

Latent Growth Curve Example

```
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=
  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);

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 with s;
  [i s];
  [cesd1-cesd6@0];

! Mplus has shortcut syntax for growth models, the following
! statements produce the same results as the above statements;
!model: i s | cesd1@0 cesd2@1 cesd3@2 cesd4@3 cesd5@4 cesd6@5;

! The plot syntax below generates graphs of individual growth curves;
plot: type=plot1;
  series=cesd1(0) cesd2(1) cesd3(2) cesd4(3) cesd5(4) cesd6(5);

output: sampstat stdyx;
```

SUMMARY OF ANALYSIS

Number of groups	1
Number of observations	5335

Estimator	MLM
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MODEL FIT INFORMATION

Number of Free Parameters	11
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Loglikelihood

H0 Value	-16135.175
H1 Value	-16017.920

Information Criteria

Akaike (AIC)	32292.350
Bayesian (BIC)	32364.753
Sample-Size Adjusted BIC	32329.798
(n* = (n + 2) / 24)	

Chi-Square Test of Model Fit

Value	235.387*
Degrees of Freedom	16
P-Value	0.0000
Scaling Correction Factor for MLM	0.9963

* 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	0.051
90 Percent C.I.	0.045 0.057
Probability RMSEA <= .05	0.408

CFI/TLI

CFI	0.982
TLI	0.983

Chi-Square Test of Model Fit for the Baseline Model

Value	11999.717
Degrees of Freedom	15
P-Value	0.0000

SRMR (Standardized Root Mean Square Residual)

Value	0.033
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MODEL RESULTS

	Estimate	S.E.	Est./S.E.	Two-Tailed 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 WITH				
S	-0.004	0.001	-5.457	0.000
Means				
I	0.304	0.006	52.403	0.000
S	0.004	0.001	3.226	0.001
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
Variances				
I	0.122	0.004	32.855	0.000
S	0.002	0.000	10.290	0.000

Residual Variances				
CESD1	0.115	0.003	36.447	0.000
CESD2	0.114	0.003	43.242	0.000
CESD3	0.112	0.003	44.800	0.000
CESD4	0.107	0.002	44.326	0.000
CESD5	0.105	0.002	42.946	0.000
CESD6	0.109	0.003	36.580	0.000

STANDARDIZED MODEL RESULTS

STDYX Standardization

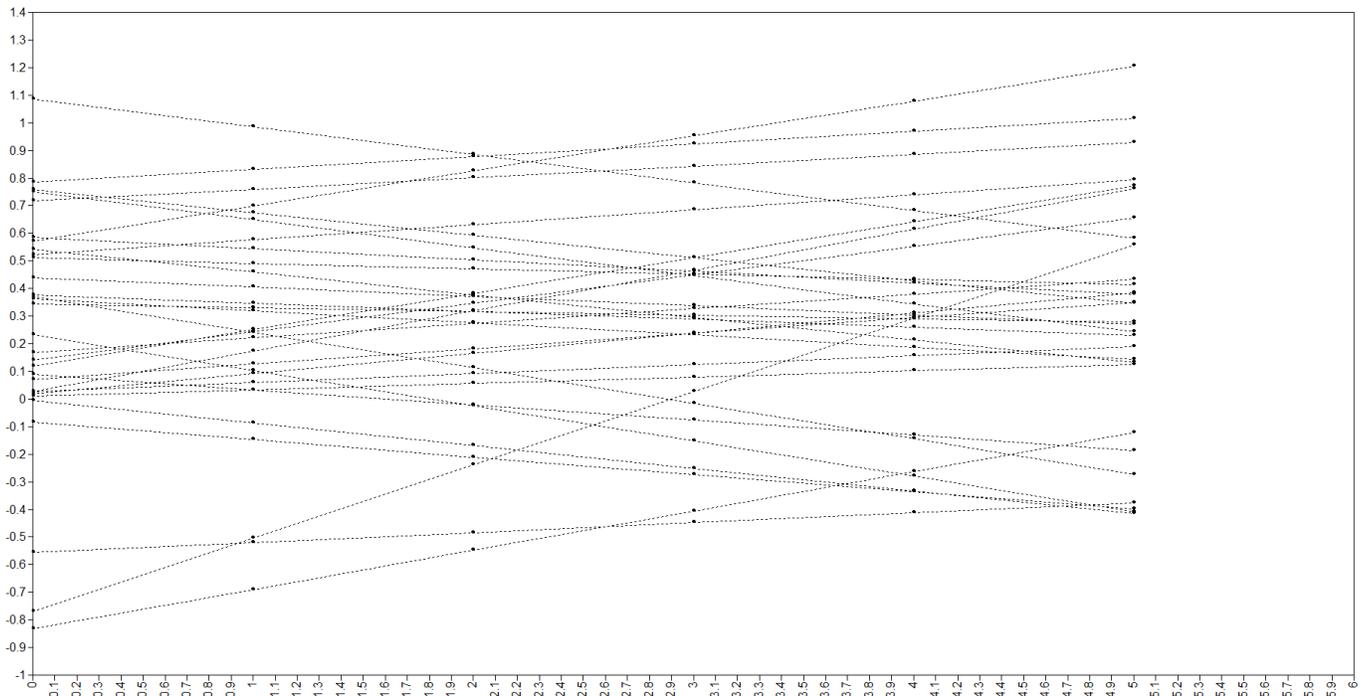
	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
I BY				
CESD1	0.718	0.008	89.998	0.000
CESD2	0.728	0.008	88.521	0.000
CESD3	0.732	0.009	81.996	0.000
CESD4	0.737	0.010	72.892	0.000
CESD5	0.729	0.011	66.856	0.000
CESD6	0.707	0.012	61.355	0.000
S BY				
CESD1	0.000	0.000	999.000	999.000
CESD2	0.092	0.004	20.469	0.000
CESD3	0.185	0.009	20.469	0.000
CESD4	0.279	0.014	20.496	0.000
CESD5	0.368	0.018	20.550	0.000
CESD6	0.446	0.022	20.421	0.000
I WITH S				
	-0.231	0.033	-6.969	0.000
Means				
I	0.870	0.021	40.589	0.000
S	0.091	0.029	3.184	0.001
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
Variances				
I	1.000	0.000	999.000	999.000
S	1.000	0.000	999.000	999.000
Residual Variances				
CESD1	0.484	0.011	42.263	0.000
CESD2	0.493	0.009	54.515	0.000
CESD3	0.493	0.008	60.649	0.000
CESD4	0.474	0.008	57.755	0.000
CESD5	0.458	0.009	52.933	0.000
CESD6	0.446	0.011	41.590	0.000

R-SQUARE

Observed Variable	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
CESD1	0.516	0.011	44.999	0.000
CESD2	0.507	0.009	56.086	0.000
CESD3	0.507	0.008	62.455	0.000
CESD4	0.526	0.008	64.000	0.000
CESD5	0.542	0.009	62.750	0.000
CESD6	0.554	0.011	51.579	0.000

Mplus Graphing

Go to *Plot*, choose *View Plots*, then, choose *Observed Individual Values*. Choose *random* order and some number of select curves to plot (I used 20) and check the *individually-fitted curves* button (keep *linear* as the curve type).



Write-up

To investigate changes in depression over five six waves, a latent growth curve model was tested using Mplus 8.4 with the Satorra-Bentler scaled chi-square and robust standard errors (Satorra & Bentler, 1988,1994). Although the chi-square was significant, $\chi^2(N = 5335, 16) = 235.387, p = .508$, alternative fit indices suggested the model fit the data well, CFI = .982, SRMR = .033. The average baseline score on the depression scale was approximately .3 ($\alpha_0 = .304$), and there was significant variability in these scores across individuals at baseline ($\psi_{00} = .122, p < .000$). On average, scores on the depression scale increased by .004 each year (unstandardized $\alpha_1 = .004$, standardized $\alpha_1 = .091$), which was significant, $p < .005$. Slopes varied significantly across individuals ($\psi = .002, p < .001$), suggesting that depression did not increase at the same rate for all participants. There was a significant negative correlation between baseline scores and slopes ($\psi_{01} = -.004, p < .001$), however, indicating that those with higher depression levels at the beginning of the study were most likely to experience decline in depression over 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(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
+
+ #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 ~ 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
+
>
> fit = sem(model, data = mydata, estimator="mlm")
> summary(fit, fit.measures=TRUE, rsquare=TRUE, standardized=TRUE)
lavaan 0.6-18 ended normally after 49 iterations
  
```

Estimator	ML					
Optimization method	NLMINB					
Number of free parameters	11					
Number of observations	5335					
Model Test User Model:						
Test Statistic	Standard	Robust				
Degrees of freedom	234.510	237.546				
P-value (Chi-square)	16	16				
Scaling correction factor	0.000	0.000				
for the Satorra-Bentler correction		0.987				
Model Test Baseline Model:						
Test statistic	11985.170	9377.134				
Degrees of freedom	15	15				
P-value	0.000	0.000				
Scaling correction factor		1.278				
User Model versus Baseline Model:						
Comparative Fit Index (CFI)	0.982	0.976				
Tucker-Lewis Index (TLI)	0.983	0.978				
Robust Comparative Fit Index (CFI)		0.982				
Robust Tucker-Lewis Index (TLI)		0.983				
Loglikelihood and Information Criteria:						
Loglikelihood user model (H0)	-16135.175	-16135.175				
Loglikelihood unrestricted model (H1)	-16017.920	-16017.920				
Akaike (AIC)	32292.350	32292.350				
Bayesian (BIC)	32364.753	32364.753				
Sample-size adjusted Bayesian (BIC)	32329.798	32329.798				
Root Mean Square Error of Approximation:						
RMSEA	0.051	0.051				
90 Percent confidence interval - lower	0.045	0.045				
90 Percent confidence interval - upper	0.056	0.057				
P-value RMSEA <= 0.05	0.419	0.381				
Robust RMSEA		0.051				
90 Percent confidence interval - lower		0.045				
90 Percent confidence interval - upper		0.056				
Standardized Root Mean Square Residual:						
SRMR	0.033	0.033				
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				0.349	0.718
cesd2	1.000				0.349	0.728
cesd3	1.000				0.349	0.732
cesd4	1.000				0.349	0.737
cesd5	1.000				0.349	0.729

cesd6	1.000				0.349	0.707
s =~						
cesd1	0.000				0.000	0.000
cesd2	1.000				0.044	0.092
cesd3	2.000				0.088	0.185
cesd4	3.000				0.132	0.279
cesd5	4.000				0.176	0.368
cesd6	5.000				0.220	0.446
Covariances:						
	Estimate	Std.Err	z-value	P(> z)	Std.lv	Std.all
i =~						
s	-0.004	0.001	-5.423	0.000	-0.231	-0.231
Intercepts:						
	Estimate	Std.Err	z-value	P(> z)	Std.lv	Std.all
i	0.304	0.006	52.106	0.000	0.870	0.870
s	0.004	0.001	3.218	0.001	0.091	0.091
.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
Variances:						
	Estimate	Std.Err	z-value	P(> z)	Std.lv	Std.all
.cesd1	0.115	0.003	36.311	0.000	0.115	0.484
.cesd2	0.114	0.003	42.955	0.000	0.114	0.493
.cesd3	0.112	0.003	44.584	0.000	0.112	0.493
.cesd4	0.107	0.002	44.095	0.000	0.107	0.474
.cesd5	0.105	0.002	42.877	0.000	0.105	0.458
.cesd6	0.109	0.003	36.433	0.000	0.109	0.446
i	0.122	0.004	32.486	0.000	1.000	1.000
s	0.002	0.000	10.248	0.000	1.000	1.000
R-Square:						
	Estimate					
cesd1	0.516					
cesd2	0.507					
cesd3	0.507					
cesd4	0.526					
cesd5	0.542					
cesd6	0.554					

R lavaan does not have a plotting feature, but see my handout for my multilevel class for one approach to plotting growth curves in R. https://web.pdx.edu/~newsomj/mlrclass/ho_plotting%20growth%20curves.pdf