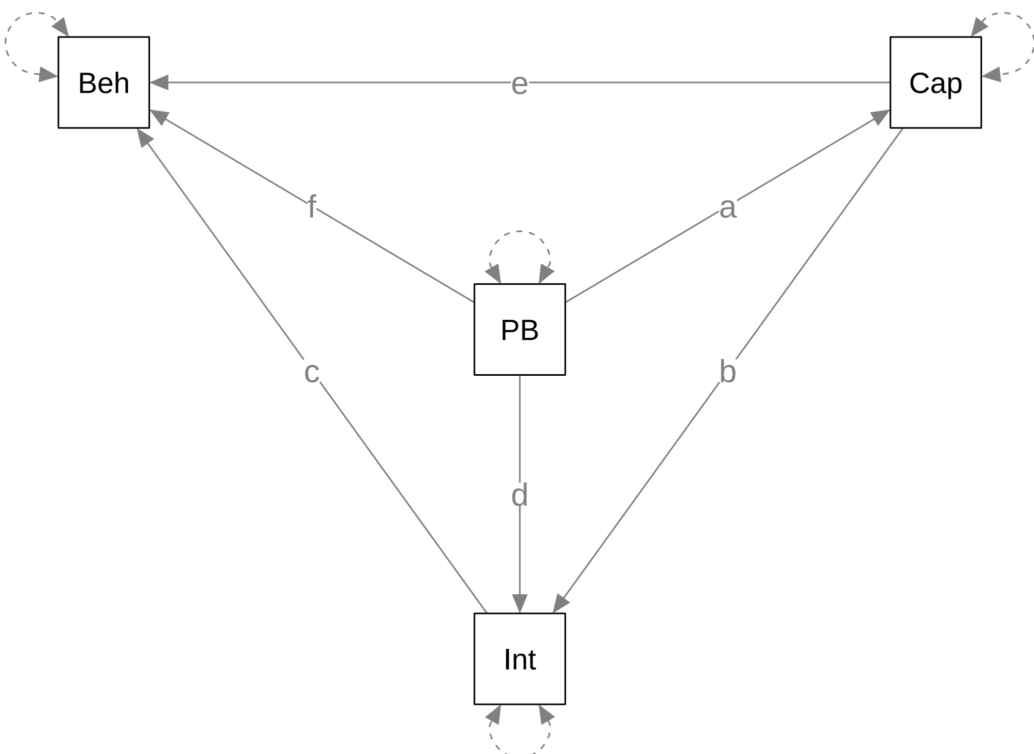
```
##      Cap  Int  Beh   PB
## Cap 6207 6207 6207 6207
## Int 6207 6207 6207 6207
## Beh 6207 6207 6207 6207
## PB  6207 6207 6207 6207
```

Meta-analyzing the indirect and direct effects

Caculation of indirect and direct effects

```
## Calculate indirect and direct effects as effect sizes in each study
## PB -> Cap -> Int -> Beh
model3 <- "Cap ~ a*PB
           Int ~ b*Cap + d*PB
           Beh ~ e*Cap + c*Int + f*PB
           PB ~~ 1*PB
           ## Define indirect and direct effects
           Ind_CapInt := a*b*c
           Ind_Cap := a*e
           Ind_Int := d*c
           Dir_PB := f"

## Display the proposed model
plot(model3, layout="circle")
```




```
## Estimate the indirect and direct effects
IE.df3 <- mapply(function(x, y) {calEffSizes(model=model3, n=y, Cov=x)},
                                 df3$data, df3$n, SIMPLIFY = FALSE)

## Rename the variances and covariances of the effect sizes from Cov1 to Cov10 for ease of reference
```

```r
IE.df3 <- t(sapply(IE.df3,
                   function(x) { acov <- vech(x$VCOV)
                                 names(acov) <- paste0("Cov", 1:10)
                                 c(x$ES, acov)} ))

## Show the first few studies
head(IE.df3)
```

```
##     Ind_CapInt       Ind_Cap    Ind_Int    Dir_PB         Cov1          Cov2
## 3  0.071885136  0.0843125034 0.08997364 0.4628287 2.607644e-04 -1.760859e-04
## 20 0.007398725 -0.0241413532 0.19498075 0.5897619 4.200800e-04 -1.340406e-03
## 29 0.046706843  0.1109320176 0.15686866 0.3154925 3.453848e-05 -1.035705e-05
## 30 0.036920098 -0.0035879815 0.14675358 0.4709143 2.251086e-04 -8.246915e-05
## 33 0.018842373 -0.0005248949 0.28657736 0.4511052 2.116888e-05 -5.401043e-06
## 34 0.091772694  0.0005940434 0.15946469 0.5281686 1.996415e-04 -1.418000e-04
##            Cov3          Cov4         Cov5          Cov6          Cov7
## 3  2.205859e-04 -2.546141e-04 7.887380e-04 -2.546141e-04 -2.986314e-04
## 20 9.615378e-05 -1.027291e-04 4.383998e-03 -1.027291e-04  8.353152e-05
## 29 6.081536e-05 -7.006819e-05 1.699606e-04 -7.006819e-05 -5.407892e-05
## 30 2.349596e-04 -2.905685e-04 4.706487e-04 -2.905685e-04 -1.060688e-04
## 33 7.062148e-05 -7.886719e-05 6.817815e-05 -7.886719e-05  1.588054e-05
## 34 2.130739e-04 -2.466634e-04 4.793815e-04 -2.466634e-04 -9.076113e-05
##            Cov8          Cov9       Cov10
## 3  0.0004161066 -0.0003186828 0.001902638
## 20 0.0047310537 -0.0027072504 0.008616020
## 29 0.0002709037 -0.0002353296 0.000712635
## 30 0.0017336374 -0.0011549800 0.005282320
## 33 0.0013017396 -0.0011995066 0.001980436
## 34 0.0005194685 -0.0004286035 0.001341391
```

Meta-analysis of indirect and direct effects

```r
## Random-effects model with independent random effects
IE3 <- meta(y=IE.df3[, c("Ind_CapInt", "Ind_Cap", "Ind_Int", "Dir_PB")],
            v=IE.df3[, paste0("Cov", 1:10)],
            RE.constraints = Diag(paste0("0.01*Tau2_", 1:4, "_", 1:4)))
summary(IE3)
```

```
##
## Call:
## meta(y = IE.df3[, c("Ind_CapInt", "Ind_Cap", "Ind_Int", "Dir_PB")],
##     v = IE.df3[, paste0("Cov", 1:10)], RE.constraints = Diag(paste0("0.01*Tau2_",
##         1:4, "_", 1:4)))
##
## 95% confidence intervals: z statistic approximation (robust=FALSE)
## Coefficients:
##              Estimate  Std.Error     lbound     ubound z value  Pr(>|z|)
## Intercept1 2.4290e-02 5.7142e-03 1.3090e-02 3.5489e-02  4.2507 2.131e-05 ***
## Intercept2 2.7997e-02 1.0805e-02 6.8197e-03 4.9174e-02  2.5911  0.009566 **
## Intercept3 8.6211e-02 1.8510e-02 4.9931e-02 1.2249e-01  4.6574 3.202e-06 ***
## Intercept4 4.1141e-01 3.8419e-02 3.3611e-01 4.8671e-01 10.7084 < 2.2e-16 ***
## Tau2_1_1   4.4162e-04 1.9985e-04 4.9931e-05 8.3332e-04  2.2098  0.027118 *
## Tau2_2_2   1.5262e-03 7.0018e-04 1.5388e-04 2.8985e-03  2.1797  0.029276 *
## Tau2_3_3   5.2568e-03 2.1140e-03 1.1134e-03 9.4001e-03  2.4866  0.012895 *
```

```
## Tau2_4_4   2.3981e-02 9.6504e-03 5.0661e-03 4.2895e-02  2.4849  0.012958 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Q statistic on the homogeneity of effect sizes: 750.4992
## Degrees of freedom of the Q statistic: 76
## P value of the Q statistic: 0
##
## Heterogeneity indices (based on the estimated Tau2):
##                              Estimate
## Intercept1: I2 (Q statistic)   0.8653
## Intercept2: I2 (Q statistic)   0.7551
## Intercept3: I2 (Q statistic)   0.9305
## Intercept4: I2 (Q statistic)   0.8825
##
## Number of studies (or clusters): 20
## Number of observed statistics: 80
## Number of estimated parameters: 8
## Degrees of freedom: 72
## -2 log likelihood: -201.1973
## OpenMx status1: 0 ("0" or "1": The optimization is considered fine.
## Other values may indicate problems.)
```

TSSEM

Stage 1 analysis

```
## Random-effects model
random1 <- tssem1(df3$data, df3$n)
summary(random1)
```

```
##
## Call:
## meta(y = ES, v = acovR, RE.constraints = Diag(paste0(RE.startvalues,
##     "*Tau2_", 1:no.es, "_", 1:no.es)), RE.lbound = RE.lbound,
##     I2 = I2, model.name = model.name, suppressWarnings = TRUE,
##     silent = silent, run = run)
##
## 95% confidence intervals: z statistic approximation (robust=FALSE)
## Coefficients:
##             Estimate Std.Error    lbound    ubound z value  Pr(>|z|)
## Intercept1 0.5493203 0.0324270 0.4857645 0.6128761 16.9402 < 2.2e-16 ***
## Intercept2 0.3646155 0.0384858 0.2891847 0.4400463  9.4740 < 2.2e-16 ***
## Intercept3 0.3833904 0.0370397 0.3107939 0.4559870 10.3508 < 2.2e-16 ***
## Intercept4 0.4911759 0.0411916 0.4104419 0.5719099 11.9242 < 2.2e-16 ***
## Intercept5 0.5612951 0.0335067 0.4956233 0.6269670 16.7517 < 2.2e-16 ***
## Intercept6 0.5560411 0.0422023 0.4733261 0.6387560 13.1756 < 2.2e-16 ***
## Tau2_1_1   0.0179174 0.0067110 0.0047641 0.0310708  2.6698  0.007589 **
## Tau2_2_2   0.0248312 0.0096502 0.0059171 0.0437453  2.5731  0.010079 *
## Tau2_3_3   0.0230433 0.0084870 0.0064092 0.0396775  2.7151  0.006625 **
## Tau2_4_4   0.0301790 0.0104189 0.0097583 0.0505996  2.8966  0.003773 **
## Tau2_5_5   0.0196359 0.0068293 0.0062507 0.0330211  2.8752  0.004037 **
## Tau2_6_6   0.0325412 0.0113591 0.0102778 0.0548045  2.8648  0.004173 **
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Q statistic on the homogeneity of effect sizes: 1425.322
## Degrees of freedom of the Q statistic: 114
## P value of the Q statistic: 0
##
## Heterogeneity indices (based on the estimated Tau2):
##                               Estimate
## Intercept1: I2 (Q statistic)    0.9221
## Intercept2: I2 (Q statistic)    0.9133
## Intercept3: I2 (Q statistic)    0.9152
## Intercept4: I2 (Q statistic)    0.9420
## Intercept5: I2 (Q statistic)    0.9339
## Intercept6: I2 (Q statistic)    0.9564
##
## Number of studies (or clusters): 20
## Number of observed statistics: 120
## Number of estimated parameters: 12
## Degrees of freedom: 108
## -2 log likelihood: -80.71655
## OpenMx status1: 0 ("0" or "1": The optimization is considered fine.
## Other values may indicate problems.)
```

```
## Average correlation matrix under a random-effects model
averageR <- vec2symMat(coef(random1, select="fixed"), diag = FALSE)
dimnames(averageR) <- list(obs.vars3, obs.vars3)
averageR
```

```
##           Cap       Int       Beh        PB
## Cap 1.0000000 0.5493203 0.3646155 0.3833904
## Int 0.5493203 1.0000000 0.4911759 0.5612951
## Beh 0.3646155 0.4911759 1.0000000 0.5560411
## PB  0.3833904 0.5612951 0.5560411 1.0000000
```

```
## Heterogeneity variances of the random-effects
coef(random1, select="random")
```

```
##   Tau2_1_1   Tau2_2_2   Tau2_3_3   Tau2_4_4   Tau2_5_5   Tau2_6_6
## 0.01791744 0.02483116 0.02304334 0.03017898 0.01963589 0.03254117
```

Stage 2 analysis

```
RAM3 <- lavaan2RAM(model3, obs.variables=obs.vars3)
RAM3
```

```
## $A
##     Cap   Int   Beh PB
## Cap "0"   "0"   "0" "0*a"
## Int "0*b" "0"   "0" "0*d"
## Beh "0*e" "0*c" "0" "0*f"
## PB  "0"   "0"   "0" "0"
##
## $S
##     Cap             Int             Beh             PB
## Cap "0*CapWITHCap" "0"             "0"             "0"
## Int "0"             "0*IntWITHInt" "0"             "0"
```

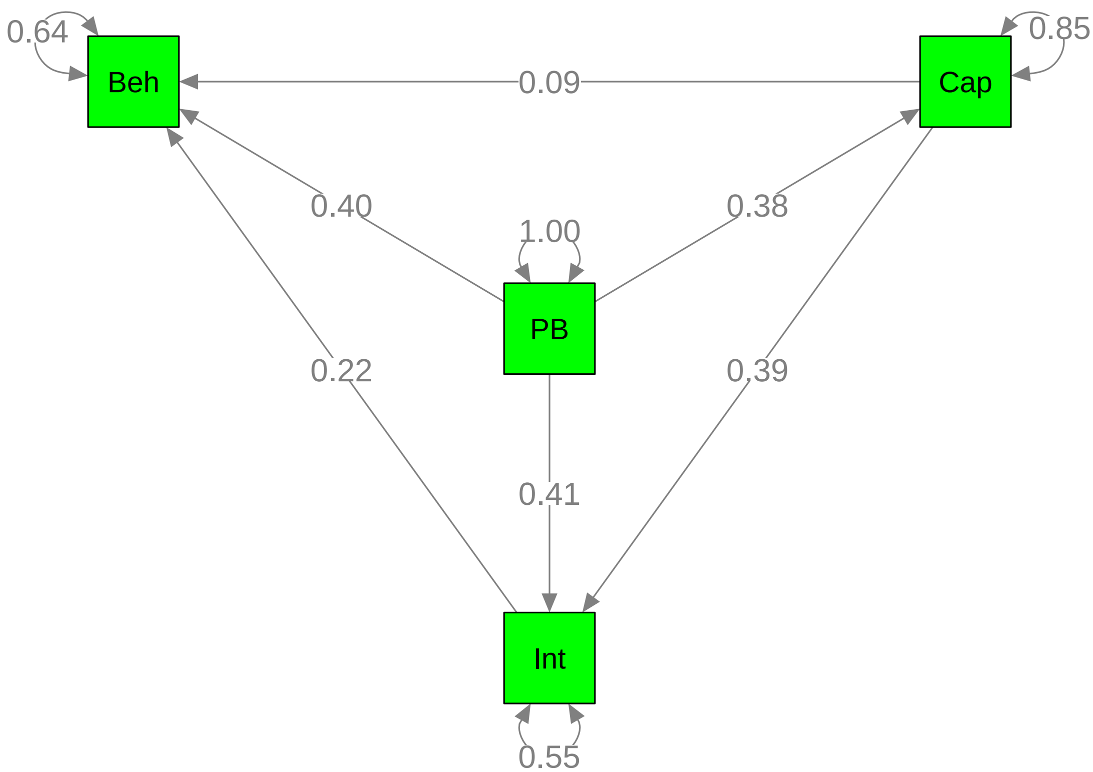
```
## Beh "0"            "0"            "0*BehWITHBeh" "0"
## PB  "0"            "0"            "0"            "1"
##
## $F
##     Cap Int Beh PB
## Cap   1   0   0  0
## Int   0   1   0  0
## Beh   0   0   1  0
## PB    0   0   0  1
##
## $M
##   Cap Int Beh PB
## 1   0   0   0  0
```

```
tssem.fit <- tssem2(random1, RAM=RAM3, intervals.type = "LB",
                    mx.algebras = list(Ind_CapInt=mxAlgebra(a*b*c, name="Ind_CapInt"),
                                       Ind_Cap=mxAlgebra(a*e, name="Ind_Cap"),
                                       Ind_Int=mxAlgebra(d*c, name="Ind_Int"),
                                       Dir_PB=mxAlgebra(f, name="Dir_PB")))
summary(tssem.fit)
```

```
##
## Call:
## wls(Cov = pooledS, aCov = aCov, n = tssem1.obj$total.n, RAM = RAM,
##     Amatrix = Amatrix, Smatrix = Smatrix, Fmatrix = Fmatrix,
##     diag.constraints = diag.constraints, cor.analysis = cor.analysis,
##     intervals.type = intervals.type, mx.algebras = mx.algebras,
##     model.name = model.name, suppressWarnings = suppressWarnings,
##     silent = silent, run = run)
##
## 95% confidence intervals: Likelihood-based statistic
## Coefficients:
##    Estimate Std.Error    lbound    ubound z value Pr(>|z|)
## e  0.092868        NA -0.037890  0.219674      NA       NA
## c  0.216138        NA  0.041888  0.381300      NA       NA
## f  0.399119        NA  0.263144  0.534516      NA       NA
## a  0.383390        NA  0.310685  0.456008      NA       NA
## b  0.391700        NA  0.308610  0.471730      NA       NA
## d  0.411121        NA  0.326512  0.493045      NA       NA
##
## mxAlgebras objects (and their 95% likelihood-based CIs):
##                      lbound   Estimate     ubound
## Ind_CapInt[1,1]  0.006078469 0.03245834 0.06309525
## Ind_Cap[1,1]    -0.015368592 0.03560474 0.08264548
## Ind_Int[1,1]     0.017858129 0.08885880 0.15963736
## Dir_PB[1,1]      0.263144219 0.39911921 0.53451622
##
## Goodness-of-fit indices:
##                                             Value
## Sample size                               6207.00
## Chi-square of target model                   0.00
## DF of target model                           0.00
## p value of target model                      0.00
## Number of constraints imposed on "Smatrix"   0.00
## DF manually adjusted                         0.00
```

```
## Chi-square of independence model            903.82
## DF of independence model                        6.00
## RMSEA                                           0.00
## RMSEA lower 95% CI                              0.00
## RMSEA upper 95% CI                              0.00
## SRMR                                            0.00
## TLI                                             -Inf
## CFI                                             1.00
## AIC                                             0.00
## BIC                                             0.00
## OpenMx status1: 0 ("0" or "1": The optimization is considered fine.
## Other values indicate problems.)
```

```
plot(tssem.fit, layout="circle", color="green")
```




```
sessionInfo()
```

```
## R version 4.0.3 (2020-10-10)
## Platform: x86_64-pc-linux-gnu (64-bit)
## Running under: Ubuntu 20.04.2 LTS
##
## Matrix products: default
## BLAS:   /usr/lib/x86_64-linux-gnu/blas/libblas.so.3.9.0
## LAPACK: /usr/lib/x86_64-linux-gnu/lapack/liblapack.so.3.9.0
##
## locale:
##  [1] LC_CTYPE=en_SG.UTF-8       LC_NUMERIC=C
##  [3] LC_TIME=en_SG.UTF-8        LC_COLLATE=en_SG.UTF-8
##  [5] LC_MONETARY=en_SG.UTF-8    LC_MESSAGES=en_SG.UTF-8
##  [7] LC_PAPER=en_SG.UTF-8       LC_NAME=C
##  [9] LC_ADDRESS=C               LC_TELEPHONE=C
```

```
## [11] LC_MEASUREMENT=en_SG.UTF-8 LC_IDENTIFICATION=C
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
## [1] metaSEM_1.2.5.1 OpenMx_2.19.5
##
## loaded via a namespace (and not attached):
##  [1] nlme_3.1-152        RColorBrewer_1.1-2  mi_1.0
##  [4] tools_4.0.3         backports_1.2.1     R6_2.5.0
##  [7] rpart_4.1-15        Hmisc_4.4-1         colorspace_1.4-1
## [10] nnet_7.3-14         tidyselect_1.1.0    gridExtra_2.3
## [13] mnormt_2.0.2        compiler_4.0.3      fdrtool_1.2.15
## [16] qgraph_1.6.9        htmlTable_2.1.0     regsem_1.6.2
## [19] scales_1.1.1        checkmate_2.0.0     psych_2.0.9
## [22] mvtnorm_1.1-1       pbapply_1.4-3       sem_3.1-11
## [25] stringr_1.4.0       digest_0.6.27       pbivnorm_0.6.0
## [28] foreign_0.8-80      minqa_1.2.4         rmarkdown_2.7
## [31] base64enc_0.1-3     jpeg_0.1-8.1        pkgconfig_2.0.3
## [34] htmltools_0.5.0     lme4_1.1-26         lisrelToR_0.1.4
## [37] htmlwidgets_1.5.2   rlang_0.4.10        rstudioapi_0.11
## [40] generics_0.0.2      gtools_3.8.2        dplyr_1.0.2
## [43] zip_2.1.1           magrittr_1.5        Formula_1.2-3
## [46] Matrix_1.2-18       Rcpp_1.0.5          munsell_0.5.0
## [49] abind_1.4-5         rockchalk_1.8.144   lifecycle_0.2.0
## [52] stringi_1.5.3       yaml_2.2.1          carData_3.0-4
## [55] MASS_7.3-53         plyr_1.8.6          matrixcalc_1.0-3
## [58] lavaan_0.6-8        grid_4.0.3          parallel_4.0.3
## [61] crayon_1.3.4        lattice_0.20-41     semPlot_1.1.2
## [64] kutils_1.70         splines_4.0.3       tmvnsim_1.0-2
## [67] knitr_1.30          pillar_1.4.6        igraph_1.2.6
## [70] boot_1.3-25         corpcor_1.6.9       reshape2_1.4.4
## [73] stats4_4.0.3        XML_3.99-0.5        glue_1.4.2
## [76] evaluate_0.14       latticeExtra_0.6-29 data.table_1.13.2
## [79] png_0.1-7           vctrs_0.3.4         nloptr_1.2.2.2
## [82] gtable_0.3.0        purrr_0.3.4         ggplot2_3.3.2
## [85] xfun_0.19           openxlsx_4.2.2      xtable_1.8-4
## [88] coda_0.19-4         Rsolnp_1.16         glasso_1.11
## [91] survival_3.2-7      truncnorm_1.0-8     tibble_3.0.4
## [94] arm_1.11-2          ellipse_0.4.2       cluster_2.1.0
## [97] statmod_1.4.35      ellipsis_0.3.1
```