

Week 9 Homework

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1. Fit a measurement model to your constructs at one time point. Try out the different types of scaling discussed in class. What changes what stays the same?

```
mod.1 <- 'phonemic =~ ctopp_el_raw_KG_1 + ctopp_nr_raw_KG_1 + ctopp_sm_raw_KG_1
         reading =~ wj_wordid_raw_KG_1 + wj_wordattack_raw_KG_1'

fit.1 <- cfa(mod.1, data=Chicago.wide)

summary(fit.1, fit.measures=TRUE, standardized = TRUE) # Josh included standardized=TRUE. What does tha
```

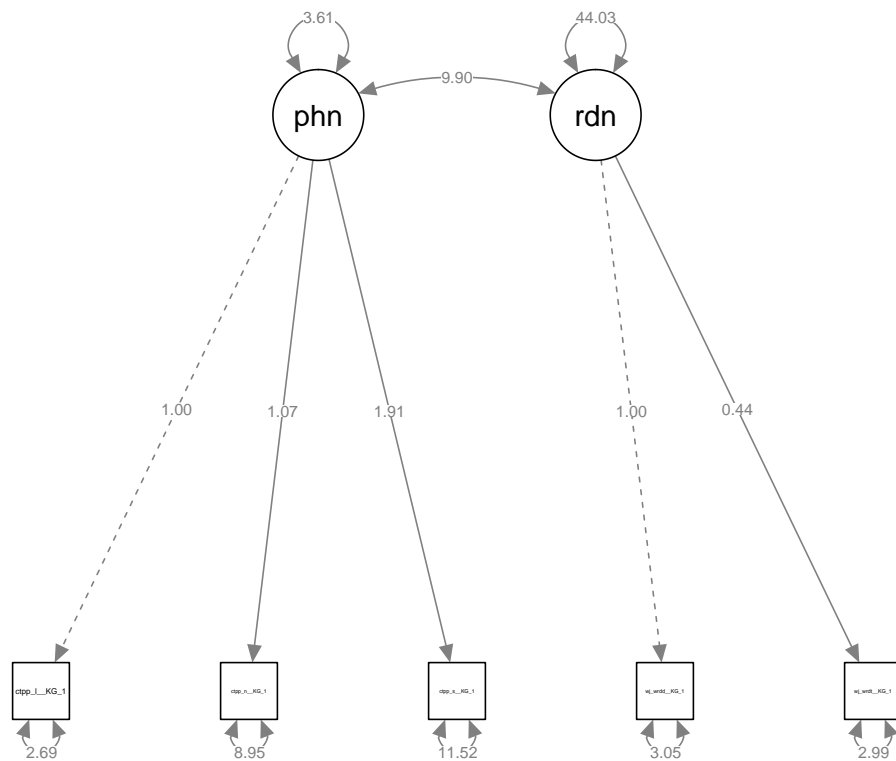
```
## lavaan (0.5-23.1097) converged normally after 77 iterations
##
##                                     Used      Total
##   Number of observations                53        57
##
##   Estimator                          ML
##   Minimum Function Test Statistic      2.878
##   Degrees of freedom                   4
##   P-value (Chi-square)                 0.578
##
## Model test baseline model:
##
##   Minimum Function Test Statistic      129.196
##   Degrees of freedom                   10
##   P-value                             0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)          1.000
##   Tucker-Lewis Index (TLI)            1.024
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)        -682.080
##   Loglikelihood unrestricted model (H1) -680.641
##
##   Number of free parameters            11
##   Akaike (AIC)                        1386.159
##   Bayesian (BIC)                      1407.833
##   Sample-size adjusted Bayesian (BIC)  1373.281
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                0.000
```

```

## 90 Percent Confidence Interval          0.000  0.179
## P-value RMSEA <= 0.05                  0.639
##
## Standardized Root Mean Square Residual:
##
## SRMR                                   0.035
##
## Parameter Estimates:
##
## Information                          Expected
## Standard Errors                     Standard
##
## Latent Variables:
##      Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
## phonemic =~
##   ctppl_rw_KG_1    1.000
##   ctpplr_r_KG_1    1.072    0.293    3.664    0.000    2.038    0.563
##   ctppl_sm_r_KG_1    1.914    0.414    4.623    0.000    3.639    0.731
## reading =~
##   wj_wrdd_r_KG_1    1.000
##   wj_wrddt_KG_1    0.444    0.058    7.679    0.000    2.947    0.862
##
## Covariances:
##      Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
## phonemic ~~
##   reading      9.903    2.699    3.669    0.000    0.785    0.785
##
## Variances:
##      Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
## .ctpp_l_rw_KG_1    2.689    0.780    3.446    0.001    2.689    0.427
## .ctpp_nr_r_KG_1    8.955    1.953    4.586    0.000    8.955    0.683
## .ctpp_sm_r_KG_1   11.520    3.113    3.701    0.000   11.520    0.465
## .wj_wrdd_r_KG_1    3.053    4.354    0.701    0.483    3.053    0.065
## .wj_wrddt_KG_1     2.991    1.030    2.904    0.004    2.991    0.256
## phonemic          3.615    1.250    2.892    0.004    1.000    1.000
## reading          44.028   10.095    4.362    0.000    1.000    1.000

```

```
semPaths(fit.1, layout = "tree", whatLabels = "est")
```



*# semPaths(fit.1, layout = "tree", what = "std") What is this doing??
 # no triangles means no mean structure - which is fine when not doing longitudinal (think of those triangles in the path diagram)*

Fixed factor approach rather than a marker variable approach

```
mod.2 <- 'phonemic =~ ctopp_el_raw_KG_1 + ctopp_nr_raw_KG_1 + ctopp_sm_raw_KG_1
         reading =~ wj_wordid_raw_KG_1 + wj_wordattack_raw_KG_1'
```

```
fit.2 <- cfa(mod.2, std.lv=TRUE, data=Chicago.wide)
```

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

```
## lavaan (0.5-23.1097) converged normally after 43 iterations
```

```
##
```

	Used	Total
Number of observations	53	57

```
##
```

	ML
Estimator	ML

	2.878
Minimum Function Test Statistic	2.878

	4
Degrees of freedom	4

	0.578
P-value (Chi-square)	0.578

```
##
```

```
## Model test baseline model:
```

```
##
```

	129.196
Minimum Function Test Statistic	129.196

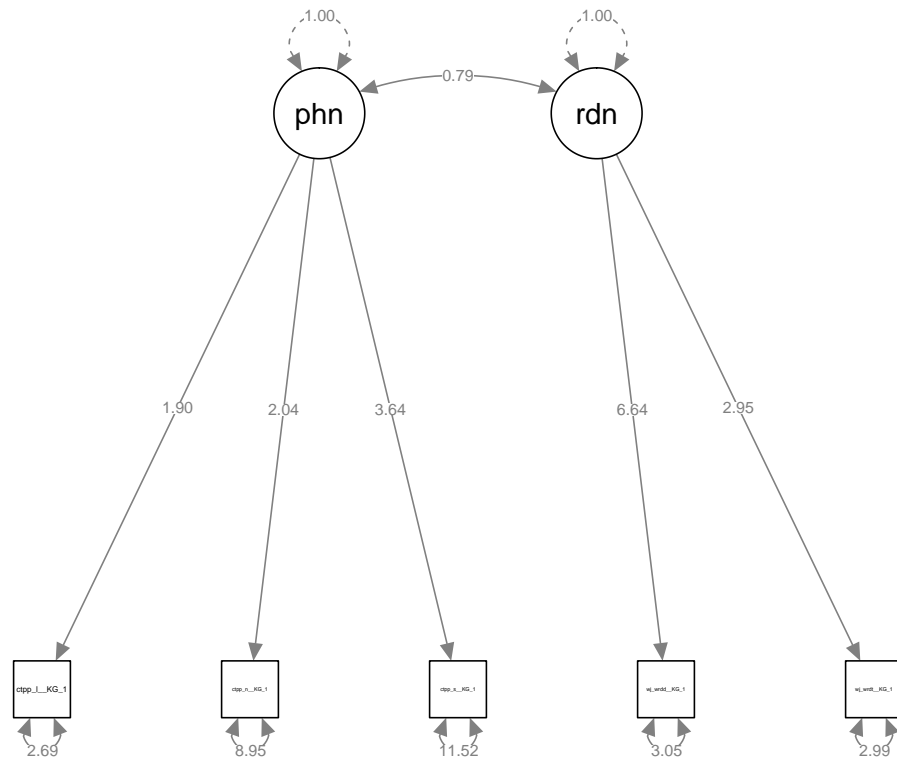
	10
Degrees of freedom	10

```

##      P-value                                0.000
##
## User model versus baseline model:
##
##      Comparative Fit Index (CFI)                1.000
##      Tucker-Lewis Index (TLI)                  1.024
##
## Loglikelihood and Information Criteria:
##
##      Loglikelihood user model (H0)              -682.080
##      Loglikelihood unrestricted model (H1)       -680.641
##
##      Number of free parameters                  11
##      Akaike (AIC)                              1386.159
##      Bayesian (BIC)                             1407.833
##      Sample-size adjusted Bayesian (BIC)        1373.281
##
## Root Mean Square Error of Approximation:
##
##      RMSEA                                0.000
##      90 Percent Confidence Interval          0.000  0.179
##      P-value RMSEA <= 0.05                  0.639
##
## Standardized Root Mean Square Residual:
##
##      SRMR                                0.035
##
## Parameter Estimates:
##
##      Information                                Expected
##      Standard Errors                          Standard
##
## Latent Variables:
##
##      Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      phonemic =~
##      ctppl_rw_KG_1    1.901    0.329    5.784    0.000    1.901    0.757
##      ctpplr_r_KG_1    2.038    0.505    4.032    0.000    2.038    0.563
##      ctpplsm_r_KG_1    3.639    0.656    5.545    0.000    3.639    0.731
##      reading =~
##      wj_wrdd_r_KG_1    6.635    0.761    8.723    0.000    6.635    0.967
##      wj_wrddt_KG_1    2.947    0.399    7.385    0.000    2.947    0.862
##
## Covariances:
##
##      Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      phonemic ~~
##      reading      0.785    0.088    8.878    0.000    0.785    0.785
##
## Variances:
##
##      Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      .ctpp_l_rw_KG_1    2.689    0.780    3.446    0.001    2.689    0.427
##      .ctpp_nr_r_KG_1    8.955    1.953    4.586    0.000    8.955    0.683
##      .ctpp_sm_r_KG_1   11.520    3.113    3.701    0.000   11.520    0.465
##      .wj_wrdd_r_KG_1    3.053    4.354    0.701    0.483    3.053    0.065
##      .wj_wrddt_KG_1    2.991    1.030    2.904    0.004    2.991    0.256

```

```
##      phonemic      1.000      1.000      1.000
##      reading      1.000      1.000      1.000
semPaths(fit.2, layout = "tree", whatLabels = "est")
```



Under the marker method, parameter estimates (means) were fixed at 1 for the first indicators (i.e. ctopp_el_raw_KG_1 and wj_wordid_raw_KG_1).

Under the fixed factor method, in contrast, parameter estimates (variances) were fixed to 1 for the latent variables (i.e. phonemic and reading).

In both cases, fit indices (e.g., logLikelihood, TLI, CFI, RMSEA) remain constant.

2. What do the fit statistics say about your latent variable? Good/bad? Is your latent variable Just identified/saturated, under identified or over identified?

RMSEA = .000, SRMR = .035, TLI = 1.02, CFI = 1.00

TLI and CFI > .90 and RMSEA and SRMR < .08, all suggesting good fit.

This model is over identified, as evidenced by the positive degrees of freedom (4).

3. Fit a longitudinal CFA model where you a) first correlate your latent factors across time and then b) a second model that predicts later times by a previous time (ie auto regressive; $t1 \rightarrow t2 \rightarrow t3$). What are your conclusions? How does one differ from the other?

```
# latent variables correlated across time
mod.3 <- '
## define latent variables
    Phonemic_t1 =~ ctopp_el_raw_KG_1 + ctopp_nr_raw_KG_1 + ctopp_sm_raw_KG_1
    Phonemic_t2 =~ ctopp_el_raw_KG_3 + ctopp_nr_raw_KG_3 + ctopp_sm_raw_KG_3
    Phonemic_t3 =~ ctopp_el_raw_FG_1 + ctopp_nr_raw_FG_1 + ctopp_sm_raw_FG_1

## correlated residuals across time
    ctopp_el_raw_KG_1 ~~ ctopp_el_raw_KG_3 + ctopp_el_raw_FG_1
    ctopp_el_raw_KG_3 ~~ ctopp_el_raw_FG_1
    ctopp_nr_raw_KG_1 ~~ ctopp_nr_raw_KG_3 + ctopp_nr_raw_FG_1
    ctopp_nr_raw_KG_3 ~~ ctopp_nr_raw_FG_1
    ctopp_sm_raw_KG_1 ~~ ctopp_sm_raw_KG_3 + ctopp_sm_raw_FG_1
    ctopp_sm_raw_KG_3 ~~ ctopp_sm_raw_FG_1'

fit.3 <- cfa(mod.3,data = Chicago.wide, meanstructure=TRUE, std.lv = TRUE)
summary(fit.3, standardized=TRUE, fit.measures=TRUE)
```

```
## lavaan (0.5-23.1097) converged normally after 122 iterations
##
##                                     Used      Total
##   Number of observations                40        57
##
##   Estimator                          ML
##   Minimum Function Test Statistic      19.135
##   Degrees of freedom                   15
##   P-value (Chi-square)                 0.208
##
## Model test baseline model:
##
##   Minimum Function Test Statistic      209.349
##   Degrees of freedom                   36
##   P-value                             0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)          0.976
##   Tucker-Lewis Index (TLI)           0.943
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)        -890.787
##   Loglikelihood unrestricted model (H1) -881.220
##
##   Number of free parameters            39
##   Akaike (AIC)                        1859.575
##   Bayesian (BIC)                      1925.441
```

```

## Sample-size adjusted Bayesian (BIC) 1803.400
##
## Root Mean Square Error of Approximation:
##
## RMSEA 0.083
## 90 Percent Confidence Interval 0.000 0.181
## P-value RMSEA <= 0.05 0.296
##
## Standardized Root Mean Square Residual:
##
## SRMR 0.050
##
## Parameter Estimates:
##
## Information Expected
## Standard Errors Standard
##
## Latent Variables:
## Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## Phonemic_t1 =~
## ctppl_rw_KG_1 1.872 0.388 4.825 0.000 1.872 0.720
## ctpplr_r_KG_1 2.496 0.525 4.755 0.000 2.496 0.706
## ctppl_sm_r_KG_1 3.417 0.721 4.740 0.000 3.417 0.734
## Phonemic_t2 =~
## ctppl_rw_KG_3 2.754 0.587 4.692 0.000 2.754 0.733
## ctpplr_r_KG_3 1.639 0.548 2.989 0.003 1.639 0.489
## ctppl_sm_r_KG_3 2.422 0.757 3.201 0.001 2.422 0.545
## Phonemic_t3 =~
## ctppl_rw_FG_1 2.553 0.611 4.176 0.000 2.553 0.643
## ctpplr_r_FG_1 1.386 0.476 2.910 0.004 1.386 0.463
## ctppl_sm_r_FG_1 3.724 0.804 4.632 0.000 3.724 0.720
##
## Covariances:
## Estimate Std.Err z-value P(>|z|) Std.lv
## .ctopp_el_raw_KG_1 ~~
## .ctpp_l_rw_KG_3 1.931 1.126 1.714 0.086 1.931
## .ctpp_l_rw_FG_1 1.650 1.237 1.333 0.182 1.650
## .ctopp_el_raw_KG_3 ~~
## .ctpp_l_rw_FG_1 4.046 1.939 2.086 0.037 4.046
## .ctopp_nr_raw_KG_1 ~~
## .ctpp_nr_r_KG_3 1.256 1.367 0.919 0.358 1.256
## .ctpp_nr_r_FG_1 0.813 1.247 0.652 0.514 0.813
## .ctopp_nr_raw_KG_3 ~~
## .ctpp_nr_r_FG_1 4.110 1.510 2.722 0.006 4.110
## .ctopp_sm_raw_KG_1 ~~
## .ctpp_sm_r_KG_3 0.054 2.510 0.022 0.983 0.054
## .ctpp_sm_r_FG_1 -2.914 2.766 -1.054 0.292 -2.914
## .ctopp_sm_raw_KG_3 ~~
## .ctpp_sm_r_FG_1 7.480 3.256 2.297 0.022 7.480
## Phonemic_t1 ~~
## Phonemic_t2 0.974 0.098 9.975 0.000 0.974
## Phonemic_t3 1.070 0.093 11.570 0.000 1.070
## Phonemic_t2 ~~
## Phonemic_t3 1.052 0.066 15.975 0.000 1.052

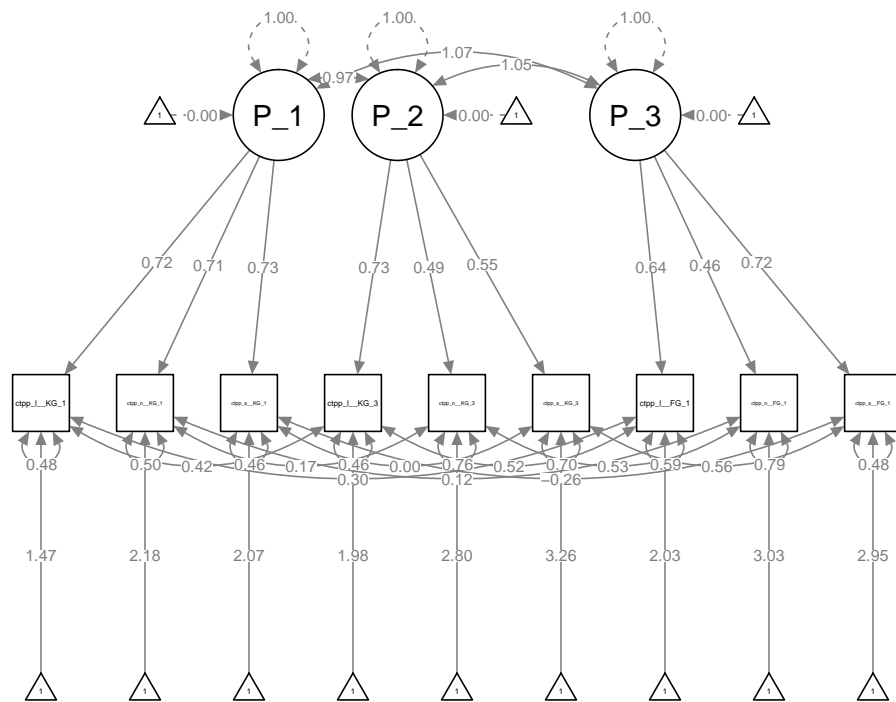
```

```

## Std.all
##
## 0.419
## 0.301
##
## 0.520
##
## 0.171
## 0.122
##
## 0.529
##
## 0.005
## -0.257
##
## 0.560
##
## 0.974
## 1.070
##
## 1.052
##
## Intercepts:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .ctpp_l_rw_KG_1 3.825 0.411 9.308 0.000 3.825 1.472
## .ctpp_nr_r_KG_1 7.700 0.559 13.777 0.000 7.700 2.178
## .ctpp_sm_r_KG_1 9.625 0.736 13.083 0.000 9.625 2.069
## .ctpp_l_rw_KG_3 7.425 0.594 12.494 0.000 7.425 1.975
## .ctpp_nr_r_KG_3 9.400 0.530 17.724 0.000 9.400 2.802
## .ctpp_sm_r_KG_3 14.475 0.702 20.623 0.000 14.475 3.261
## .ctpp_l_rw_FG_1 8.050 0.628 12.819 0.000 8.050 2.027
## .ctpp_nr_r_FG_1 9.075 0.473 19.177 0.000 9.075 3.032
## .ctpp_sm_r_FG_1 15.275 0.818 18.683 0.000 15.275 2.954
## Phonemic_t1 0.000 0.000 0.000 0.000 0.000 0.000
## Phonemic_t2 0.000 0.000 0.000 0.000 0.000 0.000
## Phonemic_t3 0.000 0.000 0.000 0.000 0.000 0.000
##
## Variances:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .ctpp_l_rw_KG_1 3.250 0.940 3.458 0.001 3.250 0.481
## .ctpp_nr_r_KG_1 6.264 1.728 3.625 0.000 6.264 0.501
## .ctpp_sm_r_KG_1 9.970 3.286 3.034 0.002 9.970 0.461
## .ctpp_l_rw_KG_3 6.545 2.196 2.980 0.003 6.545 0.463
## .ctpp_nr_r_KG_3 8.566 2.065 4.148 0.000 8.566 0.761
## .ctpp_sm_r_KG_3 13.842 3.635 3.808 0.000 13.842 0.702
## .ctpp_l_rw_FG_1 9.254 2.414 3.833 0.000 9.254 0.587
## .ctpp_nr_r_FG_1 7.037 1.640 4.291 0.000 7.037 0.786
## .ctpp_sm_r_FG_1 12.872 4.037 3.188 0.001 12.872 0.481
## Phonemic_t1 1.000 1.000 1.000 0.000 1.000 1.000
## Phonemic_t2 1.000 1.000 1.000 0.000 1.000 1.000
## Phonemic_t3 1.000 1.000 1.000 0.000 1.000 1.000

```

```
semPaths(fit.3, whatLabels = "std")
```

```
#Auto regressive, later times predicted by earlier times
mod.4 <- 'Phonemic_t1 =~ L1*ctopp_el_raw_KG_1 + L2*ctopp_nr_raw_KG_1 + L3*ctopp_sm_raw_KG_1
Phonemic_t2 =~ L1*ctopp_el_raw_KG_3 + L2*ctopp_nr_raw_KG_3 + L3*ctopp_sm_raw_KG_3
Phonemic_t3 =~ L1*ctopp_el_raw_FG_1 + L2*ctopp_nr_raw_FG_1 + L3*ctopp_sm_raw_FG_1

##correlated residuals across time
ctopp_el_raw_KG_1 ~~ ctopp_el_raw_KG_3 + ctopp_el_raw_FG_1
ctopp_el_raw_KG_3 ~~ ctopp_el_raw_FG_1
ctopp_nr_raw_KG_1 ~~ ctopp_nr_raw_KG_3 + ctopp_nr_raw_FG_1
ctopp_nr_raw_KG_3 ~~ ctopp_nr_raw_FG_1
ctopp_sm_raw_KG_1 ~~ ctopp_sm_raw_KG_3 + ctopp_sm_raw_FG_1
ctopp_sm_raw_KG_3 ~~ ctopp_sm_raw_FG_1

##directional regression paths
Phonemic_t3 ~ Phonemic_t2
Phonemic_t2 ~ Phonemic_t1

## free latent variances at later times (only set the scale once)
Phonemic_t2 =~ NA*Phonemic_t2
Phonemic_t3 =~ NA*Phonemic_t3'

fit.4 <- sem(mod.4, data=Chicago.wide, std.lv = TRUE)
summary(fit.4, fit.measures = TRUE)

## lavaan (0.5-23.1097) converged normally after 103 iterations
##
```

```

##                               Used      Total
##   Number of observations              40        57
##
##   Estimator                          ML
##   Minimum Function Test Statistic    29.819
##   Degrees of freedom                 20
##   P-value (Chi-square)               0.073
##
## Model test baseline model:
##
##   Minimum Function Test Statistic    209.349
##   Degrees of freedom                 36
##   P-value                           0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)        0.943
##   Tucker-Lewis Index (TLI)         0.898
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)      -896.130
##   Loglikelihood unrestricted model (H1) -881.220
##
##   Number of free parameters          25
##   Akaike (AIC)                      1842.259
##   Bayesian (BIC)                    1884.481
##   Sample-size adjusted Bayesian (BIC) 1806.250
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                             0.111
##   90 Percent Confidence Interval      0.000 0.189
##   P-value RMSEA <= 0.05              0.131
##
## Standardized Root Mean Square Residual:
##
##   SRMR                              0.140
##
## Parameter Estimates:
##
##   Information                      Expected
##   Standard Errors                  Standard
##
## Latent Variables:
##           Estimate  Std.Err  z-value  P(>|z|)
##   Phonemic_t1 =~
##     ct___KG_1 (L1)    2.000    0.388    5.156    0.000
##     ct___KG_1 (L2)    1.978    0.426    4.642    0.000
##     ct___KG_1 (L3)    3.177    0.634    5.009    0.000
##   Phonemic_t2 =~
##     ct___KG_3 (L1)    2.000    0.388    5.156    0.000
##     ct___KG_3 (L2)    1.978    0.426    4.642    0.000
##     ct___KG_3 (L3)    3.177    0.634    5.009    0.000

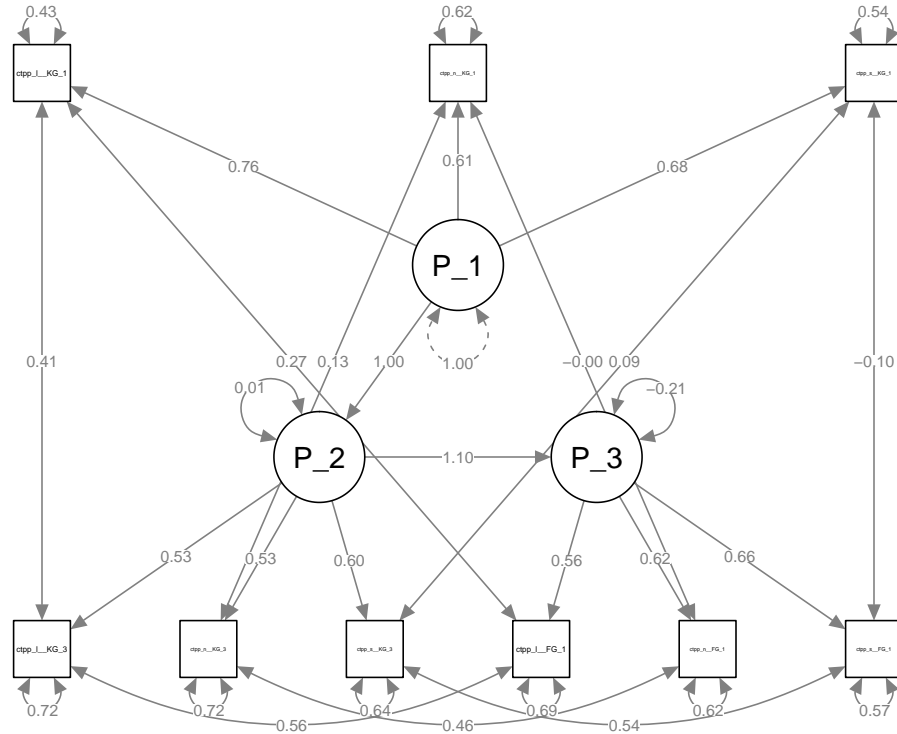
```

```

## Phonemic_t3 =~
## ct___FG_1 (L1) 2.000 0.388 5.156 0.000
## ct___FG_1 (L2) 1.978 0.426 4.642 0.000
## ct___FG_1 (L3) 3.177 0.634 5.009 0.000
##
## Regressions:
## Estimate Std.Err z-value P(>|z|)
## Phonemic_t3 ~
## Phonemic_t2 1.260 0.160 7.870 0.000
## Phonemic_t2 ~
## Phonemic_t1 0.908 0.174 5.214 0.000
##
## Covariances:
## Estimate Std.Err z-value P(>|z|)
## .ctopp_el_raw_KG_1 ~~
## .ctpp_l_rw_KG_3 2.048 1.117 1.834 0.067
## .ctpp_l_rw_FG_1 1.433 1.235 1.161 0.246
## .ctopp_el_raw_KG_3 ~~
## .ctpp_l_rw_FG_1 5.054 1.932 2.616 0.009
## .ctopp_nr_raw_KG_1 ~~
## .ctpp_nr_r_KG_3 0.923 1.375 0.671 0.502
## .ctpp_nr_r_FG_1 -0.029 1.299 -0.022 0.982
## .ctopp_nr_raw_KG_3 ~~
## .ctpp_nr_r_FG_1 3.482 1.591 2.188 0.029
## .ctopp_sm_raw_KG_1 ~~
## .ctpp_sm_r_KG_3 1.128 2.772 0.407 0.684
## .ctpp_sm_r_FG_1 -1.305 2.888 -0.452 0.651
## .ctopp_sm_raw_KG_3 ~~
## .ctpp_sm_r_FG_1 7.807 3.514 2.222 0.026
##
## Variances:
## Estimate Std.Err z-value P(>|z|)
## .Phonemic_t2 0.007 0.145 0.050 0.960
## .Phonemic_t3 -0.232 0.150 -1.553 0.120
## .ctpp_l_rw_KG_1 2.959 0.969 3.053 0.002
## .ctpp_nr_r_KG_1 6.506 1.691 3.848 0.000
## .ctpp_sm_r_KG_1 11.907 3.436 3.466 0.001
## .ctpp_l_rw_KG_3 8.436 2.075 4.065 0.000
## .ctpp_nr_r_KG_3 8.359 2.055 4.068 0.000
## .ctpp_sm_r_KG_3 14.730 3.909 3.768 0.000
## .ctpp_l_rw_FG_1 9.652 2.408 4.009 0.000
## .ctpp_nr_r_FG_1 6.805 1.758 3.871 0.000
## .ctpp_sm_r_FG_1 14.357 4.004 3.585 0.000
## Phonemic_t1 1.000

```

```
semPaths(fit.4, whatLabels = "std")
```



For the longitudinal CFA model with correlated latent factors (mod.3), I conclude that my latent factors are strongly correlated across time. Moreover, across all three time points, indicators load strongly & significantly onto their respective latent constructs. For the autoregressive CFA model (mod.4), a similar picture emerges, suggesting that Semantic_1 is highly predictive of Semantic_2, which is highly predictive of Semantic_3. Of note, standardized variances for S_2 and S_3 are insignificant ($p = .10$ and $.62$, respectively), likely due to the fact that their variability is accounted for by

4. Fit a longitudinal growth model in SEM and in HLM. Compare and contrast the differences.

```
library(lme4)

## Loading required package: Matrix
##
## Attaching package: 'Matrix'
## The following object is masked from 'package:tidyr':
##
##     expand
mod.HLM <- lmer(wj_wordid_raw ~ Timepoint + (1 | Participant), data = Chicago) #fixed slope
summary(mod.HLM) # intercept: 17.53, slope: 7.24

## Linear mixed model fit by REML ['lmerMod']
## Formula: wj_wordid_raw ~ Timepoint + (1 | Participant)
```

```

## Data: Chicago
##
## REML criterion at convergence: 1408.7
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.6783 -0.6278  0.0320  0.5122  3.5035
##
## Random effects:
##   Groups      Name      Variance Std.Dev.
## Participant (Intercept) 55.46    7.447
## Residual              24.30    4.930
## Number of obs: 213, groups: Participant, 57
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)   17.529      1.140   15.38
## Timepoint      7.238      0.305   23.73
##
## Correlation of Fixed Effects:
##          (Intr)
## Timepoint -0.402
mod.HLM2 <- lmer(wj_wordid_raw ~ Timepoint + (Timepoint | Participant), data = Chicago) #fixed slope
summary(mod.HLM2) # intercept: 17.51, slope: 7.24

## Linear mixed model fit by REML ['lmerMod']
## Formula: wj_wordid_raw ~ Timepoint + (Timepoint | Participant)
## Data: Chicago
##
## REML criterion at convergence: 1406
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.7081 -0.5881 -0.0291  0.5255  3.6546
##
## Random effects:
##   Groups      Name      Variance Std.Dev. Corr
## Participant (Intercept) 44.0879  6.640
##              Timepoint   0.4957  0.704   0.70
## Residual              23.5879  4.857
## Number of obs: 213, groups: Participant, 57
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)   17.5094      1.0440   16.77
## Timepoint      7.2441      0.3151   22.99
##
## Correlation of Fixed Effects:
##          (Intr)
## Timepoint -0.239
mod.SEM <- 'intercept =~ 1*wj_wordid_raw_KG_1 + 1*wj_wordid_raw_KG_3 + 1*wj_wordid_raw_FG_1 + 1*wj_wordid_raw_FG_3
slope =~ 0*wj_wordid_raw_KG_1 + 1*wj_wordid_raw_KG_3 + 2*wj_wordid_raw_FG_1 + 3*wj_wordid_raw_FG_3
slope ~~ 0*slope' #fixed slope, no variance

```

```
mod.SEM.fixed <- growth(mod.SEM, missing = "ML", data = Chicago.wide)
summary(mod.SEM.fixed) # intercept: 17.34, slope: 7.11
```

```
## lavaan (0.5-23.1097) converged normally after 70 iterations
```

```
##
##   Number of observations                57
##
##   Number of missing patterns           6
##
##   Estimator                           ML
##   Minimum Function Test Statistic      46.918
##   Degrees of freedom                   6
##   P-value (Chi-square)                 0.000
##
```

```
## Parameter Estimates:
```

```
##
##   Information                        Observed
##   Standard Errors                   Standard
##
```

```
## Latent Variables:
```

```
##           Estimate Std.Err z-value P(>|z|)
## intercept =~
##   wj_wrdd_r_KG_1    1.000
##   wj_wrdd_r_KG_3    1.000
##   wj_wrdd_r_FG_1    1.000
##   wj_wrdd_r_FG_3    1.000
## slope =~
##   wj_wrdd_r_KG_1    0.000
##   wj_wrdd_r_KG_3    1.000
##   wj_wrdd_r_FG_1    2.000
##   wj_wrdd_r_FG_3    3.000
##
```

```
## Covariances:
```

```
##           Estimate Std.Err z-value P(>|z|)
## intercept ~~
##   slope             4.786   2.726   1.755   0.079
##
```

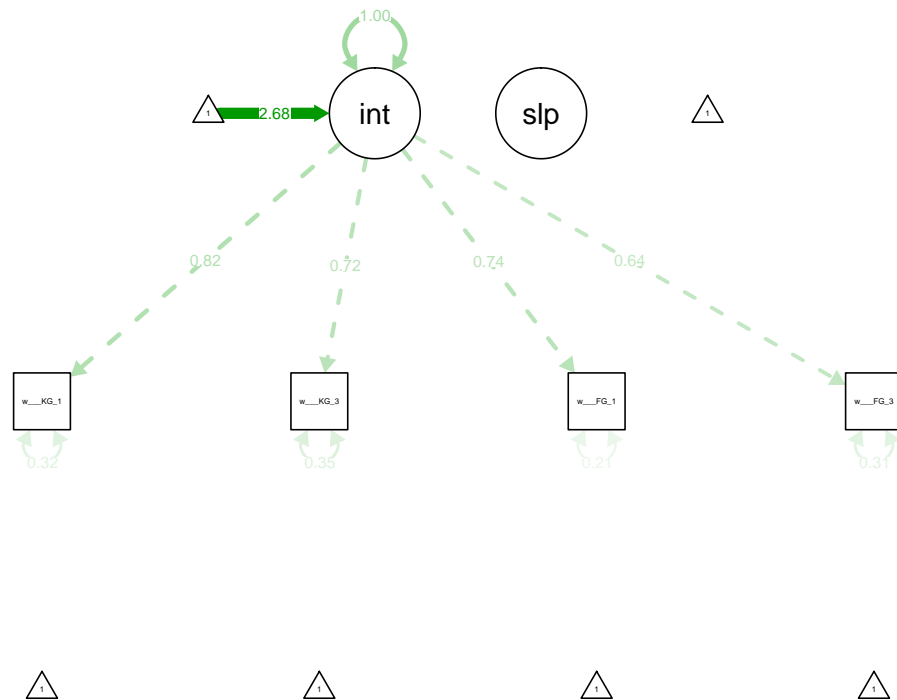
```
## Intercepts:
```

```
##           Estimate Std.Err z-value P(>|z|)
## .wj_wrdd_r_KG_1    0.000
## .wj_wrdd_r_KG_3    0.000
## .wj_wrdd_r_FG_1    0.000
## .wj_wrdd_r_FG_3    0.000
## intercept         17.341   1.029  16.856   0.000
## slope              7.107   0.350  20.296   0.000
##
```

```
## Variances:
```

```
##           Estimate Std.Err z-value P(>|z|)
## slope         0.000
## .wj_wrdd_r_KG_1 20.109   4.985   4.034   0.000
## .wj_wrdd_r_KG_3 28.348   6.856   4.135   0.000
## .wj_wrdd_r_FG_1 16.412   5.862   2.800   0.005
## .wj_wrdd_r_FG_3 32.312   9.066   3.564   0.000
## intercept      41.959  11.468   3.659   0.000
```

```
semPaths(mod.SEM.fixed, what = "std")
```



```
mod.SEM2 <- 'intercept =~ 1*wj_wordid_raw_KG_1 + 1*wj_wordid_raw_KG_3 + 1*wj_wordid_raw_FG_1 + 1*wj_wordid_raw_FG_3
slope =~ 0*wj_wordid_raw_KG_1 + 1*wj_wordid_raw_KG_3 + 2*wj_wordid_raw_FG_1 + 3*wj_wordid_raw_FG_3'
mod.SEM.random <- growth(mod.SEM2, missing = "ML", data = Chicago.wide)
summary(mod.SEM.random) # intercept: 17.28, slope: 7.17
```

```
## lavaan (0.5-23.1097) converged normally after 74 iterations
```

```
##
##   Number of observations                57
##
##   Number of missing patterns            6
##
##   Estimator                            ML
##   Minimum Function Test Statistic      46.839
##   Degrees of freedom                    5
##   P-value (Chi-square)                  0.000
##
```

```
## Parameter Estimates:
```

```
##
##   Information                          Observed
##   Standard Errors                      Standard
##
```

```
## Latent Variables:
```

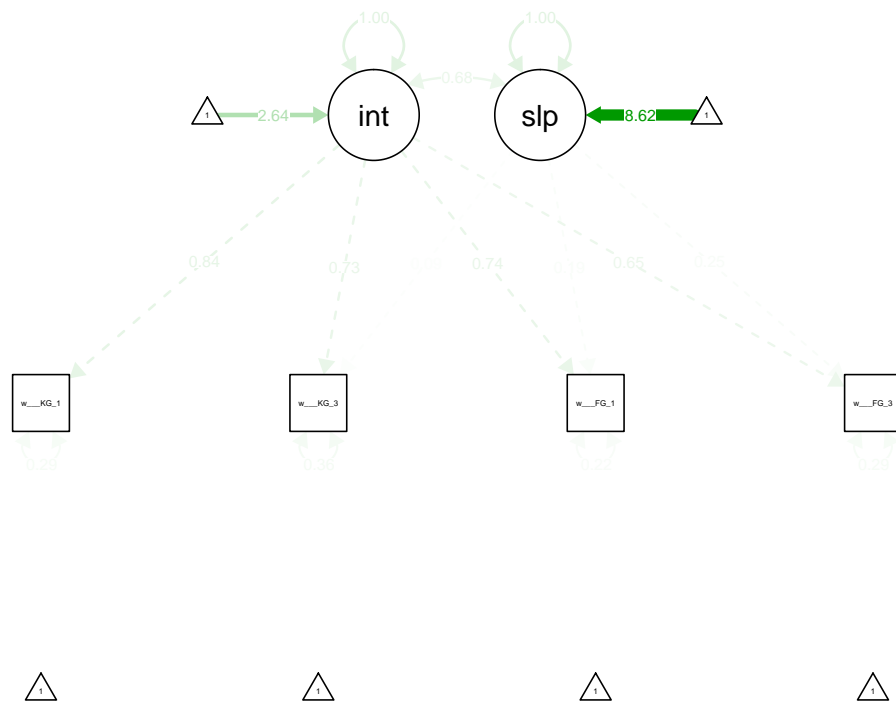
```
##           Estimate Std.Err z-value P(>|z|)
## intercept =~
```

```

##      wj_wrdd_r_KG_1      1.000
##      wj_wrdd_r_KG_3      1.000
##      wj_wrdd_r_FG_1      1.000
##      wj_wrdd_r_FG_3      1.000
##      slope =~
##      wj_wrdd_r_KG_1      0.000
##      wj_wrdd_r_KG_3      1.000
##      wj_wrdd_r_FG_1      2.000
##      wj_wrdd_r_FG_3      3.000
##
## Covariances:
##      Estimate Std.Err z-value P(>|z|)
##      intercept ~~
##      slope      3.677    4.938    0.745    0.456
##
## Intercepts:
##      Estimate Std.Err z-value P(>|z|)
##      .wj_wrdd_r_KG_1    0.000
##      .wj_wrdd_r_KG_3    0.000
##      .wj_wrdd_r_FG_1    0.000
##      .wj_wrdd_r_FG_3    0.000
##      intercept    17.282    1.041    16.597    0.000
##      slope      7.171    0.425    16.864    0.000
##
## Variances:
##      Estimate Std.Err z-value P(>|z|)
##      .wj_wrdd_r_KG_1    17.474    10.676    1.637    0.102
##      .wj_wrdd_r_KG_3    29.132    7.750    3.759    0.000
##      .wj_wrdd_r_FG_1    17.220    6.852    2.513    0.012
##      .wj_wrdd_r_FG_3    29.256    14.210    2.059    0.040
##      intercept    42.772    11.672    3.664    0.000
##      slope      0.692    2.531    0.274    0.784

```

```
semPaths(mod.SEM.random, what = "std")
```

Estimates of intercept are similar between fixed slope SEM & HLM models and between random slope SEM & HLM models.

Estimates of slope are similar between fixed slope SEM & HLM models and between random slope SEM & HLM models.

5. Constrain the residual variances to be equal. Does this change the fit of your model?

Constraining the residual variances does not significantly change model fit. LogLikelihood tests indicate that a simpler model, where residual variances are allowed to vary, is preferred to a more complex model where they are constrained to be equal.

```
mod.SEM3 <- 'intercept =~ 1*wj_wordid_raw_KG_1 + 1*wj_wordid_raw_KG_3 + 1*wj_wordid_raw_FG_1 + 1*wj_wordid_raw_FG_3
              slope =~ 0*wj_wordid_raw_KG_1 + 1*wj_wordid_raw_KG_3 + 2*wj_wordid_raw_FG_1 + 3*wj_wordid_raw_FG_3

wj_wordid_raw_KG_1 ~~ a*wj_wordid_raw_KG_1
wj_wordid_raw_KG_3 ~~ a*wj_wordid_raw_KG_3
wj_wordid_raw_FG_1 ~~ a*wj_wordid_raw_FG_1
wj_wordid_raw_FG_3 ~~ a*wj_wordid_raw_FG_3' #random slope, residual variances equal

mod.SEM.equal.resid <- growth(mod.SEM3, missing = "ML", data = Chicago.wide)
summary(mod.SEM.equal.resid) #intercept = 17.51, slope = 7.24

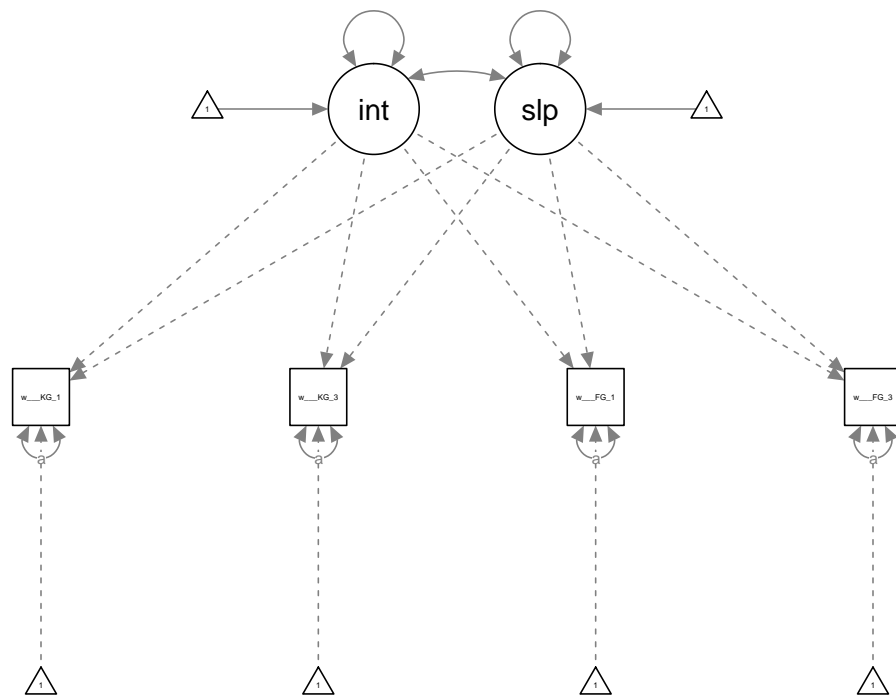
## lavaan (0.5-23.1097) converged normally after 58 iterations
##
```

```

##      Number of observations                57
##
##      Number of missing patterns           6
##
##      Estimator                           ML
##      Minimum Function Test Statistic      50.023
##      Degrees of freedom                   8
##      P-value (Chi-square)                 0.000
##
## Parameter Estimates:
##
##      Information                          Observed
##      Standard Errors                      Standard
##
## Latent Variables:
##      Estimate Std.Err z-value P(>|z|)
##      intercept =~
##      wj_wrdd_r_KG_1      1.000
##      wj_wrdd_r_KG_3      1.000
##      wj_wrdd_r_FG_1      1.000
##      wj_wrdd_r_FG_3      1.000
##      slope =~
##      wj_wrdd_r_KG_1      0.000
##      wj_wrdd_r_KG_3      1.000
##      wj_wrdd_r_FG_1      2.000
##      wj_wrdd_r_FG_3      3.000
##
## Covariances:
##      Estimate Std.Err z-value P(>|z|)
##      intercept ~~
##      slope            3.367    2.825    1.192    0.233
##
## Intercepts:
##      Estimate Std.Err z-value P(>|z|)
##      .wj_wrdd_r_KG_1      0.000
##      .wj_wrdd_r_KG_3      0.000
##      .wj_wrdd_r_FG_1      0.000
##      .wj_wrdd_r_FG_3      0.000
##      intercept      17.510    1.034    16.928    0.000
##      slope            7.244    0.312    23.202    0.000
##
## Variances:
##      Estimate Std.Err z-value P(>|z|)
##      .wj_w_KG_1 (a)    23.605    3.370    7.005    0.000
##      .wj_w_KG_3 (a)    23.605    3.370    7.005    0.000
##      .wj_w_FG_1 (a)    23.605    3.370    7.005    0.000
##      .wj_w_FG_3 (a)    23.605    3.370    7.005    0.000
##      intercept      42.936   12.033    3.568    0.000
##      slope            0.387    1.280    0.303    0.762

```

```
semPaths(mod.SEM.equal.resid)
```



```
anova(mod.SEM.random, mod.SEM.equal.resid)
```

```
## Chi Square Difference Test
```

```
##
```

```
##           Df      AIC      BIC  Chisq Chisq diff Df diff Pr(>Chisq)
```

```
## mod.SEM.random      5 1422.2 1440.6 46.839
```

```
## mod.SEM.equal.resid  8 1419.4 1431.6 50.023      3.1842      3      0.3641
```

Constraining the residual variances does not significantly change model fit. LogLikelihood tests indicate that a simpler model, where residual variances are allowed to vary, is preferred to a more complex model where they are constrained to be equal.

6. Constrain your slope to be fixed, not random. How does this change your model?

```
summary(mod.SEM.fixed) # model from question #4 with fixed slope.
```

```
## lavaan (0.5-23.1097) converged normally after 70 iterations
```

```
##
```

```
##   Number of observations                        57
```

```
##
```

```
##   Number of missing patterns                      6
```

```
##
```

```
##   Estimator                                      ML
```

```
##   Minimum Function Test Statistic                46.918
```

```

## Degrees of freedom                                6
## P-value (Chi-square)                             0.000
##
## Parameter Estimates:
##
## Information                                     Observed
## Standard Errors                               Standard
##
## Latent Variables:
##      Estimate Std.Err z-value P(>|z|)
## intercept =~
##   wj_wrdd_r_KG_1    1.000
##   wj_wrdd_r_KG_3    1.000
##   wj_wrdd_r_FG_1    1.000
##   wj_wrdd_r_FG_3    1.000
## slope =~
##   wj_wrdd_r_KG_1    0.000
##   wj_wrdd_r_KG_3    1.000
##   wj_wrdd_r_FG_1    2.000
##   wj_wrdd_r_FG_3    3.000
##
## Covariances:
##      Estimate Std.Err z-value P(>|z|)
## intercept ~~
##   slope          4.786    2.726    1.755    0.079
##
## Intercepts:
##      Estimate Std.Err z-value P(>|z|)
## .wj_wrdd_r_KG_1    0.000
## .wj_wrdd_r_KG_3    0.000
## .wj_wrdd_r_FG_1    0.000
## .wj_wrdd_r_FG_3    0.000
## intercept        17.341    1.029   16.856    0.000
## slope             7.107    0.350   20.296    0.000
##
## Variances:
##      Estimate Std.Err z-value P(>|z|)
## slope          0.000
## .wj_wrdd_r_KG_1   20.109    4.985    4.034    0.000
## .wj_wrdd_r_KG_3   28.348    6.856    4.135    0.000
## .wj_wrdd_r_FG_1   16.412    5.862    2.800    0.005
## .wj_wrdd_r_FG_3   32.312    9.066    3.564    0.000
## intercept        41.959   11.468    3.659    0.000

```

```
anova(mod.SEM.random, mod.SEM.fixed)
```

```
## Chi Square Difference Test
```

```

##
##      Df    AIC    BIC Chisq Chisq diff Df diff Pr(>Chisq)
## mod.SEM.random  5 1422.2 1440.6 46.839
## mod.SEM.fixed   6 1420.3 1436.6 46.918    0.079614      1    0.7778

```

Constraining slopes to be fixed does not significantly change my model ($p = .78$).

7. Change the time metric in your SEM growth model. How does that change your estimates? Does it change your fit statistics?

changed my time metric such that the intercept was centered at the end of first grade rather than at the beginning of kindergarten. This increased the intercept from around 17.5 to 38.8 (which makes sense, given age-related change) but the slope did not change much and model fit did not change.

```
mod.SEM4 <- 'intercept =~ 1*wj_wordid_raw_KG_1 + 1*wj_wordid_raw_KG_3 + 1*wj_wordid_raw_FG_1 + 1*wj_wordid_raw_FG_3
              slope =~ -3*wj_wordid_raw_KG_1 + -2*wj_wordid_raw_KG_3 + -1*wj_wordid_raw_FG_1 + 0*wj_wordid_raw_FG_3'
mod.SEM.time <- growth(mod.SEM4, missing = "ML", data = Chicago.wide)
summary(mod.SEM.time)
```

```
## lavaan (0.5-23.1097) converged normally after 101 iterations
```

```
##
##   Number of observations                57
##
##   Number of missing patterns           6
##
##   Estimator                            ML
##   Minimum Function Test Statistic      46.839
##   Degrees of freedom                   5
##   P-value (Chi-square)                 0.000
```

```
## Parameter Estimates:
```

```
##
##   Information                        Observed
##   Standard Errors                   Standard
##
```

```
## Latent Variables:
```

```
##           Estimate Std.Err z-value P(>|z|)
## intercept =~
##   wj_wrdd_r_KG_1    1.000
##   wj_wrdd_r_KG_3    1.000
##   wj_wrdd_r_FG_1    1.000
##   wj_wrdd_r_FG_3    1.000
## slope =~
##   wj_wrdd_r_KG_1   -3.000
##   wj_wrdd_r_KG_3   -2.000
##   wj_wrdd_r_FG_1   -1.000
##   wj_wrdd_r_FG_3    0.000
```

```
## Covariances:
```

```
##           Estimate Std.Err z-value P(>|z|)
## intercept ~~
##   slope            5.754   4.469   1.288   0.198
```

```
## Intercepts:
```

```
##           Estimate Std.Err z-value P(>|z|)
## .wj_wrdd_r_KG_1    0.000
## .wj_wrdd_r_KG_3    0.000
## .wj_wrdd_r_FG_1    0.000
## .wj_wrdd_r_FG_3    0.000
## intercept        38.795   1.431  27.109   0.000
## slope             7.171   0.425  16.864   0.000
```

```
##
## Variances:
##           Estimate Std.Err z-value P(>|z|)
## .wj_wrdd_r_KG_1  17.474  10.676   1.637   0.102
## .wj_wrdd_r_KG_3  29.132   7.750   3.759   0.000
## .wj_wrdd_r_FG_1  17.220   6.852   2.513   0.012
## .wj_wrdd_r_FG_3  29.256  14.210   2.059   0.040
## intercept       71.065  17.517   4.057   0.000
## slope           0.692   2.531   0.274   0.784
anova(mod.SEM.random, mod.SEM.time)

## Chi Square Difference Test
##
##           Df      AIC      BIC Chisq Chisq diff Df diff Pr(>Chisq)
## mod.SEM.random  5 1422.2 1440.6 46.839
## mod.SEM.time    5 1422.2 1440.6 46.839 -1.009e-12      0      1
```

8. Try a different type of estimation (see lavaan tutorial for details). How does that change your model?

Changing the estimator to MLR did not change the estimates. Instead, it changes the standard errors. And it added an extra “Robust” column to the fit statistics to indicate the robust goodness of fit.

```
mod.SEM.random.MLR <- growth(mod.SEM2, missing = "ML", estimator = "MLR", data = Chicago.wide)
summary(mod.SEM.random)
```

```
## lavaan (0.5-23.1097) converged normally after 74 iterations
##
## Number of observations                    57
##
## Number of missing patterns                6
##
## Estimator                                ML
## Minimum Function Test Statistic          46.839
## Degrees of freedom                       5
## P-value (Chi-square)                     0.000
##
## Parameter Estimates:
##
## Information                                Observed
## Standard Errors                          Standard
##
## Latent Variables:
##           Estimate Std.Err z-value P(>|z|)
## intercept =~
##   wj_wrdd_r_KG_1    1.000
##   wj_wrdd_r_KG_3    1.000
##   wj_wrdd_r_FG_1    1.000
##   wj_wrdd_r_FG_3    1.000
## slope =~
##   wj_wrdd_r_KG_1    0.000
##   wj_wrdd_r_KG_3    1.000
```

```

##      wj_wrdd_r_FG_1      2.000
##      wj_wrdd_r_FG_3      3.000
##
## Covariances:
##              Estimate Std.Err z-value P(>|z|)
## intercept ~~
##      slope          3.677   4.938   0.745   0.456
##
## Intercepts:
##              Estimate Std.Err z-value P(>|z|)
##      .wj_wrdd_r_KG_1    0.000
##      .wj_wrdd_r_KG_3    0.000
##      .wj_wrdd_r_FG_1    0.000
##      .wj_wrdd_r_FG_3    0.000
##      intercept      17.282   1.041  16.597   0.000
##      slope           7.171   0.425  16.864   0.000
##
## Variances:
##              Estimate Std.Err z-value P(>|z|)
##      .wj_wrdd_r_KG_1   17.474  10.676   1.637   0.102
##      .wj_wrdd_r_KG_3   29.132   7.750   3.759   0.000
##      .wj_wrdd_r_FG_1   17.220   6.852   2.513   0.012
##      .wj_wrdd_r_FG_3   29.256  14.210   2.059   0.040
##      intercept      42.772  11.672   3.664   0.000
##      slope           0.692   2.531   0.274   0.784

```

```
summary(mod.SEM.random.MLR)
```

```

## lavaan (0.5-23.1097) converged normally after 74 iterations
##
##      Number of observations                    57
##
##      Number of missing patterns                6
##
##      Estimator                                ML      Robust
##      Minimum Function Test Statistic          46.839  37.301
##      Degrees of freedom                        5        5
##      P-value (Chi-square)                     0.000    0.000
##      Scaling correction factor                 1.256
##      for the Yuan-Bentler correction
##
## Parameter Estimates:
##
##      Information                                Observed
##      Standard Errors                          Robust.huber.white
##
## Latent Variables:
##              Estimate Std.Err z-value P(>|z|)
## intercept =~
##      wj_wrdd_r_KG_1    1.000
##      wj_wrdd_r_KG_3    1.000
##      wj_wrdd_r_FG_1    1.000
##      wj_wrdd_r_FG_3    1.000
## slope =~
##      wj_wrdd_r_KG_1    0.000

```

```
##      wj_wrdd_r_KG_3      1.000
##      wj_wrdd_r_FG_1      2.000
##      wj_wrdd_r_FG_3      3.000
##
## Covariances:
##              Estimate Std.Err z-value P(>|z|)
## intercept ~~
##      slope          3.677   5.068   0.726   0.468
##
## Intercepts:
##              Estimate Std.Err z-value P(>|z|)
##      .wj_wrdd_r_KG_1      0.000
##      .wj_wrdd_r_KG_3      0.000
##      .wj_wrdd_r_FG_1      0.000
##      .wj_wrdd_r_FG_3      0.000
##      intercept      17.282   1.139  15.179   0.000
##      slope           7.171   0.524  13.680   0.000
##
## Variances:
##              Estimate Std.Err z-value P(>|z|)
##      .wj_wrdd_r_KG_1     17.474  13.597   1.285   0.199
##      .wj_wrdd_r_KG_3     29.132   9.916   2.938   0.003
##      .wj_wrdd_r_FG_1     17.220   8.341   2.064   0.039
##      .wj_wrdd_r_FG_3     29.256  17.236   1.697   0.090
##      intercept      42.772  15.669   2.730   0.006
##      slope           0.692   2.796   0.248   0.804
```

—NEW QUESTIONS—

10. Test measurement invariance across time for your construct. Can you run growth models? If there is evidence of non-invariance, what seems to be the problem?

The config model fits significantly better than the weak model and the cfi decreases by more than .01, suggesting measurement invariance.

```
config.fit <- fit.3
```

```
summary(config.fit, standardized = TRUE, fit.measures = T)
```

```
## lavaan (0.5-23.1097) converged normally after 122 iterations
##
##              Used      Total
## Number of observations          40          57
##
## Estimator              ML
## Minimum Function Test Statistic      19.135
## Degrees of freedom              15
## P-value (Chi-square)          0.208
##
## Model test baseline model:
```



```

##
## Minimum Function Test Statistic          209.349
## Degrees of freedom                      36
## P-value                                0.000
##
## User model versus baseline model:
##
## Comparative Fit Index (CFI)              0.976
## Tucker-Lewis Index (TLI)                0.943
##
## Loglikelihood and Information Criteria:
##
## Loglikelihood user model (H0)            -890.787
## Loglikelihood unrestricted model (H1)    -881.220
##
## Number of free parameters                39
## Akaike (AIC)                            1859.575
## Bayesian (BIC)                          1925.441
## Sample-size adjusted Bayesian (BIC)     1803.400
##
## Root Mean Square Error of Approximation:
##
## RMSEA                                  0.083
## 90 Percent Confidence Interval          0.000 0.181
## P-value RMSEA <= 0.05                  0.296
##
## Standardized Root Mean Square Residual:
##
## SRMR                                  0.050
##
## Parameter Estimates:
##
## Information                            Expected
## Standard Errors                      Standard
##
## Latent Variables:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## Phonemic_t1 =~
##   ctppl_rw_KG_1  1.872  0.388  4.825  0.000  1.872  0.720
##   ctpplr_r_KG_1  2.496  0.525  4.755  0.000  2.496  0.706
##   ctppl_sm_r_KG_1 3.417  0.721  4.740  0.000  3.417  0.734
## Phonemic_t2 =~
##   ctppl_rw_KG_3  2.754  0.587  4.692  0.000  2.754  0.733
##   ctpplr_r_KG_3  1.639  0.548  2.989  0.003  1.639  0.489
##   ctppl_sm_r_KG_3 2.422  0.757  3.201  0.001  2.422  0.545
## Phonemic_t3 =~
##   ctppl_rw_FG_1  2.553  0.611  4.176  0.000  2.553  0.643
##   ctpplr_r_FG_1  1.386  0.476  2.910  0.004  1.386  0.463
##   ctppl_sm_r_FG_1 3.724  0.804  4.632  0.000  3.724  0.720
##
## Covariances:
##      Estimate Std.Err z-value P(>|z|) Std.lv
## .ctopp_el_raw_KG_1 ~~
##   .ctpp_l_rw_KG_3      1.931  1.126  1.714  0.086  1.931

```

##	.ctpp_l_rw_FG_1	1.650	1.237	1.333	0.182	1.650
##	.ctopp_el_raw_KG_3 ~~					
##	.ctpp_l_rw_FG_1	4.046	1.939	2.086	0.037	4.046
##	.ctopp_nr_raw_KG_1 ~~					
##	.ctpp_nr_r_KG_3	1.256	1.367	0.919	0.358	1.256
##	.ctpp_nr_r_FG_1	0.813	1.247	0.652	0.514	0.813
##	.ctopp_nr_raw_KG_3 ~~					
##	.ctpp_nr_r_FG_1	4.110	1.510	2.722	0.006	4.110
##	.ctopp_sm_raw_KG_1 ~~					
##	.ctpp_sm_r_KG_3	0.054	2.510	0.022	0.983	0.054
##	.ctpp_sm_r_FG_1	-2.914	2.766	-1.054	0.292	-2.914
##	.ctopp_sm_raw_KG_3 ~~					
##	.ctpp_sm_r_FG_1	7.480	3.256	2.297	0.022	7.480
##	Phonemic_t1 ~~					
##	Phonemic_t2	0.974	0.098	9.975	0.000	0.974
##	Phonemic_t3	1.070	0.093	11.570	0.000	1.070
##	Phonemic_t2 ~~					
##	Phonemic_t3	1.052	0.066	15.975	0.000	1.052
##	Std.all					
##						
##	0.419					
##	0.301					
##						
##	0.520					
##						
##	0.171					
##	0.122					
##						
##	0.529					
##						
##	0.005					
##	-0.257					
##						
##	0.560					
##						
##	0.974					
##	1.070					
##						
##	1.052					
##						

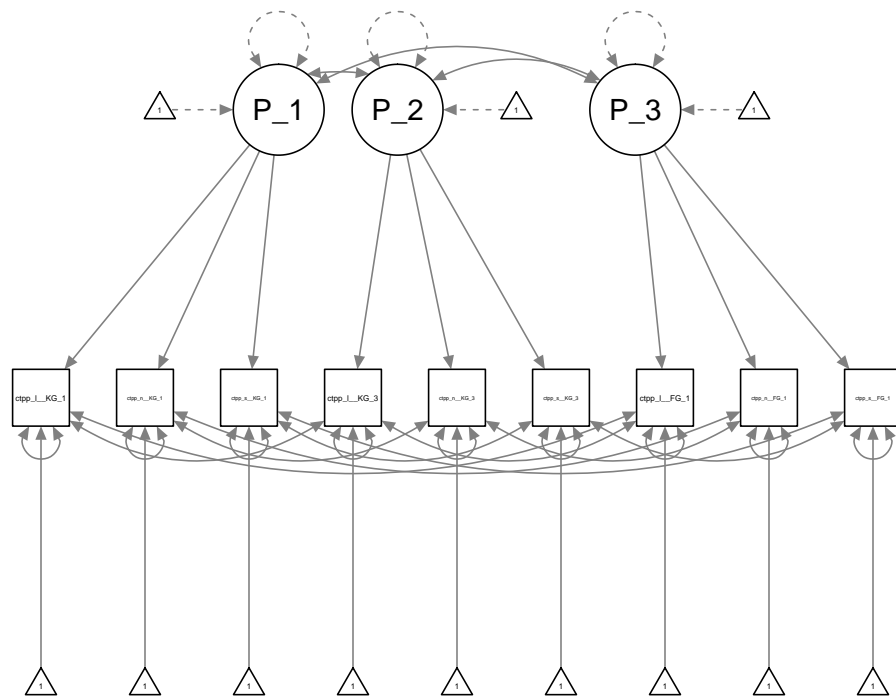
Intercepts:

##		Estimate	Std.Err	z-value	P(> z)	Std.lv	Std.all
##	.ctpp_l_rw_KG_1	3.825	0.411	9.308	0.000	3.825	1.472
##	.ctpp_nr_r_KG_1	7.700	0.559	13.777	0.000	7.700	2.178
##	.ctpp_sm_r_KG_1	9.625	0.736	13.083	0.000	9.625	2.069
##	.ctpp_l_rw_KG_3	7.425	0.594	12.494	0.000	7.425	1.975
##	.ctpp_nr_r_KG_3	9.400	0.530	17.724	0.000	9.400	2.802
##	.ctpp_sm_r_KG_3	14.475	0.702	20.623	0.000	14.475	3.261
##	.ctpp_l_rw_FG_1	8.050	0.628	12.819	0.000	8.050	2.027
##	.ctpp_nr_r_FG_1	9.075	0.473	19.177	0.000	9.075	3.032
##	.ctpp_sm_r_FG_1	15.275	0.818	18.683	0.000	15.275	2.954
##	Phonemic_t1	0.000				0.000	0.000
##	Phonemic_t2	0.000				0.000	0.000
##	Phonemic_t3	0.000				0.000	0.000

```
##
## Variances:
##
```

	Estimate	Std.Err	z-value	P(> z)	Std.lv	Std.all
## .ctpp_l_rw_KG_1	3.250	0.940	3.458	0.001	3.250	0.481
## .ctpp_nr_r_KG_1	6.264	1.728	3.625	0.000	6.264	0.501
## .ctpp_sm_r_KG_1	9.970	3.286	3.034	0.002	9.970	0.461
## .ctpp_l_rw_KG_3	6.545	2.196	2.980	0.003	6.545	0.463
## .ctpp_nr_r_KG_3	8.566	2.065	4.148	0.000	8.566	0.761
## .ctpp_sm_r_KG_3	13.842	3.635	3.808	0.000	13.842	0.702
## .ctpp_l_rw_FG_1	9.254	2.414	3.833	0.000	9.254	0.587
## .ctpp_nr_r_FG_1	7.037	1.640	4.291	0.000	7.037	0.786
## .ctpp_sm_r_FG_1	12.872	4.037	3.188	0.001	12.872	0.481
## Phonemic_t1	1.000				1.000	1.000
## Phonemic_t2	1.000				1.000	1.000
## Phonemic_t3	1.000				1.000	1.000

```
semPaths(config.fit)
```



```
# Weak - constrain factor loadings to be the same across time
```

```
weak <- '
## define latent variables, constrain factor loadings
Phonemic_t1 =~ L1*ctopp_el_raw_KG_1 + L2*ctopp_nr_raw_KG_1 + L3*ctopp_sm_raw_KG_1
Phonemic_t2 =~ L1*ctopp_el_raw_KG_3 + L2*ctopp_nr_raw_KG_3 + L3*ctopp_sm_raw_KG_3
Phonemic_t3 =~ L1*ctopp_el_raw_FG_1 + L2*ctopp_nr_raw_FG_1 + L3*ctopp_sm_raw_FG_1

## free latent variances at later times
```

```

Phonemic_t2 ~~ NA*Phonemic_t2
Phonemic_t3 ~~ NA*Phonemic_t3

## correlated residuals across time
      ctopp_el_raw_KG_1 ~~ ctopp_el_raw_KG_3 + ctopp_el_raw_FG_1
      ctopp_el_raw_KG_3 ~~ ctopp_el_raw_FG_1
      ctopp_nr_raw_KG_1 ~~ ctopp_nr_raw_KG_3 + ctopp_nr_raw_FG_1
      ctopp_nr_raw_KG_3 ~~ ctopp_nr_raw_FG_1
      ctopp_sm_raw_KG_1 ~~ ctopp_sm_raw_KG_3 + ctopp_sm_raw_FG_1
      ctopp_sm_raw_KG_3 ~~ ctopp_sm_raw_FG_1'

weak.fit <- cfa(weak, data=Chicago.wide, meanstructure=TRUE, std.lv=TRUE)

summary(weak.fit, standardized=TRUE, fit.measures=TRUE)

## lavaan (0.5-23.1097) converged normally after 104 iterations
##
##
##           Used           Total
## Number of observations           40           57
##
## Estimator                     ML
## Minimum Function Test Statistic    29.789
## Degrees of freedom                19
## P-value (Chi-square)              0.055
##
## Model test baseline model:
##
## Minimum Function Test Statistic    209.349
## Degrees of freedom                36
## P-value                          0.000
##
## User model versus baseline model:
##
## Comparative Fit Index (CFI)        0.938
## Tucker-Lewis Index (TLI)          0.882
##
## Loglikelihood and Information Criteria:
##
## Loglikelihood user model (H0)      -896.114
## Loglikelihood unrestricted model (H1) -881.220
##
## Number of free parameters           35
## Akaike (AIC)                      1862.229
## Bayesian (BIC)                    1921.340
## Sample-size adjusted Bayesian (BIC) 1811.815
##
## Root Mean Square Error of Approximation:
##
## RMSEA                          0.119
## 90 Percent Confidence Interval    0.000 0.198
## P-value RMSEA <= 0.05            0.102
##
## Standardized Root Mean Square Residual:
##

```

```

##      SRMR                                0.127
##
## Parameter Estimates:
##
##      Information                                Expected
##      Standard Errors                                Standard
##
## Latent Variables:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
##      Phonemic_t1 =~
##      ct___KG_1 (L1)    2.001    0.388    5.153    0.000    2.001    0.758
##      ct___KG_1 (L2)    1.956    0.424    4.609    0.000    1.956    0.607
##      ct___KG_1 (L3)    3.150    0.632    4.987    0.000    3.150    0.672
##      Phonemic_t2 =~
##      ct___KG_3 (L1)    2.001    0.388    5.153    0.000    1.871    0.545
##      ct___KG_3 (L2)    1.956    0.424    4.609    0.000    1.828    0.535
##      ct___KG_3 (L3)    3.150    0.632    4.987    0.000    2.944    0.614
##      Phonemic_t3 =~
##      ct___FG_1 (L1)    2.001    0.388    5.153    0.000    2.107    0.562
##      ct___FG_1 (L2)    1.956    0.424    4.609    0.000    2.059    0.619
##      ct___FG_1 (L3)    3.150    0.632    4.987    0.000    3.317    0.659
##
## Covariances:
##      Estimate Std.Err z-value P(>|z|) Std.lv
##      .ctopp_el_raw_KG_1 ~~
##      .ctpp_l_rw_KG_3      2.062    1.119    1.842    0.065    2.062
##      .ctpp_l_rw_FG_1      1.387    1.243    1.116    0.264    1.387
##      .ctopp_el_raw_KG_3 ~~
##      .ctpp_l_rw_FG_1      4.958    1.925    2.575    0.010    4.958
##      .ctopp_nr_raw_KG_1 ~~
##      .ctpp_nr_r_KG_3      0.984    1.380    0.713    0.476    0.984
##      .ctpp_nr_r_FG_1     -0.022    1.303   -0.017    0.986   -0.022
##      .ctopp_nr_raw_KG_3 ~~
##      .ctpp_nr_r_FG_1      3.521    1.595    2.208    0.027    3.521
##      .ctopp_sm_raw_KG_1 ~~
##      .ctpp_sm_r_KG_3      0.974    2.758    0.353    0.724    0.974
##      .ctpp_sm_r_FG_1     -1.359    2.900   -0.469    0.639   -1.359
##      .ctopp_sm_raw_KG_3 ~~
##      .ctpp_sm_r_FG_1      7.725    3.503    2.205    0.027    7.725
##      Phonemic_t1 ~~
##      Phonemic_t2      0.916    0.178    5.149    0.000    0.980
##      Phonemic_t3      1.159    0.196    5.916    0.000    1.101
##      Phonemic_t2 ~~
##      Phonemic_t3      1.074    0.318    3.382    0.001    1.091
##      Std.all
##
##      0.416
##      0.260
##
##      0.556
##
##      0.133
##      -0.003
##

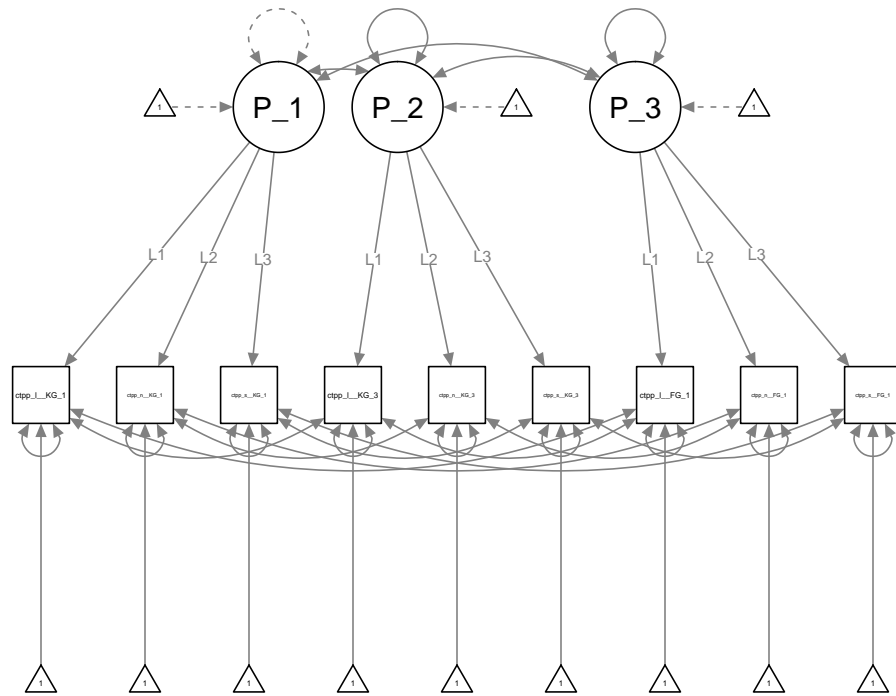
```

```

##      0.467
##
##      0.074
##     -0.103
##
##      0.538
##
##      0.980
##      1.101
##
##      1.091
##
## Intercepts:
##           Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .ctpp_l_rw_KG_1    3.825   0.417   9.165   0.000   3.825   1.449
## .ctpp_nr_r_KG_1    7.700   0.509  15.114   0.000   7.700   2.390
## .ctpp_sm_r_KG_1    9.625   0.741  12.995   0.000   9.625   2.055
## .ctpp_l_rw_KG_3    7.425   0.543  13.680   0.000   7.425   2.163
## .ctpp_nr_r_KG_3    9.400   0.540  17.401   0.000   9.400   2.751
## .ctpp_sm_r_KG_3   14.475   0.758  19.086   0.000  14.475   3.018
## .ctpp_l_rw_FG_1    8.050   0.592  13.589   0.000   8.050   2.149
## .ctpp_nr_r_FG_1    9.075   0.526  17.244   0.000   9.075   2.727
## .ctpp_sm_r_FG_1   15.275   0.796  19.182   0.000  15.275   3.033
## Phonemic_t1         0.000                0.000   0.000
## Phonemic_t2         0.000                0.000   0.000
## Phonemic_t3         0.000                0.000   0.000
##
## Variances:
##           Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## Phonemic_t2         0.874   0.321   2.725   0.006   1.000   1.000
## Phonemic_t3         1.109   0.348   3.182   0.001   1.000   1.000
## .ctpp_l_rw_KG_1    2.962   0.975   3.039   0.002   2.962   0.425
## .ctpp_nr_r_KG_1    6.558   1.694   3.871   0.000   6.558   0.632
## .ctpp_sm_r_KG_1   12.024   3.444   3.491   0.000  12.024   0.548
## .ctpp_l_rw_KG_3    8.285   2.119   3.909   0.000   8.285   0.703
## .ctpp_nr_r_KG_3    8.331   2.120   3.930   0.000   8.331   0.714
## .ctpp_sm_r_KG_3   14.340   4.063   3.530   0.000  14.340   0.623
## .ctpp_l_rw_FG_1    9.597   2.404   3.992   0.000   9.597   0.684
## .ctpp_nr_r_FG_1    6.837   1.762   3.880   0.000   6.837   0.617
## .ctpp_sm_r_FG_1   14.366   4.012   3.581   0.000  14.366   0.566
## Phonemic_t1         1.000                1.000   1.000

```

```
semPaths(weak.fit)
```



Strong - constrain means/intercepts of indicators to be equal

```
strong <- '
## define latent variables, constrain factor loadings
Phonemic_t1 =~ L1*ctopp_el_raw_KG_1 + L2*ctopp_nr_raw_KG_1 + L3*ctopp_sm_raw_KG_1
Phonemic_t2 =~ L1*ctopp_el_raw_KG_3 + L2*ctopp_nr_raw_KG_3 + L3*ctopp_sm_raw_KG_3
Phonemic_t3 =~ L1*ctopp_el_raw_FG_1 + L2*ctopp_nr_raw_FG_1 + L3*ctopp_sm_raw_FG_1

## free latent variances at later times
Phonemic_t2 ~~ NA*Phonemic_t2
Phonemic_t3 ~~ NA*Phonemic_t3

## correlated residuals across time
ctopp_el_raw_KG_1 ~~ ctopp_el_raw_KG_3 + ctopp_el_raw_FG_1
ctopp_el_raw_KG_3 ~~ ctopp_el_raw_FG_1
ctopp_nr_raw_KG_1 ~~ ctopp_nr_raw_KG_3 + ctopp_nr_raw_FG_1
ctopp_nr_raw_KG_3 ~~ ctopp_nr_raw_FG_1
ctopp_sm_raw_KG_1 ~~ ctopp_sm_raw_KG_3 + ctopp_sm_raw_FG_1
ctopp_sm_raw_KG_3 ~~ ctopp_sm_raw_FG_1

## constrain intercepts across time
ctopp_el_raw_KG_1 ~ A*1
ctopp_nr_raw_KG_1 ~ B*1
ctopp_sm_raw_KG_1 ~ C*1
```

```

ctopp_el_raw_KG_3 ~ A*1
ctopp_nr_raw_KG_3 ~ B*1
ctopp_sm_raw_KG_3 ~ C*1

ctopp_el_raw_FG_1 ~ A*1
ctopp_nr_raw_FG_1 ~ B*1
ctopp_sm_raw_FG_1 ~ C*1

##free latent means at later times
    Phonemic_t2 ~ NA*1
    Phonemic_t3 ~ NA*1'

strong.fit <- cfa(strong, data=Chicago.wide, meanstructure=TRUE, std.lv=TRUE)

summary(strong.fit, standardized=TRUE, fit.measures=TRUE)

```

```

## lavaan (0.5-23.1097) converged normally after 126 iterations
##
##                                     Used      Total
##   Number of observations                40         57
##
##   Estimator                          ML
##   Minimum Function Test Statistic      35.216
##   Degrees of freedom                   23
##   P-value (Chi-square)                 0.050
##
## Model test baseline model:
##
##   Minimum Function Test Statistic      209.349
##   Degrees of freedom                   36
##   P-value                             0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)          0.930
##   Tucker-Lewis Index (TLI)            0.890
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)        -898.828
##   Loglikelihood unrestricted model (H1) -881.220
##
##   Number of free parameters            31
##   Akaike (AIC)                        1859.656
##   Bayesian (BIC)                      1912.011
##   Sample-size adjusted Bayesian (BIC)  1815.004
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                0.115
##   90 Percent Confidence Interval      0.006  0.187
##   P-value RMSEA <= 0.05              0.099
##
## Standardized Root Mean Square Residual:

```



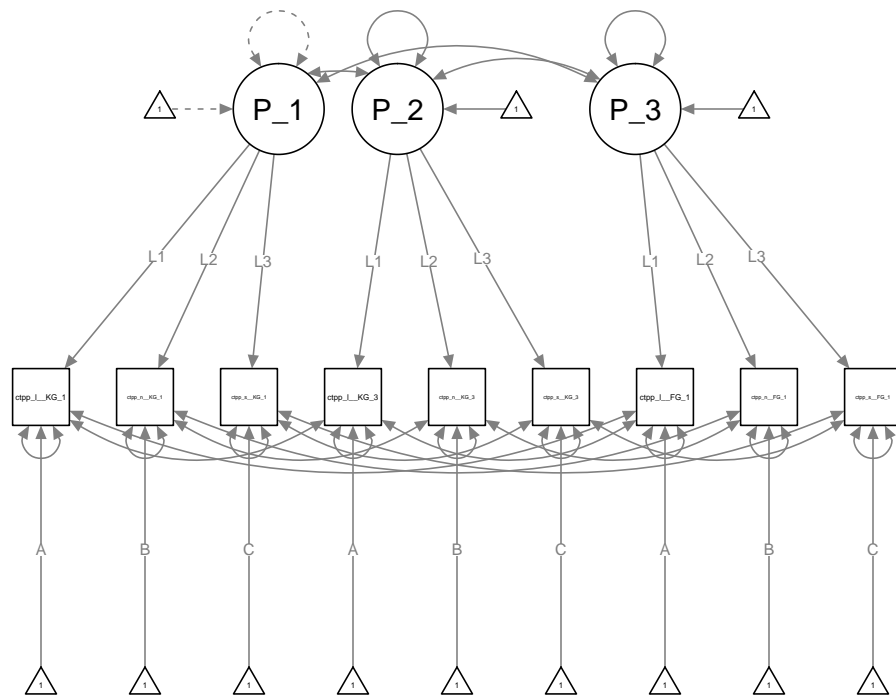
```

##
##      SRMR                      0.126
##
## Parameter Estimates:
##
##      Information                      Expected
##      Standard Errors                  Standard
##
## Latent Variables:
##      Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      Phonemic_t1 =~
##      ct___KG_1 (L1)    2.123    0.379    5.595    0.000    2.123    0.779
##      ct___KG_1 (L2)    1.153    0.281    4.098    0.000    1.153    0.364
##      ct___KG_1 (L3)    2.827    0.521    5.424    0.000    2.827    0.621
##      Phonemic_t2 =~
##      ct___KG_3 (L1)    2.123    0.379    5.595    0.000    2.509    0.701
##      ct___KG_3 (L2)    1.153    0.281    4.098    0.000    1.363    0.414
##      ct___KG_3 (L3)    2.827    0.521    5.424    0.000    3.341    0.691
##      Phonemic_t3 =~
##      ct___FG_1 (L1)    2.123    0.379    5.595    0.000    2.795    0.707
##      ct___FG_1 (L2)    1.153    0.281    4.098    0.000    1.518    0.493
##      ct___FG_1 (L3)    2.827    0.521    5.424    0.000    3.722    0.717
##
## Covariances:
##      Estimate  Std.Err  z-value  P(>|z|)  Std.lv
##      .ctopp_el_raw_KG_1 ~~
##      .ctpp_l_rw_KG_3      1.694    1.225    1.383    0.167    1.694
##      .ctpp_l_rw_FG_1      0.772    1.375    0.562    0.574    0.772
##      .ctopp_el_raw_KG_3 ~~
##      .ctpp_l_rw_FG_1      3.008    1.902    1.581    0.114    3.008
##      .ctopp_nr_raw_KG_1 ~~
##      .ctpp_nr_r_KG_3      2.115    1.494    1.416    0.157    2.115
##      .ctpp_nr_r_FG_1      0.893    1.319    0.677    0.498    0.893
##      .ctopp_nr_raw_KG_3 ~~
##      .ctpp_nr_r_FG_1      4.160    1.526    2.727    0.006    4.160
##      .ctopp_sm_raw_KG_1 ~~
##      .ctpp_sm_r_KG_3     -0.025    2.681   -0.009    0.992   -0.025
##      .ctpp_sm_r_FG_1     -1.860    2.905   -0.640    0.522   -1.860
##      .ctopp_sm_raw_KG_3 ~~
##      .ctpp_sm_r_FG_1      5.979    3.461    1.727    0.084    5.979
##      Phonemic_t1 ~~
##      Phonemic_t2      1.120    0.233    4.801    0.000    0.947
##      Phonemic_t3      1.425    0.274    5.209    0.000    1.082
##      Phonemic_t2 ~~
##      Phonemic_t3      1.659    0.480    3.453    0.001    1.066
##      Std.all
##
##      0.389
##      0.162
##
##      0.422
##
##      0.239
##      0.113

```

```
##
##      0.518
##
##     -0.002
##     -0.144
##
##      0.473
##
##      0.947
##      1.082
##
##      1.066
##
## Intercepts:
##           Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .ctp___KG_1 (A)    3.867   0.428   9.035   0.000   3.867   1.419
## .ctp___KG_1 (B)    7.306   0.446  16.369   0.000   7.306   2.307
## .ctp___KG_1 (C)    9.740   0.683  14.252   0.000   9.740   2.140
## .ctp___KG_3 (A)    3.867   0.428   9.035   0.000   3.867   1.081
## .ctp___KG_3 (B)    7.306   0.446  16.369   0.000   7.306   2.218
## .ctp___KG_3 (C)    9.740   0.683  14.252   0.000   9.740   2.013
## .ctp___FG_1 (A)    3.867   0.428   9.035   0.000   3.867   0.978
## .ctp___FG_1 (B)    7.306   0.446  16.369   0.000   7.306   2.373
## .ctp___FG_1 (C)    9.740   0.683  14.252   0.000   9.740   1.877
## Phonemc_t2         1.686   0.323   5.223   0.000   1.427   1.427
## Phonemc_t3         1.895   0.352   5.378   0.000   1.440   1.440
## Phonemc_t1         0.000               0.000   0.000
##
## Variances:
##           Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## Phonemic_t2         1.397   0.469   2.976   0.003   1.000   1.000
## Phonemic_t3         1.734   0.527   3.291   0.001   1.000   1.000
## .ctpp_l_rw_KG_1     2.915   1.149   2.537   0.011   2.915   0.393
## .ctpp_nr_r_KG_1     8.702   1.995   4.362   0.000   8.702   0.867
## .ctpp_sm_r_KG_1    12.718   3.460   3.676   0.000  12.718   0.614
## .ctpp_l_rw_KG_3     6.499   2.057   3.159   0.002   6.499   0.508
## .ctpp_nr_r_KG_3     8.995   2.101   4.282   0.000   8.995   0.829
## .ctpp_sm_r_KG_3    12.237   3.843   3.185   0.001  12.237   0.523
## .ctpp_l_rw_FG_1     7.831   2.408   3.252   0.001   7.831   0.501
## .ctpp_nr_r_FG_1     7.177   1.674   4.287   0.000   7.177   0.757
## .ctpp_sm_r_FG_1    13.080   4.135   3.163   0.002  13.080   0.486
## Phonemic_t1         1.000               1.000   1.000
```

```
semPaths(strong.fit)
```



```
anova(config.fit, weak.fit)
```

```
## Chi Square Difference Test
##
##           Df    AIC    BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## config.fit 15 1859.6 1925.4 19.134
## weak.fit   19 1862.2 1921.3 29.789    10.654      4   0.03074 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
anova(weak.fit, strong.fit)
```

```
## Chi Square Difference Test
##
##           Df    AIC    BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## weak.fit   19 1862.2 1921.3 29.789
## strong.fit 23 1859.7 1912.0 35.216     5.4272      4   0.2462
```

```
fitmeasures(config.fit)['cfi']
```

```
##          cfi
## 0.9761492
```

```
fitmeasures(weak.fit)['cfi']
```

```
##          cfi
## 0.9377633
```

```
fitmeasures(strong.fit)['cfi']
```

```
##          cfi
## 0.9295299
```

11. Fit a second order growth model. Compare and contrast the estimates with the normal latent growth model.

Overall the estimates are not that different. The estimates of the first order model vs. the second order model:

Intercept: 6.734 vs. 7.445 Slope: 1.426 vs. 1.696

```
sec.order <- '
## define latent variables
    Phonemic_t1 =~ NA*L1*ctopp_el_raw_KG_1 + L1*ctopp_el_raw_KG_1 + L2*ctopp_nr_raw_KG_1 + L3*ctopp_sm_raw_KG_1
    Phonemic_t2 =~ NA*L1*ctopp_el_raw_KG_3 + L1*ctopp_el_raw_KG_3 + L2*ctopp_nr_raw_KG_3 + L3*ctopp_sm_raw_KG_3
    Phonemic_t3 =~ NA*L1*ctopp_el_raw_FG_1 + L1*ctopp_el_raw_FG_1 + L2*ctopp_nr_raw_FG_1 + L3*ctopp_sm_raw_FG_1

## intercepts
ctopp_el_raw_KG_1 ~ A*1
ctopp_nr_raw_KG_1 ~ B*1
ctopp_sm_raw_KG_1 ~ C*1

ctopp_el_raw_KG_3 ~ A*1
ctopp_nr_raw_KG_3 ~ B*1
ctopp_sm_raw_KG_3 ~ C*1

ctopp_el_raw_FG_1 ~ A*1
ctopp_nr_raw_FG_1 ~ B*1
ctopp_sm_raw_FG_1 ~ C*1

## correlated residuals across time
    ctopp_el_raw_KG_1 ~~ ctopp_el_raw_KG_3 + ctopp_el_raw_FG_1
    ctopp_el_raw_KG_3 ~~ ctopp_el_raw_FG_1
    ctopp_nr_raw_KG_1 ~~ ctopp_nr_raw_KG_3 + ctopp_nr_raw_FG_1
    ctopp_nr_raw_KG_3 ~~ ctopp_nr_raw_FG_1
    ctopp_sm_raw_KG_1 ~~ ctopp_sm_raw_KG_3 + ctopp_sm_raw_FG_1
    ctopp_sm_raw_KG_3 ~~ ctopp_sm_raw_FG_1

## latent variable intercepts
Phonemic_t1 ~ 0*1
Phonemic_t2 ~ 0*1
Phonemic_t3 ~ 0*1

#model constraints for effect coding
## loadings must average to 1
L1 == 3 - L2 - L3
## means must average to 0
A == 0 - B - C
```

```

i =~ 1*Phonemic_t1 + 1*Phonemic_t2 + 1*Phonemic_t3
s =~ 0*Phonemic_t1 + 1*Phonemic_t2 + 2*Phonemic_t3 '

fit.sec.order <- growth(sec.order, data=Chicago.wide, meanstructure = TRUE, missing = "ML")

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

## lavaan (0.5-23.1097) converged normally after 123 iterations
##
##   Number of observations                  57
##
##   Number of missing patterns              6
##
##   Estimator                             ML
##   Minimum Function Test Statistic        72.418
##   Degrees of freedom                     25
##   P-value (Chi-square)                   0.000
##
## Model test baseline model:
##
##   Minimum Function Test Statistic        262.409
##   Degrees of freedom                     36
##   P-value                                0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)            0.791
##   Tucker-Lewis Index (TLI)              0.698
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)          -1207.226
##   Loglikelihood unrestricted model (H1)  -1171.017
##
##   Number of free parameters              29
##   Akaike (AIC)                          2472.453
##   Bayesian (BIC)                        2531.701
##   Sample-size adjusted Bayesian (BIC)    2440.538
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                0.182
##   90 Percent Confidence Interval         0.134  0.232
##   P-value RMSEA <= 0.05                  0.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                0.157
##
## Parameter Estimates:
##
##   Information                          Observed
##   Standard Errors                      Standard

```

```

##
## Latent Variables:
##      Estimate   Std.Err   z-value   P(>|z|)
## Phonemic_t1 =~
##   ct___KG_1 (L1)    1.000
##   ct___KG_1 (L2)    0.606    0.089    6.781    0.000
##   ct___KG_1 (L3)    1.394    0.089   15.594    0.000
## Phonemic_t2 =~
##   ct___KG_3 (L1)    1.000
##   ct___KG_3 (L2)    0.606    0.089    6.781    0.000
##   ct___KG_3 (L3)    1.394    0.089   15.594    0.000
## Phonemic_t3 =~
##   ct___FG_1 (L1)    1.000
##   ct___FG_1 (L2)    0.606    0.089    6.781    0.000
##   ct___FG_1 (L3)    1.394    0.089   15.594    0.000
## i =~
##   Phonmc_t1          1.000
##   Phonmc_t2          1.000
##   Phonmc_t3          1.000
## s =~
##   Phonmc_t1          0.000
##   Phonmc_t2          1.000
##   Phonmc_t3          2.000
##
## Covariances:
##      Estimate   Std.Err   z-value   P(>|z|)
## .ctopp_el_raw_KG_1 ~~
##   .ctpp_l_rw_KG_3      1.749    1.095    1.598    0.110
##   .ctpp_l_rw_FG_1      0.297    1.255    0.237    0.813
## .ctopp_el_raw_KG_3 ~~
##   .ctpp_l_rw_FG_1      4.276    1.668    2.564    0.010
## .ctopp_nr_raw_KG_1 ~~
##   .ctpp_nr_r_KG_3       2.904    1.607    1.807    0.071
##   .ctpp_nr_r_FG_1      0.903    1.391    0.650    0.516
## .ctopp_nr_raw_KG_3 ~~
##   .ctpp_nr_r_FG_1      4.645    1.496    3.105    0.002
## .ctopp_sm_raw_KG_1 ~~
##   .ctpp_sm_r_KG_3     -1.086    2.567   -0.423    0.672
##   .ctpp_sm_r_FG_1     -1.864    3.196   -0.583    0.560
## .ctopp_sm_raw_KG_3 ~~
##   .ctpp_sm_r_FG_1      4.214    3.080    1.368    0.171
## i ~~
##   s                    1.645    0.878    1.873    0.061
##
## Intercepts:
##      Estimate   Std.Err   z-value   P(>|z|)
##   .ctp___KG_1 (A)    -3.181    0.225  -14.131    0.000
##   .ctp___KG_1 (B)     2.788    0.869    3.210    0.001
##   .ctp___KG_1 (C)     0.393    0.854    0.460    0.645
##   .ctp___KG_3 (A)    -3.181    0.225  -14.131    0.000
##   .ctp___KG_3 (B)     2.788    0.869    3.210    0.001
##   .ctp___KG_3 (C)     0.393    0.854    0.460    0.645
##   .ctp___FG_1 (A)    -3.181    0.225  -14.131    0.000
##   .ctp___FG_1 (B)     2.788    0.869    3.210    0.001

```

```
## .ctp___FG_1 (C)    0.393    0.854    0.460    0.645
## Phonemc_t1        0.000
## Phonemc_t2        0.000
## Phonemc_t3        0.000
## i                 7.445    0.449   16.590    0.000
## s                 1.696    0.195    8.716    0.000
```

```
##
## Variances:
##           Estimate Std.Err z-value P(>|z|)
## .ctpp_l_rw_KG_1    2.447   1.068   2.291   0.022
## .ctpp_nr_r_KG_1    9.627   1.999   4.817   0.000
## .ctpp_sm_r_KG_1   16.415   3.989   4.115   0.000
## .ctpp_l_rw_KG_3    6.974   1.941   3.593   0.000
## .ctpp_nr_r_KG_3   10.026   2.203   4.550   0.000
## .ctpp_sm_r_KG_3    7.519   3.271   2.299   0.022
## .ctpp_l_rw_FG_1    8.977   2.183   4.113   0.000
## .ctpp_nr_r_FG_1    7.199   1.464   4.918   0.000
## .ctpp_sm_r_FG_1   13.514   3.857   3.504   0.000
## Phonemic_t1        2.248   2.119   1.061   0.289
## Phonemic_t2        2.251   1.354   1.663   0.096
## Phonemic_t3       -1.261   2.543  -0.496   0.620
## i                 2.189   1.869   1.171   0.241
## s                -0.366   1.162  -0.315   0.753
```

```
##
## Constraints:
##                                     |Slack|
## L1 - (3-L2-L3)                   0.000
## A - (0-B-C)                      0.000
```

```
#Normal latent growth model
```

```
first.order <- '
    i =~ 1*ctopp_el_raw_KG_1 + 1*ctopp_nr_raw_KG_1 + 1*ctopp_sm_raw_KG_1 +
          1*ctopp_el_raw_KG_3 + 1*ctopp_nr_raw_KG_3 + 1*ctopp_sm_raw_KG_3 +
          1*ctopp_el_raw_FG_1 + 1*ctopp_nr_raw_FG_1 + 1*ctopp_sm_raw_FG_1
    s =~ 0*ctopp_el_raw_KG_1 + 0*ctopp_nr_raw_KG_1 + 0*ctopp_sm_raw_KG_1 +
          1*ctopp_el_raw_KG_3 + 1*ctopp_nr_raw_KG_3 + 1*ctopp_sm_raw_KG_3 +
          2*ctopp_el_raw_FG_1 + 2*ctopp_nr_raw_FG_1 + 2*ctopp_sm_raw_FG_1'

fit.first.order <- growth(first.order, data=Chicago.wide, meanstructure = TRUE, missing = "ML")
summary(fit.first.order, fit.measures=TRUE)
```

```
## lavaan (0.5-23.1097) converged normally after 70 iterations
##
## Number of observations                    57
##
## Number of missing patterns                6
##
## Estimator                                ML
## Minimum Function Test Statistic          356.961
## Degrees of freedom                       40
## P-value (Chi-square)                    0.000
##
## Model test baseline model:
##
## Minimum Function Test Statistic          262.409
```

```

## Degrees of freedom          36
## P-value                    0.000
##
## User model versus baseline model:
##
## Comparative Fit Index (CFI)          0.000
## Tucker-Lewis Index (TLI)           -0.260
##
## Loglikelihood and Information Criteria:
##
## Loglikelihood user model (H0)        -1349.498
## Loglikelihood unrestricted model (H1) -1171.017
##
## Number of free parameters           14
## Akaike (AIC)                       2726.996
## Bayesian (BIC)                     2755.598
## Sample-size adjusted Bayesian (BIC) 2711.589
##
## Root Mean Square Error of Approximation:
##
## RMSEA                             0.373
## 90 Percent Confidence Interval      0.338  0.409
## P-value RMSEA <= 0.05              0.000
##
## Standardized Root Mean Square Residual:
##
## SRMR                             0.546
##
## Parameter Estimates:
##
## Information                      Observed
## Standard Errors                  Standard
##
## Latent Variables:
##      Estimate  Std.Err  z-value  P(>|z|)
## i =~
##   ctppl_rw_KG_1    1.000
##   ctpplr_r_KG_1    1.000
##   ctppl_sm_r_KG_1  1.000
##   ctppl_rw_KG_3    1.000
##   ctpplr_r_KG_3    1.000
##   ctppl_sm_r_KG_3  1.000
##   ctppl_rw_FG_1    1.000
##   ctpplr_r_FG_1    1.000
##   ctppl_sm_r_FG_1  1.000
## s =~
##   ctppl_rw_KG_1    0.000
##   ctpplr_r_KG_1    0.000
##   ctppl_sm_r_KG_1  0.000
##   ctppl_rw_KG_3    1.000
##   ctpplr_r_KG_3    1.000
##   ctppl_sm_r_KG_3  1.000
##   ctppl_rw_FG_1    2.000
##   ctpplr_r_FG_1    2.000

```



```

##      ctpm_sm_r_FG_1      2.000
##
## Covariances:
##              Estimate Std.Err z-value P(>|z|)
##      i ~~
##      s              1.240    0.588    2.109    0.035
##
## Intercepts:
##              Estimate Std.Err z-value P(>|z|)
##      .ctpp_l_rw_KG_1    0.000
##      .ctpp_nr_r_KG_1    0.000
##      .ctpp_sm_r_KG_1    0.000
##      .ctpp_l_rw_KG_3    0.000
##      .ctpp_nr_r_KG_3    0.000
##      .ctpp_sm_r_KG_3    0.000
##      .ctpp_l_rw_FG_1    0.000
##      .ctpp_nr_r_FG_1    0.000
##      .ctpp_sm_r_FG_1    0.000
##      i              6.734    0.526   12.808    0.000
##      s              1.426    0.272    5.247    0.000
##
## Variances:
##              Estimate Std.Err z-value P(>|z|)
##      .ctpp_l_rw_KG_1   11.753    3.280    3.583    0.000
##      .ctpp_nr_r_KG_1   10.851    2.672    4.061    0.000
##      .ctpp_sm_r_KG_1   26.637    6.104    4.364    0.000
##      .ctpp_l_rw_KG_3    7.288    1.837    3.967    0.000
##      .ctpp_nr_r_KG_3    8.916    2.239    3.981    0.000
##      .ctpp_sm_r_KG_3   53.826   10.844    4.964    0.000
##      .ctpp_l_rw_FG_1   11.644    2.679    4.347    0.000
##      .ctpp_nr_r_FG_1    7.872    1.766    4.457    0.000
##      .ctpp_sm_r_FG_1   50.544   10.505    4.811    0.000
##      i              4.187    1.687    2.482    0.013
##      s             -1.195    0.359   -3.325    0.001

```

12. Fit a series of multiple group models. Constrain some parameters and compare the fit.

```

group1 <- '
## define latent variables
  Phonemic_t1 =~ ctopp_el_raw_KG_1 + ctopp_nr_raw_KG_1 + ctopp_sm_raw_KG_1
  Phonemic_t2 =~ ctopp_el_raw_KG_3 + ctopp_nr_raw_KG_3 + ctopp_sm_raw_KG_3
  Phonemic_t3 =~ ctopp_el_raw_FG_1 + ctopp_nr_raw_FG_1 + ctopp_sm_raw_FG_1

## correlated residuals across time
  ctopp_el_raw_KG_1 ~~ ctopp_el_raw_KG_3 + ctopp_el_raw_FG_1
  ctopp_el_raw_KG_3 ~~ ctopp_el_raw_FG_1
  ctopp_nr_raw_KG_1 ~~ ctopp_nr_raw_KG_3 + ctopp_nr_raw_FG_1
  ctopp_nr_raw_KG_3 ~~ ctopp_nr_raw_FG_1
  ctopp_sm_raw_KG_1 ~~ ctopp_sm_raw_KG_3 + ctopp_sm_raw_FG_1
  ctopp_sm_raw_KG_3 ~~ ctopp_sm_raw_FG_1

```

```

Phonemic_t1 ~~ NA*Phonemic_t2 + NA*Phonemic_t3
Phonemic_t2 ~~ c(1,1)*Phonemic_t3'

fit.group.1 <- cfa(group1, data=Chicago.wide, std.lv=TRUE, group = "Sex_KG_1")

## Warning in lav_object_post_check(object): lavaan WARNING: covariance matrix of latent variables
##           is not positive definite in group 1;
##           use inspect(fit,"cov.lv") to investigate.
## Warning in lav_object_post_check(object): lavaan WARNING: covariance matrix of latent variables
##           is not positive definite in group 2;
##           use inspect(fit,"cov.lv") to investigate.
summary(fit.group.1, standardized=TRUE, fit.measures=TRUE)

## lavaan (0.5-23.1097) converged normally after 248 iterations
##
##                                     Used      Total
##   Number of observations per group
##   1                               19          26
##   0                               21          31
##
##   Estimator                      ML
##   Minimum Function Test Statistic 42.132
##   Degrees of freedom              32
##   P-value (Chi-square)            0.108
##
## Chi-square for each group:
##
##   1          29.701
##   0          12.431
##
## Model test baseline model:
##
##   Minimum Function Test Statistic 262.896
##   Degrees of freedom              72
##   P-value                        0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)      0.947
##   Tucker-Lewis Index (TLI)        0.881
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)      -861.052
##   Loglikelihood unrestricted model (H1) -839.987
##
##   Number of free parameters          76
##   Akaike (AIC)                      1874.105
##   Bayesian (BIC)                    2002.460
##   Sample-size adjusted Bayesian (BIC) 1764.636
##

```

```

## Root Mean Square Error of Approximation:
##
##   RMSEA                                0.126
##   90 Percent Confidence Interval      0.000  0.220
##   P-value RMSEA <= 0.05              0.153
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                0.115
##
## Parameter Estimates:
##
##   Information                        Expected
##   Standard Errors                    Standard
##
##
## Group 1 [1]:
##
## Latent Variables:
##           Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   Phonemic_t1 =~
##     ctppl_rw_KG_1    1.656    0.502    3.298    0.001    1.656    0.766
##     ctpplr_r_KG_1    2.473    0.691    3.580    0.000    2.473    0.780
##     ctppl_sm_r_KG_1  2.290    0.985    2.325    0.020    2.290    0.533
##   Phonemic_t2 =~
##     ctppl_rw_KG_3    1.724    0.687    2.511    0.012    1.724    0.610
##     ctpplr_r_KG_3    0.907    0.713    1.272    0.203    0.907    0.300
##     ctppl_sm_r_KG_3  3.899    1.004    3.882    0.000    3.899    0.840
##   Phonemic_t3 =~
##     ctppl_rw_FG_1    2.174    0.567    3.833    0.000    2.174    0.818
##     ctpplr_r_FG_1    1.199    0.536    2.235    0.025    1.199    0.491
##     ctppl_sm_r_FG_1  3.134    0.971    3.228    0.001    3.134    0.701
##
## Covariances:
##           Estimate  Std.Err  z-value  P(>|z|)   Std.lv
##   .ctopp_el_raw_KG_1 ~~
##     .ctpp_l_rw_KG_3      0.069    0.968    0.071    0.943    0.069
##     .ctpp_l_rw_FG_1     -0.764    0.908   -0.841    0.400   -0.764
##   .ctopp_el_raw_KG_3 ~~
##     .ctpp_l_rw_FG_1      0.289    1.321    0.219    0.827    0.289
##   .ctopp_nr_raw_KG_1 ~~
##     .ctpp_nr_r_KG_3      0.275    1.514    0.181    0.856    0.275
##     .ctpp_nr_r_FG_1      0.816    1.245    0.656    0.512    0.816
##   .ctopp_nr_raw_KG_3 ~~
##     .ctpp_nr_r_FG_1      4.486    1.799    2.494    0.013    4.486
##   .ctopp_sm_raw_KG_1 ~~
##     .ctpp_sm_r_KG_3      4.101    3.054    1.343    0.179    4.101
##     .ctpp_sm_r_FG_1      5.484    3.374    1.625    0.104    5.484
##   .ctopp_sm_raw_KG_3 ~~
##     .ctpp_sm_r_FG_1      5.263    4.153    1.267    0.205    5.263
##   Phonemic_t1 ~~
##     Phonemic_t2          0.630    0.200    3.146    0.002    0.630
##     Phonemic_t3          0.881    0.139    6.349    0.000    0.881
##   Phonemic_t2 ~~

```

```

##      Phonemic_t3          1.000          1.000
## Std.all
##
##      0.022
##     -0.359
##
##      0.084
##
##      0.048
##      0.193
##
##      0.730
##
##      0.447
##      0.473
##
##      0.655
##
##      0.630
##      0.881
##
##      1.000
##
## Intercepts:
##           Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .ctpp_l_rw_KG_1    3.421   0.496   6.895   0.000   3.421   1.582
## .ctpp_nr_r_KG_1    6.684   0.728   9.183   0.000   6.684   2.107
## .ctpp_sm_r_KG_1    9.053   0.986   9.181   0.000   9.053   2.106
## .ctpp_l_rw_KG_3    6.632   0.648  10.234   0.000   6.632   2.348
## .ctpp_nr_r_KG_3    9.316   0.695  13.408   0.000   9.316   3.076
## .ctpp_sm_r_KG_3   13.474   1.065  12.646   0.000  13.474   2.901
## .ctpp_l_rw_FG_1    7.053   0.610  11.566   0.000   7.053   2.653
## .ctpp_nr_r_FG_1    9.421   0.560  16.827   0.000   9.421   3.860
## .ctpp_sm_r_FG_1   14.842   1.025  14.476   0.000  14.842   3.321
## Phonemic_t1         0.000         0.000   0.000   0.000   0.000   0.000
## Phonemic_t2         0.000         0.000   0.000   0.000   0.000   0.000
## Phonemic_t3         0.000         0.000   0.000   0.000   0.000   0.000
##
## Variances:
##           Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .ctpp_l_rw_KG_1    1.935   1.113   1.739   0.082   1.935   0.414
## .ctpp_nr_r_KG_1    3.949   2.157   1.831   0.067   3.949   0.392
## .ctpp_sm_r_KG_1   13.226   4.652   2.843   0.004  13.226   0.716
## .ctpp_l_rw_KG_3    5.005   2.049   2.443   0.015   5.005   0.627
## .ctpp_nr_r_KG_3    8.348   2.755   3.030   0.002   8.348   0.910
## .ctpp_sm_r_KG_3    6.365   5.000   1.273   0.203   6.365   0.295
## .ctpp_l_rw_FG_1    2.337   1.428   1.637   0.102   2.337   0.331
## .ctpp_nr_r_FG_1    4.519   1.513   2.988   0.003   4.519   0.759
## .ctpp_sm_r_FG_1   10.153   4.176   2.431   0.015  10.153   0.508
## Phonemic_t1         1.000         1.000   1.000   1.000   1.000   1.000
## Phonemic_t2         1.000         1.000   1.000   1.000   1.000   1.000
## Phonemic_t3         1.000         1.000   1.000   1.000   1.000   1.000
##
##

```

```

## Group 2 [0]:
##
## Latent Variables:
##      Estimate   Std.Err   z-value   P(>|z|)   Std.lv   Std.all
## Phonemic_t1 =~
##   ctppl_rw_KG_1   2.099   0.555   3.784   0.000   2.099   0.739
##   ctpplr_r_KG_1   2.538   0.726   3.498   0.000   2.538   0.689
##   ctppl_sm_r_KG_1  3.839   1.027   3.739   0.000   3.839   0.774
## Phonemic_t2 =~
##   ctppl_rw_KG_3   2.459   0.897   2.741   0.006   2.459   0.571
##   ctpplr_r_KG_3   1.738   0.752   2.312   0.021   1.738   0.481
##   ctppl_sm_r_KG_3  0.245   0.724   0.338   0.735   0.245   0.064
## Phonemic_t3 =~
##   ctppl_rw_FG_1   1.949   0.947   2.058   0.040   1.949   0.412
##   ctpplr_r_FG_1   1.508   0.678   2.226   0.026   1.508   0.442
##   ctppl_sm_r_FG_1  2.917   1.096   2.661   0.008   2.917   0.538
##
## Covariances:
##      Estimate   Std.Err   z-value   P(>|z|)   Std.lv
## .ctopp_el_raw_KG_1 ~~
##   .ctpp_l_rw_KG_3   3.032   2.035   1.490   0.136   3.032
##   .ctpp_l_rw_FG_1   2.885   2.228   1.295   0.195   2.885
## .ctopp_el_raw_KG_3 ~~
##   .ctpp_l_rw_FG_1   12.059   4.134   2.917   0.004   12.059
## .ctopp_nr_raw_KG_1 ~~
##   .ctpp_nr_r_KG_3   2.672   2.194   1.218   0.223   2.672
##   .ctpp_nr_r_FG_1   2.145   2.092   1.025   0.305   2.145
## .ctopp_nr_raw_KG_3 ~~
##   .ctpp_nr_r_FG_1   4.803   2.281   2.106   0.035   4.803
## .ctopp_sm_raw_KG_1 ~~
##   .ctpp_sm_r_KG_3   -1.819   3.409   -0.534   0.594   -1.819
##   .ctpp_sm_r_FG_1   -9.256   4.663   -1.985   0.047   -9.256
## .ctopp_sm_raw_KG_3 ~~
##   .ctpp_sm_r_FG_1   12.433   4.355   2.855   0.004   12.433
## Phonemic_t1 ~~
##   Phonemic_t2   1.262   0.187   6.747   0.000   1.262
##   Phonemic_t3   1.339   0.236   5.678   0.000   1.339
## Phonemic_t2 ~~
##   Phonemic_t3   1.000
## Std.all
##
##   0.449
##   0.350
##
##   0.792
##
##   0.315
##   0.262
##
##   0.495
##
##  -0.152
##  -0.645
##

```

```

##      0.713
##
##      1.262
##      1.339
##
##      1.000
##
## Intercepts:
##           Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .ctpp_l_rw_KG_1    4.190   0.619   6.765   0.000   4.190   1.476
## .ctpp_nr_r_KG_1    8.619   0.804  10.717   0.000   8.619   2.339
## .ctpp_sm_r_KG_1   10.143   1.082   9.375   0.000  10.143   2.046
## .ctpp_l_rw_KG_3    8.143   0.939   8.669   0.000   8.143   1.892
## .ctpp_nr_r_KG_3    9.476   0.789  12.008   0.000   9.476   2.620
## .ctpp_sm_r_KG_3   15.381   0.834  18.439   0.000  15.381   4.024
## .ctpp_l_rw_FG_1    8.952   1.032   8.672   0.000   8.952   1.892
## .ctpp_nr_r_FG_1    8.762   0.744  11.771   0.000   8.762   2.569
## .ctpp_sm_r_FG_1   15.667   1.183  13.242   0.000  15.667   2.890
## Phonemic_t1        0.000          0.000   0.000   0.000   0.000   0.000
## Phonemic_t2        0.000          0.000   0.000   0.000   0.000   0.000
## Phonemic_t3        0.000          0.000   0.000   0.000   0.000   0.000
##
## Variances:
##           Estimate Std.Err z-value P(>|z|) Std.lv Std.all
## .ctpp_l_rw_KG_1    3.654   1.306   2.798   0.005   3.654   0.453
## .ctpp_nr_r_KG_1    7.142   2.392   2.986   0.003   7.142   0.526
## .ctpp_sm_r_KG_1    9.844   4.915   2.003   0.045   9.844   0.400
## .ctpp_l_rw_KG_3   12.485   4.027   3.101   0.002  12.485   0.674
## .ctpp_nr_r_KG_3   10.056   3.090   3.255   0.001  10.056   0.769
## .ctpp_sm_r_KG_3   14.552   4.486   3.244   0.001  14.552   0.996
## .ctpp_l_rw_FG_1   18.580   5.575   3.333   0.001  18.580   0.830
## .ctpp_nr_r_FG_1    9.362   2.789   3.356   0.001   9.362   0.805
## .ctpp_sm_r_FG_1   20.886   6.401   3.263   0.001  20.886   0.711
## Phonemic_t1        1.000          1.000   0.000   0.000   1.000   1.000
## Phonemic_t2        1.000          1.000   0.000   0.000   1.000   1.000
## Phonemic_t3        1.000          1.000   0.000   0.000   1.000   1.000
##
fit.group.2 <- cfa(group1, data=Chicago.wide, std.lv=TRUE, group = "Sex_KG_1", group.equal = c("loading", "variance"))

## Warning in lav_object_post_check(object): lavaan WARNING: covariance matrix of latent variables
## is not positive definite in group 1;
## use inspect(fit,"cov.lv") to investigate.

## Warning in lav_object_post_check(object): lavaan WARNING: covariance matrix of latent variables
## is not positive definite in group 2;
## use inspect(fit,"cov.lv") to investigate.

summary(fit.group.2)

## lavaan (0.5-23.1097) converged normally after 205 iterations
##
##                                     Used      Total
## Number of observations per group
## 1                                19         26
## 0                                21         31

```

```

##
## Estimator ML
## Minimum Function Test Statistic 59.854
## Degrees of freedom 47
## P-value (Chi-square) 0.099
##
## Chi-square for each group:
##
## 1 35.498
## 0 24.356
##
## Parameter Estimates:
##
## Information Expected
## Standard Errors Standard
##
## Group 1 [1]:
##
## Latent Variables:
## Estimate Std.Err z-value P(>|z|)
## Phonemic_t1 =~
## c___KG_ (.p1.) 1.455 0.314 4.637 0.000
## c___KG_ (.p2.) 1.915 0.459 4.175 0.000
## c___KG_ (.p3.) 3.522 0.667 5.277 0.000
## Phonemic_t2 =~
## c___KG_ (.p4.) 2.359 0.480 4.917 0.000
## c___KG_ (.p5.) 1.206 0.489 2.467 0.014
## c___KG_ (.p6.) 2.548 0.733 3.474 0.001
## Phonemic_t3 =~
## c___FG_ (.p7.) 1.277 0.452 2.828 0.005
## c___FG_ (.p8.) 1.258 0.381 3.301 0.001
## c___FG_ (.p9.) 3.090 0.761 4.058 0.000
##
## Covariances:
## Estimate Std.Err z-value P(>|z|)
## .ctopp_el_raw_KG_1 ~~
## .ctpp_l_rw_KG_3 -0.596 0.997 -0.598 0.550
## .ctpp_l_rw_FG_1 0.075 1.059 0.071 0.943
## .ctopp_el_raw_KG_3 ~~
## .ctpp_l_rw_FG_1 1.067 1.222 0.873 0.382
## .ctopp_nr_raw_KG_1 ~~
## .ctpp_nr_r_KG_3 -0.672 1.858 -0.362 0.718
## .ctpp_nr_r_FG_1 0.047 1.347 0.035 0.972
## .ctopp_nr_raw_KG_3 ~~
## .ctpp_nr_r_FG_1 4.146 1.665 2.491 0.013
## .ctopp_sm_raw_KG_1 ~~
## .ctpp_sm_r_KG_3 0.979 3.227 0.303 0.762
## .ctpp_sm_r_FG_1 2.246 3.467 0.648 0.517
## .ctopp_sm_raw_KG_3 ~~
## .ctpp_sm_r_FG_1 10.942 4.616 2.370 0.018
## Phonemic_t1 ~~
## Phonemic_t2 1.058 0.153 6.898 0.000
## Phonemic_t3 1.165 0.131 8.916 0.000

```

```

## Phonemic_t2 ~~
## Phonemic_t3 1.000
##
## Intercepts:
## Estimate Std.Err z-value P(>|z|)
## .c___KG_ (.34.) 3.412 0.462 7.393 0.000
## .c___KG_ (.35.) 7.233 0.642 11.273 0.000
## .c___KG_ (.36.) 8.806 0.974 9.043 0.000
## .c___KG_ (.37.) 6.638 0.644 10.314 0.000
## .c___KG_ (.38.) 8.974 0.565 15.883 0.000
## .c___KG_ (.39.) 13.854 0.901 15.370 0.000
## .c___FG_ (.40.) 7.507 0.547 13.718 0.000
## .c___FG_ (.41.) 9.157 0.485 18.885 0.000
## .c___FG_ (.42.) 14.976 1.019 14.698 0.000
## Phnmc_1 0.000
## Phnmc_2 0.000
## Phnmc_3 0.000
##
## Variances:
## Estimate Std.Err z-value P(>|z|)
## .ctpp_l_rw_KG_1 2.934 1.132 2.593 0.010
## .ctpp_nr_r_KG_1 7.136 2.468 2.891 0.004
## .ctpp_sm_r_KG_1 6.925 3.381 2.048 0.041
## .ctpp_l_rw_KG_3 2.623 1.765 1.486 0.137
## .ctpp_nr_r_KG_3 8.200 2.720 3.014 0.003
## .ctpp_sm_r_KG_3 14.884 5.283 2.817 0.005
## .ctpp_l_rw_FG_1 5.205 1.747 2.979 0.003
## .ctpp_nr_r_FG_1 4.147 1.366 3.035 0.002
## .ctpp_sm_r_FG_1 13.916 5.071 2.744 0.006
## Phonemic_t1 1.000
## Phonemic_t2 1.000
## Phonemic_t3 1.000
##
##
## Group 2 [0]:
##
## Latent Variables:
## Estimate Std.Err z-value P(>|z|)
## Phonemic_t1 =~
## c___KG_ (.p1.) 1.455 0.314 4.637 0.000
## c___KG_ (.p2.) 1.915 0.459 4.175 0.000
## c___KG_ (.p3.) 3.522 0.667 5.277 0.000
## Phonemic_t2 =~
## c___KG_ (.p4.) 2.359 0.480 4.917 0.000
## c___KG_ (.p5.) 1.206 0.489 2.467 0.014
## c___KG_ (.p6.) 2.548 0.733 3.474 0.001
## Phonemic_t3 =~
## c___FG_ (.p7.) 1.277 0.452 2.828 0.005
## c___FG_ (.p8.) 1.258 0.381 3.301 0.001
## c___FG_ (.p9.) 3.090 0.761 4.058 0.000
##
## Covariances:
## Estimate Std.Err z-value P(>|z|)
## .ctopp_el_raw_KG_1 ~~

```



```

##      .ctpp_l_rw_KG_3      4.070      1.915      2.125      0.034
##      .ctpp_l_rw_FG_1      3.078      2.209      1.393      0.163
##      .ctopp_el_raw_KG_3 ~~
##      .ctpp_l_rw_FG_1      11.413      4.077      2.799      0.005
##      .ctopp_nr_raw_KG_1 ~~
##      .ctpp_nr_r_KG_3      4.356      2.171      2.006      0.045
##      .ctpp_nr_r_FG_1      1.685      2.099      0.803      0.422
##      .ctopp_nr_raw_KG_3 ~~
##      .ctpp_nr_r_FG_1      4.275      2.258      1.894      0.058
##      .ctopp_sm_raw_KG_1 ~~
##      .ctpp_sm_r_KG_3      -6.926      3.925      -1.764      0.078
##      .ctpp_sm_r_FG_1     -15.386      5.625      -2.735      0.006
##      .ctopp_sm_raw_KG_3 ~~
##      .ctpp_sm_r_FG_1      11.174      4.955      2.255      0.024
##      Phonemic_t1 ~~
##      Phonemic_t2      1.032      0.147      7.017      0.000
##      Phonemic_t3      1.734      0.320      5.414      0.000
##      Phonemic_t2 ~~
##      Phonemic_t3      1.000
##
## Intercepts:
##      Estimate Std.Err z-value P(>|z|)
##      .c___KG_ (.34.)      3.412      0.462      7.393      0.000
##      .c___KG_ (.35.)      7.233      0.642     11.273      0.000
##      .c___KG_ (.36.)      8.806      0.974      9.043      0.000
##      .c___KG_ (.37.)      6.638      0.644     10.314      0.000
##      .c___KG_ (.38.)      8.974      0.565     15.883      0.000
##      .c___KG_ (.39.)     13.854      0.901     15.370      0.000
##      .c___FG_ (.40.)      7.507      0.547     13.718      0.000
##      .c___FG_ (.41.)      9.157      0.485     18.885      0.000
##      .c___FG_ (.42.)     14.976      1.019     14.698      0.000
##      Phnmc_1      0.489      0.377      1.298      0.194
##      Phnmc_2      0.398      0.395      1.009      0.313
##      Phnmc_3      0.040      0.435      0.091      0.927
##
## Variances:
##      Estimate Std.Err z-value P(>|z|)
##      .ctpp_l_rw_KG_1      4.302      1.272      3.382      0.001
##      .ctpp_nr_r_KG_1      8.090      2.416      3.348      0.001
##      .ctpp_sm_r_KG_1     10.853      5.280      2.055      0.040
##      .ctpp_l_rw_KG_3     10.324      3.694      2.795      0.005
##      .ctpp_nr_r_KG_3     10.561      3.323      3.178      0.001
##      .ctpp_sm_r_KG_3     12.427      4.985      2.493      0.013
##      .ctpp_l_rw_FG_1     21.318      6.152      3.465      0.001
##      .ctpp_nr_r_FG_1     10.157      2.787      3.645      0.000
##      .ctpp_sm_r_FG_1     23.676      7.054      3.357      0.001
##      Phonemic_t1      1.000
##      Phonemic_t2      1.000
##      Phonemic_t3      1.000

```

```
anova(fit.group.1, fit.group.2)
```

```
## Chi Square Difference Test
```

```
##
```

```
##      Df      AIC      BIC Chisq Chisq diff Df diff Pr(>Chisq)
```

```
## fit.group.1 32 1874.1 2002.5 42.132
## fit.group.2 47 1861.8 1964.8 59.854      17.722      15      0.2775
```