

MODELOS LONGITUDINALES CON VARIABLES LATENTES PARA LA INVESTIGACIÓN EN PSICOLOGÍA

Modelos de ecuaciones estructurales (SEM)

Fabiola Gómez

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Paquetes a utilizar en esta sesión.

- lavaan*: Un paquete para la estimación de modelos de variables latentes como CFA, además permite realizar path analysis, modelación de ecuaciones estructurales, curvas de crecimiento latente, etc.
- psych*: Paquete que incluye funciones útiles para la investigación en psicología.
- MVN*: Paquete que usaremos para evaluar normalidad multivariada.

Durante esta sesión trabajaremos con una base de datos que contiene información de 543 jóvenes mayores de 18 años. Estos datos contienen información sobre el sexo de los participantes (hombre= 0 y mujer= 1), edad (años cumplidos) y nivel de religiosidad. Además contiene los resultados en las siguientes escalas: Justificación del Sistema (3 ítems) y Homonegatividad Moderna (7 ítems). Todas las escalas están medidas con una escala likert de cinco puntos.

Los investigadores están interesados en evaluar el efecto que tiene la religiosidad y la justificación del sistema sobre los niveles de homonegatividad moderna. Adicionalmente, quieren evaluar si este modelo es invariante entre hombres y mujeres.

Ellos hipotetizan que estas dos variables tendrán un efecto positivo y significativo sobre los niveles de homonegatividad hacia los hombres gays. Además, se espera que el nivel de medición de esta escala sea invariante entre hombres y mujeres.

Cargar la base de datos y exploración de las variables

```
setwd("/Users/fa/Dropbox/Docencia/2024/Doctorado/Optativo Doctorado UTalca/Clases/Clase  
base<- read.csv("sem.csv", header = T, sep = ";", na= -9)  
names(base) # nombre de las variables  
## [1] "CASE" "sexo" "edad" "religiosidad" "sj_01"  
## [6] "sj_02" "sj_03" "homo1_gay" "homo2_gay" "homo3_gay"
```

```
## [11] "homo4_gay"      "homo5_gay"      "homo6_gay"      "homo7_gay"
```

str(base) # estructura de la base de datos y variables

```
## 'data.frame': 543 obs. of 14 variables:
## $ CASE      : int  524 34 564 576 540 77 115 272 294 457 ...
## $ sexo      : int  1 1 1 1 1 1 0 1 1 1 ...
## $ edad      : int  24 24 24 23 23 22 22 22 22 22 ...
## $ religiosidad: int  5 1 6 7 4 3 1 4 2 5 ...
## $ sj_01     : int  2 1 2 3 3 3 3 1 2 2 ...
## $ sj_02     : int  2 1 3 2 2 2 2 3 1 2 ...
## $ sj_03     : int  1 1 3 4 4 2 2 2 1 3 ...
## $ homo1_gay : int  2 3 3 1 1 3 2 3 1 2 ...
## $ homo2_gay : int  3 2 2 1 1 2 1 1 1 2 ...
## $ homo3_gay : int  2 2 4 2 5 2 1 3 1 4 ...
## $ homo4_gay : int  3 2 4 4 3 2 1 1 1 3 ...
## $ homo5_gay : int  3 2 3 2 1 2 1 2 1 3 ...
## $ homo6_gay : int  4 2 3 1 1 3 2 2 1 2 ...
## $ homo7_gay : int  3 2 4 1 1 3 1 1 1 3 ...
```

library(psych)
describe(base[3:14]) # descriptivos

	vars	n	mean	sd	median	trimmed	mad	min	max	range	skew
edad	1	540	21.33	2.12	21	21.28	2.97	18	25	7	0.17
religiosidad	2	541	3.17	1.82	3	3.03	2.97	1	7	6	0.34
sj_01	3	543	2.15	0.87	2	2.13	1.48	1	5	4	0.26
sj_02	4	543	2.23	0.97	2	2.15	1.48	1	5	4	0.62
sj_03	5	541	1.90	0.94	2	1.77	1.48	1	5	4	0.97
homo1_gay	6	541	1.99	1.07	2	1.85	1.48	1	5	4	0.78
homo2_gay	7	541	1.53	0.99	1	1.29	0.00	1	5	4	2.16
homo3_gay	8	540	2.45	1.30	2	2.34	1.48	1	5	4	0.41
homo4_gay	9	541	2.09	1.19	2	1.92	1.48	1	5	4	0.89
homo5_gay	10	540	2.24	1.27	2	2.09	1.48	1	5	4	0.72
homo6_gay	11	540	2.15	1.23	2	1.99	1.48	1	5	4	0.77
homo7_gay	12	541	2.14	1.26	2	1.97	1.48	1	5	4	0.76
	kurtosis		se								
edad		-1.03	0.09								
religiosidad		-1.07	0.08								
sj_01		-0.48	0.04								
sj_02		-0.23	0.04								
sj_03		0.39	0.04								

```
## homo1_gay      -0.29 0.05
## homo2_gay      4.17 0.04
## homo3_gay     -1.01 0.06
## homo4_gay     -0.23 0.05
## homo5_gay     -0.63 0.05
## homo6_gay     -0.40 0.05
## homo7_gay     -0.59 0.05

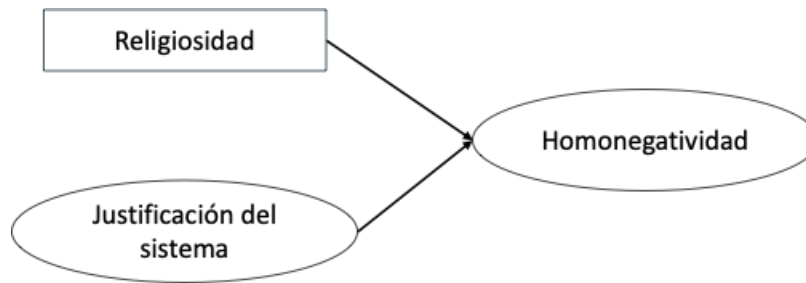
library(MVN)
mvn(base[4:14], desc = F)

## $multivariateNormality
##           Test          HZ p value MVN
## 1 Henze-Zirkler 2.891059          0 NO
##
## $univariateNormality
##           Test      Variable Statistic    p value Normality
## 1 Anderson-Darling religiosidad    17.9995 <0.001      NO
## 2 Anderson-Darling    sj_01     31.3253 <0.001      NO
## 3 Anderson-Darling    sj_02     30.5472 <0.001      NO
## 4 Anderson-Darling    sj_03     38.1744 <0.001      NO
## 5 Anderson-Darling homo1_gay    37.5046 <0.001      NO
## 6 Anderson-Darling homo2_gay    88.9063 <0.001      NO
## 7 Anderson-Darling homo3_gay    23.4981 <0.001      NO
## 8 Anderson-Darling homo4_gay    35.4575 <0.001      NO
## 9 Anderson-Darling homo5_gay    31.0099 <0.001      NO
## 10 Anderson-Darling homo6_gay    33.5500 <0.001      NO
## 11 Anderson-Darling homo7_gay    37.5804 <0.001      NO
```

Principales operadores usados en SEM

Lavaan	Mplus	Significado	Ejemplo
~	on	Predicción, se utiliza para la regresión de resultados observados a predictores observados	$y \sim x$ y ON x
=~	by	Indicador, se utiliza para la variable latente a indicador observado en modelos de medición de análisis factorial	$f = \sim q + r + s$ f BY q + r + s
~~	with	Covarianza	$x \sim\sim x ; x \sim\sim y$ x WITH x; x WITH y
~1	[]	Intercepto o media (estima la media de...)	$x \sim 1$ [x]

Especificación del modelo



Estimación y evaluación de ajuste del modelo estructural

```
library(lavaan)

## This is lavaan 0.6-18
## lavaan is FREE software! Please report any bugs.

##
## Attaching package: 'lavaan'

## The following object is masked from 'package:psych':
##
## cor2cov

mod1<- 'justif=~ sj_01 + sj_02 + sj_03
      homoneg=~ homo1_gay + homo2_gay + homo3_gay +
                homo4_gay + homo5_gay + homo6_gay +
                homo7_gay
      homoneg~ justif + religiosidad
      '

## std.lv= T, sample.mean = T, meanstructure=T
fit1<- sem(mod1, estimator = "MLR",
           data=base)

## std.lv= T, sample.mean = T
summary(fit1, fit.measures = T, standardized = T, rsquare = T)

## lavaan 0.6-18 ended normally after 33 iterations
##
## Estimator ML
```

```

## Optimization method NLMINB
## Number of model parameters 22
##
## Used Total
## Number of observations 534 543
##
## Model Test User Model:
## Standard Scaled
## Test Statistic 181.222 162.019
## Degrees of freedom 43 43
## P-value (Chi-square) 0.000 0.000
## Scaling correction factor 1.119
## Yuan-Bentler correction (Mplus variant)
##
## Model Test Baseline Model:
##
## Test statistic 2394.616 1894.431
## Degrees of freedom 55 55
## P-value 0.000 0.000
## Scaling correction factor 1.264
##
## User Model versus Baseline Model:
##
## Comparative Fit Index (CFI) 0.941 0.935
## Tucker-Lewis Index (TLI) 0.924 0.917
##
## Robust Comparative Fit Index (CFI) 0.943
## Robust Tucker-Lewis Index (TLI) 0.927
##
## Loglikelihood and Information Criteria:
##
## Loglikelihood user model (H0) -6934.841 -6934.841
## Scaling correction factor 1.451
## for the MLR correction
## Loglikelihood unrestricted model (H1) -6844.230 -6844.230
## Scaling correction factor 1.231
## for the MLR correction
##
## Akaike (AIC) 13913.681 13913.681
## Bayesian (BIC) 14007.850 14007.850
## Sample-size adjusted Bayesian (SABIC) 13938.015 13938.015
##

```

```

## Root Mean Square Error of Approximation:
##
## RMSEA                                0.078      0.072
## 90 Percent confidence interval - lower 0.066      0.061
## 90 Percent confidence interval - upper 0.089      0.083
## P-value H_0: RMSEA <= 0.050          0.000      0.001
## P-value H_0: RMSEA >= 0.080          0.381      0.125
##
## Robust RMSEA                                0.076
## 90 Percent confidence interval - lower 0.064
## 90 Percent confidence interval - upper 0.089
## P-value H_0: Robust RMSEA <= 0.050    0.000
## P-value H_0: Robust RMSEA >= 0.080    0.319
##
## Standardized Root Mean Square Residual:
##
## SRMR                                0.063      0.063
##
## Parameter Estimates:
##
## Standard errors                        Sandwich
## Information bread                      Observed
## Observed information based on          Hessian
##
## Latent Variables:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
##      justif =~
##      sj_01      1.000
##      sj_02      1.355    0.187    7.258    0.000    0.659    0.677
##      sj_03      1.097    0.168    6.540    0.000    0.533    0.571
##      homoneg =~
##      homo1_gay    1.000
##      homo2_gay    0.476    0.071    6.734    0.000    0.369    0.389
##      homo3_gay    1.313    0.073   17.980    0.000    1.017    0.790
##      homo4_gay    1.145    0.086   13.362    0.000    0.887    0.745
##      homo5_gay    1.452    0.073   19.775    0.000    1.125    0.894
##      homo6_gay    0.982    0.078   12.613    0.000    0.761    0.621
##      homo7_gay    1.402    0.083   16.890    0.000    1.086    0.869
##
## Regressions:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
##      homoneg ~

```

```

##      justif      0.262      0.105      2.488      0.013      0.165      0.165
##      religiosidad      0.100      0.020      4.901      0.000      0.129      0.234
##
## Variances:
##              Estimate Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      .sj_01          0.513    0.045   11.468    0.000    0.513    0.684
##      .sj_02          0.513    0.071    7.265    0.000    0.513    0.542
##      .sj_03          0.589    0.063    9.397    0.000    0.589    0.674
##      .homo1_gay      0.517    0.044   11.854    0.000    0.517    0.463
##      .homo2_gay      0.760    0.101    7.520    0.000    0.760    0.848
##      .homo3_gay      0.623    0.067    9.320    0.000    0.623    0.376
##      .homo4_gay      0.631    0.069    9.141    0.000    0.631    0.445
##      .homo5_gay      0.319    0.040    7.895    0.000    0.319    0.201
##      .homo6_gay      0.921    0.070   13.120    0.000    0.921    0.614
##      .homo7_gay      0.382    0.045    8.457    0.000    0.382    0.245
##      justif          0.236    0.048    4.951    0.000    1.000    1.000
##      .homoneg        0.551    0.064    8.549    0.000    0.918    0.918
##
## R-Square:
##              Estimate
##      sj_01          0.316
##      sj_02          0.458
##      sj_03          0.326
##      homo1_gay      0.537
##      homo2_gay      0.152
##      homo3_gay      0.624
##      homo4_gay      0.555
##      homo5_gay      0.799
##      homo6_gay      0.386
##      homo7_gay      0.755
##      homoneg        0.082

```


Análisis Multigrupo

```
config <- sem(mod1, data=base, std.lv= F,
              estimator = "MLR", meanstructure=T, sample.mean = T,
              group="sexo")
summary(config, fit.measures = T, standardized = T, rsquare = T)

## lavaan 0.6-18 ended normally after 65 iterations
##
##      Estimator                      ML
##      Optimization method          NLMINB
##      Number of model parameters      64
##
##      Number of observations per group:      Used      Total
##      1                                347      353
##      0                                187      190
##
## Model Test User Model:
##
##      Standard      Scaled
##      Test Statistic  242.169  223.107
##      Degrees of freedom      86      86
##      P-value (Chi-square)    0.000    0.000
##      Scaling correction factor      1.085
##      Yuan-Bentler correction (Mplus variant)
##      Test statistic for each group:
##      1                163.242    150.393
##      0                78.926    72.714
##
## Model Test Baseline Model:
##
##      Test statistic  2424.359    1976.905
##      Degrees of freedom      110    110
##      P-value            0.000    0.000
##      Scaling correction factor      1.226
##
## User Model versus Baseline Model:
##
##      Comparative Fit Index (CFI)      0.933    0.927
##      Tucker-Lewis Index (TLI)        0.914    0.906
##
##      Robust Comparative Fit Index (CFI)      0.935
##      Robust Tucker-Lewis Index (TLI)        0.917
```

```

##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)            -6872.257   -6872.257
##   Scaling correction factor                  1.286
##   for the MLR correction
##   Loglikelihood unrestricted model (H1)      -6751.173   -6751.173
##   Scaling correction factor                  1.171
##   for the MLR correction
##
##   Akaike (AIC)                             13872.514   13872.514
##   Bayesian (BIC)                           14146.460   14146.460
##   Sample-size adjusted Bayesian (SABIC)     13943.304   13943.304
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                     0.082       0.077
##   90 Percent confidence interval - lower     0.070       0.065
##   90 Percent confidence interval - upper     0.095       0.089
##   P-value H_0: RMSEA <= 0.050              0.000       0.000
##   P-value H_0: RMSEA >= 0.080              0.642       0.365
##
##   Robust RMSEA                                0.081
##   90 Percent confidence interval - lower     0.068
##   90 Percent confidence interval - upper     0.094
##   P-value H_0: Robust RMSEA <= 0.050        0.000
##   P-value H_0: Robust RMSEA >= 0.080        0.539
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                     0.064       0.064
##
## Parameter Estimates:
##
##   Standard errors                          Sandwich
##   Information bread                        Observed
##   Observed information based on            Hessian
##
##
## Group 1 [1]:
##
## Latent Variables:

```

```

##               Estimate Std.Err z-value P(>|z|) Std.lv Std.all
##   justif =~
##     sj_01      1.000
##     sj_02      1.555    0.257    6.049    0.000    0.732    0.746
##     sj_03      1.160    0.184    6.286    0.000    0.546    0.598
##   homoneg =~
##     homo1_gay   1.000
##     homo2_gay   0.453    0.088    5.144    0.000    0.353    0.390
##     homo3_gay   1.213    0.083   14.666    0.000    0.944    0.759
##     homo4_gay   1.019    0.104    9.797    0.000    0.793    0.689
##     homo5_gay   1.367    0.076   17.941    0.000    1.063    0.913
##     homo6_gay   0.898    0.093    9.644    0.000    0.698    0.614
##     homo7_gay   1.289    0.096   13.442    0.000    1.003    0.852
##
## Regressions:
##               Estimate Std.Err z-value P(>|z|) Std.lv Std.all
##   homoneg ~
##     justif      0.122    0.125    0.979    0.327    0.074    0.074
##     religiosidad 0.132    0.026    5.153    0.000    0.169    0.311
##
## Intercepts:
##               Estimate Std.Err z-value P(>|z|) Std.lv Std.all
##   .sj_01      2.210    0.046   48.160    0.000    2.210    2.585
##   .sj_02      2.219    0.053   42.173    0.000    2.219    2.264
##   .sj_03      1.839    0.049   37.532    0.000    1.839    2.015
##   .homo1_gay   1.403    0.092   15.252    0.000    1.403    1.380
##   .homo2_gay   1.235    0.061   20.246    0.000    1.235    1.368
##   .homo3_gay   1.731    0.120   14.461    0.000    1.731    1.392
##   .homo4_gay   1.515    0.099   15.310    0.000    1.515    1.316
##   .homo5_gay   1.394    0.119   11.682    0.000    1.394    1.197
##   .homo6_gay   1.604    0.091   17.564    0.000    1.604    1.411
##   .homo7_gay   1.383    0.113   12.187    0.000    1.383    1.175
##
## Variances:
##               Estimate Std.Err z-value P(>|z|) Std.lv Std.all
##   .sj_01      0.510    0.051    9.929    0.000    0.510    0.697
##   .sj_02      0.425    0.094    4.547    0.000    0.425    0.443
##   .sj_03      0.535    0.060    8.900    0.000    0.535    0.642
##   .homo1_gay   0.428    0.043    9.835    0.000    0.428    0.414
##   .homo2_gay   0.691    0.125    5.550    0.000    0.691    0.848
##   .homo3_gay   0.655    0.084    7.794    0.000    0.655    0.423

```

```

##      .homo4_gay      0.697      0.094      7.405      0.000      0.697      0.526
##      .homo5_gay      0.226      0.038      5.870      0.000      0.226      0.166
##      .homo6_gay      0.805      0.083      9.746      0.000      0.805      0.623
##      .homo7_gay      0.379      0.057      6.644      0.000      0.379      0.274
##      justif          0.221      0.056      3.983      0.000      1.000      1.000
##      .homoneg        0.543      0.082      6.646      0.000      0.898      0.898
##
## R-Square:
##              Estimate
##      sj_01          0.303
##      sj_02          0.557
##      sj_03          0.358
##      homo1_gay      0.586
##      homo2_gay      0.152
##      homo3_gay      0.577
##      homo4_gay      0.474
##      homo5_gay      0.834
##      homo6_gay      0.377
##      homo7_gay      0.726
##      homoneg        0.102
##
##
## Group 2 [0]:
##
## Latent Variables:
##              Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      justif =~
##      sj_01          1.000          0.543      0.622
##      sj_02          0.946      0.242      3.911      0.000      0.514      0.535
##      sj_03          0.927      0.348      2.662      0.008      0.504      0.524
##      homoneg =~
##      homo1_gay      1.000          0.710      0.655
##      homo2_gay      0.515      0.137      3.769      0.000      0.365      0.362
##      homo3_gay      1.468      0.147      9.979      0.000      1.042      0.805
##      homo4_gay      1.400      0.165      8.479      0.000      0.994      0.812
##      homo5_gay      1.566      0.158      9.908      0.000      1.111      0.850
##      homo6_gay      1.085      0.149      7.307      0.000      0.770      0.582
##      homo7_gay      1.636      0.174      9.398      0.000      1.161      0.889
##
## Regressions:
##              Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      homoneg ~

```

```

##      justif      0.386      0.175      2.210      0.027      0.296      0.296
##      religiosidad      0.114      0.033      3.494      0.000      0.161      0.268
##
## Intercepts:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
##      .sj_01      2.037      0.064      31.890      0.000      2.037      2.332
##      .sj_02      2.225      0.070      31.668      0.000      2.225      2.316
##      .sj_03      2.027      0.070      28.826      0.000      2.027      2.108
##      .homo1_gay      1.932      0.111      17.440      0.000      1.932      1.784
##      .homo2_gay      1.478      0.088      16.757      0.000      1.478      1.464
##      .homo3_gay      2.355      0.161      14.646      0.000      2.355      1.821
##      .homo4_gay      1.900      0.143      13.262      0.000      1.900      1.553
##      .homo5_gay      2.191      0.158      13.860      0.000      2.191      1.675
##      .homo6_gay      2.120      0.125      16.991      0.000      2.120      1.603
##      .homo7_gay      1.971      0.162      12.195      0.000      1.971      1.510
##
## Variances:
##      Estimate Std.Err z-value P(>|z|) Std.lv Std.all
##      .sj_01      0.468      0.104      4.520      0.000      0.468      0.613
##      .sj_02      0.659      0.090      7.314      0.000      0.659      0.714
##      .sj_03      0.671      0.139      4.808      0.000      0.671      0.725
##      .homo1_gay      0.669      0.089      7.522      0.000      0.669      0.571
##      .homo2_gay      0.885      0.169      5.228      0.000      0.885      0.869
##      .homo3_gay      0.588      0.117      5.043      0.000      0.588      0.351
##      .homo4_gay      0.509      0.083      6.147      0.000      0.509      0.340
##      .homo5_gay      0.476      0.089      5.316      0.000      0.476      0.278
##      .homo6_gay      1.155      0.129      8.936      0.000      1.155      0.661
##      .homo7_gay      0.357      0.071      5.067      0.000      0.357      0.210
##      justif      0.295      0.110      2.681      0.007      1.000      1.000
##      .homoneg      0.423      0.093      4.545      0.000      0.841      0.841
##
## R-Square:
##      Estimate
##      sj_01      0.387
##      sj_02      0.286
##      sj_03      0.275
##      homo1_gay      0.429
##      homo2_gay      0.131
##      homo3_gay      0.649
##      homo4_gay      0.660
##      homo5_gay      0.722
##      homo6_gay      0.339

```

```
##      homo7_gay      0.790
##      homoneg      0.159
```

```
debil <- sem(mod1, data=base, std.lv= T, estimator = "MLR",
             group="sexo",
             group.equal="loadings")
```

```
fuerte <- sem(mod1, data=base, std.lv= T, estimator = "MLR",
              group="sexo",
              group.equal= c("loadings", "intercepts"))
```

```
estricta <- sem(mod1, data=base, std.lv= T, estimator = "MLR",
                group="sexo",
                group.equal= c("loadings", "intercepts", "residuals"))
```

```
## Comparación de ajuste de los modelos
```

```
anova(config, debil, fuerte, estricta)
```

```
##
```

```
## Scaled Chi-Squared Difference Test (method = "satorra.bentler.2001")
```

```
##
```

```
## lavaan->lavTestLRT():
```

```
##      lavaan NOTE: The "Chisq" column contains standard test statistics, not the
##      robust test that should be reported per model. A robust difference test is
##      a function of two standard (not robust) statistics.
```

	Df	AIC	BIC	Chisq	Chisq diff	Df diff	Pr(>Chisq)
## config	86	13872	14146	242.17			
## debil	94	13867	14107	252.68	8.9425	8	0.347171
## fuerte	102	13870	14076	272.10	19.3107	8	0.013284 *
## estricta	112	13892	14054	313.24	25.0882	10	0.005181 **

```
## ---
```

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