Latent Growth Curve with Time-invariant Covariate

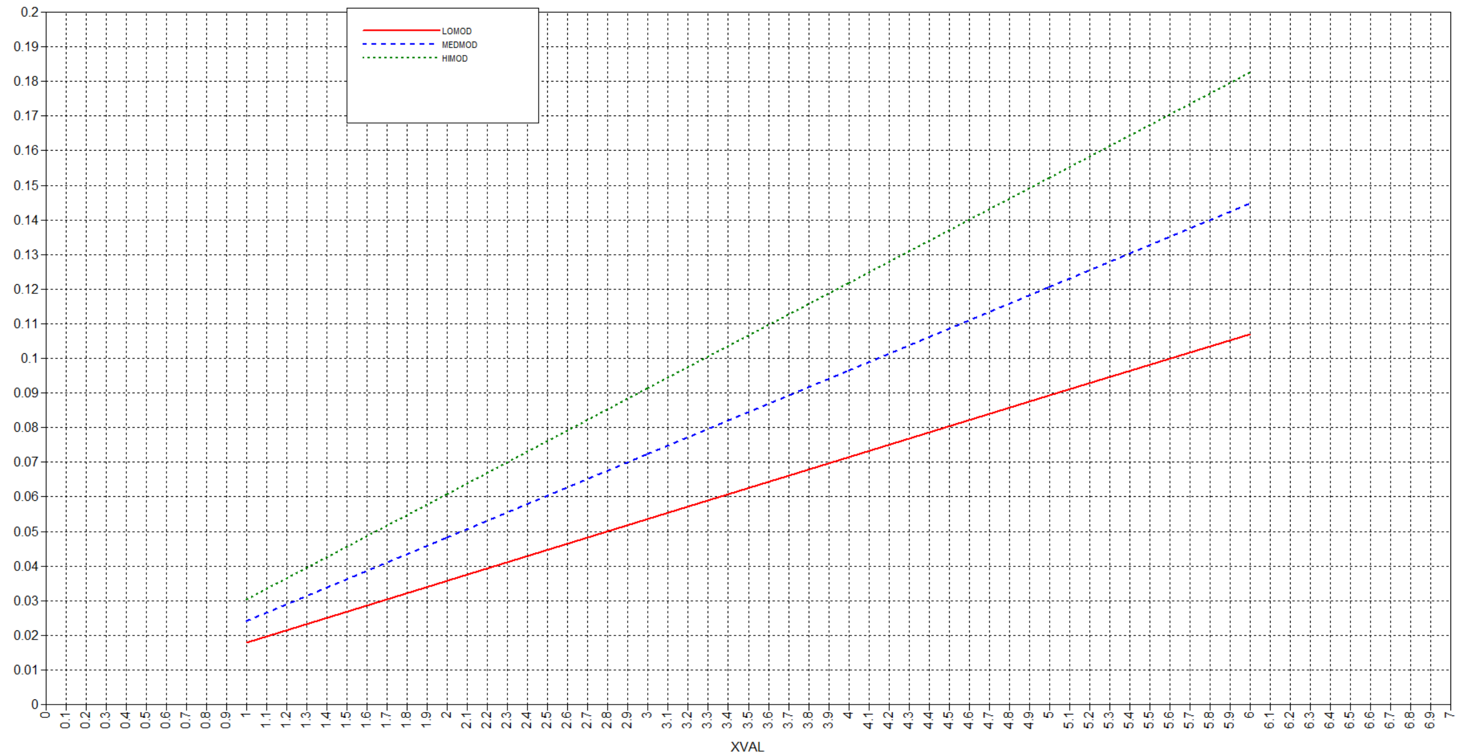
```
title:  Latent growth curve example (health.dat is data from LSEM Ch 7);

 data: file=health.dat; format=free;

 variable:
     names=
     age
     srh1 srh2 srh3 srh4 srh5 srh6
     bmi1 bmi2 bmi3 bmi4 bmi5 bmi6
     cesdna1 cesdpa1 cesdso1
     cesdna2 cesdpa2 cesdso2
     cesdna3 cesdpa3 cesdso3
     cesdna4 cesdpa4 cesdso4
     cesdna5 cesdpa5 cesdso5
     cesdna6 cesdpa6 cesdso6
     diab1 diab2 diab3 diab4 diab5 diab6;

    usevariables=
     srh1 cesd1 cesd2 cesd3 cesd4 cesd5 cesd6;

     define:
     cesd1 = mean (cesdna1 cesdpa1 cesdso1);
     cesd2 = mean (cesdna2 cesdpa2 cesdso2);
     cesd3 = mean (cesdna3 cesdpa3 cesdso3);
     cesd4 = mean (cesdna4 cesdpa4 cesdso4);
     cesd5 = mean (cesdna5 cesdpa5 cesdso5);
     cesd6 = mean (cesdna6 cesdpa6 cesdso6);
     center srh1(grandmean);


 analysis: type=general; estimator=mlm;
 model:
     i by cesd1@1 cesd2@1 cesd3@1 cesd4@1 cesd5@1 cesd6@1;
     s by cesd1@0 cesd2@1 cesd3@2 cesd4@3 cesd5@4 cesd6@5;
     i s;
     i on srh1;
     s on srh1 (b3);
     srh1 (srh);
     i with s;
     [i] (b2);
     [s] (b1);
     [cesd1-cesd6@0];

 !SIMPLE SLOPES COMPUTATIONS;
 model constraint:
   ! srh mean is 3.521 obtained from prior analysis (var=1.217, SD=1.103);

   !declare new names for W values and simple slopes;
   NEW(LOW_W MED_W HIGH_W SIMP_LO SIMP_MED SIMP_HI);

   !simple slope equations;
   LOW_W = 3.521 - 1*(sqrt(srh)) ; !-1 SD below mean of W;
   MED_W = 3.521 ; ! mean of W;
   HIGH_W = 3.521 + 1*(sqrt(srh)); ! +1 SD below mean of W;

  ! Now calc simple slopes for each value of W;
   SIMP_LO = b1 + b3*LOW_W;
   SIMP_MED = b1 + b3*MED_W;
   SIMP_HI = b1 + b3*HIGH_W;

   ! Use loop plot to plot slopes of X on Y for low, med, high values of W
   ! NOTE - values from -3 to 3 in LOOP() statement since
   ! X is factor with mean set at default of 0
   !From user guide on loop function: "The LOOP option names
   !the variable that will be plotted on the x-axis, gives
   !the numbers that are the lower and upper values of the variable, and the
   !incremental value of the variable to be used in the computations;
  PLOT(LOMOD MEDMOD HIMOD);
  LOOP(XVAL,1,6,1);
  LOMOD = (b1 + b3*LOW_W)*XVAL;
  MEDMOD = (b1 + b3*MED_W)*XVAL;
  HIMOD = (b1 + b3*HIGH_W)*XVAL;

 PLOT:
```

```
   TYPE = plot2;

  output:  sampstat stdyx;



INPUT READING TERMINATED NORMALLY



Latent growth curve example (health.dat is data from LSEM Ch 7);

SUMMARY OF ANALYSIS

Number of groups                                                 1
Number of observations                                        5335



Estimator                                                      MLM
Information matrix                                        EXPECTED


MODEL FIT INFORMATION

Number of Free Parameters                       15

Loglikelihood

          H0 Value                      -23588.057
          H1 Value                      -23444.915

Information Criteria

          Akaike (AIC)                   47206.114
          Bayesian (BIC)                 47304.845
          Sample-Size Adjusted BIC       47257.180
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                            286.781*
          Degrees of Freedom                    20
          P-Value                           0.0000
          Scaling Correction Factor         0.9983
            for MLM

*   The chi-square value for MLM, MLMV, MLR, ULSMV, WLSM and WLSMV cannot be used
    for chi-square difference testing in the regular way.  MLM, MLR and WLSM
    chi-square difference testing is described on the Mplus website.  MLMV, WLSMV,
    and ULSMV difference testing is done using the DIFFTEST option.

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.050
          90 Percent C.I.                    0.045  0.055
          Probability RMSEA <= .05           0.488

CFI/TLI

          CFI                                0.980
          TLI                                0.979

Chi-Square Test of Model Fit for the Baseline Model

          Value                          13329.487
          Degrees of Freedom                    21
          P-Value                           0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.031



MODEL RESULTS
```

```
                                                    Two-Tailed
                    Estimate       S.E.  Est./S.E.    P-Value

 I        BY
    CESD1              1.000      0.000    999.000    999.000
    CESD2              1.000      0.000    999.000    999.000
    CESD3              1.000      0.000    999.000    999.000
    CESD4              1.000      0.000    999.000    999.000
    CESD5              1.000      0.000    999.000    999.000
    CESD6              1.000      0.000    999.000    999.000

 S        BY
    CESD1              0.000      0.000    999.000    999.000
    CESD2              1.000      0.000    999.000    999.000
    CESD3              2.000      0.000    999.000    999.000
    CESD4              3.000      0.000    999.000    999.000
    CESD5              4.000      0.000    999.000    999.000
    CESD6              5.000      0.000    999.000    999.000

 I        ON
    SRH1              -0.166      0.005    -34.478      0.000

 S        ON
    SRH1               0.006      0.001      5.080      0.000

 I        WITH
    S                 -0.003      0.001     -4.358      0.000

 Means
    SRH1               0.000      0.015      0.000      1.000

 Intercepts
    CESD1              0.000      0.000    999.000    999.000
    CESD2              0.000      0.000    999.000    999.000
    CESD3              0.000      0.000    999.000    999.000
    CESD4              0.000      0.000    999.000    999.000
    CESD5              0.000      0.000    999.000    999.000
    CESD6              0.000      0.000    999.000    999.000
    I                  0.304      0.005     58.021      0.000
    S                  0.004      0.001      3.249      0.001

 Variances
    SRH1               1.217      0.024     51.679      0.000

 Residual Variances
    CESD1              0.111      0.003     36.448      0.000
    CESD2              0.114      0.003     43.761      0.000
    CESD3              0.114      0.002     45.458      0.000
    CESD4              0.108      0.002     44.785      0.000
    CESD5              0.105      0.002     42.978      0.000
    CESD6              0.108      0.003     36.544      0.000
    I                  0.089      0.003     29.296      0.000
    S                  0.002      0.000     10.569      0.000

New/Additional Parameters
    LOW_W              2.418      0.011    226.481      0.000
    MED_W              3.521      0.000      0.000      1.000
    HIGH_W             4.624      0.011    433.199      0.000
    SIMP_LO            0.018      0.003      6.009      0.000
    SIMP_MED           0.024      0.004      5.845      0.000
    SIMP_HI            0.030      0.005      5.712      0.000


STANDARDIZED MODEL RESULTS


STDYX Standardization

                                                    Two-Tailed
                    Estimate       S.E.  Est./S.E.    P-Value

 I        BY
    CESD1              0.725      0.008     92.287      0.000
    CESD2              0.728      0.008     89.372      0.000
    CESD3              0.732      0.009     82.520      0.000
```

```
   CESD4              0.737      0.010     73.384      0.000
   CESD5              0.731      0.011     67.353      0.000
   CESD6              0.710      0.011     61.808      0.000

S        BY
   CESD1              0.000      0.000    999.000    999.000
   CESD2              0.093      0.004     21.424      0.000
   CESD3              0.188      0.009     21.419      0.000
   CESD4              0.284      0.013     21.453      0.000
   CESD5              0.375      0.017     21.526      0.000
   CESD6              0.456      0.021     21.403      0.000

I        ON
   SRH1              -0.522      0.013    -39.466      0.000

S        ON
   SRH1               0.140      0.028      4.971      0.000

I        WITH
   S                 -0.199      0.037     -5.378      0.000

Means
   SRH1               0.000      0.014      0.000      1.000

Intercepts
   CESD1              0.000      0.000    999.000    999.000
   CESD2              0.000      0.000    999.000    999.000
   CESD3              0.000      0.000    999.000    999.000
   CESD4              0.000      0.000    999.000    999.000
   CESD5              0.000      0.000    999.000    999.000
   CESD6              0.000      0.000    999.000    999.000
   I                  0.867      0.020     43.059      0.000
   S                  0.090      0.028      3.211      0.001

Variances
   SRH1               1.000      0.000    999.000    999.000

Residual Variances
   CESD1              0.475      0.011     41.759      0.000
   CESD2              0.494      0.009     54.978      0.000
   CESD3              0.496      0.008     61.429      0.000
   CESD4              0.477      0.008     58.286      0.000
   CESD5              0.457      0.009     52.931      0.000
   CESD6              0.444      0.011     41.403      0.000
   I                  0.728      0.014     52.731      0.000
   S                  0.980      0.008    124.008      0.000


R-SQUARE

   Observed                                        Two-Tailed
   Variable        Estimate       S.E.  Est./S.E.    P-Value

   CESD1              0.525      0.011     46.144      0.000
   CESD2              0.506      0.009     56.376      0.000
   CESD3              0.504      0.008     62.529      0.000
   CESD4              0.523      0.008     64.033      0.000
   CESD5              0.543      0.009     62.835      0.000
   CESD6              0.556      0.011     51.942      0.000

    Latent                                         Two-Tailed
   Variable        Estimate       S.E.  Est./S.E.    P-Value

   I                  0.272      0.014     19.733      0.000
   S                  0.020      0.008      2.485      0.013
```

Plotting is the same as in the “Simple Slopes for Continuous Measured and Latent Variable Interactions” handout. Plots will be available by including the commands `PLOT: TYPE = plot2;` Go to the Plot menu and choose View Plots, then choose “Plot one parameter at a time”.



lavaan code *(excerpts)*

Because `lavaan` does not have programmable plots for models, I did not illustrate the plot of the simple slopes, but the lines could be easily plotted in R manually (please see the handout "Plotting Growth Curves: SPSS, R, and HLM" from my multilevel regression class for illustration, http://web.pdx.edu/~newsomj/mlrclass).

```
> library(QuantPsyc)
> d$srh1 = meanCenter(d$srh1)
> #always check to make sure centering worked
> #describe(d)
>
> library(lavaan)
> model = '
+ #specify growth loadings for intercept and slope factors
+ i =~ 1*cesd1 + 1*cesd2 + 1*cesd3 + 1*cesd4 + 1*cesd5 + 1*cesd6
+ s =~ 0*cesd1 + 1*cesd2 + 2*cesd3+ 3*cesd4 + 4*cesd5+ 5*cesd6
+
+ i ~ b2*srh1
+ s ~ b3*srh1
+
+ #estimate the covariance/correlation between intercept and slope
+ i ~~ s
+ #estimate the intercept and slope factor means (value 1 means freely estimate the mean)
+ i ~ 1
+ s ~ b1*1
+
+ #set measurement intercepts to 0 because factor means are estimated
+ cesd1 ~ 0
+ cesd2 ~ 0
+ cesd3 ~ 0
+ cesd4 ~ 0
+ cesd5 ~ 0
+ cesd6 ~ 0
+
+ #freely estimate measurement residual variances (could set them equal for homogeneity of residuals)
+ cesd1 ~~ cesd1
+ cesd2 ~~ cesd2
+ cesd3 ~~ cesd3
+ cesd4 ~~ cesd4
+ cesd5 ~~ cesd5
+ cesd6 ~~ cesd6
+ srh1 ~~ srh*srh1
+
+ #constraints for simple slopes
+
+ #NEW(LOW_W MED_W HIGH_W SIMP_LO SIMP_MED SIMP_HI);
+
+   #simple slope equations;
+   LOW_W := 3.521 - 1*(sqrt(srh)) ;  #-1 SD below mean of W;
```

```
+   MED_W := 3.521                    # mean of W;
+   HIGH_W := 3.521 + 1*(sqrt(srh));  # +1 SD below mean of W;
+
+  # Now calc simple slopes for each value of W;
+   SIMP_LO := b1 + b3*LOW_W;
+   SIMP_MED := b1 + b3*MED_W;
+   SIMP_HI := b1 + b3*HIGH_W;
+ '
>
> fit = sem(model,data = d,mimic = "Mplus",estimator="mlm")
> summary(fit,fit.measures=TRUE, rsquare=TRUE, standardized=TRUE)
lavaan 0.6-18 ended normally after 60 iterations

  Estimator                                         ML
  Optimization method                           NLMINB
  Number of model parameters                        15

  Number of observations                          5335

Model Test User Model:
                                               Standard      Scaled
  Test Statistic                                286.284     286.781
  Degrees of freedom                                 20          20
  P-value (Chi-square)                            0.000       0.000
  Scaling correction factor                                   0.998
    Satorra-Bentler correction (Mplus variant)

Model Test Baseline Model:

  Test statistic                              13320.570   13329.487
  Degrees of freedom                                 21          21
  P-value                                         0.000       0.000
  Scaling correction factor                                   0.999

User Model versus Baseline Model:

  Comparative Fit Index (CFI)                     0.980       0.980
  Tucker-Lewis Index (TLI)                        0.979       0.979

  Robust Comparative Fit Index (CFI)                          0.980
  Robust Tucker-Lewis Index (TLI)                             0.979

Loglikelihood and Information Criteria:

  Loglikelihood user model (H0)              -23588.057  -23588.057
  Loglikelihood unrestricted model (H1)      -23444.915  -23444.915

  Akaike (AIC)                                47206.114   47206.114
  Bayesian (BIC)                              47304.845   47304.845
  Sample-size adjusted Bayesian (SABIC)       47257.180   47257.180

Root Mean Square Error of Approximation:

  RMSEA                                           0.050       0.050
  90 Percent confidence interval - lower          0.045       0.045
  90 Percent confidence interval - upper          0.055       0.055
  P-value H_0: RMSEA <= 0.050                     0.494       0.488
  P-value H_0: RMSEA >= 0.080                     0.000       0.000

  Robust RMSEA                                                0.050
  90 Percent confidence interval - lower                      0.045
  90 Percent confidence interval - upper                      0.055
  P-value H_0: Robust RMSEA <= 0.050                          0.493
  P-value H_0: Robust RMSEA >= 0.080                          0.000

Standardized Root Mean Square Residual:

  SRMR                                            0.031       0.031

Parameter Estimates:

  Standard errors                            Robust.sem
  Information                                  Expected
  Information saturated (h1) model           Structured

Latent Variables:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
  i =~
    cesd1             1.000                               0.350    0.725
    cesd2             1.000                               0.350    0.728
    cesd3             1.000                               0.350    0.732
    cesd4             1.000                               0.350    0.737
    cesd5             1.000                               0.350    0.731
    cesd6             1.000                               0.350    0.710
  s =~
    cesd1             0.000                               0.000    0.000
```

```
    cesd2             1.000                                      0.045    0.093
    cesd3             2.000                                      0.090    0.188
    cesd4             3.000                                      0.135    0.284
    cesd5             4.000                                      0.180    0.375
    cesd6             5.000                                      0.225    0.456

Regressions:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
  i ~
    srh1      (b2)   -0.166    0.005  -34.478    0.000   -0.473   -0.522
  s ~
    srh1      (b3)    0.006    0.001    5.080    0.000    0.127    0.140

Covariances:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
 .i ~~
   .s                -0.003    0.001   -4.358    0.000   -0.199   -0.199

Intercepts:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
   .i                 0.304    0.005   58.021    0.000    0.867    0.867
   .s         (b1)    0.004    0.001    3.249    0.001    0.090    0.090
   .cesd1             0.000                               0.000    0.000
   .cesd2             0.000                               0.000    0.000
   .cesd3             0.000                               0.000    0.000
   .cesd4             0.000                               0.000    0.000
   .cesd5             0.000                               0.000    0.000
   .cesd6             0.000                               0.000    0.000
    srh1              0.000    0.015    0.000    1.000    0.000    0.000

Variances:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
   .cesd1             0.111    0.003   36.448    0.000    0.111    0.475
   .cesd2             0.114    0.003   43.761    0.000    0.114    0.494
   .cesd3             0.114    0.002   45.458    0.000    0.114    0.496
   .cesd4             0.108    0.002   44.785    0.000    0.108    0.477
   .cesd5             0.105    0.002   42.978    0.000    0.105    0.457
   .cesd6             0.108    0.003   36.544    0.000    0.108    0.444
    srh1     (srh)    1.217    0.024   51.679    0.000    1.217    1.000
   .i                 0.089    0.003   29.296    0.000    0.728    0.728
   .s                 0.002    0.000   10.569    0.000    0.980    0.980

R-Square:
                   Estimate
    cesd1             0.525
    cesd2             0.506
    cesd3             0.504
    cesd4             0.523
    cesd5             0.543
    cesd6             0.556
    i                 0.272
    s                 0.020

Defined Parameters:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
    LOW_W             2.418    0.011  226.481    0.000    2.418    2.521
    MED_W             3.521                               3.521    3.521
    HIGH_W            4.624    0.011  433.199    0.000    4.624    4.521
    SIMP_LO           0.018    0.003    6.009    0.000    0.397    0.443
    SIMP_MED          0.024    0.004    5.845    0.000    0.537    0.583
    SIMP_HI           0.030    0.005    5.712    0.000    0.677    0.723
```

`lavaan` does not have the same type of plotting function as Mplus, so plots would need to be generated in R outside of `lavaan`. One option is to convert the data to long format and use the plotting approach I illustrate in my handout “Plotting Growth Curves: SPSS, R, and HLM” from my multilevel class page.