SEM

Brent Rappaport

October 30, 2017

Load in data

```
data_wide <- read.csv("/Users/BrentRappaport/Box Sync/WashU/Classes/Longtudinal Methods/1-descriptives-a
data_wide <- data_wide[,-1]

#Make sex_01 a binary variable where 0=Male and 1=Female
data_wide$sex_01 <- data_wide$sex-1

#Make sex_c a factor variable
data_wide$sex_c <- ifelse(data_wide$sex_01==0,"Male","Female")
data_wide$sex_c <- as.factor(data_wide$sex_c)

#Center SES
data_wide$T1Income_to_Need_c <- as.numeric(scale(data_wide$T1Income_to_Need, center=T, scale=F))

#Make age0_ a variable of age from beginning of study (relative age to beginning), rather than aboslute
data_wide <- data_wide %>%
  mutate(age0_1 = age_1 - age_1,
         age0_3 = age_3 - age_1,
         age0_5 = age_5 - age_1,
         age0_10 = age_10 - age_1,
         age0_12 = age_12 - age_1,
         age0_14 = age_14 - age_1,
         age0_16 = age_16 - age_1,
         age0_18 = age_18 - age_1)

#Convert data to long form
data_long <- data_wide %>%
  gather(c(-ID,-sex,-sex_01,-sex_c,-T1_ACES_sum,-ethin,-T1Income_to_Need,-T1Income_to_Need_c,-IQ),
         key = "time", value = "value") %>%
  separate(time, into = c("variable", "wave")) %>%
  spread(variable,value)

data_long$wave <- as.integer(data_long$wave)

#sort by id
data_long <- data_long[order(data_long$ID),]
```

Question 1

```
#1. Specify your model: Marker variable approach
mod.1 <- 'peer =~ PPeerScale_1 + TPeerScale_1
          aggression =~ PAggScale_1 + TAggScale_1
          prosocial =~ PProScale_1 + TProScale_1'
```

```r
#2. Fit the model
fit.1 <- cfa(mod.1, data=data_wide)
# other functions include sem, growth, and lavaan. All have different defaults (See below). we will use

#3. Display the summary output
summary(fit.1, fit.measures=TRUE)
```

```
## lavaan (0.5-23.1097) converged normally after  91 iterations
##
##                                                   Used       Total
##   Number of observations                           199         306
##
##   Estimator                                         ML
##   Minimum Function Test Statistic               27.127
##   Degrees of freedom                                 6
##   P-value (Chi-square)                           0.000
##
## Model test baseline model:
##
##   Minimum Function Test Statistic              189.807
##   Degrees of freedom                                15
##   P-value                                        0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.879
##   Tucker-Lewis Index (TLI)                       0.698
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -3427.816
##   Loglikelihood unrestricted model (H1)      -3414.253
##
##   Number of free parameters                         15
##   Akaike (AIC)                                6885.632
##   Bayesian (BIC)                              6935.032
##   Sample-size adjusted Bayesian (BIC)         6887.511
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.133
##   90 Percent Confidence Interval          0.085  0.186
##   P-value RMSEA <= 0.05                          0.004
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.056
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Standard Errors                             Standard
##
## Latent Variables:
```

```
##                    Estimate  Std.Err  z-value  P(>|z|)
##   peer =~
##     PPeerScale_1      1.000
##     TPeerScale_1      1.605    0.340    4.715    0.000
##   aggression =~
##     PAggScale_1       1.000
##     TAggScale_1       1.271    0.324    3.924    0.000
##   prosocial =~
##     PProScale_1       1.000
##     TProScale_1       1.492    0.301    4.954    0.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   peer ~~
##     aggression        4.534    1.404    3.229    0.001
##     prosocial         5.634    1.480    3.807    0.000
##   aggression ~~
##     prosocial         1.594    0.509    3.135    0.002
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .PPeerScale_1     51.229    6.112    8.382    0.000
##    .TPeerScale_1     57.974   10.323    5.616    0.000
##    .PAggScale_1       6.616    1.048    6.311    0.000
##    .TAggScale_1       6.621    1.469    4.507    0.000
##    .PProScale_1       6.406    0.811    7.902    0.000
##    .TProScale_1       6.189    1.265    4.893    0.000
##     peer             15.614    5.432    2.874    0.004
##     aggression        3.281    1.097    2.991    0.003
##     prosocial         2.600    0.805    3.231    0.001
```

```r
#Fixed factor approach
fit.2 <- cfa(mod.1, std.lv=TRUE, data=data_wide)

summary(fit.2, fit.measures=TRUE, standardized=TRUE)
```

```
## lavaan (0.5-23.1097) converged normally after  70 iterations
##
##                                                   Used       Total
##   Number of observations                           199         306
##
##   Estimator                                         ML
##   Minimum Function Test Statistic               27.127
##   Degrees of freedom                                 6
##   P-value (Chi-square)                           0.000
##
## Model test baseline model:
##
##   Minimum Function Test Statistic              189.807
##   Degrees of freedom                                15
##   P-value                                        0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.879
```

```
##   Tucker-Lewis Index (TLI)                       0.698
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -3427.816
##   Loglikelihood unrestricted model (H1)      -3414.253
##
##   Number of free parameters                         15
##   Akaike (AIC)                                6885.632
##   Bayesian (BIC)                              6935.032
##   Sample-size adjusted Bayesian (BIC)         6887.511
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.133
##   90 Percent Confidence Interval          0.085  0.186
##   P-value RMSEA <= 0.05                          0.004
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.056
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   peer =~
##     PPeerScale_1      3.951    0.687    5.749    0.000    3.951    0.483
##     TPeerScale_1      6.341    0.919    6.898    0.000    6.341    0.640
##   aggression =~
##     PAggScale_1       1.811    0.303    5.982    0.000    1.811    0.576
##     TAggScale_1       2.302    0.357    6.442    0.000    2.302    0.667
##   prosocial =~
##     PProScale_1       1.612    0.250    6.461    0.000    1.612    0.537
##     TProScale_1       2.406    0.313    7.683    0.000    2.406    0.695
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   peer ~~
##     aggression        0.633    0.124    5.126    0.000    0.633    0.633
##     prosocial         0.884    0.120    7.351    0.000    0.884    0.884
##   aggression ~~
##     prosocial         0.546    0.115    4.766    0.000    0.546    0.546
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##    .PPeerScale_1     51.229    6.112    8.382    0.000   51.229    0.766
##    .TPeerScale_1     57.974   10.323    5.616    0.000   57.974    0.591
##    .PAggScale_1       6.616    1.048    6.311    0.000    6.616    0.668
##    .TAggScale_1       6.621    1.469    4.507    0.000    6.621    0.556
##    .PProScale_1       6.406    0.811    7.902    0.000    6.406    0.711
```

```
##    .TProScale_1       6.189    1.265    4.893    0.000    6.189    0.517
##     peer              1.000                               1.000    1.000
##     aggression        1.000                               1.000    1.000
##     prosocial         1.000                               1.000    1.000
```

```r
#Effects coding approach
mod.3 <- 'peer =~ NA*PPeerScale_1 + pe1*PPeerScale_1 + pe2*TPeerScale_1
          aggression =~ NA*PAggScale_1 +a1*PAggScale_1 + a2*TAggScale_1
          prosocial =~ NA*PProScale_1 + pr1*PProScale_1 + pr2*TProScale_1

     pe1 == 2 - pe2
     a1 == 2 - a2
     pr1 == 2 - pr2
'

fit.3 <- cfa(mod.3, data=data_wide)
summary(fit.3, fit.measures=TRUE, standardized=TRUE)
```

```
## lavaan (0.5-23.1097) converged normally after  86 iterations
##
##                                                   Used       Total
##   Number of observations                           199         306
##
##   Estimator                                         ML
##   Minimum Function Test Statistic               27.127
##   Degrees of freedom                                 6
##   P-value (Chi-square)                           0.000
##
## Model test baseline model:
##
##   Minimum Function Test Statistic              189.807
##   Degrees of freedom                                15
##   P-value                                        0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.879
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##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -3427.816
##   Loglikelihood unrestricted model (H1)      -3414.253
##
##   Number of free parameters                         15
##   Akaike (AIC)                                6885.632
##   Bayesian (BIC)                              6935.032
##   Sample-size adjusted Bayesian (BIC)         6887.511
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.133
##   90 Percent Confidence Interval          0.085  0.186
##   P-value RMSEA <= 0.05                          0.004
##
```

```
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.056
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   peer =~
##     PPrScl_1 (pe1)    0.768    0.100    7.653    0.000    3.951    0.483
##     TPrScl_1 (pe2)    1.232    0.100   12.280    0.000    6.341    0.640
##   aggression =~
##     PAggSc_1  (a1)    0.881    0.126    7.011    0.000    1.811    0.576
##     TAggSc_1  (a2)    1.119    0.126    8.909    0.000    2.302    0.667
##   prosocial =~
##     PPrScl_1 (pr1)    0.802    0.097    8.273    0.000    1.612    0.537
##     TPrScl_1 (pr2)    1.198    0.097   12.347    0.000    2.406    0.695
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   peer ~~
##     aggression        6.703    1.498    4.475    0.000    0.633    0.633
##     prosocial         9.144    1.534    5.960    0.000    0.884    0.884
##   aggression ~~
##     prosocial         2.256    0.542    4.160    0.000    0.546    0.546
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##    .PPeerScale_1     51.229    6.112    8.382    0.000   51.229    0.766
##    .TPeerScale_1     57.974   10.323    5.616    0.000   57.974    0.591
##    .PAggScale_1       6.616    1.048    6.311    0.000    6.616    0.668
##    .TAggScale_1       6.621    1.469    4.507    0.000    6.621    0.556
##    .PProScale_1       6.406    0.811    7.902    0.000    6.406    0.711
##    .TProScale_1       6.189    1.265    4.893    0.000    6.189    0.517
##     peer             26.482    6.249    4.237    0.000    1.000    1.000
##     aggression        4.230    0.837    5.055    0.000    1.000    1.000
##     prosocial         4.038    0.806    5.009    0.000    1.000    1.000
##
## Constraints:
##                                                |Slack|
##     pe1 - (2-pe2)                                0.000
##     a1 - (2-a2)                                  0.000
##     pr1 - (2-pr2)                                0.000
```

```
anova(fit.1,fit.3)
```

```
## Chi Square Difference Test
##
##       Df    AIC  BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit.1  6 6885.6 6935 27.127
## fit.3  6 6885.6 6935 27.127 -1.414e-12       0          1
```

Across the three models, the estimates of the latent variables (or the factor loadings) obviously change, but consistently indicate a larger factor loading teacher report onto the latent variable than parent report. The std.all does not change across models, since it is the standardized indicator of how much variance is being accounted for by the latent variable.

In the fixed factor model, the covariance estimates indicate the correlation between the latent variables, here indicating that the Peer and Prosocial variables are highly correlated (0.884), while Peer and Aggression and Aggression and Prosocial are moderately related (0.633 and 0.546, repectively).

The variance estimates for the latent variables also change. In the first model (marker variable approach), the estimates for the latent variables indicate that they are accounting for substantial variance in the scores. In the second model (fixed factor), the variance estimates are fixed to 1, and the variances of the residuals remains unchanged. In the third model (effects coding), the standarized estimates (std.all) are fixed to 1.

Question 2

The RMSEA is above 0.1 (0.133), indicating a poor fit, however the SRMR is 0.056 indicating an acceptable fit. The CFI and TFI additionally fall below 0.90 at 0.879 and 0.698, respectively, suggesting a less than optimal fit. The model indicates 15 degrees of freedom indicating that is it overidentified (good).

Question 3

```
#Longitudinal CFA
mod.4.full <- '
peer1 =~ PPeerScale_1 + TPeerScale_1
peer2 =~ PPeerScale_3 + TPeerScale_3
peer3 =~ PPeerScale_5 + TPeerScale_5
peer4 =~ PPeerScale_10 + TPeerScale_10
peer5 =~ PPeerScale_12 + TPeerScale_12
peer6 =~ PPeerScale_14 + TPeerScale_14
peer7 =~ PPeerScale_16 + TPeerScale_16
peer8 =~ PPeerScale_18 + TPeerScale_18

agg1 =~ PAggScale_1 + TAggScale_1
agg2 =~ PAggScale_3 + TAggScale_3
agg3 =~ PAggScale_5 + TAggScale_5
agg4 =~ PAggScale_10 + TAggScale_10
agg5 =~ PAggScale_12 + TAggScale_12
agg6 =~ PAggScale_14 + TAggScale_14
agg7 =~ PAggScale_16 + TAggScale_16
agg8 =~ PAggScale_18 + TAggScale_18

pro1 =~ PProScale_1 + TProScale_1
pro2 =~ PProScale_3 + TProScale_3
pro3 =~ PProScale_5 + TProScale_5
pro4 =~ PProScale_10 + TProScale_10
pro5 =~ PProScale_12 + TProScale_12
pro6 =~ PProScale_14 + TProScale_14
pro7 =~ PProScale_16 + TProScale_16
pro8 =~ PProScale_18 + TProScale_18

## correlated residuals across time
PPeerScale_1 ~~ PPeerScale_3 + PPeerScale_5 + PPeerScale_10 + PPeerScale_12 + PPeerScale_14 +
```

```
PPeerScale_16 + PPeerScale_18
PPeerScale_3 ~~ PPeerScale_5 + PPeerScale_10 + PPeerScale_12 + PPeerScale_14 +
PPeerScale_16 + PPeerScale_18
PPeerScale_5 ~~ PPeerScale_10 + PPeerScale_12 + PPeerScale_14 + PPeerScale_16 + PPeerScale_18
PPeerScale_10 ~~ PPeerScale_12 + PPeerScale_14 + PPeerScale_16 + PPeerScale_18
PPeerScale_12 ~~ PPeerScale_14 + PPeerScale_16 + PPeerScale_18
PPeerScale_14 ~~ PPeerScale_16 + PPeerScale_18
PPeerScale_16 ~~ PPeerScale_18

TPeerScale_1 ~~ TPeerScale_3 + TPeerScale_5 + TPeerScale_10 + TPeerScale_12 + TPeerScale_14 +
TPeerScale_16 + TPeerScale_18
TPeerScale_3 ~~ TPeerScale_5 + TPeerScale_10 + TPeerScale_12 + TPeerScale_14 +
TPeerScale_16 + TPeerScale_18
TPeerScale_5 ~~ TPeerScale_10 + TPeerScale_12 + TPeerScale_14 + TPeerScale_16 + TPeerScale_18
TPeerScale_10 ~~ TPeerScale_12 + TPeerScale_14 + TPeerScale_16 + TPeerScale_18
TPeerScale_12 ~~ TPeerScale_14 + TPeerScale_16 + TPeerScale_18
TPeerScale_14 ~~ TPeerScale_16 + TPeerScale_18
TPeerScale_16 ~~ TPeerScale_18

PAggScale_1 ~~ PAggScale_3 + PAggScale_5 + PAggScale_10 + PAggScale_12 + PAggScale_14 +
PAggScale_16 + PAggScale_18
PAggScale_3 ~~ PAggScale_5 + PAggScale_10 + PAggScale_12 + PAggScale_14 +
PAggScale_16 + PAggScale_18
PAggScale_5 ~~ PAggScale_10 + PAggScale_12 + PAggScale_14 + PAggScale_16 + PAggScale_18
PAggScale_10 ~~ PAggScale_12 + PAggScale_14 + PAggScale_16 + PAggScale_18
PAggScale_12 ~~ PAggScale_14 + PAggScale_16 + PAggScale_18
PAggScale_14 ~~ PAggScale_16 + PAggScale_18
PAggScale_16 ~~ PAggScale_18

TAggScale_1 ~~ TAggScale_3 + TAggScale_5 + TAggScale_10 + TAggScale_12 + TAggScale_14 +
TAggScale_16 + TAggScale_18
TAggScale_3 ~~ TAggScale_5 + TAggScale_10 + TAggScale_12 + TAggScale_14 +
TAggScale_16 + TAggScale_18
TAggScale_5 ~~ TAggScale_10 + TAggScale_12 + TAggScale_14 + TAggScale_16 + TAggScale_18
TAggScale_10 ~~ TAggScale_12 + TAggScale_14 + TAggScale_16 + TAggScale_18
TAggScale_12 ~~ TAggScale_14 + TAggScale_16 + TAggScale_18
TAggScale_14 ~~ TAggScale_16 + TAggScale_18
TAggScale_16 ~~ TAggScale_18

PProScale_1 ~~ PProScale_3 + PProScale_5 + PProScale_10 + PProScale_12 + PProScale_14 +
PProScale_16 + PProScale_18
PProScale_3 ~~ PProScale_5 + PProScale_10 + PProScale_12 + PProScale_14 +
PProScale_16 + PProScale_18
PProScale_5 ~~ PProScale_10 + PProScale_12 + PProScale_14 + PProScale_16 + PProScale_18
PProScale_10 ~~ PProScale_12 + PProScale_14 + PProScale_16 + PProScale_18
PProScale_12 ~~ PProScale_14 + PProScale_16 + PProScale_18
PProScale_14 ~~ PProScale_16 + PProScale_18
PProScale_16 ~~ PProScale_18

TProScale_1 ~~ TProScale_3 + TProScale_5 + TProScale_10 + TProScale_12 + TProScale_14 +
TProScale_16 + TProScale_18
TProScale_3 ~~ TProScale_5 + TProScale_10 + TProScale_12 + TProScale_14 +
TProScale_16 + TProScale_18
```

```
TProScale_5 ~~ TProScale_10 + TProScale_12 + TProScale_14 + TProScale_16 + TProScale_18
TProScale_10 ~~ TProScale_12 + TProScale_14 + TProScale_16 + TProScale_18
TProScale_12 ~~ TProScale_14 + TProScale_16 + TProScale_18
TProScale_14 ~~ TProScale_16 + TProScale_18
TProScale_16 ~~ TProScale_18
'

mod.4 <- '
peer1 =~ PPeerScale_1 + TPeerScale_1
peer2 =~ PPeerScale_3 + TPeerScale_3
peer3 =~ PPeerScale_5 + TPeerScale_5
peer4 =~ PPeerScale_10 + TPeerScale_10
peer5 =~ PPeerScale_12 + TPeerScale_12
peer6 =~ PPeerScale_14 + TPeerScale_14

agg1 =~ PAggScale_1 + TAggScale_1
agg2 =~ PAggScale_3 + TAggScale_3
agg3 =~ PAggScale_5 + TAggScale_5
agg4 =~ PAggScale_10 + TAggScale_10
agg5 =~ PAggScale_12 + TAggScale_12
agg6 =~ PAggScale_14 + TAggScale_14

pro1 =~ PProScale_1 + TProScale_1
pro2 =~ PProScale_3 + TProScale_3
pro3 =~ PProScale_5 + TProScale_5
pro4 =~ PProScale_10 + TProScale_10
pro5 =~ PProScale_12 + TProScale_12
pro6 =~ PProScale_14 + TProScale_14

## correlated residuals across time
PPeerScale_1 ~~ PPeerScale_3 + PPeerScale_5 + PPeerScale_10 + PPeerScale_12 + PPeerScale_14
PPeerScale_3 ~~ PPeerScale_5 + PPeerScale_10 + PPeerScale_12 + PPeerScale_14
PPeerScale_5 ~~ PPeerScale_10 + PPeerScale_12 + PPeerScale_14
PPeerScale_10 ~~ PPeerScale_12 + PPeerScale_14
PPeerScale_12 ~~ PPeerScale_14

TPeerScale_1 ~~ TPeerScale_3 + TPeerScale_5 + TPeerScale_10 + TPeerScale_12 + TPeerScale_14
TPeerScale_3 ~~ TPeerScale_5 + TPeerScale_10 + TPeerScale_12 + TPeerScale_14
TPeerScale_5 ~~ TPeerScale_10 + TPeerScale_12 + TPeerScale_14
TPeerScale_10 ~~ TPeerScale_12 + TPeerScale_14
TPeerScale_12 ~~ TPeerScale_14

PAggScale_1 ~~ PAggScale_3 + PAggScale_5 + PAggScale_10 + PAggScale_12 + PAggScale_14
PAggScale_3 ~~ PAggScale_5 + PAggScale_10 + PAggScale_12 + PAggScale_14
PAggScale_5 ~~ PAggScale_10 + PAggScale_12 + PAggScale_14
PAggScale_10 ~~ PAggScale_12 + PAggScale_14
PAggScale_12 ~~ PAggScale_14

TAggScale_1 ~~ TAggScale_3 + TAggScale_5 + TAggScale_10 + TAggScale_12 + TAggScale_14
TAggScale_3 ~~ TAggScale_5 + TAggScale_10 + TAggScale_12 + TAggScale_14
TAggScale_5 ~~ TAggScale_10 + TAggScale_12 + TAggScale_14
TAggScale_10 ~~ TAggScale_12 + TAggScale_14
TAggScale_12 ~~ TAggScale_14
```

```
PProScale_1 ~~ PProScale_3 + PProScale_5 + PProScale_10 + PProScale_12 + PProScale_14
PProScale_3 ~~ PProScale_5 + PProScale_10 + PProScale_12 + PProScale_14
PProScale_5 ~~ PProScale_10 + PProScale_12 + PProScale_14
PProScale_10 ~~ PProScale_12 + PProScale_14
PProScale_12 ~~ PProScale_14

TProScale_1 ~~ TProScale_3 + TProScale_5 + TProScale_10 + TProScale_12 + TProScale_14
TProScale_3 ~~ TProScale_5 + TProScale_10 + TProScale_12 + TProScale_14
TProScale_5 ~~ TProScale_10 + TProScale_12 + TProScale_14
TProScale_10 ~~ TProScale_12 + TProScale_14
TProScale_12 ~~ TProScale_14
'

#fit.4 <- cfa(mod.4, data=data_wide, missing="ML", std.lv=TRUE)
#inspect(fit.4,"cov.lv")

#summary(fit.4, standardized=TRUE, fit.measures=TRUE)
```

Received warning that covariance matrix was not positive definite.

```
#Longitudinal cross-lagged model predicting later times by previous times (autoregressive)
mod.5.full <- '
##define latent variables
peer1 =~ L1*PPeerScale_1 + L2*TPeerScale_1
peer2 =~ L1*PPeerScale_3 + L2*TPeerScale_3
peer3 =~ L1*PPeerScale_5 + L2*TPeerScale_5
peer4 =~ L1*PPeerScale_10 + L2*TPeerScale_10
peer5 =~ L1*PPeerScale_12 + L2*TPeerScale_12
peer6 =~ L1*PPeerScale_14 + L2*TPeerScale_14
peer7 =~ L1*PPeerScale_16 + L2*TPeerScale_16
peer8 =~ L1*PPeerScale_18 + L2*TPeerScale_18

agg1 =~ L1*PAggScale_1 + L2*TAggScale_1
agg2 =~ L1*PAggScale_3 + L2*TAggScale_3
agg3 =~ L1*PAggScale_5 + L2*TAggScale_5
agg4 =~ L1*PAggScale_10 + L2*TAggScale_10
agg5 =~ L1*PAggScale_12 + L2*TAggScale_12
agg6 =~ L1*PAggScale_14 + L2*TAggScale_14
agg7 =~ L1*PAggScale_16 + L2*TAggScale_16
agg8 =~ L1*PAggScale_18 + L2*TAggScale_18

pro1 =~ L1*PProScale_1 + L2*TProScale_1
pro2 =~ L1*PProScale_3 + L2*TProScale_3
pro3 =~ L1*PProScale_5 + L2*TProScale_5
pro4 =~ L1*PProScale_10 + L2*TProScale_10
pro5 =~ L1*PProScale_12 + L2*TProScale_12
pro6 =~ L1*PProScale_14 + L2*TProScale_14
pro7 =~ L1*PProScale_16 + L2*TProScale_16
pro8 =~ L1*PProScale_18 + L2*TProScale_18

## free latent variances at later times (only set the scale once)
peer2 ~~ NA*peer2
peer3 ~~ NA*peer3
peer4 ~~ NA*peer4
```

```
peer5 ~~ NA*peer5
peer6 ~~ NA*peer6
peer7 ~~ NA*peer7
peer8 ~~ NA*peer8

agg2 ~~ NA*agg2
agg3 ~~ NA*agg3
agg4 ~~ NA*agg4
agg5 ~~ NA*agg5
agg6 ~~ NA*agg6
agg7 ~~ NA*agg7
agg8 ~~ NA*agg8

pro2 ~~ NA*pro2
pro3 ~~ NA*pro3
pro4 ~~ NA*pro4
pro5 ~~ NA*pro5
pro6 ~~ NA*pro6
pro7 ~~ NA*pro7
pro8 ~~ NA*pro8

peer1 ~~ agg1 + pro1
agg1 ~~ pro1
peer2 ~~ agg2 + pro2
agg2 ~~ pro2
peer3 ~~ agg3 + pro3
agg3 ~~ pro3
peer4 ~~ agg4 + pro4
agg4 ~~ pro4
peer5 ~~ agg5 + pro5
agg5 ~~ pro5
peer6 ~~ agg6 + pro6
agg6 ~~ pro6
peer7 ~~ agg7 + pro7
agg7 ~~ pro7
peer8 ~~ agg8 + pro8
agg8 ~~ pro8

## directional regression paths
peer2 ~ peer1 + agg1 + pro1
agg2 ~ peer1 + agg1 + pro1
pro2 ~ peer1 + agg1 + pro1

peer3 ~ peer2 + agg2 + pro2
agg3 ~ peer2 + agg2 + pro2
pro3 ~ peer2 + agg2 + pro2

peer4 ~ peer3 + agg3 + pro3
agg4 ~ peer3 + agg3 + pro3
pro4 ~ peer3 + agg3 + pro3

peer5 ~ peer4 + agg4 + pro4
agg5 ~ peer4 + agg4 + pro4
```

```
pro5 ~ peer4 + agg4 + pro4

peer6 ~ peer5 + agg5 + pro5
agg6 ~ peer5 + agg5 + pro5
pro6 ~ peer5 + agg5 + pro5

peer7 ~ peer6 + agg6 + pro6
agg7 ~ peer6 + agg6 + pro6
pro7 ~ peer6 + agg6 + pro6

peer8 ~ peer7 + agg7 + pro7
agg8 ~ peer7 + agg7 + pro7
pro8 ~ peer7 + agg7 + pro7

## correlated residuals across time
PPeerScale_1 ~~ PPeerScale_3 + PPeerScale_5 + PPeerScale_10 + PPeerScale_12 + PPeerScale_14 +
PPeerScale_16 + PPeerScale_18
PPeerScale_3 ~~ PPeerScale_5 + PPeerScale_10 + PPeerScale_12 + PPeerScale_14 +
PPeerScale_16 + PPeerScale_18
PPeerScale_5 ~~ PPeerScale_10 + PPeerScale_12 + PPeerScale_14 + PPeerScale_16 + PPeerScale_18
PPeerScale_10 ~~ PPeerScale_12 + PPeerScale_14 + PPeerScale_16 + PPeerScale_18
PPeerScale_12 ~~ PPeerScale_14 + PPeerScale_16 + PPeerScale_18
PPeerScale_14 ~~ PPeerScale_16 + PPeerScale_18
PPeerScale_16 ~~ PPeerScale_18

TPeerScale_1 ~~ TPeerScale_3 + TPeerScale_5 + TPeerScale_10 + TPeerScale_12 + TPeerScale_14 +
TPeerScale_16 + TPeerScale_18
TPeerScale_3 ~~ TPeerScale_5 + TPeerScale_10 + TPeerScale_12 + TPeerScale_14 +
TPeerScale_16 + TPeerScale_18
TPeerScale_5 ~~ TPeerScale_10 + TPeerScale_12 + TPeerScale_14 + TPeerScale_16 + TPeerScale_18
TPeerScale_10 ~~ TPeerScale_12 + TPeerScale_14 + TPeerScale_16 + TPeerScale_18
TPeerScale_12 ~~ TPeerScale_14 + TPeerScale_16 + TPeerScale_18
TPeerScale_14 ~~ TPeerScale_16 + TPeerScale_18
TPeerScale_16 ~~ TPeerScale_18

PAggScale_1 ~~ PAggScale_3 + PAggScale_5 + PAggScale_10 + PAggScale_12 + PAggScale_14 +
PAggScale_16 + PAggScale_18
PAggScale_3 ~~ PAggScale_5 + PAggScale_10 + PAggScale_12 + PAggScale_14 +
PAggScale_16 + PAggScale_18
PAggScale_5 ~~ PAggScale_10 + PAggScale_12 + PAggScale_14 + PAggScale_16 + PAggScale_18
PAggScale_10 ~~ PAggScale_12 + PAggScale_14 + PAggScale_16 + PAggScale_18
PAggScale_12 ~~ PAggScale_14 + PAggScale_16 + PAggScale_18
PAggScale_14 ~~ PAggScale_16 + PAggScale_18
PAggScale_16 ~~ PAggScale_18

TAggScale_1 ~~ TAggScale_3 + TAggScale_5 + TAggScale_10 + TAggScale_12 + TAggScale_14 +
TAggScale_16 + TAggScale_18
TAggScale_3 ~~ TAggScale_5 + TAggScale_10 + TAggScale_12 + TAggScale_14 +
TAggScale_16 + TAggScale_18
TAggScale_5 ~~ TAggScale_10 + TAggScale_12 + TAggScale_14 + TAggScale_16 + TAggScale_18
TAggScale_10 ~~ TAggScale_12 + TAggScale_14 + TAggScale_16 + TAggScale_18
TAggScale_12 ~~ TAggScale_14 + TAggScale_16 + TAggScale_18
TAggScale_14 ~~ TAggScale_16 + TAggScale_18
```

```
TAggScale_16 ~~ TAggScale_18

PProScale_1 ~~ PProScale_3 + PProScale_5 + PProScale_10 + PProScale_12 + PProScale_14 +
PProScale_16 + PProScale_18
PProScale_3 ~~ PProScale_5 + PProScale_10 + PProScale_12 + PProScale_14 +
PProScale_16 + PProScale_18
PProScale_5 ~~ PProScale_10 + PProScale_12 + PProScale_14 + PProScale_16 + PProScale_18
PProScale_10 ~~ PProScale_12 + PProScale_14 + PProScale_16 + PProScale_18
PProScale_12 ~~ PProScale_14 + PProScale_16 + PProScale_18
PProScale_14 ~~ PProScale_16 + PProScale_18
PProScale_16 ~~ PProScale_18

TProScale_1 ~~ TProScale_3 + TProScale_5 + TProScale_10 + TProScale_12 + TProScale_14 +
TProScale_16 + TProScale_18
TProScale_3 ~~ TProScale_5 + TProScale_10 + TProScale_12 + TProScale_14 +
TProScale_16 + TProScale_18
TProScale_5 ~~ TProScale_10 + TProScale_12 + TProScale_14 + TProScale_16 + TProScale_18
TProScale_10 ~~ TProScale_12 + TProScale_14 + TProScale_16 + TProScale_18
TProScale_12 ~~ TProScale_14 + TProScale_16 + TProScale_18
TProScale_14 ~~ TProScale_16 + TProScale_18
TProScale_16 ~~ TProScale_18
'

mod.5 <- '
##define latent variables
peer1 =~ L1*PPeerScale_1 + L2*TPeerScale_1
peer2 =~ L1*PPeerScale_3 + L2*TPeerScale_3
peer3 =~ L1*PPeerScale_5 + L2*TPeerScale_5
peer4 =~ L1*PPeerScale_10 + L2*TPeerScale_10
peer5 =~ L1*PPeerScale_12 + L2*TPeerScale_12
peer6 =~ L1*PPeerScale_14 + L2*TPeerScale_14

agg1 =~ L1*PAggScale_1 + L2*TAggScale_1
agg2 =~ L1*PAggScale_3 + L2*TAggScale_3
agg3 =~ L1*PAggScale_5 + L2*TAggScale_5
agg4 =~ L1*PAggScale_10 + L2*TAggScale_10
agg5 =~ L1*PAggScale_12 + L2*TAggScale_12
agg6 =~ L1*PAggScale_14 + L2*TAggScale_14

pro1 =~ L1*PProScale_1 + L2*TProScale_1
pro2 =~ L1*PProScale_3 + L2*TProScale_3
pro3 =~ L1*PProScale_5 + L2*TProScale_5
pro4 =~ L1*PProScale_10 + L2*TProScale_10
pro5 =~ L1*PProScale_12 + L2*TProScale_12
pro6 =~ L1*PProScale_14 + L2*TProScale_14

## free latent variances at later times (only set the scale once)
peer2 ~~ NA*peer2
peer3 ~~ NA*peer3
peer4 ~~ NA*peer4
peer5 ~~ NA*peer5
peer6 ~~ NA*peer6
```

```
agg2 ~~ NA*agg2
agg3 ~~ NA*agg3
agg4 ~~ NA*agg4
agg5 ~~ NA*agg5
agg6 ~~ NA*agg6

pro2 ~~ NA*pro2
pro3 ~~ NA*pro3
pro4 ~~ NA*pro4
pro5 ~~ NA*pro5
pro6 ~~ NA*pro6

peer1 ~~ agg1 + pro1
agg1 ~~ pro1
peer2 ~~ agg2 + pro2
agg2 ~~ pro2
peer3 ~~ agg3 + pro3
agg3 ~~ pro3
peer4 ~~ agg4 + pro4
agg4 ~~ pro4
peer5 ~~ agg5 + pro5
agg5 ~~ pro5
peer6 ~~ agg6 + pro6
agg6 ~~ pro6

## directional regression paths
peer2 ~ peer1 + agg1 + pro1
agg2 ~ peer1 + agg1 + pro1
pro2 ~ peer1 + agg1 + pro1

peer3 ~ peer2 + agg2 + pro2
agg3 ~ peer2 + agg2 + pro2
pro3 ~ peer2 + agg2 + pro2

peer4 ~ peer3 + agg3 + pro3
agg4 ~ peer3 + agg3 + pro3
pro4 ~ peer3 + agg3 + pro3

peer5 ~ peer4 + agg4 + pro4
agg5 ~ peer4 + agg4 + pro4
pro5 ~ peer4 + agg4 + pro4

peer6 ~ peer5 + agg5 + pro5
agg6 ~ peer5 + agg5 + pro5
pro6 ~ peer5 + agg5 + pro5

## correlated residuals across time
PPeerScale_1 ~~ PPeerScale_3 + PPeerScale_5 + PPeerScale_10 + PPeerScale_12 + PPeerScale_14
PPeerScale_3 ~~ PPeerScale_5 + PPeerScale_10 + PPeerScale_12 + PPeerScale_14
PPeerScale_5 ~~ PPeerScale_10 + PPeerScale_12 + PPeerScale_14
PPeerScale_10 ~~ PPeerScale_12 + PPeerScale_14
PPeerScale_12 ~~ PPeerScale_14
```

```
TPeerScale_1 ~~ TPeerScale_3 + TPeerScale_5 + TPeerScale_10 + TPeerScale_12 + TPeerScale_14
TPeerScale_3 ~~ TPeerScale_5 + TPeerScale_10 + TPeerScale_12 + TPeerScale_14
TPeerScale_5 ~~ TPeerScale_10 + TPeerScale_12 + TPeerScale_14
TPeerScale_10 ~~ TPeerScale_12 + TPeerScale_14
TPeerScale_12 ~~ TPeerScale_14

PAggScale_1 ~~ PAggScale_3 + PAggScale_5 + PAggScale_10 + PAggScale_12 + PAggScale_14
PAggScale_3 ~~ PAggScale_5 + PAggScale_10 + PAggScale_12 + PAggScale_14
PAggScale_5 ~~ PAggScale_10 + PAggScale_12 + PAggScale_14
PAggScale_10 ~~ PAggScale_12 + PAggScale_14
PAggScale_12 ~~ PAggScale_14

TAggScale_1 ~~ TAggScale_3 + TAggScale_5 + TAggScale_10 + TAggScale_12 + TAggScale_14
TAggScale_3 ~~ TAggScale_5 + TAggScale_10 + TAggScale_12 + TAggScale_14
TAggScale_5 ~~ TAggScale_10 + TAggScale_12 + TAggScale_14
TAggScale_10 ~~ TAggScale_12 + TAggScale_14
TAggScale_12 ~~ TAggScale_14

PProScale_1 ~~ PProScale_3 + PProScale_5 + PProScale_10 + PProScale_12 + PProScale_14
PProScale_3 ~~ PProScale_5 + PProScale_10 + PProScale_12 + PProScale_14
PProScale_5 ~~ PProScale_10 + PProScale_12 + PProScale_14
PProScale_10 ~~ PProScale_12 + PProScale_14
PProScale_12 ~~ PProScale_14

TProScale_1 ~~ TProScale_3 + TProScale_5 + TProScale_10 + TProScale_12 + TProScale_14
TProScale_3 ~~ TProScale_5 + TProScale_10 + TProScale_12 + TProScale_14
TProScale_5 ~~ TProScale_10 + TProScale_12 + TProScale_14
TProScale_10 ~~ TProScale_12 + TProScale_14
TProScale_12 ~~ TProScale_14
'

#fit.5 <- sem(mod.5, data=data_wide, missing = "FIML", std.lv=TRUE)
#summary(fit.5, standardized=TRUE, fit.measures=TRUE)
```

Converged (but again had to remove the last 2 time points)! It shows a poor fit, but only used 39/306 observations!! When I reran it using FIML for missing data, it ran into an error.

```
#Longitudinal growth model with a fixed slope
mod.6.fixed <- ' i =~ 1*PPeerScale_1 + 1*PPeerScale_3 + 1*PPeerScale_5 +  1*PPeerScale_10 + 1*PPeerScale
                        1*PPeerScale_14 + 1*PPeerScale_16 + 1*PPeerScale_18
                 s =~ 0*PPeerScale_1 + 1*PPeerScale_3 + 2*PPeerScale_5 +  3*PPeerScale_10 + 4*PPeerScale
                        5*PPeerScale_14 + 6*PPeerScale_16 + 7*PPeerScale_18

                 s ~~ 0*s #fixed slopes, no variance'
fit.6.fixed <- growth(mod.6.fixed, missing = "ML", data = data_wide)
inspect(fit.6.fixed, "cov.lv")
```

```
##   i      s
## i 37.746
## s  0.998  0.000
```

```
#slope is 0.000

#Longitudinal growth model with a random slope
mod.6.random <- ' i =~ 1*PPeerScale_1 + 1*PPeerScale_3 + 1*PPeerScale_5 +  1*PPeerScale_10 + 1*PPeerScal
```

```
                        1*PPeerScale_14 + 1*PPeerScale_16 + 1*PPeerScale_18
                  s =~ 0*PPeerScale_1 + 2*PPeerScale_3 + 4*PPeerScale_5 +  9*PPeerScale_10 + 11*PPeerSca
                        13*PPeerScale_14 + 15*PPeerScale_16 + 17*PPeerScale_18'
fit.6.random <- growth(mod.6.random, missing = "FIML", data = data_wide)


#Calculate a more precise time metric
apply(data_wide[,82:89], 2, mean, na.rm=T)
```

```
##   age0_1   age0_3   age0_5  age0_10  age0_12  age0_14  age0_16  age0_18
## 0.000000 1.022622 2.012532 4.597019 5.724867 6.709552 7.955476 9.164656
```

```
#Longitudinal growth model with a random slope and more precise time metric
mod.6.precise <- ' i =~ 1*PPeerScale_1 + 1*PPeerScale_3 + 1*PPeerScale_5 +  1*PPeerScale_10 + 1*PPeerSca
                        1*PPeerScale_14 + 1*PPeerScale_16 + 1*PPeerScale_18
                  s =~ 0*PPeerScale_1 + 1.022622*PPeerScale_3 + 2.012532*PPeerScale_5 +  4.597019*PPeerS
                        5.724867*PPeerScale_12 + 6.709552*PPeerScale_14 + 7.955476*PPeerScale_16 +
                        9.164656*PPeerScale_18'
fit.6.precise <- growth(mod.6.precise, missing = "FIML", data = data_wide)

#Mulitlevel model with a random slope
mod.6.MLM <- lmer(PPeerScale ~ age0 + (age0 | ID), data_long)
summary(mod.6.MLM)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: PPeerScale ~ age0 + (age0 | ID)
##    Data: data_long
##
## REML criterion at convergence: 11238.1
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -6.8136 -0.3847  0.1067  0.4964  2.8507
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  ID       (Intercept) 49.7981  7.0568
##           age0         0.8674  0.9313   -0.36
##  Residual             30.4889  5.5217
## Number of obs: 1660, groups:  ID, 298
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 61.16479    0.47041  130.03
## age0         0.14442    0.07681    1.88
##
## Correlation of Fixed Effects:
##      (Intr)
## age0 -0.481
```

```
summary(fit.6.precise)
```

```
## lavaan (0.5-23.1097) converged normally after 117 iterations
##
##                                                   Used       Total
```

```
##   Number of observations                         302         306
##
##   Number of missing patterns                      52
##
##   Estimator                                       ML
##   Minimum Function Test Statistic             75.186
##   Degrees of freedom                              31
##   P-value (Chi-square)                         0.000
##
## Parameter Estimates:
##
##   Information                                 Observed
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i =~
##     PPeerScale_1      1.000
##     PPeerScale_3      1.000
##     PPeerScale_5      1.000
##     PPeerScale_10     1.000
##     PPeerScale_12     1.000
##     PPeerScale_14     1.000
##     PPeerScale_16     1.000
##     PPeerScale_18     1.000
##   s =~
##     PPeerScale_1      0.000
##     PPeerScale_3      1.023
##     PPeerScale_5      2.013
##     PPeerScale_10     4.597
##     PPeerScale_12     5.725
##     PPeerScale_14     6.710
##     PPeerScale_16     7.955
##     PPeerScale_18     9.165
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i ~~
##     s                -2.300    0.721   -3.191    0.001
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .PPeerScale_1      0.000
##    .PPeerScale_3      0.000
##    .PPeerScale_5      0.000
##    .PPeerScale_10     0.000
##    .PPeerScale_12     0.000
##    .PPeerScale_14     0.000
##    .PPeerScale_16     0.000
##    .PPeerScale_18     0.000
##     i                61.337    0.474  129.331    0.000
##     s                 0.121    0.077    1.564    0.118
##
## Variances:
```

```
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .PPeerScale_1     40.855    4.693    8.706    0.000
##    .PPeerScale_3     27.885    3.442    8.102    0.000
##    .PPeerScale_5     24.093    2.915    8.266    0.000
##    .PPeerScale_10    31.176    3.487    8.940    0.000
##    .PPeerScale_12    30.816    3.419    9.014    0.000
##    .PPeerScale_14    28.606    3.655    7.826    0.000
##    .PPeerScale_16    29.246    5.140    5.690    0.000
##    .PPeerScale_18    32.290    8.094    3.989    0.000
##     i                49.535    5.556    8.915    0.000
##     s                 0.826    0.138    6.002    0.000
```

The mean estimate from the growth model (intercept= 61.337, and slope= 0.121) differs slightly from the fixed effects of the multilevel model (intercept= 61.1291, slope= 0.1551). The variance of the growth model (intercept= 49.535, slope= 0.826), also differs slightly from the random effect of the multilevel model (intercept= 43.36, slope= 0.8674).

Question 5

```
#Longitudinal growth model with a random slope, constraining residual variances to 0
mod.7 <- ' i =~ 1*PPeerScale_1 + 1*PPeerScale_3 + 1*PPeerScale_5 +  1*PPeerScale_10 + 1*PPeerScale_12 +
                        1*PPeerScale_14 + 1*PPeerScale_16 + 1*PPeerScale_18
                  s =~ 0*PPeerScale_1 + 2*PPeerScale_3 + 4*PPeerScale_5 +  9*PPeerScale_10 + 11*PPeerSca
                        13*PPeerScale_14 + 15*PPeerScale_16 + 17*PPeerScale_18

PPeerScale_1 ~~ 0*PPeerScale_1
PPeerScale_3 ~~ 0*PPeerScale_3
PPeerScale_5 ~~ 0*PPeerScale_5
PPeerScale_10 ~~ 0*PPeerScale_10
PPeerScale_12 ~~ 0*PPeerScale_12
PPeerScale_14 ~~ 0*PPeerScale_14
PPeerScale_16 ~~ 0*PPeerScale_16
PPeerScale_18 ~~ 0*PPeerScale_18
'
#fit.7 <- growth(mod.7, missing="ML", data=data_wide)
#inspect(fit.7, "cov.lv")
```

Model won't run.

Question 6

```
#Longitudinal growth model with a fixed slope
mod.6.fixed <- ' i =~ 1*PPeerScale_1 + 1*PPeerScale_3 + 1*PPeerScale_5 +  1*PPeerScale_10 + 1*PPeerScal
                        1*PPeerScale_14 + 1*PPeerScale_16 + 1*PPeerScale_18
                 s =~ 0*PPeerScale_1 + 2*PPeerScale_3 + 4*PPeerScale_5 +  9*PPeerScale_10 + 11*PPeerScal
                        13*PPeerScale_14 + 15*PPeerScale_16 + 17*PPeerScale_18

                 s ~~ 0*s #fixed slopes, no variance'
fit.6.fixed <- growth(mod.6.fixed, missing = "ML", data = data_wide)
inspect(fit.6.fixed, "cov.lv")
```

```
##   i      s
```

```
## i 37.866
## s  0.377  0.000
```

```
#slope-slope covariance is 0.000
```

Model won't run.

Question 7

```
#Longitudinal growth model with a random slope, with a different time metric
mod.6.centered <- ' i =~ 1*PPeerScale_1 + 1*PPeerScale_3 + 1*PPeerScale_5 +  1*PPeerScale_10 + 1*PPeerS
                        1*PPeerScale_14 + 1*PPeerScale_16 + 1*PPeerScale_18
                  s =~ -3*PPeerScale_1 + -2*PPeerScale_3 + -1*PPeerScale_5 +  0*PPeerScale_10 + 1*PPeerS
                        2*PPeerScale_14 + 3*PPeerScale_16 + 4*PPeerScale_18'
fit.6.centered <- growth(mod.6.centered, missing = "FIML", data = data_wide)

summary(fit.6.centered)
```

```
## lavaan (0.5-23.1097) converged normally after  90 iterations
##
##                                                   Used       Total
##   Number of observations                           302         306
##
##   Number of missing patterns                        52
##
##   Estimator                                         ML
##   Minimum Function Test Statistic               79.852
##   Degrees of freedom                                31
##   P-value (Chi-square)                           0.000
##
## Parameter Estimates:
##
##   Information                                 Observed
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i =~
##     PPeerScale_1      1.000
##     PPeerScale_3      1.000
##     PPeerScale_5      1.000
##     PPeerScale_10     1.000
##     PPeerScale_12     1.000
##     PPeerScale_14     1.000
##     PPeerScale_16     1.000
##     PPeerScale_18     1.000
##   s =~
##     PPeerScale_1     -3.000
##     PPeerScale_3     -2.000
##     PPeerScale_5     -1.000
##     PPeerScale_10     0.000
##     PPeerScale_12     1.000
##     PPeerScale_14     2.000
##     PPeerScale_16     3.000
```

```
##     PPeerScale_18     4.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i ~~
##     s                 1.445    0.788    1.835    0.067
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .PPeerScale_1      0.000
##    .PPeerScale_3      0.000
##    .PPeerScale_5      0.000
##    .PPeerScale_10     0.000
##    .PPeerScale_12     0.000
##    .PPeerScale_14     0.000
##    .PPeerScale_16     0.000
##    .PPeerScale_18     0.000
##     i                61.821    0.417  148.381    0.000
##     s                 0.217    0.108    2.010    0.044
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .PPeerScale_1     39.150    4.672    8.380    0.000
##    .PPeerScale_3     29.208    3.509    8.323    0.000
##    .PPeerScale_5     25.240    2.933    8.606    0.000
##    .PPeerScale_10    31.726    3.512    9.035    0.000
##    .PPeerScale_12    31.658    3.446    9.187    0.000
##    .PPeerScale_14    28.718    3.699    7.765    0.000
##    .PPeerScale_16    28.036    5.066    5.535    0.000
##    .PPeerScale_18    31.387    8.200    3.828    0.000
##     i                44.218    4.318   10.241    0.000
##     s                 1.574    0.272    5.788    0.000
```

```
summary(fit.6.random)
```

```
## lavaan (0.5-23.1097) converged normally after 117 iterations
##
##                                                   Used       Total
##   Number of observations                           302         306
##
##   Number of missing patterns                        52
##
##   Estimator                                         ML
##   Minimum Function Test Statistic              75.186
##   Degrees of freedom                                31
##   P-value (Chi-square)                           0.000
##
## Parameter Estimates:
##
##   Information                                 Observed
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i =~
```

```
##     PPeerScale_1      1.000
##     PPeerScale_3      1.000
##     PPeerScale_5      1.000
##     PPeerScale_10     1.000
##     PPeerScale_12     1.000
##     PPeerScale_14     1.000
##     PPeerScale_16     1.000
##     PPeerScale_18     1.000
##   s =~
##     PPeerScale_1      0.000
##     PPeerScale_3      1.023
##     PPeerScale_5      2.013
##     PPeerScale_10     4.597
##     PPeerScale_12     5.725
##     PPeerScale_14     6.710
##     PPeerScale_16     7.955
##     PPeerScale_18     9.165
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i ~~
##     s                -2.300    0.721   -3.191    0.001
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .PPeerScale_1      0.000
##    .PPeerScale_3      0.000
##    .PPeerScale_5      0.000
##    .PPeerScale_10     0.000
##    .PPeerScale_12     0.000
##    .PPeerScale_14     0.000
##    .PPeerScale_16     0.000
##    .PPeerScale_18     0.000
##     i                61.337    0.474  129.331    0.000
##     s                 0.121    0.077    1.564    0.118
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .PPeerScale_1     40.855    4.693    8.706    0.000
##    .PPeerScale_3     27.885    3.442    8.102    0.000
##    .PPeerScale_5     24.093    2.915    8.266    0.000
##    .PPeerScale_10    31.176    3.487    8.940    0.000
##    .PPeerScale_12    30.816    3.419    9.014    0.000
##    .PPeerScale_14    28.606    3.655    7.826    0.000
##    .PPeerScale_16    29.246    5.140    5.690    0.000
##    .PPeerScale_18    32.290    8.094    3.989    0.000
##     i                49.535    5.556    8.915    0.000
##     s                 0.826    0.138    6.002    0.000
```

The mean estimates of the intercept and slope changes slightly, since 0 now indicates the mean at the 4th wave rather than the 1st wave. The variance for the intercept and slope also changed slightly, as does the covariance between the intercept and slope. It does not seem to affect the fit statistics though.

Question 8

```r
fit.8.precise <- growth(mod.6.precise, missing = "FIML", estimator = "MLR", data = data_wide)
summary(fit.8.precise)
```

```
## lavaan (0.5-23.1097) converged normally after 117 iterations
##
##                                                   Used       Total
##   Number of observations                           302         306
##
##   Number of missing patterns                        52
##
##   Estimator                                         ML      Robust
##   Minimum Function Test Statistic               75.186      60.401
##   Degrees of freedom                                31          31
##   P-value (Chi-square)                           0.000       0.001
##   Scaling correction factor                                  1.245
##     for the Yuan-Bentler correction
##
## Parameter Estimates:
##
##   Information                                 Observed
##   Standard Errors                   Robust.huber.white
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i =~
##     PPeerScale_1      1.000
##     PPeerScale_3      1.000
##     PPeerScale_5      1.000
##     PPeerScale_10     1.000
##     PPeerScale_12     1.000
##     PPeerScale_14     1.000
##     PPeerScale_16     1.000
##     PPeerScale_18     1.000
##   s =~
##     PPeerScale_1      0.000
##     PPeerScale_3      1.023
##     PPeerScale_5      2.013
##     PPeerScale_10     4.597
##     PPeerScale_12     5.725
##     PPeerScale_14     6.710
##     PPeerScale_16     7.955
##     PPeerScale_18     9.165
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i ~~
##     s                -2.300    0.822   -2.798    0.005
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .PPeerScale_1      0.000
##    .PPeerScale_3      0.000
```

```
##    .PPeerScale_5      0.000
##    .PPeerScale_10     0.000
##    .PPeerScale_12     0.000
##    .PPeerScale_14     0.000
##    .PPeerScale_16     0.000
##    .PPeerScale_18     0.000
##     i                61.337    0.499  122.809    0.000
##     s                 0.121    0.082    1.465    0.143
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .PPeerScale_1     40.855    8.823    4.630    0.000
##    .PPeerScale_3     27.885    8.162    3.416    0.001
##    .PPeerScale_5     24.093    3.752    6.422    0.000
##    .PPeerScale_10    31.176    4.923    6.333    0.000
##    .PPeerScale_12    30.816    9.265    3.326    0.001
##    .PPeerScale_14    28.606    6.525    4.384    0.000
##    .PPeerScale_16    29.246    6.830    4.282    0.000
##    .PPeerScale_18    32.290   12.336    2.618    0.009
##     i                49.535    7.071    7.005    0.000
##     s                 0.826    0.179    4.615    0.000
```

```
summary(fit.6.precise)
```

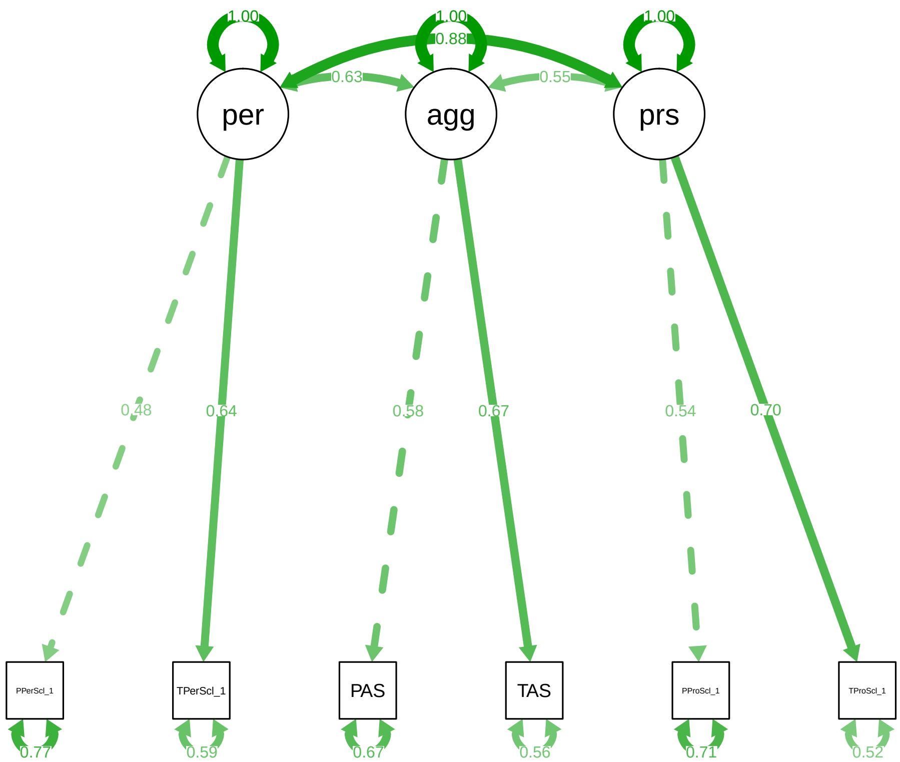
```
## lavaan (0.5-23.1097) converged normally after 117 iterations
##
##                                                   Used       Total
##   Number of observations                           302         306
##
##   Number of missing patterns                        52
##
##   Estimator                                         ML
##   Minimum Function Test Statistic               75.186
##   Degrees of freedom                                31
##   P-value (Chi-square)                           0.000
##
## Parameter Estimates:
##
##   Information                                 Observed
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i =~
##     PPeerScale_1      1.000
##     PPeerScale_3      1.000
##     PPeerScale_5      1.000
##     PPeerScale_10     1.000
##     PPeerScale_12     1.000
##     PPeerScale_14     1.000
##     PPeerScale_16     1.000
##     PPeerScale_18     1.000
##   s =~
##     PPeerScale_1      0.000
##     PPeerScale_3      1.023
```

```
##     PPeerScale_5      2.013
##     PPeerScale_10     4.597
##     PPeerScale_12     5.725
##     PPeerScale_14     6.710
##     PPeerScale_16     7.955
##     PPeerScale_18     9.165
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   i ~~
##     s                -2.300    0.721   -3.191    0.001
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .PPeerScale_1      0.000
##    .PPeerScale_3      0.000
##    .PPeerScale_5      0.000
##    .PPeerScale_10     0.000
##    .PPeerScale_12     0.000
##    .PPeerScale_14     0.000
##    .PPeerScale_16     0.000
##    .PPeerScale_18     0.000
##     i                61.337    0.474  129.331    0.000
##     s                 0.121    0.077    1.564    0.118
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .PPeerScale_1     40.855    4.693    8.706    0.000
##    .PPeerScale_3     27.885    3.442    8.102    0.000
##    .PPeerScale_5     24.093    2.915    8.266    0.000
##    .PPeerScale_10    31.176    3.487    8.940    0.000
##    .PPeerScale_12    30.816    3.419    9.014    0.000
##    .PPeerScale_14    28.606    3.655    7.826    0.000
##    .PPeerScale_16    29.246    5.140    5.690    0.000
##    .PPeerScale_18    32.290    8.094    3.989    0.000
##     i                49.535    5.556    8.915    0.000
##     s                 0.826    0.138    6.002    0.000
```

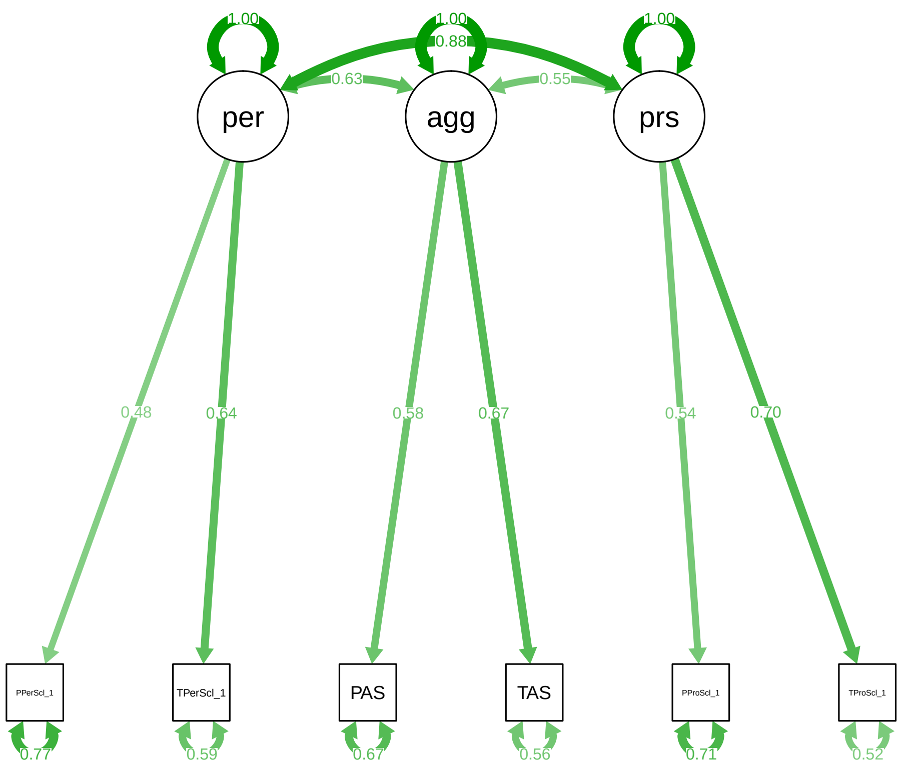
Changing the estimator to MLR seemed to only add to the fit statistics, adding an extra “Robust” column to indicate the robust goodness of fit.

Question 9

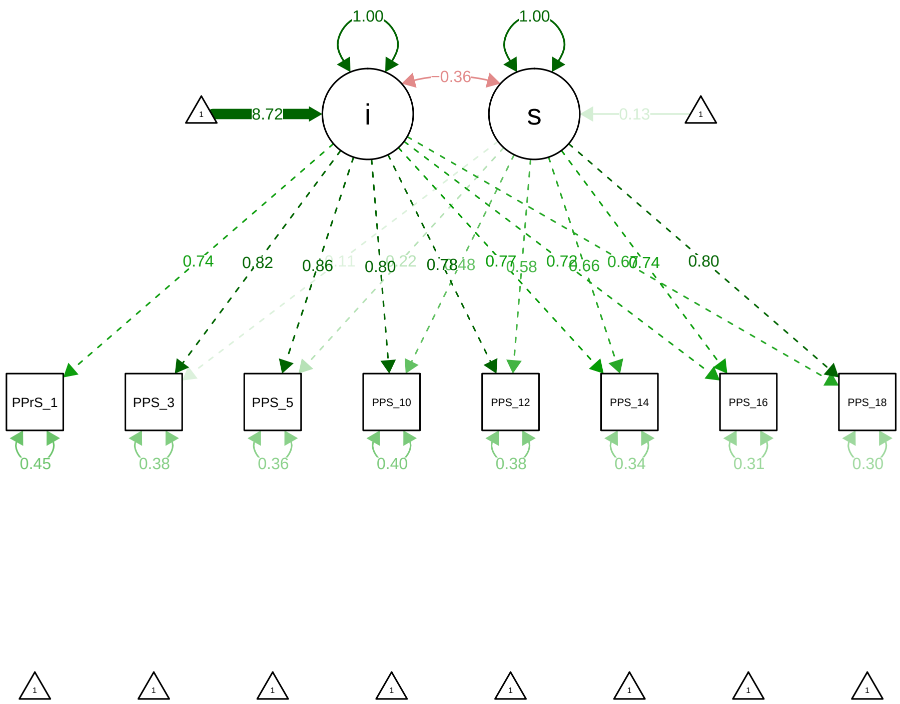
```
semPaths(fit.1, what="std")
```




```r
semPaths(fit.3, what="std")
```




```r
semPaths(fit.8.precise, what="std")
```



1.00
1.00
−0.36
8.72
i
s
0.13
0.74
0.82
0.86
0.80
0.78
0.77
0.58
0.73
0.66
0.67
0.74
0.80
0.22
PPrS_1
PPS_3
PPS_5
PPS_10
PPS_12
PPS_14
PPS_16
PPS_18
0.45
0.38
0.36
0.40
0.38
0.34
0.31
0.30