Multifactor Specification

STRUCTURAL EQUATION MODELING WITH LAVAAN IN R

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Professor

Multifactor models

```
visual.model <- 'visual =~ x1 + x2 + x3 + x7 + x8 + x9'
visual.fit <- cfa(model = visual.model,
                  data = HolzingerSwineford1939)
summary(visual.fit, standardized = TRUE,
        fit.measures = TRUE)
```

```
User model versus baseline model:
  Comparative Fit Index (CFI)                    0.701
  Tucker-Lewis Index (TLI)                       0.502
```

Why not two small models?

```
visual.model <- 'visual =~ x1 + x2 + x3'
visual.fit <- cfa(model = visual.model,
                  data = HolzingerSwineford1939)
summary(visual.fit, standardized = TRUE,
        fit.measures = TRUE)
```

```
speed.model <- 'speed =~ x7 + x8 + x9'
speed.fit <- cfa(model = speed.model,
                 data = HolzingerSwineford1939)
summary(speed.fit, standardized = TRUE,
        fit.measures = TRUE)
```

Why not two small models? (2)

```
Number of observations                              301


Estimator                                            ML
Minimum Function Test Statistic                   0.000
Degrees of freedom                                    0
Minimum Function Value                  0.0000000000000
```

- Possible parameters = 3*(3+1)/2 = 6
- Estimated parameters = 2 coefficients + 4 variances = 6
- df = 6 - 6 = 0

Specify Constraints

- Constraints set parameters to be equal
- Gain df by estimating less numbers
- Use words to set equality constraints

```
visual.model <- 'visual =~ x1 + a*x2 + a*x3'
```

Output with Constraints

```
visual.model <- 'visual =~ x1 + a*x2 + a*x3'
visual.fit <- cfa(model = visual.model,
                  data = HolzingerSwineford1939)
summary(visual.fit, standardized = TRUE,
        fit.measures = TRUE)
```

```
Latent Variables:
           Estimate Std.Err z-value P(>|z|)  Std.lv Std.all
  visual =~
    x1        1.000                            0.745    0.639
    x2  (a)   0.910   0.142   6.397   0.000   0.678    0.562
    x3  (a)   0.910   0.142   6.397   0.000   0.678    0.614
```

Specify a Multifactor Model

```
twofactor.model <- 'visual =~ x1 + x2 + x3
    speed =~ x7 + x8 + x9'
```

```
twofactor.fit <- cfa(model = twofactor.model,
                     data = HolzingerSwineford1939)
summary(twofactor.fit, standardized = TRUE,
        fit.measures = TRUE)
```

```
  Degrees of freedom                                 8
  P-value (Chi-square)                           0.000
```

Let's practice!

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Model Structure

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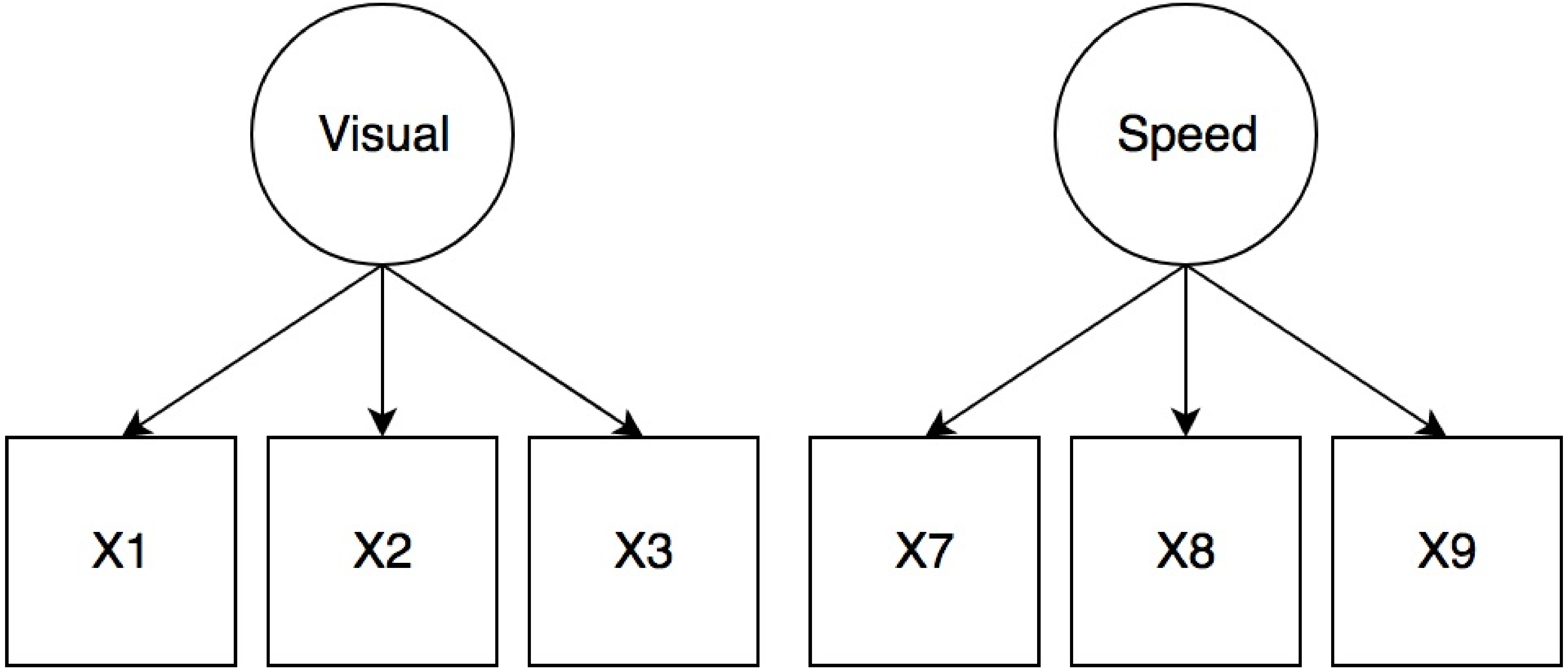
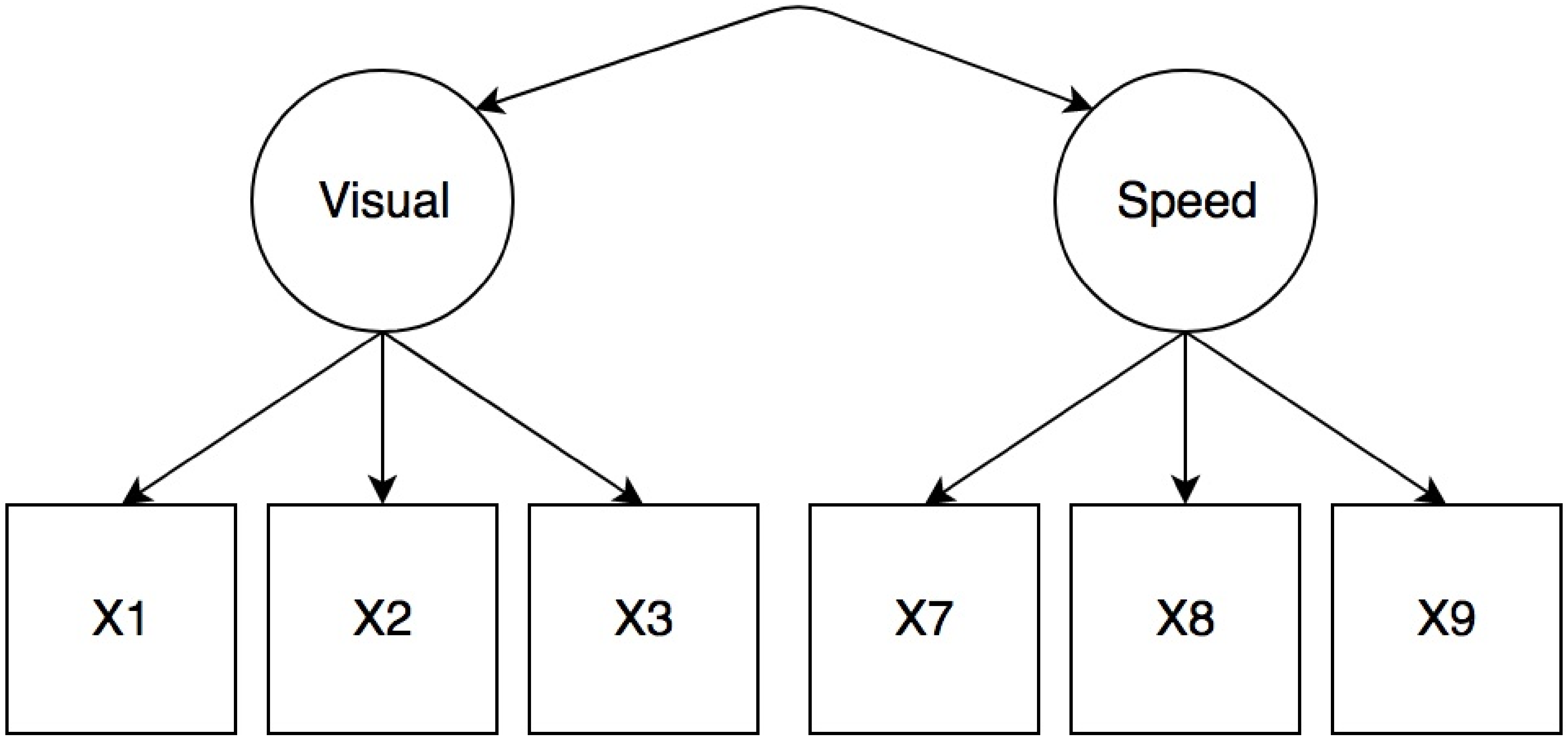
Multifactor Model Estimation

```
twofactor.model <- 'visual =~ x1 + x2 + x3
    speed =~ x7 + x8 + x9'
```



Multifactor Model Estimation

```
twofactor.model <- 'visual =~ x1 + x2 + x3
    speed =~ x7 + x8 + x9'
```



Summary Output

```
Latent Variables:
           Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
  visual =~
    x1        1.000                               0.777    0.667
    x2        0.690    0.124    5.585    0.000    0.536    0.456
    x3        0.985    0.160    6.157    0.000    0.766    0.678
  speed =~
    x7        1.000                               0.622    0.572
    x8        1.204    0.170    7.090    0.000    0.749    0.741
    x9        1.052    0.147    7.142    0.000    0.654    0.649
```

Summary Output (2)

```
Covariances:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
  visual ~~
    speed             0.223    0.052    4.290    0.000    0.460    0.460
```

Model Specification Syntax

```
Covariances:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
  visual ~~
    speed             0.223    0.052    4.290    0.000    0.460    0.460
```

- `=~` creates latent variables
- `~~` creates covariance between variables
- `~` creates direct prediction between variables
    - Remember, `y ~ x` to specify direction

Edit the Model

```
twofactor.model <- 'visual =~ x1 + x2 + x3
    speed =~ x7 + x8 + x9
    speed ~~ 0*visual'
```

```
Covariances:
            Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
  speed ~~
    visual     0.000                              0.000    0.000
```

Edit the Model (2)

```
twofactor.model <- 'visual =~ x1 + x2 + x3
    speed =~ x7 + x8 + x9
    speed~visual'
```

```
Regressions:
          Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
  speed ~
    visual  0.368    0.083    4.439    0.000    0.460    0.460
```

Let's practice!

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Modification Indices

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Updating Poor Models

```
User model versus baseline model:
  Comparative Fit Index (CFI)                    0.879
  Tucker-Lewis Index (TLI)                       0.774

Root Mean Square Error of Approximation:
  RMSEA                                          0.128
  90 Percent Confidence Interval          0.094  0.164
  P-value RMSEA <= 0.05                          0.000

Standardized Root Mean Square Residual:
  SRMR                                           0.079
```

Updating Poor Models (2)

```
Latent Variables:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
  visual =~
    x1                1.000                               0.777    0.667
    x2                0.690    0.124    5.585    0.000    0.536    0.456
    x3                0.985    0.160    6.157    0.000    0.766    0.678
  speed =~
    x7                1.000                               0.622    0.572
    x8                1.204    0.170    7.090    0.000    0.749    0.741
    x9                1.052    0.147    7.142    0.000    0.654    0.649
```

Updating Poor Models (3)

```
Variances:
               Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
   .x1            0.754    0.110    6.838    0.000    0.754    0.555
   .x2            1.094    0.103   10.661    0.000    1.094    0.792
   .x3            0.688    0.105    6.557    0.000    0.688    0.540
   .x7            0.796    0.082    9.756    0.000    0.796    0.673
   .x8            0.461    0.077    6.002    0.000    0.461    0.451
   .x9            0.587    0.071    8.273    0.000    0.587    0.578
```

```
var(HolzingerSwineford1939$x1)
```

```
1.362898
```

Modification Indices

```
modificationindices(twofactor.fit, sort = TRUE)
```

```
      lhs op rhs     mi    epc sepc.lv sepc.all sepc.nox
34     x7 ~~  x8 35.521  0.624   0.624    0.568    0.568
18 visual =~  x9 35.521  0.659   0.512    0.508    0.508
36     x8 ~~  x9 19.041 -0.527  -0.527   -0.517   -0.517
16 visual =~  x7 19.041 -0.503  -0.391   -0.359   -0.359
26     x1 ~~  x9 11.428  0.177   0.177    0.151    0.151
```

- Add one at a time
- Add parameters that make sense

Updating the Model

```
34      x7 ~~  x8 35.521  0.624   0.624    0.568    0.568
```

```
twofactor.model <- 'visual =~ x1 + x2 + x3
                        speed =~ x7 + x8 + x9
                        x7 ~~ x8'
twofactor.fit <- cfa(model = twofactor.model,
                     data = HolzingerSwineford1939)
summary(twofactor.fit, standardized = TRUE,
        fit.measures = TRUE)
```

```
User model versus baseline model:
  Comparative Fit Index (CFI)                    0.976
  Tucker-Lewis Index (TLI)                       0.949
```

Let's practice!

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Model Comparison

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Create Two Models

```
twofactor.model <- 'visual =~ x1 + x2 + x3
                        speed =~ x7 + x8 + x9'
twofactor.model1 <- 'visual =~ x1 + x2 + x3
                        speed =~ x7 + x8 + x9
                        x7 ~~ x8'
```

```
twofactor.fit <- cfa(model = twofactor.model,
                     data = HolzingerSwineford1939)
twofactor.fit1 <- cfa(model = twofactor.model1,
                     data = HolzingerSwineford1939)
```

Chi-Square Comparison

```
anova(twofactor.fit, twofactor.fit1)
```

```
Chi Square Difference Test

               Df    AIC    BIC  Chisq Chisq diff Df diff    Pr(>Chisq)
twofactor.fit1  7 5150.5 5202.4 14.753
twofactor.fit   8 5181.2 5229.4 47.413     32.661       1 0.00000001097 ***

Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 . 0.1 ' ' 1
```

- Chi-square difference created by subtracting models
- Must increase by at least 3.84 to be significant at $p < .05$
- Only useful for models with the same variables

Fit Index Comparison

- Compare fit indices for non-nested models
- Get more fit indices with `fitmeasures()`

```
fitmeasures(twofactor.fit)
```

```
            aic             bic          ntotal
       5181.168        5229.361         301.000
           bic2           rmsea  rmsea.ci.lower
       5188.132           0.128           0.094
 rmsea.ci.upper    rmsea.pvalue             rmr
          0.164           0.000           0.096
                      - - -
```

Fit Index Comparison

```
fitmeasures(twofactor.fit, c("aic", "ecvi"))
```

```
     aic      ecvi
5181.168     0.244
```

```
fitmeasures(twofactor.fit1, c("aic", "ecvi"))
```

```
     aic      ecvi
5150.508     0.142
```

Let's practice!

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