SEM Growth Models

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```
library(lavaan)
```

```
## This is lavaan 0.5-23.1097
```

```
## lavaan is BETA software! Please report any bugs.
```

```
library(lme4)
```

```
## Loading required package: Matrix
```

```
library(tidyverse)
```

```
## -- Attaching packages ---------------------------------------------------------------------- tidyv
```

```
## ✓ ggplot2 2.2.1     ✓ purrr   0.2.3
## ✓ tibble  1.3.4     ✓ dplyr   0.7.4
## ✓ tidyr   0.7.2     ✓ stringr 1.2.0
## ✓ readr   1.1.1     ✓ forcats 0.2.0
```

```
## -- Conflicts ------------------------------------------------------------------------- tidyverse_c
## x tidyr::expand() masks Matrix::expand()
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(broom)
library(dplyr)
library(psych)
```

```
##
## Attaching package: 'psych'
```

```
## The following objects are masked from 'package:ggplot2':
##
##     %+%, alpha
```

```
## The following object is masked from 'package:lavaan':
##
##     cor2cov
```

```
library(tidyr)
library(merTools)
```

```
## Loading required package: arm
```

```
## Loading required package: MASS
```

```
##
## Attaching package: 'MASS'
```

```
## The following object is masked from 'package:dplyr':
##
##     select
```

```
##
## arm (Version 1.9-3, built: 2016-11-21)
```

```
## Working directory is /Users/elizabethhawkey/ejhawkey
```

```
##
## Attaching package: 'arm'
```

```
## The following objects are masked from 'package:psych':
##
##     logit, rescale, sim
```

```
##
## Attaching package: 'merTools'
```

```
## The following object is masked from 'package:psych':
##
##     ICC
```

```
library(lavaan)
library(semTools)
```

```
##
```

```
## ###############################################################################
```

```
## This is semTools 0.4-14
```

```
## All users of R (or SEM) are invited to submit functions or ideas for functions.
```

```
## ###############################################################################
```

```
##
## Attaching package: 'semTools'
```

```
## The following object is masked from 'package:psych':
##
##     skew
```

```
library(semPlot)

growth_stats <- read.csv(file =  "~/ejhawkey/STATS_resting_state_BRIEF.csv")

#convert variables
growth_stats$T3gecrs_combined_conv <- as.numeric(growth_stats$T3_gecrscombined/100)
growth_stats$T12gecrs_conv  <- as.numeric(growth_stats$T12_gecrs/100)
growth_stats$T14gecrs_conv=growth_stats$T14_gecrs/100
```

1a. Start with a Univariate Growth Model

```
# Global Executive Composite raw scores
# with intercept only
 Intercept.only= ' i=~ 1*T3gecrs_combined_conv + 1*T12gecrs_conv + 1*T14gecrs_conv'
 Intercept.only.fit= growth(Intercept.only, data = growth_stats, missing= "ML")
```

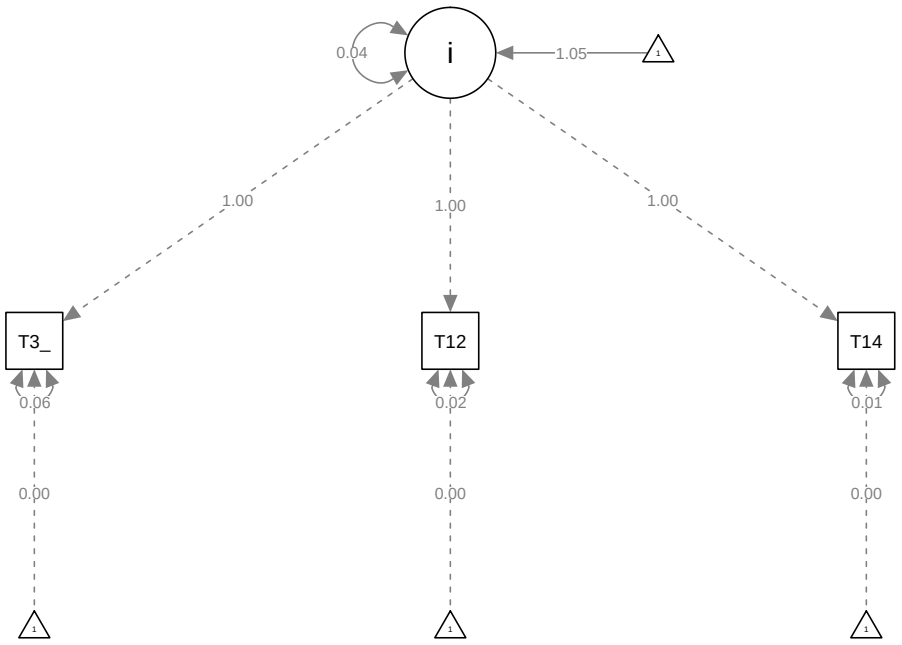
```
## Warning in lav_data_full(data = data, group = group, cluster = cluster, : lavaan WARNING: some cases
##   6 19 21 28 29 34 36 49 52 64 72 81 83 84 86 91 94 103 113 115 141 169 180 187 194 198 199 205 217 2
```

```
 summary (Intercept.only.fit)
```

```
## lavaan (0.5-23.1097) converged normally after  59 iterations
##
##                                                   Used       Total
##   Number of observations                            302         348
##
```

```
##   Number of missing patterns                          7
##
##   Estimator                                          ML
##   Minimum Function Test Statistic                 4.592
##   Degrees of freedom                                  4
##   P-value (Chi-square)                            0.332
##
## Parameter Estimates:
##
##   Information                                 Observed
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i =~
##     T3gcrs_cmbnd_c    1.000
##     T12gecrs_conv     1.000
##     T14gecrs_conv     1.000
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .T3gcrs_cmbnd_c    0.000
##    .T12gecrs_conv     0.000
##    .T14gecrs_conv     0.000
##     i                 1.048    0.015   69.868    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .T3gcrs_cmbnd_c    0.056    0.007    7.891    0.000
##    .T12gecrs_conv     0.018    0.004    4.589    0.000
##    .T14gecrs_conv     0.015    0.004    3.709    0.000
##     i                 0.044    0.005    8.056    0.000
```

```
semPaths(Intercept.only.fit, what = "paths", whatLabels= "est", layout = "tree")
```



```r
# with a fixed slope
 fixed.slope= ' i=~ 1*T3gecrs_combined_conv + 1*T12gecrs_conv + 1*T14gecrs_conv
 s=~ 0*T3gecrs_combined_conv + 1*T12gecrs_conv + 2*T14gecrs_conv
 s ~~ 0*s'  #fixes slope
 fixed.slope.fit= growth(fixed.slope, data = growth_stats, missing= "ML")
```

```
## Warning in lav_data_full(data = data, group = group, cluster = cluster, : lavaan WARNING: some cases
##   6 19 21 28 29 34 36 49 52 64 72 81 83 84 86 91 94 103 113 115 141 169 180 187 194 198 199 205 217 1
```

```
## Warning in lav_object_post_check(object): lavaan WARNING: covariance matrix of latent variables
##                 is not positive definite;
##                 use inspect(fit,"cov.lv") to investigate.
```

```r
 inspect(fixed.slope.fit, "cov.lv")
```

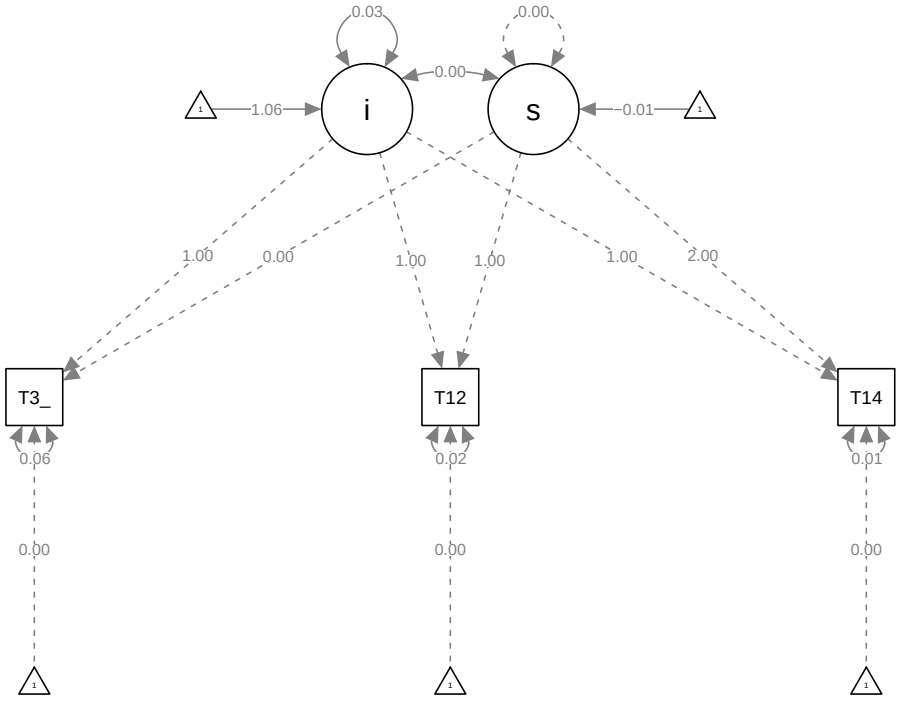
```
##   i     s
## i 0.034
## s 0.005 0.000
```

```r
 summary (fixed.slope.fit)
```

```
## lavaan (0.5-23.1097) converged normally after  44 iterations
##
##                                                   Used       Total
##   Number of observations                            302         348
##
##   Number of missing patterns                          7
##
##   Estimator                                          ML
##   Minimum Function Test Statistic                 1.473
##   Degrees of freedom                                  2
##   P-value (Chi-square)                            0.479
##
## Parameter Estimates:
##
##   Information                                 Observed
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i =~
##     T3gcrs_cmbnd_c    1.000
##     T12gecrs_conv     1.000
##     T14gecrs_conv     1.000
##   s =~
##     T3gcrs_cmbnd_c    0.000
##     T12gecrs_conv     1.000
##     T14gecrs_conv     2.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i ~~
##     s                 0.005    0.003    1.476    0.140
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|)
```

```
##    .T3gcrs_cmbnd_c    0.000
##    .T12gecrs_conv     0.000
##    .T14gecrs_conv     0.000
##     i                 1.057    0.017   61.047    0.000
##     s                -0.011    0.012   -0.941    0.347
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##     s                 0.000
##    .T3gcrs_cmbnd_c    0.061    0.008    7.460    0.000
##    .T12gecrs_conv     0.020    0.004    4.632    0.000
##    .T14gecrs_conv     0.011    0.004    2.531    0.011
##     i                 0.034    0.008    4.053    0.000
```

```
semPaths(fixed.slope.fit, what = "paths", whatLabels= "est", layout = "tree")
```




```
# with a random slope

random.intercept= ' i=~ 1*T3gecrs_combined_conv + 1*T12gecrs_conv + 1*T14gecrs_conv
s=~ -1*T3gecrs_combined_conv + 0*T12gecrs_conv + 1*T14gecrs_conv'
random.intercept.fit= growth(random.intercept, data = growth_stats, missing= "ML")
```

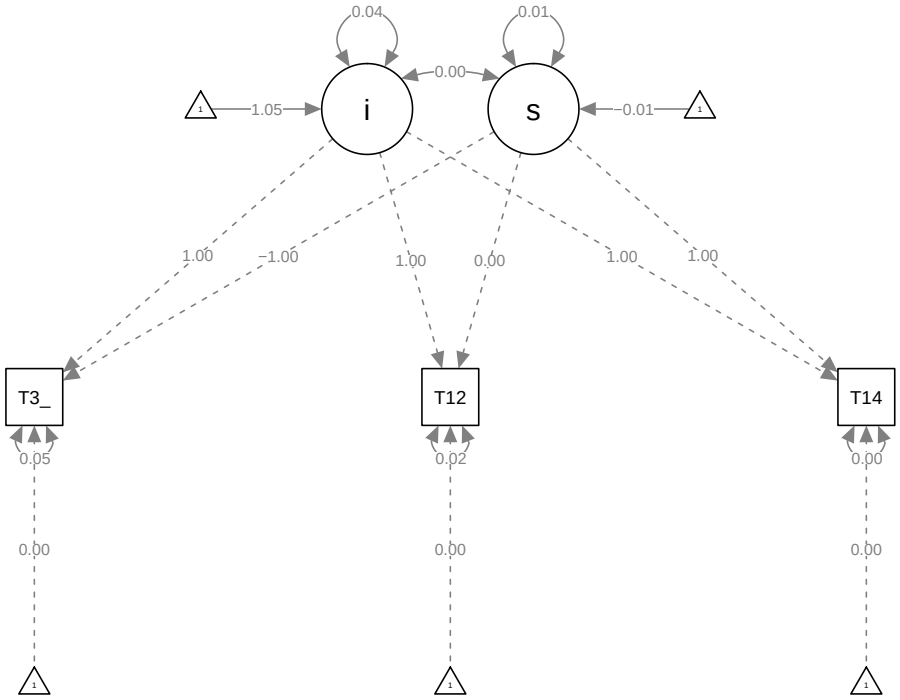
```
## Warning in lav_data_full(data = data, group = group, cluster = cluster, : lavaan WARNING: some cases
##   6 19 21 28 29 34 36 49 52 64 72 81 83 84 86 91 94 103 113 115 141 169 180 187 194 198 199 205 217 2
```

```
summary (random.intercept.fit)
```

```
## lavaan (0.5-23.1097) converged normally after  67 iterations
##
##                                                   Used       Total
##   Number of observations                            302         348
##
##   Number of missing patterns                          7
```

```
##
##   Estimator                                         ML
##   Minimum Function Test Statistic               0.477
##   Degrees of freedom                                1
##   P-value (Chi-square)                          0.490
##
## Parameter Estimates:
##
##   Information                                 Observed
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i =~
##     T3gcrs_cmbnd_c    1.000
##     T12gecrs_conv     1.000
##     T14gecrs_conv     1.000
##   s =~
##     T3gcrs_cmbnd_c   -1.000
##     T12gecrs_conv     0.000
##     T14gecrs_conv     1.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i ~~
##     s                 0.005    0.003    1.471    0.141
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .T3gcrs_cmbnd_c    0.000
##    .T12gecrs_conv     0.000
##    .T14gecrs_conv     0.000
##     i                 1.045    0.015   68.656    0.000
##     s                -0.013    0.012   -1.084    0.278
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .T3gcrs_cmbnd_c    0.053    0.011    4.791    0.000
##    .T12gecrs_conv     0.021    0.005    4.688    0.000
##    .T14gecrs_conv     0.003    0.010    0.264    0.792
##     i                 0.044    0.006    7.739    0.000
##     s                 0.006    0.006    1.000    0.317
```

```
semPaths(random.intercept.fit, what = "paths", whatLabels= "est", layout = "tree")
```




```
# compare models
 anova(Intercept.only.fit, fixed.slope)
```

```
## Chi Square Test Statistic (unscaled)
##
##            Df    AIC    BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## Saturated  0               0.0000
## Model      4 39.036 57.589 4.5922     4.5922       4     0.3318
```

```
 anova(fixed.slope.fit, random.intercept.fit)
```

```
## Chi Square Difference Test
##
##                       Df    AIC    BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## random.intercept.fit   1 40.921 70.604 0.4766
## fixed.slope.fit        2 39.917 65.890 1.4731    0.99658       1     0.3181
```

1b. Multivariate growth curves - start with this first (just using indicators - no latent variables)

As a rule of thumb you need at least three indicators for each latent variable.

```
## lavaan (0.5-23.1097) converged normally after 129 iterations
##
##                                                   Used       Total
##   Number of observations                            310         348
##
##   Number of missing patterns                         44
```

```
##
##   Estimator                                         ML
##   Minimum Function Test Statistic               6.070
##   Degrees of freedom                                7
##   P-value (Chi-square)                          0.532
##
## Parameter Estimates:
##
##   Information                                 Observed
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i.behavior =~
##     T3gcrs_cmbnd_c    1.000
##     T12gecrs_conv     1.000
##     T14gecrs_conv     1.000
##   s.behavior =~
##     T3gcrs_cmbnd_c    0.000
##     T12gecrs_conv     1.000
##     T14gecrs_conv     2.000
##   i.network =~
##     S1_FPNGEK1to5     1.000
##     S2_FPNGEK1to5     1.000
##     S3_FPNGEK1to5     1.000
##   s.network =~
##     S1_FPNGEK1to5     0.000
##     S2_FPNGEK1to5     1.000
##     S3_FPNGEK1to5     2.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i.behavior ~~
##     s.behavior       -0.002    0.007   -0.272    0.786
##     i.network        -0.000    0.003   -0.129    0.897
##     s.network        -0.001    0.002   -0.493    0.622
##   s.behavior ~~
##     i.network         0.000    0.002    0.205    0.838
##     s.network         0.000    0.001    0.013    0.990
##   i.network ~~
##     s.network        -0.000    0.001   -0.096    0.923
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .T3gcrs_cmbnd_c    0.000
##    .T12gecrs_conv     0.000
##    .T14gecrs_conv     0.000
##    .S1_FPNGEK1to5     0.000
##    .S2_FPNGEK1to5     0.000
##    .S3_FPNGEK1to5     0.000
##     i.behavior        1.058    0.017   60.666    0.000
##     s.behavior       -0.013    0.012   -1.098    0.272
##     i.network         0.225    0.008   28.585    0.000
##     s.network         0.015    0.005    3.014    0.003
```

```
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .T3gcrs_cmbnd_c    0.052    0.011    4.697    0.000
##    .T12gecrs_conv     0.021    0.005    4.702    0.000
##    .T14gecrs_conv     0.002    0.010    0.158    0.874
##    .S1_FPNGEK1to5     0.006    0.002    2.662    0.008
##    .S2_FPNGEK1to5     0.008    0.001    6.485    0.000
##    .S3_FPNGEK1to5     0.005    0.002    2.641    0.008
##     i.behavior        0.040    0.011    3.824    0.000
##     s.behavior        0.007    0.006    1.081    0.280
##     i.network         0.003    0.002    1.649    0.099
##     s.network         0.000    0.001    0.212    0.832
```

```
##                    name idx nobs    type exo user  mean   var nlev lnam
## 1 T3gecrs_combined_conv 409  247 numeric   0    0 1.057 0.094    0
## 2         T12gecrs_conv 410  162 numeric   0    0 1.052 0.066    0
## 3         T14gecrs_conv 411   97 numeric   0    0 1.024 0.062    0
## 4         S1_FPNGEK1to5 339  124 numeric   0    0 0.231 0.009    0
## 5         S2_FPNGEK1to5 343  142 numeric   0    0 0.236 0.011    0
## 6         S3_FPNGEK1to5 401  132 numeric   0    0 0.258 0.009    0
```

```
## $lambda
##                       i.bhvr s.bhvr i.ntwr s.ntwr
## T3gecrs_combined_conv      0      0      0      0
## T12gecrs_conv              0      0      0      0
## T14gecrs_conv              0      0      0      0
## S1_FPNGEK1to5              0      0      0      0
## S2_FPNGEK1to5              0      0      0      0
## S3_FPNGEK1to5              0      0      0      0
##
## $theta
##                       T3gc__ T12gc_ T14gc_ S1_FPN S2_FPN S3_FPN
## T3gecrs_combined_conv 1
## T12gecrs_conv         0      2
## T14gecrs_conv         0      0      3
## S1_FPNGEK1to5         0      0      0      4
## S2_FPNGEK1to5         0      0      0      0      5
## S3_FPNGEK1to5         0      0      0      0      0      6
##
## $psi
##            i.bhvr s.bhvr i.ntwr s.ntwr
## i.behavior  7
## s.behavior 11      8
## i.network  12     14      9
## s.network  13     15     16     10
##
## $nu
##                       intrcp
## T3gecrs_combined_conv      0
## T12gecrs_conv              0
## T14gecrs_conv              0
## S1_FPNGEK1to5              0
## S2_FPNGEK1to5              0
## S3_FPNGEK1to5              0
```

```
##
## $alpha
##             intrcp
## i.behavior      17
## s.behavior      18
## i.network       19
## s.network       20
```

2a. Second order growth models - on BRIEF (using BRIEF composite scores (GEC = BRI + MI)

Begin with a simple CFA to determine if latent variable is appropriate

```
#BRIEF: Behavioral Regulation Index
BRI.model <- ' BRI.T3 =~ T3_inhibrs + T3_shftrs + T3_emcnrs '
fit= cfa(BRI.model, data=growth_stats, missing= "ML")
##Options: std.lv = TRUE: standardizes latent var. (but not your results) uses fixed factor method
summary(fit, fit.measures=TRUE)
```

```
## lavaan (0.5-23.1097) converged normally after  42 iterations
##
##                                                   Used       Total
##   Number of observations                             67         348
##
##   Number of missing patterns                          1
##
##   Estimator                                          ML
##   Minimum Function Test Statistic                 0.000
##   Degrees of freedom                                  0
##
## Model test baseline model:
##
##   Minimum Function Test Statistic                99.389
##   Degrees of freedom                                  3
##   P-value                                         0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                     1.000
##   Tucker-Lewis Index (TLI)                        1.000
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)                -563.818
##   Loglikelihood unrestricted model (H1)        -563.818
##
##   Number of free parameters                           9
##   Akaike (AIC)                                 1145.636
##   Bayesian (BIC)                               1165.479
```

```
##   Sample-size adjusted Bayesian (BIC)         1137.141
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.000
##   90 Percent Confidence Interval          0.000  0.000
##   P-value RMSEA <= 0.05                             NA
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.000
##
## Parameter Estimates:
##
##   Information                                 Observed
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   BRI.T3 =~
##     T3_inhibrs        1.000
##     T3_shftrs         0.691    0.112    6.167    0.000
##     T3_emcnrs         1.409    0.227    6.210    0.000
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .T3_inhibrs       18.731    0.717   26.128    0.000
##    .T3_shftrs        14.194    0.464   30.590    0.000
##    .T3_emcnrs        19.045    0.736   25.870    0.000
##     BRI.T3            0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .T3_inhibrs       16.907    3.474    4.867    0.000
##    .T3_shftrs         6.056    1.379    4.392    0.000
##    .T3_emcnrs         1.510    3.743    0.404    0.687
##     BRI.T3           17.529    5.514    3.179    0.001
```

2b. Build second order growth models

```
sec.order <- '
###define latent variables
BRI_T3 =~ NA*T3_inhibrs + L1*T3_inhibrs + L2*T3_shftrs + L3*T3_emcnrs
BRI_T12 =~ NA*T12_inhibrs + L1*T12_inhibrs + L2*T12_shftrs + L3*T12_emcnrs
BRI_T14 =~ NA*T14_inhibrs + L1*T14_inhibrs + L2*T14_shftrs + L3*T14_emcnrs


### intercepts
T3_inhibrs ~ t1*1
T3_shftrs ~ t2*1
T3_emcnrs ~ t3*1
```

```
T12_inhibrs ~ t1*1
T12_shftrs ~ t2*1
T12_emcnrs ~ t3*1

T14_inhibrs ~ t1*1
T14_shftrs ~ t2*1
T14_emcnrs ~ t3*1

#this is setting the means equal across waves

## correlated residuals across time
T3_inhibrs ~~ T12_inhibrs + T14_inhibrs
T12_inhibrs ~~ T14_inhibrs
T3_shftrs ~~ T12_shftrs + T14_shftrs
T12_shftrs ~~ T14_shftrs
T3_emcnrs ~~ T12_emcnrs + T14_emcnrs
T12_emcnrs ~~ T14_emcnrs

## latent variable intercepts
BRI_T3 ~ 0*1
BRI_T12 ~ 0*1
BRI_T14 ~ 0*1

#model constraints for effect coding
## loadings must average to 1 (the three here changes to how many indicators you have; so change this ba
L1 == 2 - L2
## means of indicators must average to 0 (in terms of the indicator means; )
t1 == 0 - t2

#the intercept and slope done with effect coding will give you the actual metric from your indicator va

#final step is the normal growth model
i =~ 1*BRI_T3 + 1*BRI_T12 + 1*BRI_T14
s =~ 0*BRI_T3 + 1*BRI_T12 + 2*BRI_T14 '

fit.sec.order <- growth(sec.order, data=growth_stats, missing = "ML")
```

```
## Warning in lav_data_full(data = data, group = group, cluster = cluster, : lavaan WARNING: some cases
##   1 4 6 8 9 11 13 15 19 21 22 25 27 28 29 31 33 34 36 37 38 39 40 41 45 48 49 51 52 53 54 55 56 57 5
```

```
## Warning in lav_data_full(data = data, group = group, cluster = cluster, :
## lavaan WARNING: due to missing values, some pairwise combinations have less
## than 10% coverage
```

```
## Warning in lav_object_post_check(object): lavaan WARNING: some estimated lv
## variances are negative
```

```
## Warning in lav_object_post_check(object): lavaan WARNING: the covariance matrix of the residuals of
##                 variables (theta) is not positive definite;
##                 use inspect(fit,"theta") to investigate.
```

```
summary(fit.sec.order, fit.measures=TRUE)
```

```
## lavaan (0.5-23.1097) converged normally after 173 iterations
##
##                                                   Used       Total
```

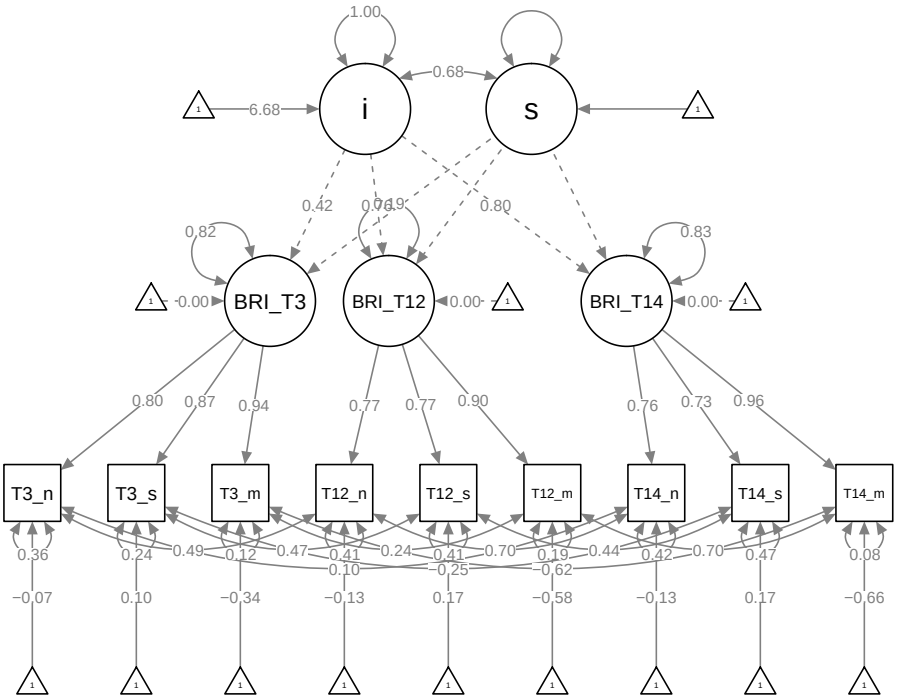
```
##   Number of observations                           205         348
##
##   Number of missing patterns                         7
##
##   Estimator                                         ML
##   Minimum Function Test Statistic               77.404
##   Degrees of freedom                                24
##   P-value (Chi-square)                           0.000
##
## Model test baseline model:
##
##   Minimum Function Test Statistic              680.471
##   Degrees of freedom                                36
##   P-value                                        0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.917
##   Tucker-Lewis Index (TLI)                       0.876
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -2380.070
##   Loglikelihood unrestricted model (H1)      -2341.368
##
##   Number of free parameters                         30
##   Akaike (AIC)                                4820.139
##   Bayesian (BIC)                              4919.830
##   Sample-size adjusted Bayesian (BIC)         4824.779
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.104
##   90 Percent Confidence Interval          0.079  0.131
##   P-value RMSEA <= 0.05                          0.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.189
##
## Parameter Estimates:
##
##   Information                                 Observed
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   BRI_T3 =~
##     T3_inhbrs (L1)    1.137    0.033   34.328    0.000
##     T3_shftrs (L2)    0.863    0.033   26.059    0.000
##     T3_emcnrs (L3)    1.341    0.067   19.986    0.000
##   BRI_T12 =~
##     T12_nhbrs (L1)    1.137    0.033   34.328    0.000
##     T12_shftr (L2)    0.863    0.033   26.059    0.000
```

```
##     T12_mcnrs (L3)    1.341    0.067   19.986    0.000
##   BRI_T14 =~
##     T14_nhbrs (L1)    1.137    0.033   34.328    0.000
##     T14_shftr (L2)    0.863    0.033   26.059    0.000
##     T14_mcnrs (L3)    1.341    0.067   19.986    0.000
##   i =~
##     BRI_T3            1.000
##     BRI_T12           1.000
##     BRI_T14           1.000
##   s =~
##     BRI_T3            0.000
##     BRI_T12           1.000
##     BRI_T14           2.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##  .T3_inhibrs ~~
##    .T12_inhibrs       4.908    1.571    3.124    0.002
##    .T14_inhibrs       0.953    2.627    0.363    0.717
##  .T12_inhibrs ~~
##    .T14_inhibrs       4.287    0.837    5.124    0.000
##  .T3_shftrs ~~
##    .T12_shftrs        2.014    0.752    2.680    0.007
##    .T14_shftrs       -1.146    0.995   -1.152    0.249
##  .T12_shftrs ~~
##    .T14_shftrs        1.648    0.527    3.124    0.002
##  .T3_emcnrs ~~
##    .T12_emcnrs        0.949    1.346    0.705    0.481
##    .T14_emcnrs       -1.424    1.283   -1.110    0.267
##  .T12_emcnrs ~~
##    .T14_emcnrs        1.162    0.620    1.876    0.061
##   i ~~
##     s                 2.367    1.671    1.417    0.157
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .T3_inhbrs (t1)   -0.491    0.420   -1.168    0.243
##    .T3_shftrs (t2)    0.491    0.420    1.168    0.243
##    .T3_emcnrs (t3)   -2.289    0.841   -2.720    0.007
##    .T12_nhbrs (t1)   -0.491    0.420   -1.168    0.243
##    .T12_shftr (t2)    0.491    0.420    1.168    0.243
##    .T12_mcnrs (t3)   -2.289    0.841   -2.720    0.007
##    .T14_nhbrs (t1)   -0.491    0.420   -1.168    0.243
##    .T14_shftr (t2)    0.491    0.420    1.168    0.243
##    .T14_mcnrs (t3)   -2.289    0.841   -2.720    0.007
##     BRI_T3            0.000
##     BRI_T12           0.000
##     BRI_T14           0.000
##     i                13.277    0.356   37.302    0.000
##     s                -0.915    0.196   -4.681    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .T3_inhibrs       16.007    3.332    4.805    0.000
```

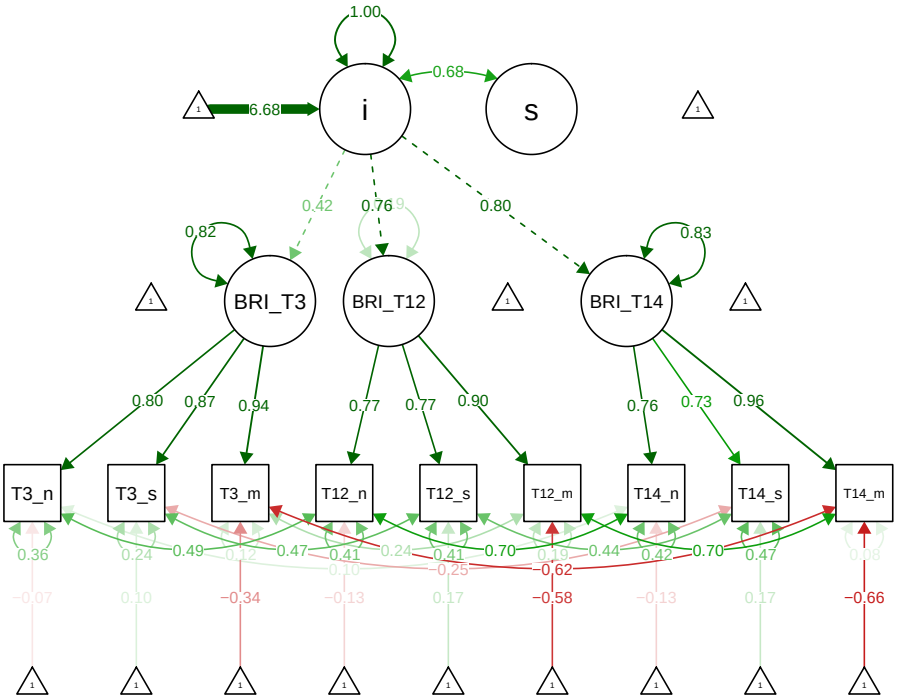
```
##    .T3_shftrs         5.298    1.282    4.131    0.000
##    .T3_emcnrs         5.594    2.388    2.342    0.019
##    .T12_inhibrs       6.317    0.904    6.989    0.000
##    .T12_shftrs        3.527    0.513    6.876    0.000
##    .T12_emcnrs        2.881    0.791    3.643    0.000
##    .T14_inhibrs       5.870    1.075    5.462    0.000
##    .T14_shftrs        4.034    0.677    5.960    0.000
##    .T14_emcnrs        0.947    0.725    1.306    0.192
##     BRI_T3           18.434    4.566    4.038    0.000
##     BRI_T12           1.314    1.073    1.225    0.221
##     BRI_T14           5.078    2.210    2.298    0.022
##     i                 3.950    2.990    1.321    0.186
##     s                -3.088    1.567   -1.971    0.049
##
## Constraints:
##                                                |Slack|
##     L1 - (2-L2)                                  0.000
##     t1 - (0-t2)                                  0.000
```

```
#josh's code
#fit.sec.order <- growth(sec.order, data=long, missing = "ML")
#summary(fit.sec.order, fit.measures=TRUE)
```

Semplots



Semplots


1.00
0.68
6.68
i
s
0.42
0.76
0.80
0.82
0.83
BRI_T3
BRI_T12
BRI_T14
0.80
0.87
0.94
0.77
0.77
0.90
0.76
0.73
0.96
T3_n
T3_s
T3_m
T12_n
T12_s
T12_m
T14_n
T14_s
T14_m
0.36
0.24
0.49
0.47
0.41
0.24
0.41
0.70
0.44
0.42
0.70
0.47
−0.07
0.10
−0.34
−0.13
0.17
−0.58
−0.13
0.17
−0.66

For longitudinal models, occasion specific variance can lead to biased estimates. We want to separate the time specific variance from the overall construct variance. Or, we want to make sure that the time specific variance doesn't make it appear that a construct is changing when really it is not.

Second-order growth models add a second level of latent variables representing a latent construct measured by multiple items at each time point

The factor loading ( ) for each item is interpreted as a regression slope relating the observed score to the latent construct. Loadings represent the amount of change in the observed score given a one unit change in the amount of the latent construct. Item intercepts ( ) represent the value of the observed score on an item when the value of the latent construct is zero.

In order to identify the measurement part of the model, one indicator at each time point is

designated the scale indicator. The loadings of the scale indicators are set to one and the intercepts are set to zero. This sets the metric of the latent variable equal to the metric of the scale indicator. Intercepts for the remaining indicators are obtained by regressing the variables on the constant 1 (represented by a triangle).