Introduction to structural equation modeling and mixed models in 

Day 9 – Part 2: SEM

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Day 9 – Part 2 Outline

- Interactions in SEM

  - ✓ Single Interactions in sub-models
  - ✓ Multigroup Analysis (model-wide interactions)

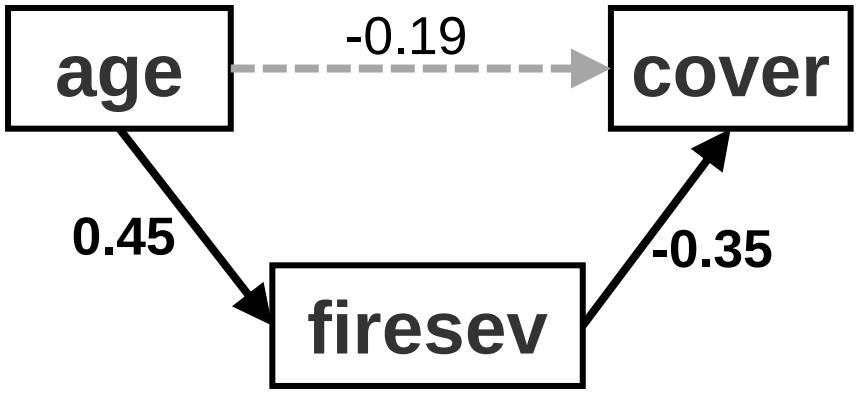
Day 9 – Part 2 Outline

- Interactions in SEM

  - ✓ **Single Interactions in sub-models**
  - ✓ Multigroup Analysis (model-wide interactions)

Interactions

- reproduces a single variance-covariance matrix




```
# Keeley data
library(piecewiseSEM)
data(keeley)
```

Data: Grace, J.B. and Keeley, J.E. 2006. A structural equation model analysis of postfire plant diversity in California shrublands. Ecological Applications 16:503-514

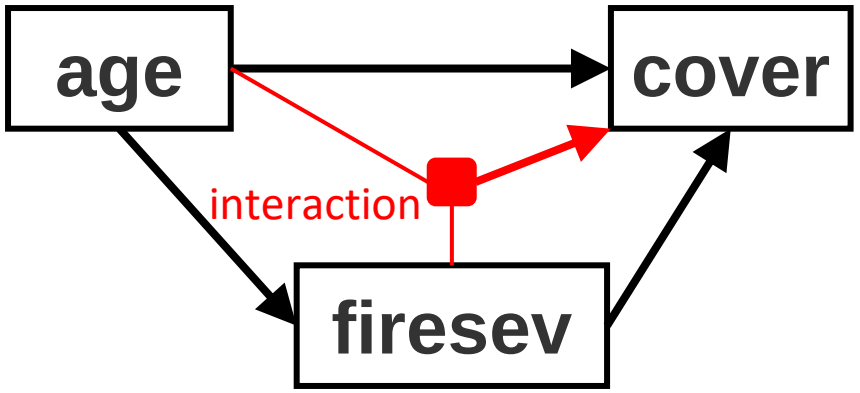
Interactions

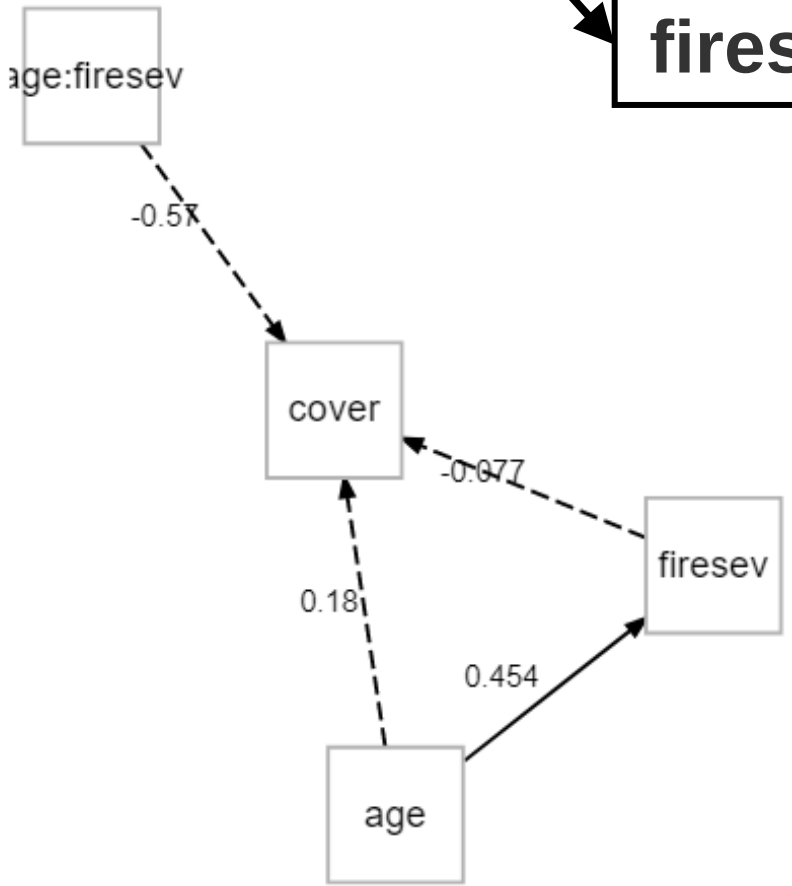
```
library(piecewiseSEM)

data(keeley)

psem_m1 <- psem(
  lm(cover ~ age*firesev, data = keeley),
  lm(firesev ~ age, data = keeley)
)

plot(psem_m1)
```





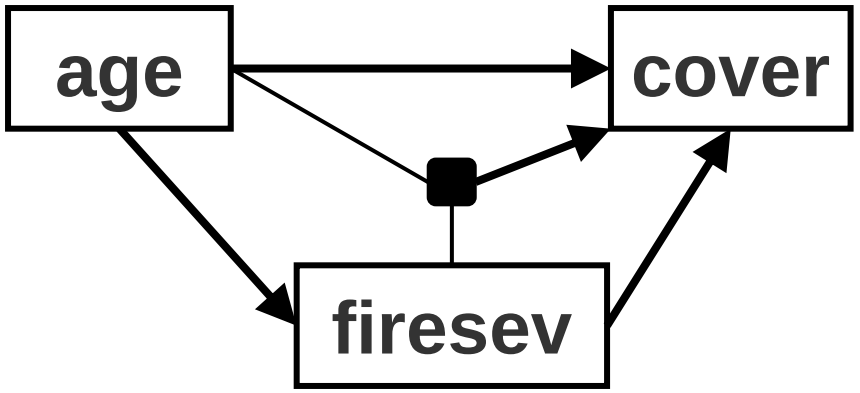
Does the effect of fire severity on plant cover depends on plant age?

Interactions

```
psem_m1 <- psem(
  lm(cover ~ age*firesev, data = keeley),
  lm(firesev ~ age, data = keeley))

fisherC(psem_m1)# This is saturated model (no DF)
LLchisq(psem_m1)
```

```
> Fisher.C df P.Value
1  NA  0      NA
> Chisq df P.Value
1     0  0       1
```



Interactions

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> Fisher.C df P.Value
1  NA  0       NA
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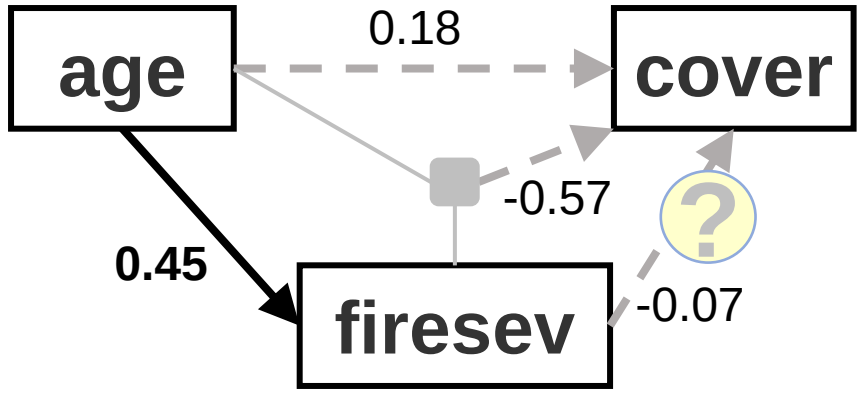
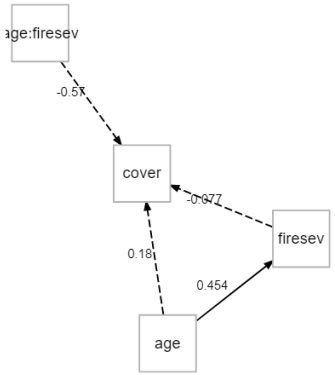
1     0  0        1
```




```
coefs(psem_m1)
>
 Response    Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
1    cover          age   0.0045    0.0067 86     0.6786  0.4992       0.1800
2    cover      firesev  -0.0149    0.0398 86    -0.3729  0.7101      -0.0774
3    cover age:firesev  -0.0021    0.0014 86    -1.5263  0.1306      -0.5700
4  firesev          age   0.0597    0.0125 88     4.7781  0.0000       0.4539 ***


with(keeley, cor(age, age*firesev))
>
[1] 0.8687952  # we have colinearity
```

Centering data helps remove collinearities.



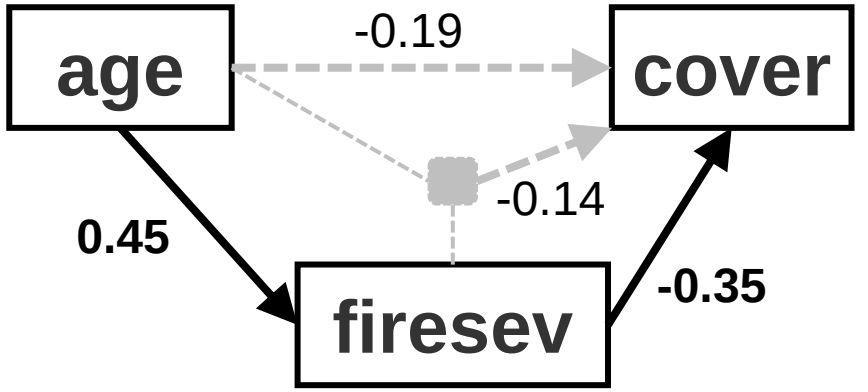
Interactions

Centering data helps remove collinearities.

```
# Centering for Interactions

data2 <- data.frame(age_c=scale(keeley$age, scale=FALSE),
                    firesev_c=scale(keeley$firesev, scale=FALSE),
                      cover=keeley$cover)


with(data2, cor(age_c, age_c*firesev_c))
>
[1] -0.06792114
```




```
psem_m2 <- psem(
  lm(cover ~ age_c*firesev_c, data = data2),
  lm(firesev_c ~ age_c, data = data2))

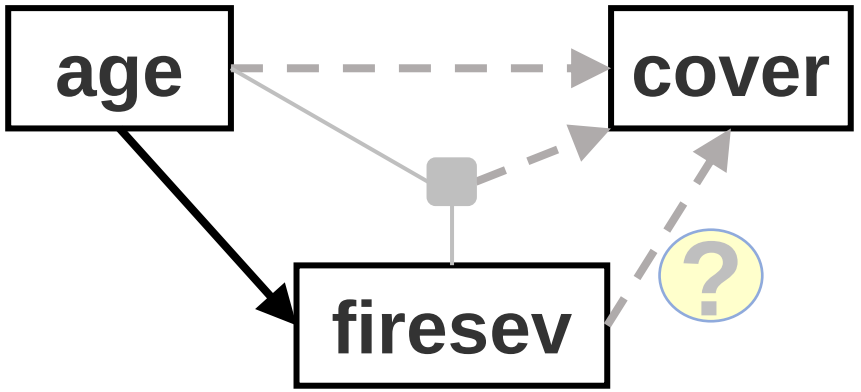

> coefs(psem_m2)
   Response          Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
1     cover              age_c  -0.0050    0.0027 86    -1.8810  0.0634      -0.1985
2     cover          firesev_c  -0.0684    0.0203 86    -3.3752  0.0011      -0.3561  **
3     cover age_c:firesev_c  -0.0021    0.0014 86    -1.5263  0.1306      -0.1438
4 firesev_c              age_c   0.0597    0.0125 88     4.7781  0.0000       0.4539 ***
```

Interactions

lavaan

```
# Interactions using lavaan

library(lavaan)
sem_m1 <-'
  firesev ~ age
  cover ~ firesev + age + firesev:age
'
sem_fit1 <- sem(sem_m1, data=keeley)
```




```
summary(sem_fit2, standardize = T)

Regressions:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
  firesev ~
    age               0.060    0.012    4.832    0.000    0.060    0.454
  cover ~
    firesev          -0.015    0.020   -0.751    0.453   -0.015   -0.079
    age               0.005    0.005    0.941    0.347    0.005    0.183
    firesev:age      -0.002    0.001   -3.073    0.002   -0.002   -0.580
```

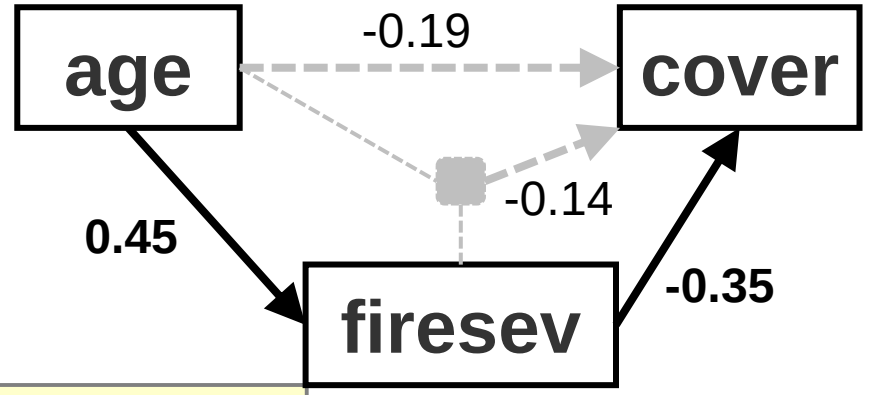
Interactions

lavaan

```
# use centered data

sem_m2<-'
  firesev_c ~ age_c
  cover ~ firesev_c + age_c + firesev_c:age_c
'
sem_fit2 <- sem(sem_m2, data=data2)
```

piecewiseSEM




```
summary(sem_fit2, standardize = T)

Regressions:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
  firesev_c ~
    age_c             0.060    0.012    4.832    0.000    0.060    0.454
  cover ~
    firesev_c        -0.068    0.020   -3.455    0.001   -0.068   -0.356
    age_c            -0.005    0.003   -1.923    0.055   -0.005   -0.198
    firesev_c:ag_c   -0.002    0.001   -1.562    0.118   -0.002   -0.144
```

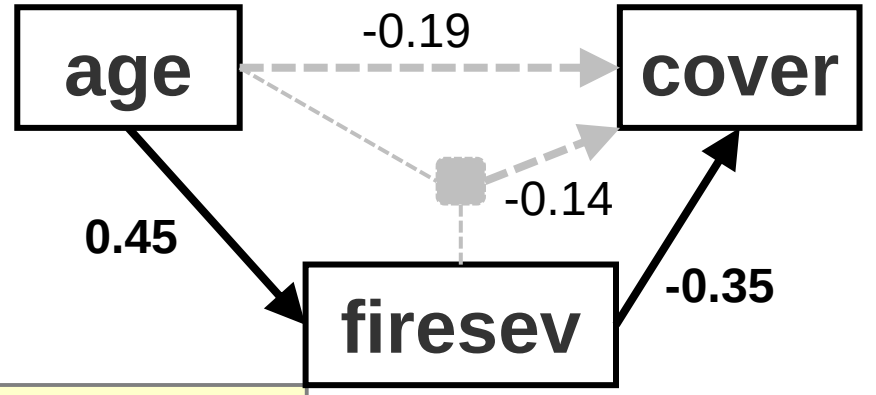
Interactions

lavaan

```
# use centered data

sem_m2<-'
  firesev_c ~ age_c
  cover ~ firesev_c + age_c + firesev_c:age_c
'
sem_fit2 <- sem(sem_m2, data=data2)
```

piecewiseSEM

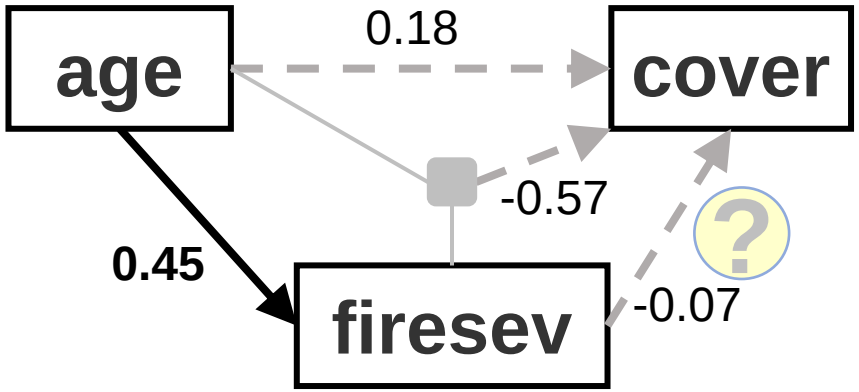



```
summary(sem_fit2, standardize = T)

Regressions:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
  firesev_c ~
    age_c             0.060    0.012    4.832    0.000    0.060    0.454
  cover ~
    firesev_c        -0.068    0.020   -3.455    0.001   -0.068   -0.356
    age_c            -0.005    0.003   -1.923    0.055   -0.005   -0.198
    firesev_c:ag_c   -0.002    0.001   -1.562    0.118   -0.002   -0.144
```

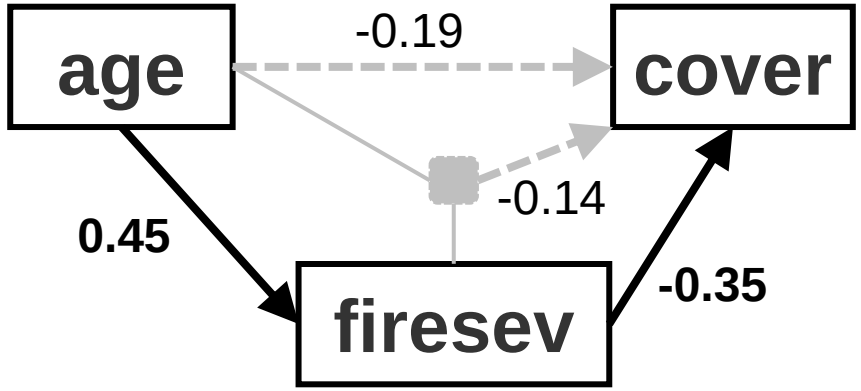
Interactions

Uncentered



Additive paths estimate the effect of one variable in the absence of the other.

Centered

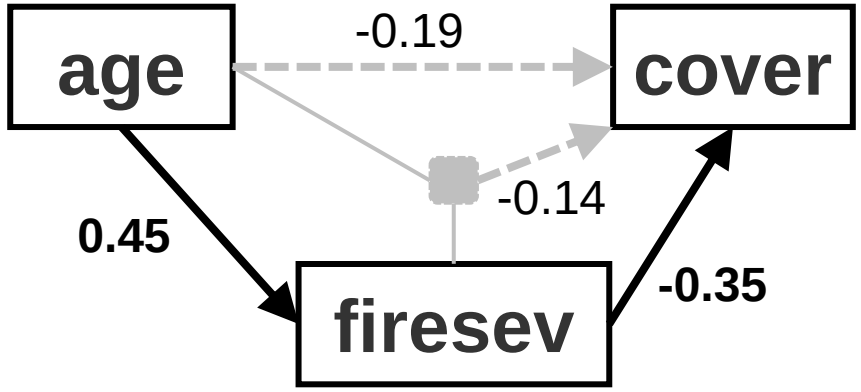


Additive paths estimate the effect of one variable at the average level of the other

Fire severity has no effect when age = 0 versus fire severity has an effect at the mean level of age.

Result for interaction: the effect of fire severity on plant cover does not differ with plant age.

Interactions



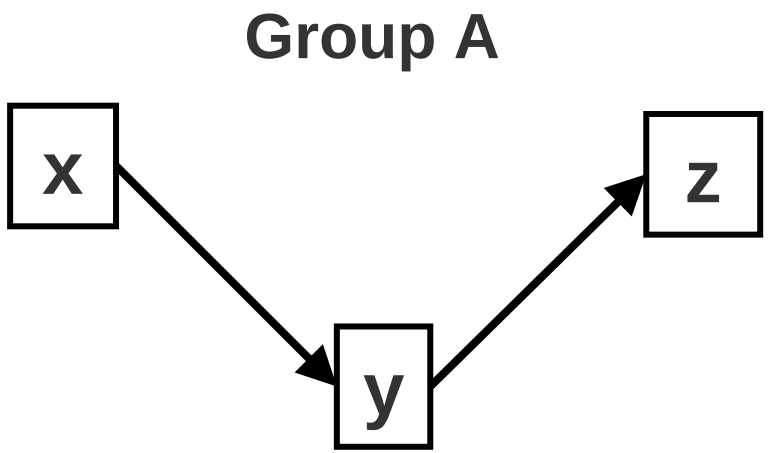
Result for interaction: the effect of fire severity on plant cover does not differ with plant age.

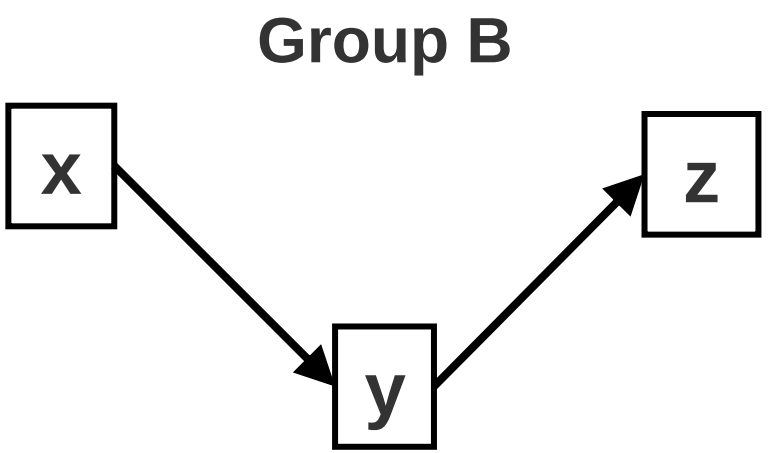
Fire severity is expected to have the same magnitude of effect regardless of what is the age of plant.

Multigroup Analysis

A **multigroup** model is a “model-wide” interaction:

- Instead of focusing on a single response, the interaction is applied across the entire SEM model;
- It asks if not just one but *all* coefficients are the same or different across groups;
- It identifies which paths have the same effect across groups and which paths vary depending on the group.





Day 9 – Part 2 Outline

- Interactions in SEM

  - ✓ Single Interactions in sub-models
  - ✓ **Multigroup Analysis (model-wide interactions)**

Global vs. Local Estimations

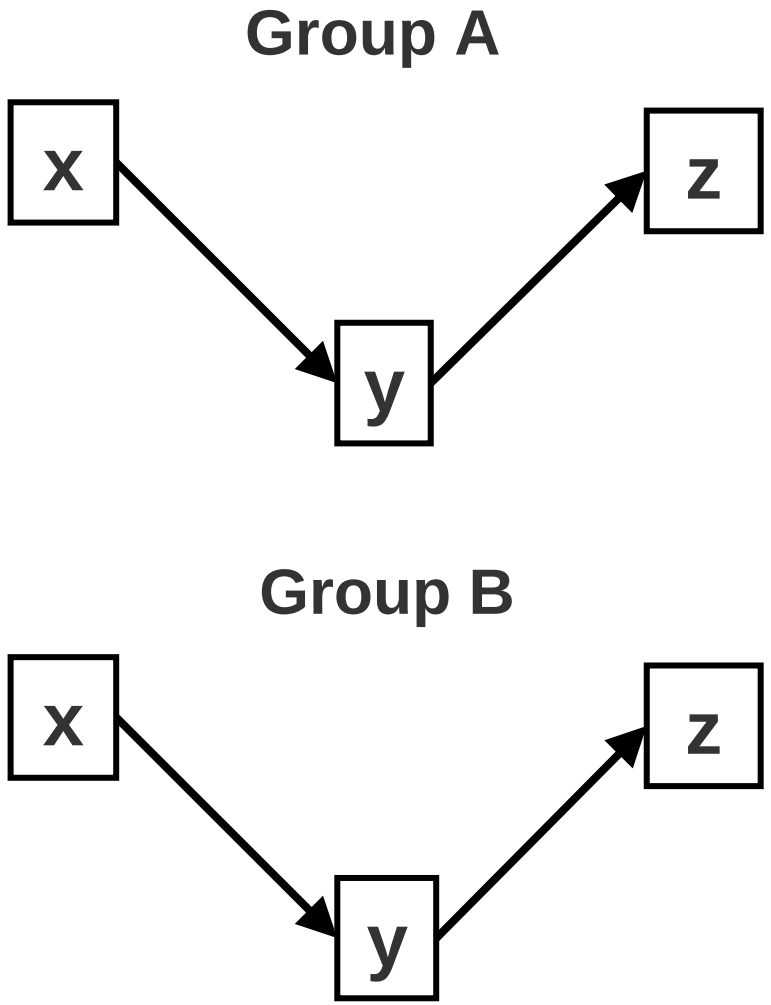
Properties:	Covariance-based SEM	Piecewise SEM
Interactions (test whether effect of one variable vary with another variable)	Allows testing interactions	Allows testing interactions
Multigroup Analysis (test whether some or all effects in the SEM vary by the grouping variable)	back-and-forth manual process of relaxing and constraining paths in ***lavaan***	***piecewiseSEM*** tests constraints and automatically selects the best output for the data

Multigroup Analysis

```
data3 <- read.csv("Data/SEMdata2.csv")

anova(lm(y ~ x * Group, data3))
>
Response: y
          Df Sum Sq Mean Sq F value    Pr(>F)
x          1 8.2740  8.2740 97.9518 2.475e-16 ***
Group      1 0.2772  0.2772  3.2811   0.07321 .
x:Group    1 0.3974  0.3974  4.7051   0.03254 *
Residuals 96 8.1091  0.0845


anova(lm(z ~ y * Group, data3))
>
Response: z
          Df  Sum Sq Mean Sq  F value Pr(>F)
y          1 15.8899 15.8899 176.3764 <2e-16 ***
Group      1  0.0366  0.0366   0.4066 0.5252
y:Group    1  0.1271  0.1271   1.4107 0.2379
Residuals 96  8.6487  0.0901
```



Multigroup Analysis

```
library(piecewiseSEM)

psem_model <- psem(
  lm(y ~ x, data3),
  lm(z ~ y, data3))

multigroup(psem_model, group = "Group")
```

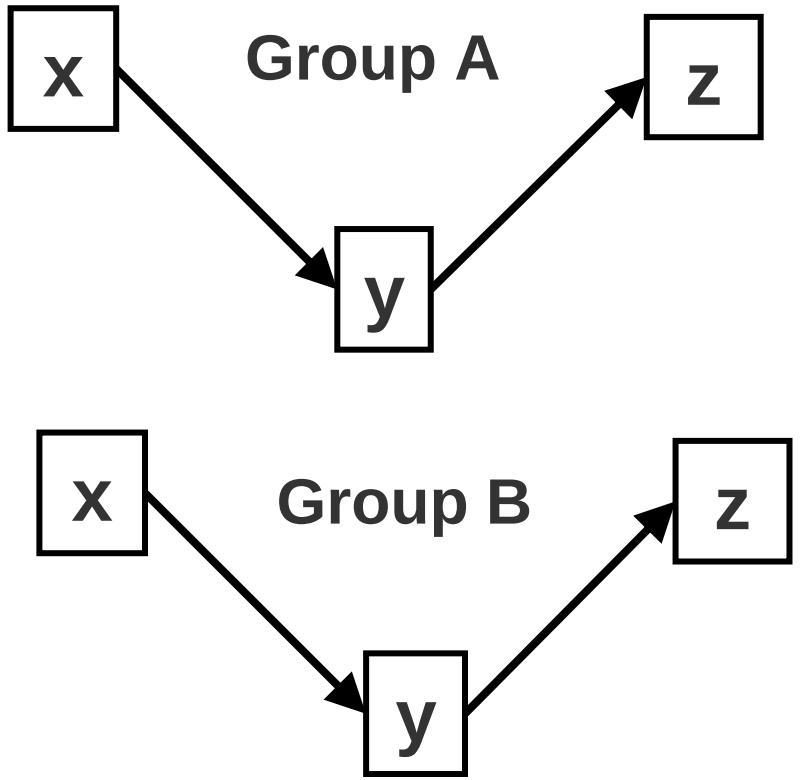
Interaction variable

```
>
Groups = Group [ A, B ]
---
Global goodness-of-fit:

  Fisher's C = 0.301 with P-value = 0.86 and on 2 degrees
of freedom
---
Model-wide Interactions:

  Response Predictor Test.Stat DF P.Value
         y   x:Group       8.3  1  0.0325 *
         z   y:Group      15.5  1  0.2379

 y -> z constrained to the global model
---
```



estimates the effect of y on z using the entire dataset and report that single constrained coefficient across all groups

Day 9 Task 1

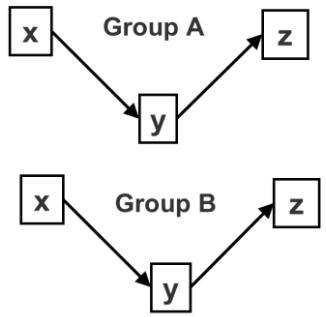
```
>
...
Group [A] coefficients:

  Response Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
         y         x   0.7712    0.1662 48     4.6387       0       0.5563 ***
         z         y   0.9652    0.0726 98    13.2931       0       0.6895 *** c

Group [B] coefficients:

  Response Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
         y         x   1.2404    0.1379 48     8.9963       0       0.7923 ***
         z         y   0.9652    0.0726 98    13.2931       0       0.8914 *** c

Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05    c = constrained
```



Day 9 Task 2

The Effects of Grazing on Finnish Coastal Meadows

Photo: Jorma Pessa

```
# meadow data
library(piecewiseSEM)
data(meadows)

> str(meadows)
'data.frame': 354 obs. of  4 variables:
 $ grazed: int  1 1 1 1 1 1 1 1 1 1 ...
 $ mass  : num  461.6 704.8 1278.8 76.4 ...
 $ elev  : num  19.2 18.8 12.5 38.2 37.4 ...
 $ rich  : int  6 2 1 6 14 12 6 10 10 17 ...
```

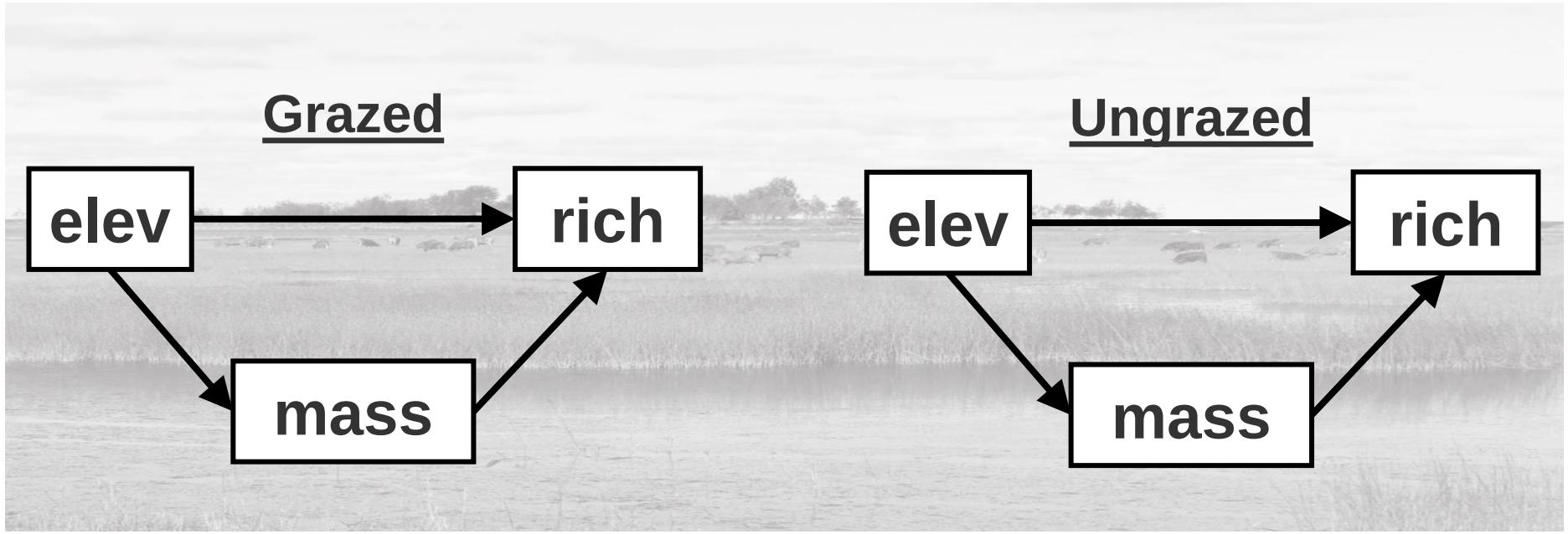
grazed is our grouping variable

Data:

Jutila, H. (1997) Vascular plant species richness in grazed and ungrazed coastal meadows, SW Finland. - Ann. Bot. Fenn. 34:245-263.

Grace, J.B. and Jutila, H. (1999) The relationship between species density and community biomass in grazed and ungrazed coastal meadows. Oikos, 85:398-408.

Hypothetical model



Task:

Perform the multigroup analysis for this hypothetical SEM model using *piecewiseSEM*