# Advanced Growth Models

A Course in `MplusAutomation`

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## Outline

- Model 01: Fixed time effects
- Model 02: Centering the Intercept
- Model 03: Freely estimated time scores
- Model 04: Time-invariant covariates and freely estimated time scores
- Model 05: Time-varying covariates
- Model 06: Time-varying covariate with time-invariant effect
- Model 07: Quadratic Growth
- Model 08: Parallel Process Growth Model
- Model 09: Piecewise Growth Model (type I)
- Model 10: Piecewise Growth Model (type II)

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## Data source:

These examples utilize public use data from the *Longitudinal Survey of American Youth (LSAY)* See documentation here

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Load packages

```
library(transformr)
library(gganimate)
library(tidyverse)
library(haven)
library(janitor)
library(MplusAutomation)
library(rhdf5)
library(here)
library(gt)
library(gtsummary)
library(semPlot)
library(naniar)
```

## LSAY data example - Science Scores across 6 timepoints

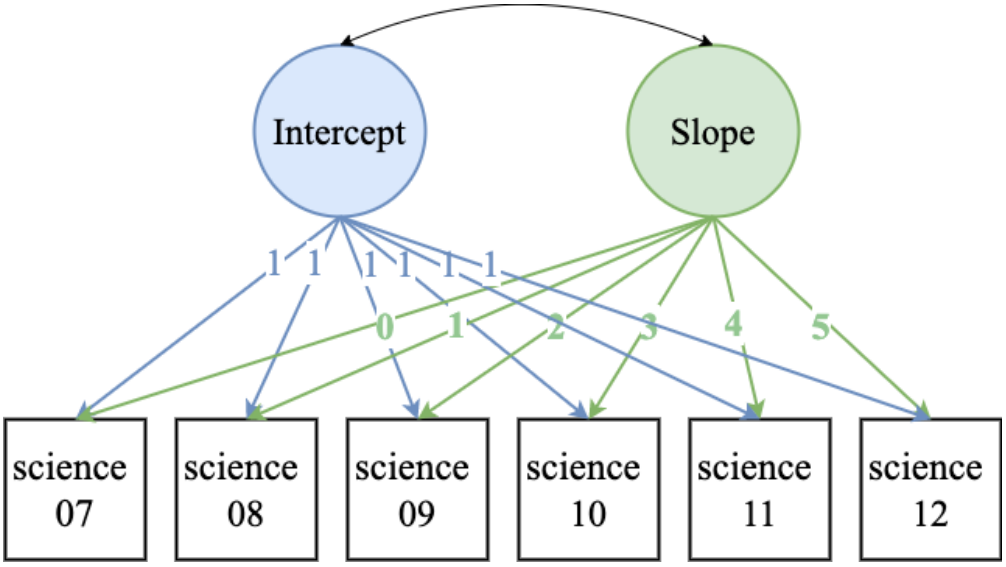
Read in the CSV file

```
lsay_lab7 <- read_csv("https://garberadamc.github.io/project-site/data/lsay_lab7_data.csv")
```

Take a look at the LSAY math & science measures

| Name | Labels | Variable type |
|---|---|---|
| math_07 | 7th grade math score | time varying covariate |
| math_08 | 8th grade math score | |
| math_09 | 9th grade math score | |
| math_10 | 10th grade math score | |
| math_11 | 11th grade math score | |
| math_12 | 12th grade math score | |
| | | |
| sci_07 | 7th grade science score | model indicators (outcomes) |
| sci_08 | 8th grade science score | |
| sci_09 | 9th grade science score | |
| sci_10 | 10th grade science score | |
| sci_11 | 11th grade science score | |
| sci_12 | 12th grade science score | |

## Model 01 - Fixed time effects




```
m1_growth  <- mplusObject(
  TITLE = "m1 growth model fixed time scores",
  VARIABLE =
    "usevar =
    sci_07-sci_12; ",

  ANALYSIS =
    "estimator = MLR" ,

  MODEL =
   "i s | sci_07@0 sci_08@1 sci_09@2 sci_10@3 sci_11@4 sci_12@5; " ,

  OUTPUT = "sampstat standardized;",

  PLOT = "type=plot3;
          series = sci_07-sci_12(*)",

  usevariables = colnames(lsay_lab7),
  rdata = lsay_lab7)

m1_growth_fit <- mplusModeler(m1_growth,
                 dataout=here("11-advanced-growth", "mplus_files", "LSAY.dat"),
                 modelout=here("11-advanced-growth", "mplus_files", "m1_growth.inp"),
                 check=TRUE, run = TRUE, hashfilename = FALSE)
```

---

Load in the `mplus.R` functions

```
source(here("11-advanced-growth", "mplus.R.txt"))
```

```
## [1] "Loaded rhdf5 package"
```

### Plotting using gh5 plot data generated by Mplus

1. View plots available for a given model
2. Generate plots using the get.plot.___ function
3. Extract data and transform to tidy format
4. Plot with ggplot

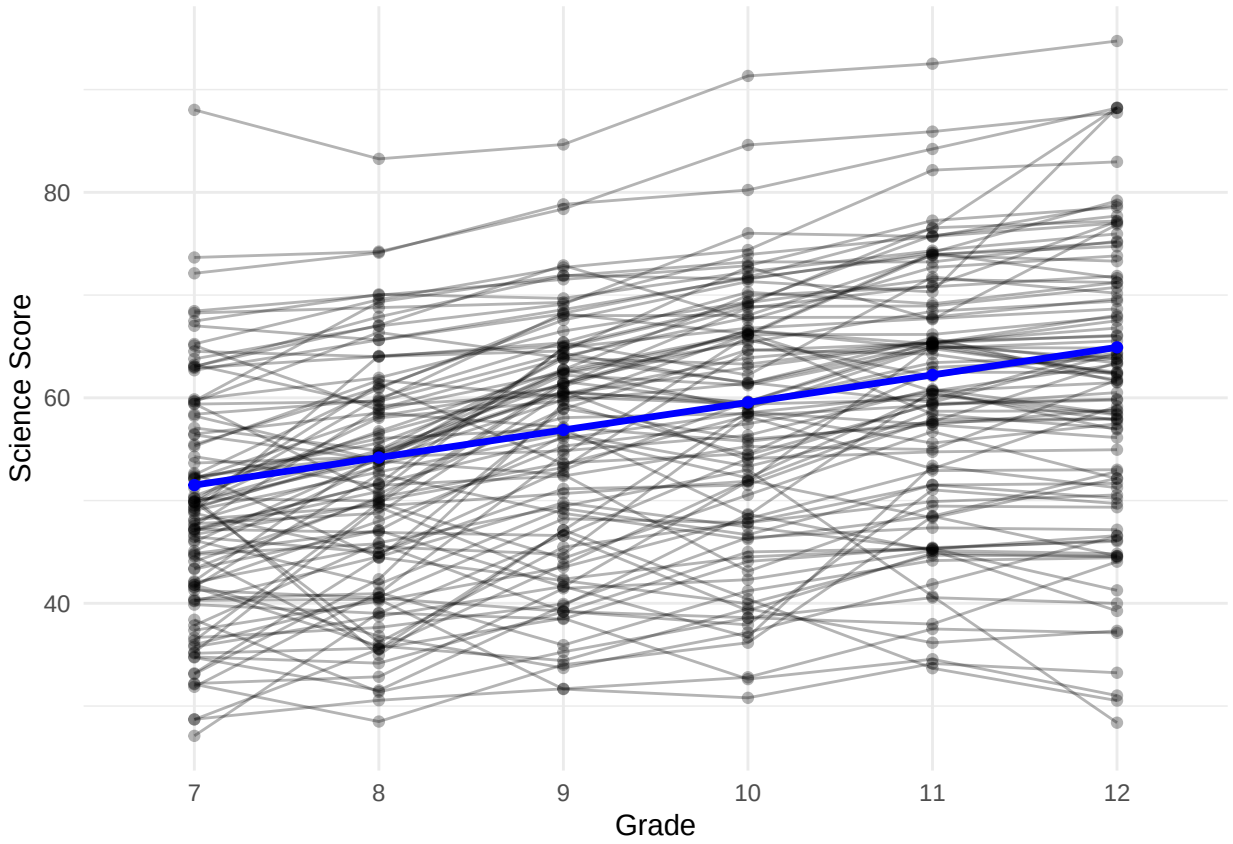
```
mplus.view.plots(here("11-advanced-growth", "mplus_files", "m1_growth.gh5"))
```

Prepare plot data

```
observed <- lsay_lab7 %>% select(starts_with("sci")) %>%
  rownames_to_column() %>% drop_na()

obs100 <- observed[1:100,]

plot_obs <- obs100 %>%
  pivot_longer(`sci_07`:`sci_12`, # The columns I'm gathering together
               names_to = "grade", # new column name for existing names
              values_to = "value") # new column name to store values

gradelevels <- colnames(observed[,2:7])

mean_est <- as.data.frame(mplus.get.estimated_means(here("11-advanced-growth",
  "mplus_files", "m1_growth.gh5"))) %>%
  mutate(grade = gradelevels)
```

Plot the model estimated means superimposted on the obserbed individual values

```
growth_plot <- ggplot() +
  geom_point(data = plot_obs,
             aes(x = grade, y = value, group = rowname), alpha = .3) +
  geom_line(data = plot_obs,
            aes(x = grade, y = value, group = rowname), alpha = .3) +
  geom_point(data=mean_est,
             aes(x=grade, y = V1), color = "Blue", size = 1.5) +
  geom_line(data=mean_est,
            aes(x=grade, y = V1, group = 1), color = "Blue", size = 1.2) +
  scale_x_discrete(labels = c("7", "8", "9", "10", "11", "12")) +
  labs(x="Grade", y="Science Score") +
  theme_minimal()

growth_plot
```




```
ggsave(here("11-advanced-growth", "figures", "spaghetti_p1.png"),
       height = 6, width = 8, dpi = "retina")
```

Animate the plot with {gganimate}

```
growth_plot +
  transition_states(rowname,
                    transition_length = 1,
                    state_length = 1) +
  shadow_mark(color = "Magenta", alpha = .3)
```

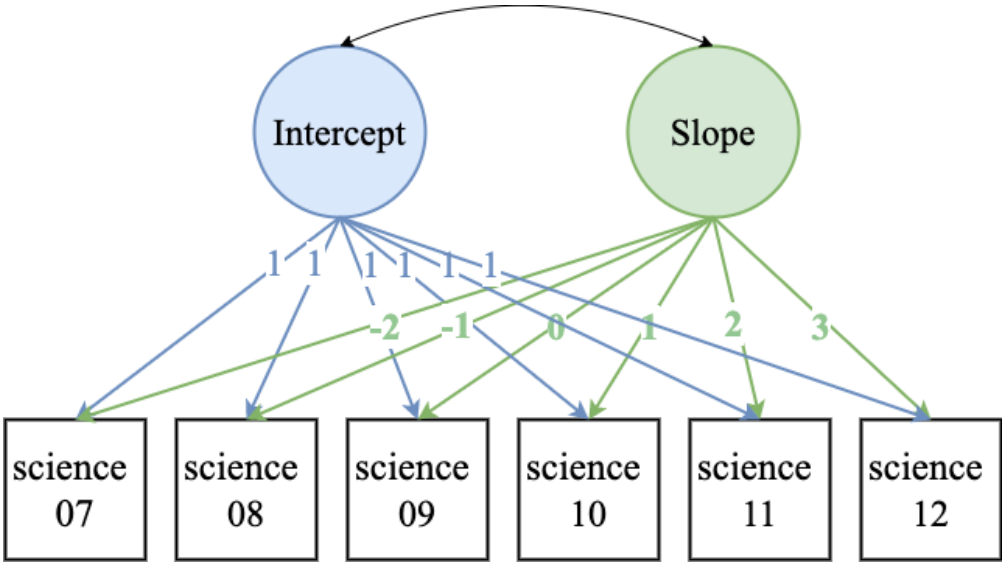
```
anim_save(here("11-advanced-growth", "figures", "spaghetti_plot.gif"),
          height = 6, width = 8, dpi = "retina")
```

---

## Model 02 - Centering the Intercept

---

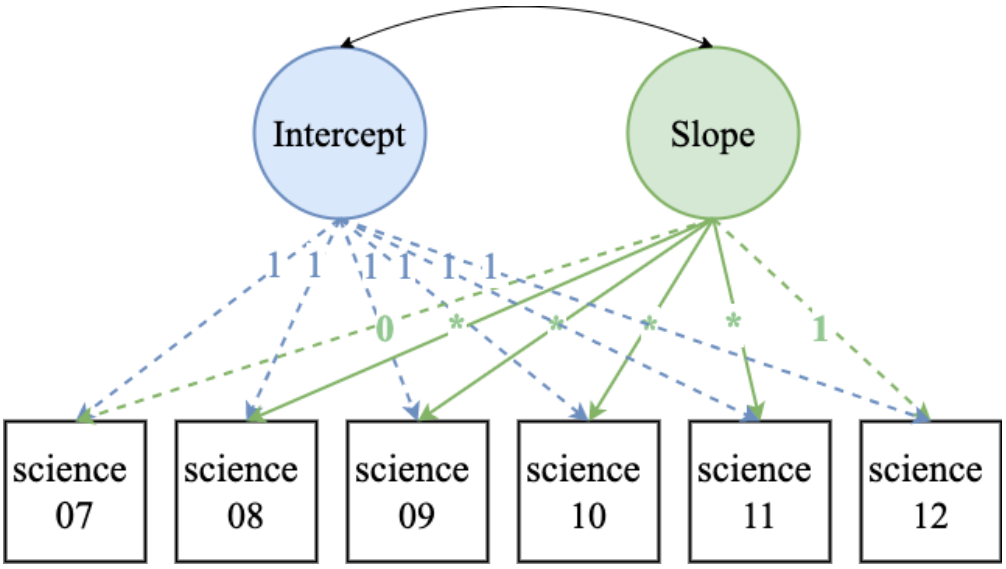
a. Centering determines the interpretation of the intercept growth factor
b. The centering point is the timepoint at which the time score is `zero`
c. A model can be estimated for different centering points depending on which interpretation is of interest




```
m2_growth  <- mplusObject(
  TITLE = "m2 growth model centering time scores",
  VARIABLE =
    "usevar =
    sci_07-sci_12; ",

  ANALYSIS =
    "estimator = MLR" ,

  MODEL =
   "i s | sci_07@-2 sci_08@-1 sci_09@0 sci_10@1 sci_11@2 sci_12@3; " ,

  OUTPUT = "sampstat standardized;",

  PLOT = "type=plot3;
          series = sci_07-sci_12(*)",

  usevariables = colnames(lsay_lab7),
  rdata = lsay_lab7)

m2_growth_fit <- mplusModeler(m2_growth,
                    dataout=here("11-advanced-growth", "mplus_files", "LSAY.dat"),
                    modelout=here("11-advanced-growth", "mplus_files", "m2_growth.inp"),
                    check=TRUE, run = TRUE, hashfilename = FALSE)
```

---

### Model 03 - freely estimated time scores



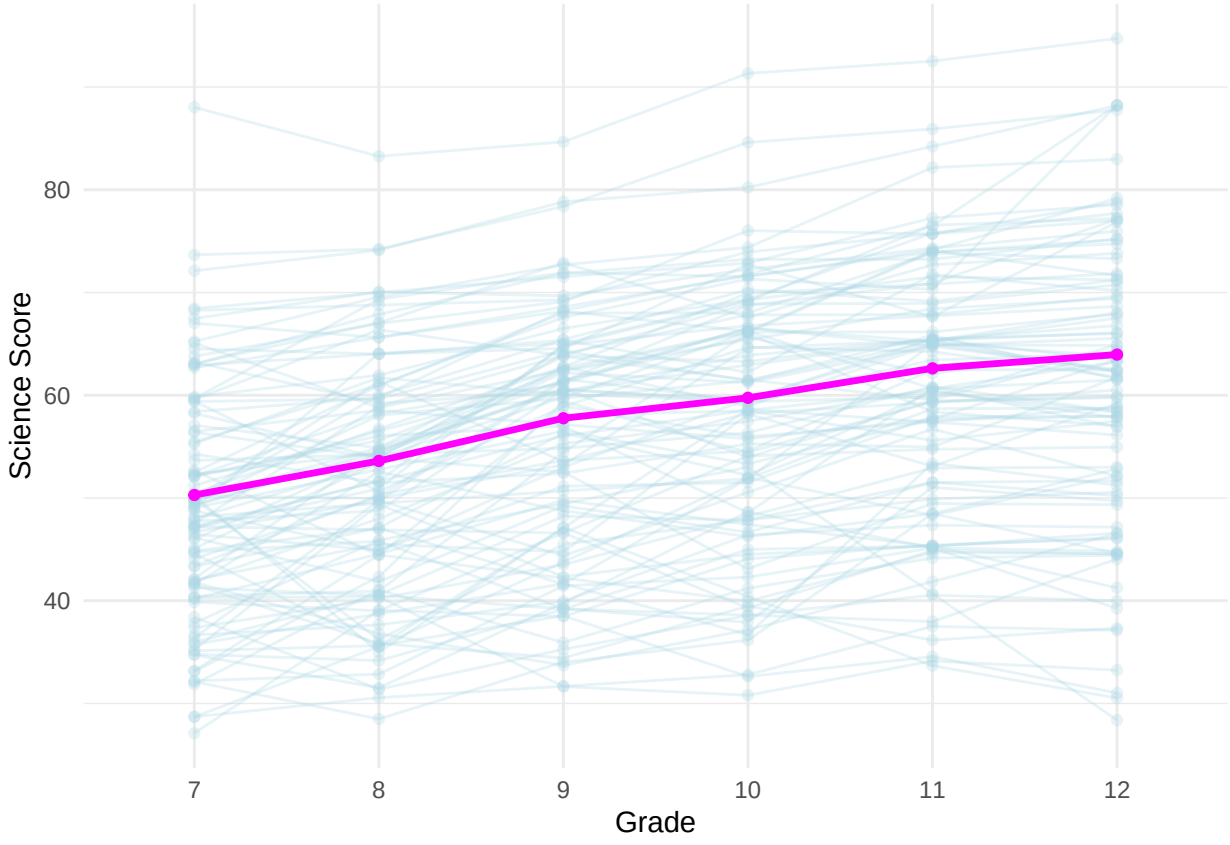

```
m3_growth  <- mplusObject(
  TITLE = "m3 growth model freely estimated time scores",
  VARIABLE =
    "usevar =
     sci_07-sci_12; ",

  ANALYSIS =
    "estimator = MLR" ,

  MODEL =
   "i s | sci_07@0 sci_08* sci_09* sci_10* sci_11* sci_12@1; " ,

  OUTPUT = "sampstat standardized;",

  PLOT = "type=plot3;
          series = sci_07-sci_12(*)",

  usevariables = colnames(lsay_lab7),
  rdata = lsay_lab7)

m3_growth_fit <- mplusModeler(m3_growth,
                 dataout=here("11-advanced-growth", "mplus_files", "LSAY.dat"),
                 modelout=here("11-advanced-growth", "mplus_files", "m3_growth.inp"),
                 check=TRUE, run = TRUE, hashfilename = FALSE)
```

Prepare plot data

```
mean_est2 <- as.data.frame(mplus.get.estimated_means(here("11-advanced-growth",
  "mplus_files", "m3_growth.gh5"))) %>%
  mutate(grade = gradelevels)
```

Plot the model estimated means superimposted on the obserbed individual values

```
growth_plot <- ggplot() +
  geom_point(data = plot_obs,
             aes(x = grade, y = value, group = rowname), color = "lightblue", alpha = .3) +
  geom_line(data = plot_obs,
            aes(x = grade, y = value, group = rowname), color = "lightblue", alpha = .3) +
  geom_point(data=mean_est2,
             aes(x=grade, y = V1), color = "magenta", size = 1.5) +
  geom_line(data=mean_est2,
            aes(x=grade, y = V1, group = 1), color = "magenta", size = 1.2) +
  scale_x_discrete(labels = c("7", "8", "9", "10", "11", "12")) +
  labs(x="Grade", y="Science Score") +
  theme_minimal()

growth_plot
```




---

## Model 04 - time-invariant covariates and freely estimated time scores

---

covariates:

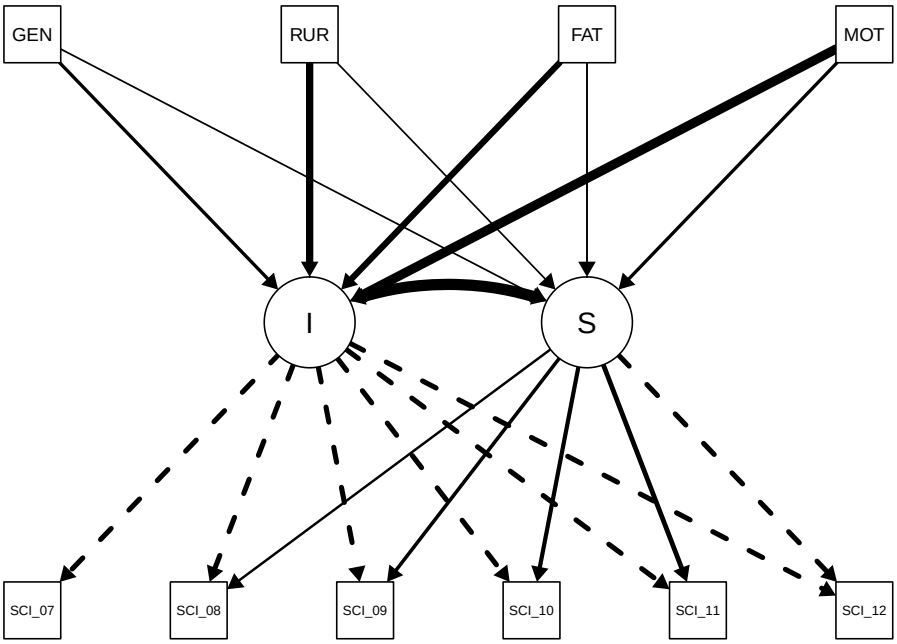
- `gender`: 1 = female
- `rural`: 1 = rural
- `fathed`: Father's reported education
- `mothed`: Mother's reported education

```
m4_growth  <- mplusObject(
  TITLE = "m4 time-invariant covariates and freely estimated time scores",
  VARIABLE =
    "usevar =
     sci_07-sci_12
     gender rural fathed mothed; ",

  ANALYSIS =
    "estimator = MLR" ,

  MODEL =
   "i s | sci_07@0 sci_08* sci_09* sci_10* sci_11* sci_12@1;

    i s on gender rural fathed mothed;" ,

  OUTPUT = "sampstat standardized;",

  PLOT = "type=plot3;
          series = sci_07-sci_12(*)",

  usevariables = colnames(lsay_lab7),
  rdata = lsay_lab7)

m4_growth_fit <- mplusModeler(m4_growth,
                      dataout=here("11-advanced-growth", "mplus_files", "LSAY.dat"),
                      modelout=here("11-advanced-growth", "mplus_files", "m4_growth.inp"),
                      check=TRUE, run = TRUE, hashfilename = FALSE)
```

---

Check the path diagram with `semPlot`

```
m4_output <- readModels(here("11-advanced-growth", "mplus_files", "m4_growth.out"), quiet = TRUE)

semPaths(m4_output,  "est",
         intercepts=FALSE, residuals = FALSE, fade = FALSE,
         edge.color = "black", edgeLabels = "")
```




---

## Model 05 - `time-varying covariates`

---

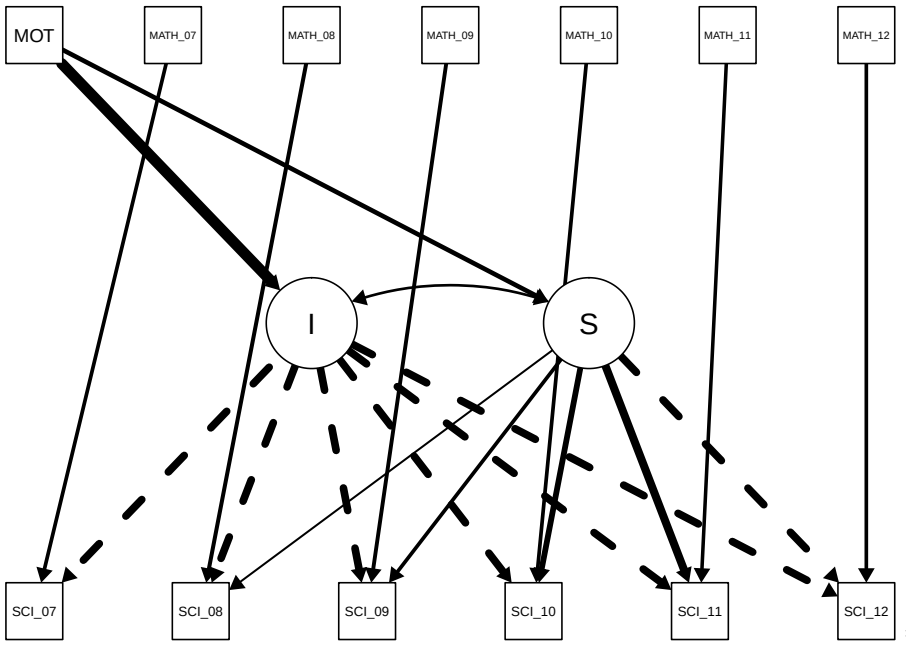
repeated measure covariate: `math scores: grades 7 to 12` time-invariant covariate: `mothed`

```
m5_growth  <- mplusObject(
  TITLE = "m05 time-varying covariates",
  VARIABLE =
    "usevar =
     sci_07-sci_12
     math_07-math_12 mothed; ",

  ANALYSIS =
    "estimator = MLR" ,

  MODEL =
   "i s | sci_07@0 sci_08* sci_09* sci_10* sci_11* sci_12@1;

    i s on mothed;

    sci_07 on math_07;
    sci_08 on math_08;
    sci_09 on math_09;
    sci_10 on math_10;
    sci_11 on math_11;
    sci_12 on math_12; ",
```

```
  OUTPUT = "sampstat standardized;",

  PLOT = "type=plot3;
          series = sci_07-sci_12(*)",

  usevariables = colnames(lsay_lab7),
  rdata = lsay_lab7)

m5_growth_fit <- mplusModeler(m5_growth,
                  dataout=here("11-advanced-growth", "mplus_files", "LSAY.dat"),
                  modelout=here("11-advanced-growth", "mplus_files", "m5_growth.inp"),
                  check=TRUE, run = TRUE, hashfilename = FALSE)
```

Check the path diagram

```
m5_output <- readModels(here("11-advanced-growth", "mplus_files", "m5_growth.out"), quiet = TRUE)

semPaths(m5_output,  "est",
         intercepts=FALSE, residuals = FALSE, fade = FALSE,
         edge.color = "black", edgeLabels = "")
```




#

## Model 06 - Time-varying covariate with time-invariant effect

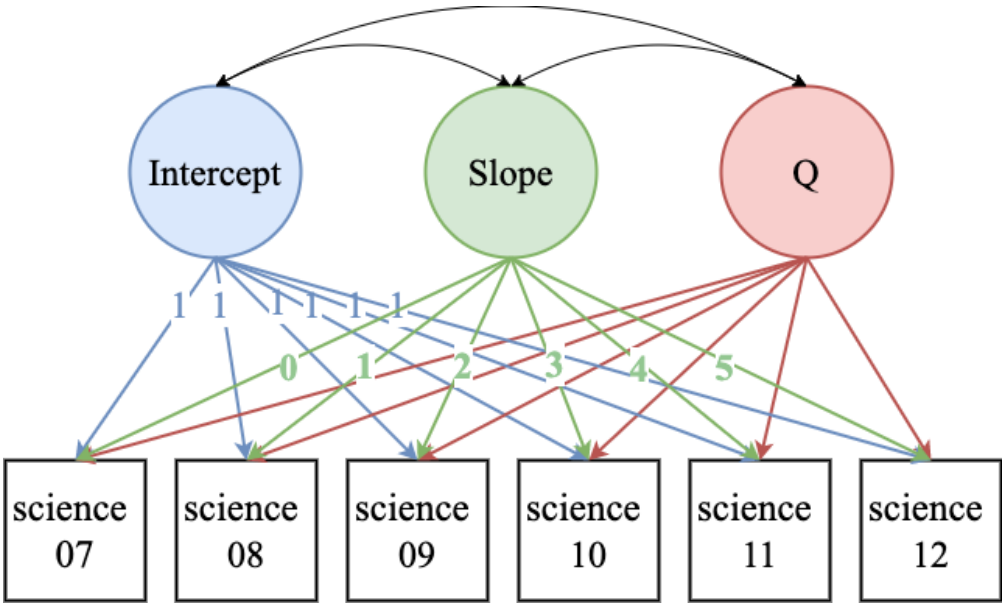
---

```
m6_growth  <- mplusObject(
  TITLE = "m06 time-varying covariates",
  VARIABLE =
```

```
    "usevar =
     sci_07-sci_12
     math_07-math_12 mothed; ",

  ANALYSIS =
    "estimator = MLR" ,

  MODEL =
   "i s | sci_07@0 sci_08* sci_09* sci_10* sci_11* sci_12@1;

    i s on mothed;

    sci_07 on math_07(1); ! TIME-INVARIANT: Fixed to equality
    sci_08 on math_08(1);
    sci_09 on math_09(1);
    sci_10 on math_10(1);
    sci_11 on math_11(1);
    sci_12 on math_12(1); ",

  OUTPUT = "sampstat standardized;",

  PLOT = "type=plot3;
          series = sci_07-sci_12(*)",

  usevariables = colnames(lsay_lab7),
  rdata = lsay_lab7)

m6_growth_fit <- mplusModeler(m6_growth,
                 dataout=here("11-advanced-growth", "mplus_files", "LSAY.dat"),
                 modelout=here("11-advanced-growth", "mplus_files", "m6_growth.inp"),
                 check=TRUE, run = TRUE, hashfilename = FALSE)
```

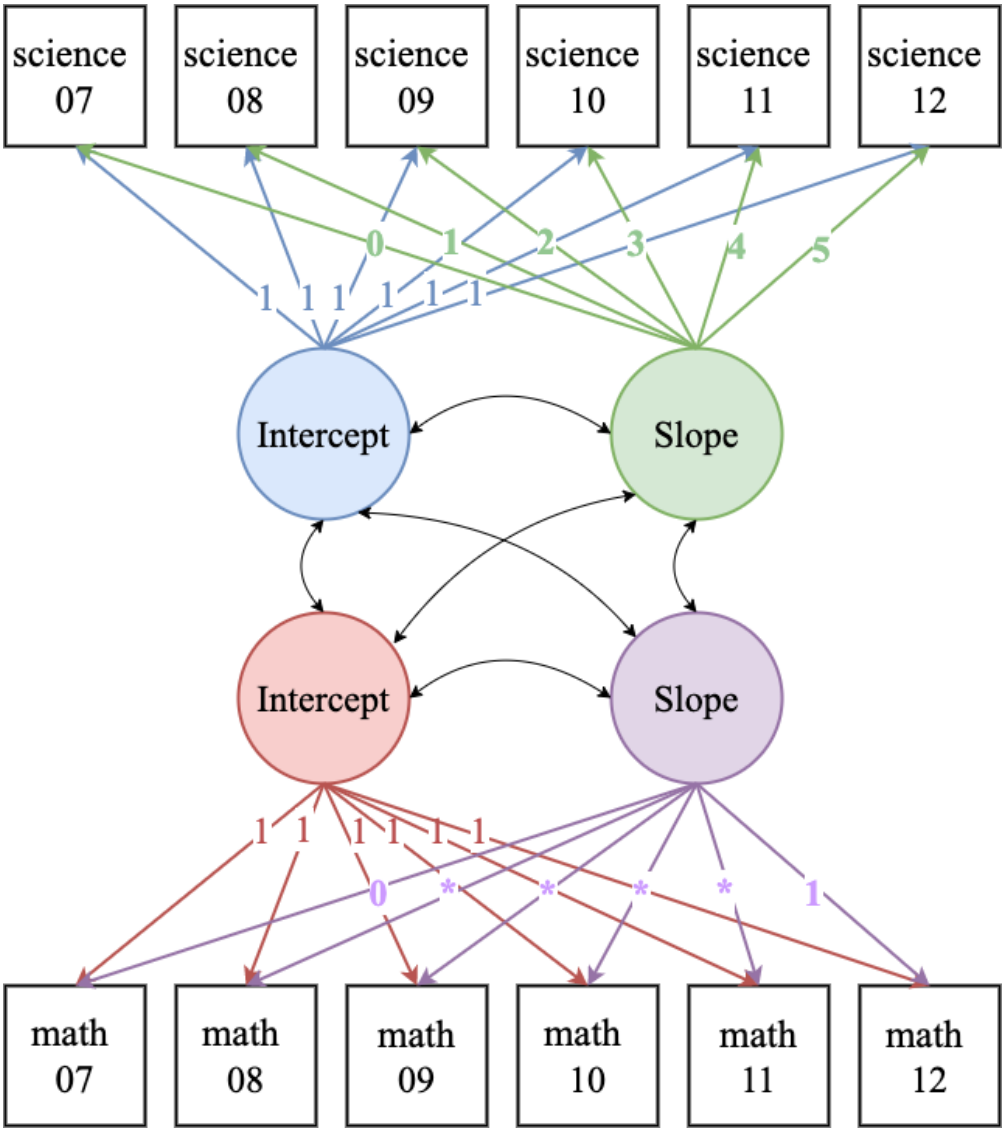
---

### Model 07 - Quadratic Growth




```
m7_growth  <- mplusObject(
  TITLE = "m07 Quadratic Growth (i s q)",
  VARIABLE =
    "usevar =
     sci_07-sci_12; ",

  ANALYSIS =
    "estimator = MLR" ,

  MODEL =
   "i s q | sci_07@0 sci_08@1 sci_09@2 sci_10@3 sci_11@4 sci_12@5; ",

  OUTPUT = "sampstat standardized;",

  PLOT = "type=plot3;
          series = sci_07-sci_12(*)",

  usevariables = colnames(lsay_lab7),
  rdata = lsay_lab7)

m7_growth_fit <- mplusModeler(m7_growth,
                  dataout=here("11-advanced-growth", "mplus_files", "LSAY.dat"),
                  modelout=here("11-advanced-growth", "mplus_files", "m7_growth.inp"),
                  check=TRUE, run = TRUE, hashfilename = FALSE)
```

## Model 08 - Parallel Process Growth Model



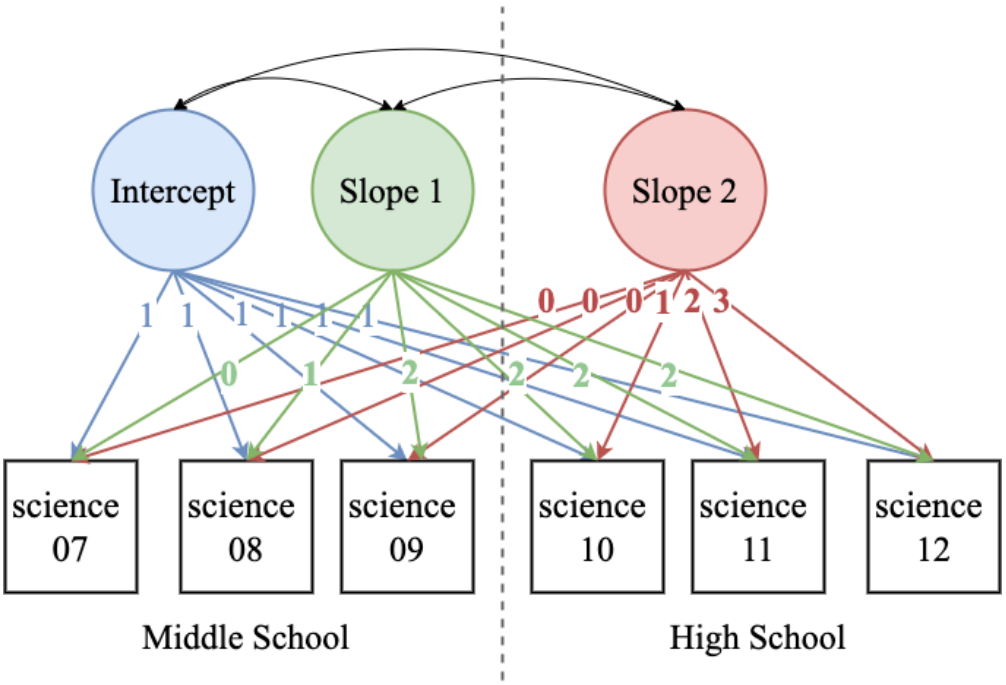

```
m8_growth  <- mplusObject(
  TITLE = "m08 Parallel Process",
  VARIABLE =
    "usevar =
     sci_07-sci_12
     math_07-math_12 mothed;",

  ANALYSIS =
    "estimator = MLR" ,

  MODEL =
   "is ss | sci_07@0 sci_08@1 sci_09@2 sci_10@3 sci_11@4 sci_12@5;

    im sm | math_07@0 math_08@1 math_09@2 math_10@3 math_11@4 math_12@5;
```

```
    is ss im sm on mothed;  ! time-invariant covariate ",

  OUTPUT = "sampstat standardized;",

  PLOT = "type=plot3;
          series = sci_07-sci_12(*)",

  usevariables = colnames(lsay_lab7),
  rdata = lsay_lab7)

m8_growth_fit <- mplusModeler(m8_growth,
                  dataout=here("11-advanced-growth", "mplus_files", "LSAY.dat"),
                  modelout=here("11-advanced-growth", "mplus_files", "m8_growth.inp"),
                  check=TRUE, run = TRUE, hashfilename = FALSE)
```

---

## Model 09 - Piecewise Process Growth Model

---




```
m9_growth  <- mplusObject(
  TITLE = "m09 piecewise growth",
  VARIABLE =
    "usevar =
     sci_07-sci_12 mothed;",

  ANALYSIS =
```

```
    "estimator = MLR" ,

  MODEL =
   "i1 s1 | sci_07@0 sci_08@1 sci_09@2 sci_10@2 sci_11@2 sci_12@2;

      s2 by sci_07@0 sci_08@0 sci_09@0 sci_10@1 sci_11@2 sci_12@3;

    i1 s1 s2 on mothed; ",

  OUTPUT = "sampstat standardized;",

  PLOT = "type=plot3;
          series = sci_07-sci_12(*)",

  usevariables = colnames(lsay_lab7),
  rdata = lsay_lab7)

m9_growth_fit <- mplusModeler(m9_growth,
                 dataout=here("11-advanced-growth", "mplus_files", "LSAY.dat"),
                 modelout=here("11-advanced-growth", "mplus_files", "m9_growth.inp"),
                 check=TRUE, run = TRUE, hashfilename = FALSE)
```

---

## Model 10 - Piecewise Process Growth Model

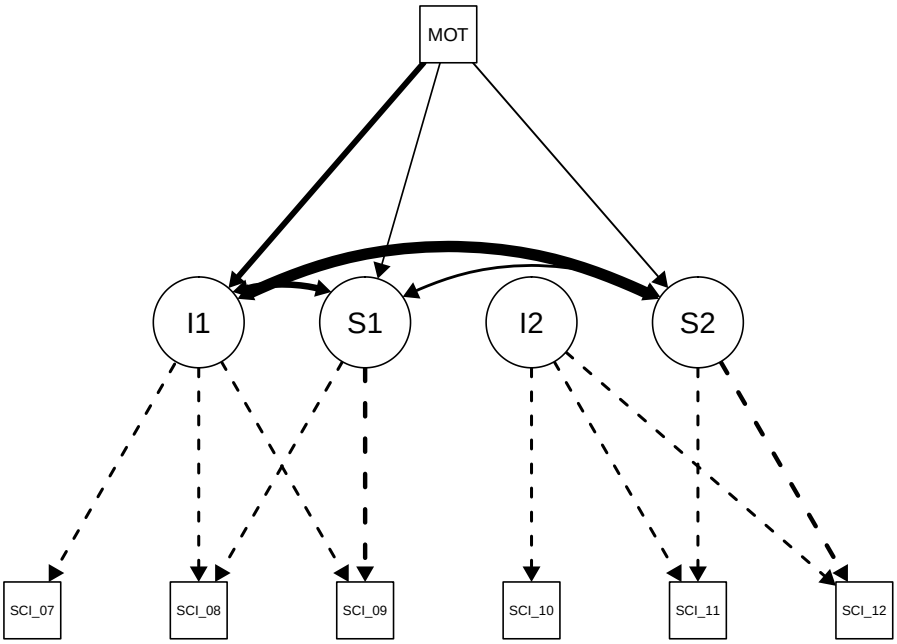
---

```
m10_growth  <- mplusObject(
  TITLE = "m10 piecewise growth",
  VARIABLE =
    "usevar =
     sci_07-sci_12 mothed;",

  ANALYSIS =
    "estimator = MLR;" ,

  MODEL =
   "i1 s1 | sci_07@0 sci_08@1 sci_09@2;
    i2 s2 | sci_10@0 sci_11@1 sci_12@2;

    [s1] (p1);
    [s2] (p2);

    i1 i2 s1 s2 on mothed; ",

  MODELTEST = "p1=p2;  !testing if the two slopes are the same",

  OUTPUT = "sampstat standardized;",
```

```
  PLOT = "type=plot3;
          series = sci_07-sci_12(*)",

  usevariables = colnames(lsay_lab7),
  rdata = lsay_lab7)

m10_growth_fit <- mplusModeler(m10_growth,
                  dataout=here("11-advanced-growth", "mplus_files", "LSAY.dat"),
                  modelout=here("11-advanced-growth", "mplus_files", "m10_growth.inp"),
                  check=TRUE, run = TRUE, hashfilename = FALSE)
```

Check the path diagram

```
m10_output <- readModels(here("11-advanced-growth", "mplus_files", "m10_growth.out"), quiet = TRUE)

semPaths(m10_output,  "est",
         intercepts=FALSE, residuals = FALSE, fade = FALSE,
         edge.color = "black", edgeLabels = "")
```

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## References


Hallquist, M. N., & Wiley, J. F. (2018). MplusAutomation: An R Package for Facilitating Large-Scale Latent Variable Analyses in Mplus. Structural equation modeling: a multidisciplinary journal, 25(4), 621-638.

Miller, J. D., Hoffer, T., Suchner, R., Brown, K., & Nelson, C. (1992). LSAY codebook. Northern Illinois University.

Muthén, B. O., Muthén, L. K., & Asparouhov, T. (2017). Regression and mediation analysis using Mplus. Los Angeles, CA: Muthén & Muthén.

Muthén, L.K. and Muthén, B.O. (1998-2017). Mplus User's Guide. Eighth Edition. Los Angeles, CA: Muthén & Muthén

R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/

Wickham et al., (2019). Welcome to the tidyverse. Journal of Open Source Software, 4(43), 1686, https://doi.org/10.21105/joss.01686

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## Further resources & examples here:

https://garberadamc.github.io/project-site/

https://www.adam-garber.com/

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