# Content Validation and Internal Validation for Dissertation

Frederico Pedrosa

2025-05-03

## Contents



This document presents the analysis of judge ratings collected during the content validation phase of a dissertation project, followed by an examination of its internal structure. This code examines the "Assessment Scale for Group Music Therapy in Substance Use Disorders (MTDQ)" (Pedrosa, 2023).

### Content validity

#### Load Libraries an preparing data

```
library(readxl)
library(psych)
```

```
## Warning: pacote 'psych' foi compilado no R versão 4.4.3
```

```
library(dplyr)
```

```
##
## Anexando pacote: 'dplyr'

## Os seguintes objetos são mascarados por 'package:stats':
##
##     filter, lag

## Os seguintes objetos são mascarados por 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
library(MVN)
library(semTools)
```

```
## Carregando pacotes exigidos: lavaan

## This is lavaan 0.6-19
## lavaan is FREE software! Please report any bugs.
```

```
##
## Anexando pacote: 'lavaan'

## O seguinte objeto é mascarado por 'package:psych':
##
##     cor2cov

##

## ################################################################################

## This is semTools 0.5-6

## All users of R (or SEM) are invited to submit functions or ideas for functions.

## ################################################################################

##
## Anexando pacote: 'semTools'

## Os seguintes objetos são mascarados por 'package:psych':
##
##     reliability, skew
```

```r
library(lavaan)
library(semPlot)

# ----------------------------------------
file_path <- "~/Doutorado/content_validity.xlsx"
# ----------------------------------------

raw_data <- read_excel(file_path)

# Remove the first two columns and convert to data frame
df_original <- as.data.frame(raw_data[, -c(1,2)])

# Define custom column names in English
custom_colnames <- c("profession", "city", "gender", "degree",
                     "1", "2", "2.1", "2.2", "3", "3.1", "3.2",
                     "4", "4.1", "4.2", "5", "5.1", "5.2",
                     "6", "6.1", "6.2", "7", "7.1", "7.2",
                     "8", "8.1", "8.2", "9", "9.1", "9.2",
                     "10", "10.1", "10.2", "11", "11.1", "11.2",
                     "12", "13", "14", "15", "16", "17", "18",
                     "19", "20", "21", "22")


# Assign names, making them syntactically valid
df_named <- setNames(df_original, make.names(custom_colnames))

# Display first few rows and column names to verify
print(colnames(df_named))
```

```
##  [1] "profession" "city"       "gender"     "degree"     "X1"
##  [6] "X2"         "X2.1"       "X2.2"       "X3"         "X3.1"
## [11] "X3.2"       "X4"         "X4.1"       "X4.2"       "X5"
## [16] "X5.1"       "X5.2"       "X6"         "X6.1"       "X6.2"
## [21] "X7"         "X7.1"       "X7.2"       "X8"         "X8.1"
## [26] "X8.2"       "X9"         "X9.1"       "X9.2"       "X10"
## [31] "X10.1"      "X10.2"      "X11"        "X11.1"      "X11.2"
## [36] "X12"        "X13"        "X14"        "X15"        "X16"
## [41] "X17"        "X18"        "X19"        "X20"        "X21"
## [46] "X22"
```

```
# Subset X: Items 2.1 to 11.2
subset_X_indices <- c(7,8,10,11,13,14,16,17,19,20,22,23,25,26,28,29,31,32,34,35)
subset_X <- df_named[, subset_X_indices]
print(colnames(subset_X))
```

```
##  [1] "X2.1"  "X2.2"  "X3.1"  "X3.2"  "X4.1"  "X4.2"  "X5.1"  "X5.2"  "X6.1"
## [10] "X6.2"  "X7.1"  "X7.2"  "X8.1"  "X8.2"  "X9.1"  "X9.2"  "X10.1" "X10.2"
## [19] "X11.1" "X11.2"
```

```
# Subset Y: Items 1 to 11.2, plus 14 to 20
subset_Y_indices <- c(6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 2
subset_Y <- df_named[, subset_Y_indices]
print(colnames(subset_Y))
```

```
##  [1] "X2"    "X2.1"  "X2.2"  "X3"    "X3.1"  "X3.2"  "X4"    "X4.1"  "X4.2"
## [10] "X5"    "X5.1"  "X5.2"  "X6"    "X6.1"  "X6.2"  "X7"    "X7.1"  "X7.2"
## [19] "X8"    "X8.1"  "X8.2"  "X9"    "X9.1"  "X9.2"  "X10"   "X10.1" "X10.2"
## [28] "X11"   "X11.1" "X11.2" "X12"   "X15"   "X16"   "X17"   "X18"   "X19"
## [37] "X20"   "X21"
```

```
# Subset Z: Items related to Q12/Q13
subset_Z_indices <- c(37, 38, 39, 40, 41, 42, 43, 44, 45)
subset_Z <- df_named[, subset_Z_indices]
print(colnames(subset_Z))
```

```
## [1] "X13" "X14" "X15" "X16" "X17" "X18" "X19" "X20" "X21"
```

### Analysis of objective Items

This section analyzes the quantitative ratings provided by the judges for the items included in Subset Y (Items 1-11.2, 14-20). We calculate the mean rating for each item and visualize them using a bar plot. A reference line is added at 0.8, which represent a target agreement threshold.

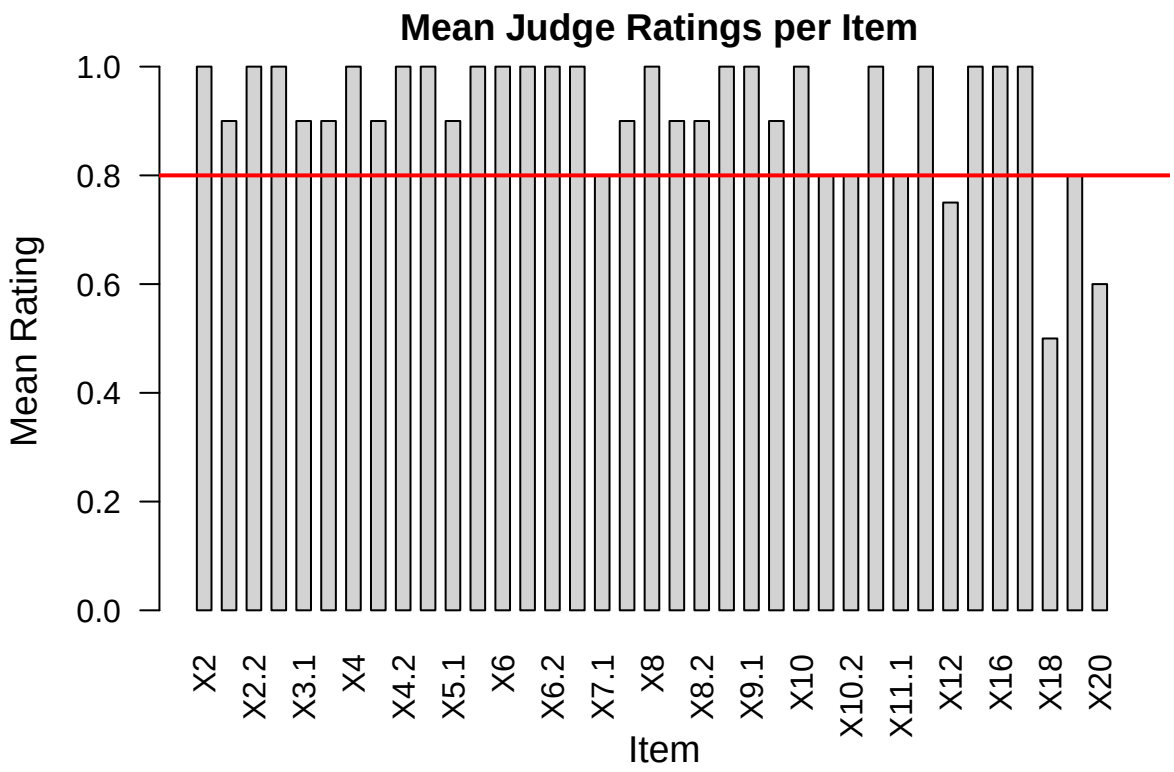
```
# Converting columns that might be character/factor due to Excel import issues
subset_Y_numeric <- data.frame(lapply(subset_Y, function(x) {
  if(is.character(x) || is.factor(x)) {
    # Attempt conversion, return NA on failure
    suppressWarnings(as.numeric(as.character(x)))
  } else {
    as.numeric(x) # Ensure it's numeric even if already integer
  }
```

```
}))


# Calculate descriptive statistics
desc_stats_Y <- describe(subset_Y_numeric)
```

```
## Warning in FUN(newX[, i], ...): nenhum argumento não faltante para min;
## retornando Inf
```

```
## Warning in FUN(newX[, i], ...): nenhum argumento não faltante para max;
## retornando -Inf
```

```
# Define labels for the bar plot
item_labels_y <- colnames(subset_Y) # Use actual column names from the subset

# Create the bar plot
par(cex.lab = 1.2, cex.axis = 1.0, mar = c(6, 4, 2, 2) + 0.1) # Adjust margins if labels overlap
barplot(desc_stats_Y$mean,
        width = 1, space = 0.7,
        names.arg = item_labels_y,
        main = "Mean Judge Ratings per Item ", # Added title
        xlab = "Item",
        ylab = "Mean Rating", # Changed label to reflect the metric
        col = "light grey",
        las = 2)

agreement_threshold = 0.8
abline(h = agreement_threshold, col = "red", lwd = 2)
```

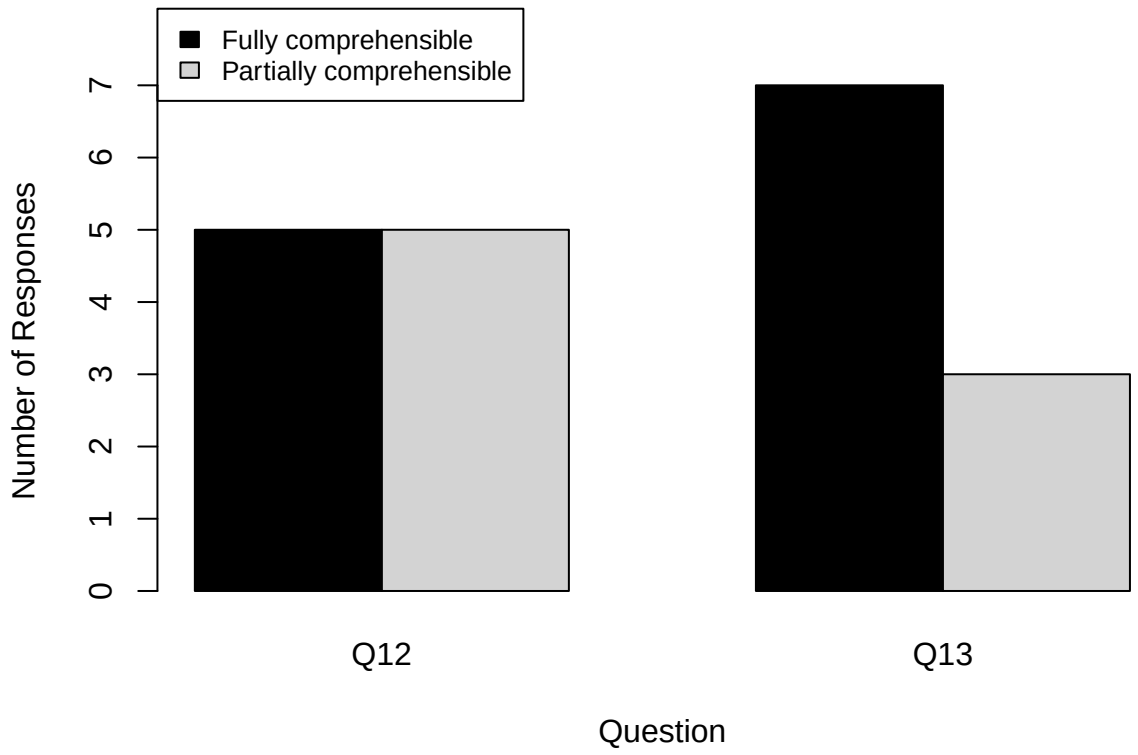



**Analysis of Comprehensibility Items (Q12 & Q13)**

Items 12 and 13 assessed the comprehensibility of specific sections or instructions and used categorical responses. These were handled separately.

```
# Responses
responses_q12_q13 <- data.frame(
  Q12 = factor(c("Fully comprehensible", "Partially comprehensible", "Partially comprehensible",
                 "Fully comprehensible", "Fully comprehensible", "Partially comprehensible",
                 "Fully comprehensible", "Partially comprehensible", "Fully comprehensible",
                 "Partially comprehensible"), levels = c("Fully comprehensible", "Partially comprehensi
  Q13 = factor(c("Fully comprehensible", "Partially comprehensible", "Fully comprehensible",
                 "Partially comprehensible", "Fully comprehensible", "Partially comprehensible",
                 "Fully comprehensible", "Fully comprehensible", "Fully comprehensible",
                 "Fully comprehensible"), levels = c("Fully comprehensible", "Partially comprehensible"
)

# Create frequency tables
freq_q12 <- table(responses_q12_q13$Q12)
freq_q13 <- table(responses_q12_q13$Q13)

# Create a data frame for plotting
# Handle cases where a category might have zero counts by accessing table elements by name
plot_data_q12_q13 <- data.frame(
  Question = c("Q12", "Q13"),
  `Fully comprehensible` = c(freq_q12["Fully comprehensible"], freq_q13["Fully comprehensible"]),
  `Partially comprehensible` = c(freq_q12["Partially comprehensible"], freq_q13["Partially comprehensib
```

```
  check.names = FALSE # Prevent R from changing column names with spaces
)
# Replace NAs (if a category was missing) with 0
plot_data_q12_q13[is.na(plot_data_q12_q13)] <- 0


# Create the grouped bar plot
barplot(height = t(as.matrix(plot_data_q12_q13[, -1])),
        beside = TRUE,
        col = c("black", "light grey"),
        names.arg = plot_data_q12_q13$Question,
        main = "", # Added title
        xlab = "Question",
        ylab = "Number of Responses",
        legend.text = colnames(plot_data_q12_q13[, -1]), # Use translated colnames
        args.legend = list(x = "topleft", inset = c(0, -0.15), cex = 0.8),
        xpd = TRUE
        )
```




## Internal Structure Validity

```
# --- Ensure this path is correct ---
data <- read_excel("~/Doutorado/dados.xlsx")
names(data) <- c("id", paste0("i", c(1:20)) , "age", "sex")
```

```
## Warning: The 'value' argument of 'names<-()' must have the same length as 'x' as of
## tibble 3.0.0.
## This warning is displayed once every 8 hours.
## Call 'lifecycle::last_lifecycle_warnings()' to see where this warning was
## generated.

## Warning: The 'value' argument of 'names<-()' can't be empty as of tibble 3.0.0.
## This warning is displayed once every 8 hours.
## Call 'lifecycle::last_lifecycle_warnings()' to see where this warning was
## generated.
```

```
# ----------------------------------
```

Sociodemographics

```
nrow(data)
```

```
## [1] 202
```

```
# Sample consists of 202 participants

##Age
describe(data$age)
```

```
##    vars   n  mean    sd median trimmed   mad min max range skew kurtosis   se
## X1    1 190 44.68 12.65     48   45.43 13.34  18  69    51 -0.5    -0.71 0.92
```

```
# Average = 44.7, SD = 12.7, min = 18 e max = 69. Obs: 12 missings

# Sex
describe(data$sex) # 77% male participants
```

```
##    vars   n mean   sd median trimmed mad min max range skew kurtosis   se
## X1    1 199 1.77 0.42      2    1.84   0   1   2     1 -1.3    -0.31 0.03
```

**Multivariate Normality Analysis**

```
mvn_results <- mvn(data[, 2:21], mvnTest = "mardia")
print(mvn_results$multivariateNormality)
```

```
##              Test        Statistic              p value Result
## 1 Mardia Skewness 2487.77624922984 8.76630059652458e-48     NO
## 2 Mardia Kurtosis 10.7565859820302                    0     NO
## 3             MVN             <NA>                 <NA>     NO
```

```
# Skewness: 2487.78, p < 0.001
# Kurtosis: 10.76, p < 0.001
# Data do not show multivariate normal distribution
# Use WLSMV estimator for CFA
```

**Confirmatory Factor Analysis (CFA) Unidimensional Model (General Factor)**

```r
# Define the unidimensional model
model_uni <- '
general =~ i1 + i2 + i3 + i4 + i5 + i6 + i7 + i8 + i9 + i10 +
i11 + i12 + i13 + i14 + i15 + i16 + i17 + i18 + i19 + i20
'
# Fit the model using WLSMV estimator for ordered data
fit_model_uni <- cfa(model_uni, data = data, ordered = TRUE,
                     estimator = "WLSMV", std.lv=TRUE)

# Get fit measures
fitMeasures(fit_model_uni, fit.measures = c("chisq","df","cfi", "rmsea",
                                            "rmsea.ci.lower", "rmsea.ci.upper"))
```

```
##          chisq             df            cfi          rmsea rmsea.ci.lower
##        283.290        170.000          0.968          0.073          0.058
## rmsea.ci.upper
##          0.087
```

```r
# chisq(df=170) = 170.000, CFI = 0.968, RMSEA = 0.073 [0.058, 0.087]
# Model was not rejected

# Get summary with standardized loadings
summary(fit_model_uni, fit.measures = TRUE, standardized = TRUE)
```

```
## lavaan 0.6-19 ended normally after 13 iterations
##
##   Estimator                                         DWLS
##   Optimization method                           NLMINB
##   Number of model parameters                       100
##
##                                                   Used       Total
##   Number of observations                           127         202
##
## Model Test User Model:
##                                               Standard      Scaled
##   Test Statistic                               283.290     327.569
##   Degrees of freedom                               170         170
##   P-value (Chi-square)                           0.000       0.000
##   Scaling correction factor                                  1.164
##   Shift parameter                                           84.098
##     simple second-order correction
##
## Model Test Baseline Model:
##
##   Test statistic                              3742.984    1405.901
##   Degrees of freedom                               190         190
##   P-value                                        0.000       0.000
##   Scaling correction factor                                  2.922
##
## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                    0.968       0.870
```

```
##   Tucker-Lewis Index (TLI)                       0.964       0.855
##
##   Robust Comparative Fit Index (CFI)                         0.668
##   Robust Tucker-Lewis Index (TLI)                            0.629
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.073       0.086
##   90 Percent confidence interval - lower         0.058       0.072
##   90 Percent confidence interval - upper         0.087       0.100
##   P-value H_0: RMSEA <= 0.050                    0.009       0.000
##   P-value H_0: RMSEA >= 0.080                    0.215       0.759
##
##   Robust RMSEA                                               0.133
##   90 Percent confidence interval - lower                     0.120
##   90 Percent confidence interval - upper                     0.147
##   P-value H_0: Robust RMSEA <= 0.050                         0.000
##   P-value H_0: Robust RMSEA >= 0.080                         1.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.097       0.097
##
## Parameter Estimates:
##
##   Parameterization                                 Delta
##   Standard errors                            Robust.sem
##   Information                                  Expected
##   Information saturated (h1) model        Unstructured
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   general =~
##     i1                0.407    0.070    5.803    0.000    0.407    0.407
##     i2                0.687    0.055   12.515    0.000    0.687    0.687
##     i3                0.449    0.070    6.422    0.000    0.449    0.449
##     i4                0.272    0.085    3.205    0.001    0.272    0.272
##     i5                0.585    0.059    9.907    0.000    0.585    0.585
##     i6                0.638    0.056   11.499    0.000    0.638    0.638
##     i7                0.537    0.064    8.416    0.000    0.537    0.537
##     i8                0.308    0.082    3.749    0.000    0.308    0.308
##     i9                0.636    0.052   12.273    0.000    0.636    0.636
##     i10               0.519    0.067    7.699    0.000    0.519    0.519
##     i11               0.559    0.061    9.105    0.000    0.559    0.559
##     i12              -0.019    0.091   -0.207    0.836   -0.019   -0.019
##     i13               0.522    0.067    7.794    0.000    0.522    0.522
##     i14               0.538    0.080    6.737    0.000    0.538    0.538
##     i15               0.716    0.045   15.849    0.000    0.716    0.716
##     i16               0.703    0.049   14.335    0.000    0.703    0.703
##     i17               0.726    0.046   15.812    0.000    0.726    0.726
##     i18               0.771    0.044   17.430    0.000    0.771    0.771
##     i19               0.740    0.046   16.025    0.000    0.740    0.740
##     i20               0.547    0.067    8.172    0.000    0.547    0.547
##
```

```
## Thresholds:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     i1|t1            -1.362    0.159   -8.577    0.000   -1.362   -1.362
##     i1|t2            -0.973    0.133   -7.306    0.000   -0.973   -0.973
##     i1|t3            -0.030    0.112   -0.265    0.791   -0.030   -0.030
##     i1|t4             0.527    0.117    4.483    0.000    0.527    0.527
##     i2|t1            -1.758    0.204   -8.632    0.000   -1.758   -1.758
##     i2|t2            -1.597    0.182   -8.754    0.000   -1.597   -1.597
##     i2|t3            -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i2|t4             0.109    0.112    0.972    0.331    0.109    0.109
##     i3|t1            -1.469    0.169   -8.712    0.000   -1.469   -1.469
##     i3|t2            -1.184    0.145   -8.149    0.000   -1.184   -1.184
##     i3|t3            -0.270    0.113   -2.384    0.017   -0.270   -0.270
##     i3|t4             0.527    0.117    4.483    0.000    0.527    0.527
##     i4|t1            -1.414    0.163   -8.654    0.000   -1.414   -1.414
##     i4|t2            -0.973    0.133   -7.306    0.000   -0.973   -0.973
##     i4|t3            -0.644    0.120   -5.344    0.000   -0.644   -0.644
##     i4|t4            -0.030    0.112   -0.265    0.791   -0.030   -0.030
##     i5|t1            -1.362    0.159   -8.577    0.000   -1.362   -1.362
##     i5|t2            -1.225    0.148   -8.270    0.000   -1.225   -1.225
##     i5|t3            -0.416    0.115   -3.613    0.000   -0.416   -0.416
##     i5|t4             0.460    0.116    3.962    0.000    0.460    0.460
##     i6|t1            -1.984    0.243   -8.172    0.000   -1.984   -1.984
##     i6|t2            -1.414    0.163   -8.654    0.000   -1.414   -1.414
##     i6|t3            -0.527    0.117   -4.483    0.000   -0.527   -0.527
##     i6|t4             0.290    0.113    2.560    0.010    0.290    0.290
##     i7|t1            -1.672    0.192   -8.720    0.000   -1.672   -1.672
##     i7|t2            -1.146    0.143   -8.021    0.000   -1.146   -1.146
##     i7|t3            -0.229    0.113   -2.031    0.042   -0.229   -0.229
##     i7|t4             0.596    0.119    5.001    0.000    0.596    0.596
##     i8|t1            -1.672    0.192   -8.720    0.000   -1.672   -1.672
##     i8|t2            -1.184    0.145   -8.149    0.000   -1.184   -1.184
##     i8|t3            -0.353    0.114   -3.087    0.002   -0.353   -0.353
##     i8|t4             0.353    0.114    3.087    0.002    0.353    0.353
##     i9|t1            -1.225    0.148   -8.270    0.000   -1.225   -1.225
##     i9|t2            -0.797    0.126   -6.351    0.000   -0.797   -0.797
##     i9|t3            -0.249    0.113   -2.207    0.027   -0.249   -0.249
##     i9|t4             0.573    0.119    4.829    0.000    0.573    0.573
##     i10|t1           -1.758    0.204   -8.632    0.000   -1.758   -1.758
##     i10|t2           -1.314    0.155   -8.486    0.000   -1.314   -1.314
##     i10|t3           -0.353    0.114   -3.087    0.002   -0.353   -0.353
##     i10|t4            0.527    0.117    4.483    0.000    0.527    0.527
##     i11|t1           -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i11|t2           -1.268    0.151   -8.383    0.000   -1.268   -1.268
##     i11|t3           -0.249    0.113   -2.207    0.027   -0.249   -0.249
##     i11|t4            0.504    0.117    4.310    0.000    0.504    0.504
##     i12|t1           -0.693    0.122   -5.683    0.000   -0.693   -0.693
##     i12|t2           -0.290    0.113   -2.560    0.010   -0.290   -0.290
##     i12|t3            0.049    0.112    0.442    0.659    0.049    0.049
##     i12|t4            0.504    0.117    4.310    0.000    0.504    0.504
##     i13|t1           -1.597    0.182   -8.754    0.000   -1.597   -1.597
##     i13|t2           -1.146    0.143   -8.021    0.000   -1.146   -1.146
##     i13|t3           -0.374    0.115   -3.262    0.001   -0.374   -0.374
##     i13|t4            0.395    0.115    3.438    0.001    0.395    0.395
```

```
##     i14|t1           -2.151    0.281   -7.657    0.000   -2.151   -2.151
##     i14|t2           -1.530    0.175   -8.748    0.000   -1.530   -1.530
##     i14|t3           -0.882    0.129   -6.837    0.000   -0.882   -0.882
##     i14|t4           -0.069    0.112   -0.619    0.536   -0.069   -0.069
##     i15|t1           -2.415    0.364   -6.629    0.000   -2.415   -2.415
##     i15|t2           -1.758    0.204   -8.632    0.000   -1.758   -1.758
##     i15|t3           -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i15|t4            0.270    0.113    2.384    0.017    0.270    0.270
##     i16|t1           -1.984    0.243   -8.172    0.000   -1.984   -1.984
##     i16|t2           -1.314    0.155   -8.486    0.000   -1.314   -1.314
##     i16|t3           -0.596    0.119   -5.001    0.000   -0.596   -0.596
##     i16|t4            0.438    0.116    3.787    0.000    0.438    0.438
##     i17|t1           -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i17|t2           -1.469    0.169   -8.712    0.000   -1.469   -1.469
##     i17|t3           -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i17|t4           -0.010    0.112   -0.088    0.930   -0.010   -0.010
##     i18|t1           -1.984    0.243   -8.172    0.000   -1.984   -1.984
##     i18|t2           -1.362    0.159   -8.577    0.000   -1.362   -1.362
##     i18|t3           -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i18|t4           -0.069    0.112   -0.619    0.536   -0.069   -0.069
##     i19|t1           -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i19|t2           -1.672    0.192   -8.720    0.000   -1.672   -1.672
##     i19|t3           -0.693    0.122   -5.683    0.000   -0.693   -0.693
##     i19|t4            0.169    0.112    1.502    0.133    0.169    0.169
##     i20|t1           -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i20|t2           -1.469    0.169   -8.712    0.000   -1.469   -1.469
##     i20|t3           -0.527    0.117   -4.483    0.000   -0.527   -0.527
##     i20|t4            0.290    0.113    2.560    0.010    0.290    0.290
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##    .i1                0.835                               0.835    0.835
##    .i2                0.528                               0.528    0.528
##    .i3                0.799                               0.799    0.799
##    .i4                0.926                               0.926    0.926
##    .i5                0.658                               0.658    0.658
##    .i6                0.592                               0.592    0.592
##    .i7                0.712                               0.712    0.712
##    .i8                0.905                               0.905    0.905
##    .i9                0.596                               0.596    0.596
##    .i10               0.731                               0.731    0.731
##    .i11               0.688                               0.688    0.688
##    .i12               1.000                               1.000    1.000
##    .i13               0.728                               0.728    0.728
##    .i14               0.711                               0.711    0.711
##    .i15               0.488                               0.488    0.488
##    .i16               0.506                               0.506    0.506
##    .i17               0.473                               0.473    0.473
##    .i18               0.406                               0.406    0.406
##    .i19               0.452                               0.452    0.452
##    .i20               0.701                               0.701    0.701
##     general           1.000                               1.000    1.000
```

```r
# Descriptive statistics of factor loadings:
loadings_model_uni <- standardizedsolution(fit_model_uni, type = "std.all")
# Selecting based on row indices
print(round(loadings_model_uni[1:20, ] %>% select(est.std) %>%
        summarise(mean = mean(abs(est.std)), sd = sd(abs(est.std)),
                  min = min(abs(est.std)), max = max(abs(est.std))), 2))
```

```
##   mean   sd  min  max
## 1 0.54 0.19 0.02 0.77
```

```r
# Mean = 0.51, SD = 0.18, min = 0.02 and max = 0.72


# Reliability
print(round(reliability(fit_model_uni), 2))
```

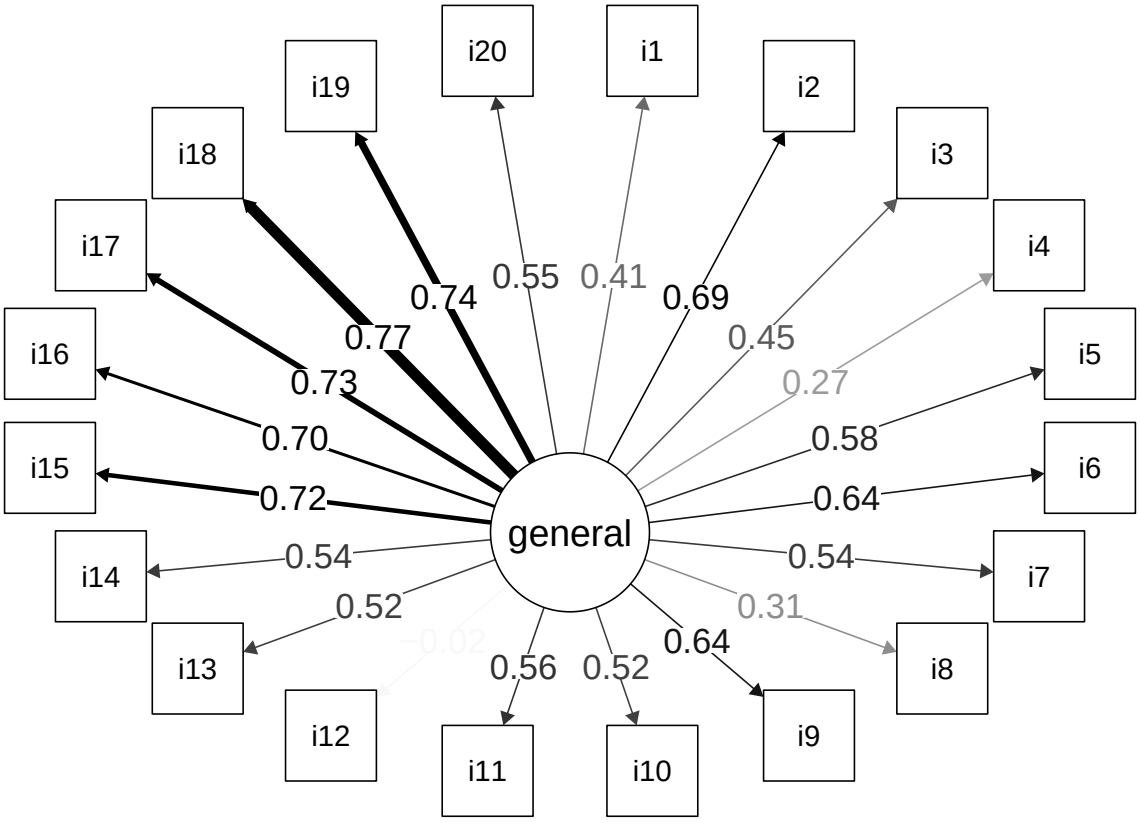
```
## For constructs with categorical indicators, Zumbo et al.‘s (2007) "ordinal alpha" is calculated in ac
```

```
##           general
## alpha        0.85
## alpha.ord    0.89
## omega        0.86
## omega2       0.86
## omega3       0.87
## avevar       0.33
```

```r
source("comp_reliability.R")
comp_reliability(fit_model_uni)
```

```
## Warning: Use of .data in tidyselect expressions was deprecated in tidyselect 1.2.0.
## i Please use ‘"lhs"‘ instead of ‘.data$lhs‘
## This warning is displayed once every 8 hours.
## Call ‘lifecycle::last_lifecycle_warnings()‘ to see where this warning was
## generated.

## Warning: Use of .data in tidyselect expressions was deprecated in tidyselect 1.2.0.
## i Please use ‘"est"‘ instead of ‘.data$est‘
## This warning is displayed once every 8 hours.
## Call ‘lifecycle::last_lifecycle_warnings()‘ to see where this warning was
## generated.

## Warning: Use of .data in tidyselect expressions was deprecated in tidyselect 1.2.0.
## i Please use ‘"op"‘ instead of ‘.data$op‘
## This warning is displayed once every 8 hours.
## Call ‘lifecycle::last_lifecycle_warnings()‘ to see where this warning was
## generated.

## # A tibble: 1 x 2
##   lhs     composite_reliability_ec
##   <chr>                      <dbl>
## 1 general                    0.745
```

```
# General: alpha = 0.85, alpha ord. = 0.89, omega McDonald = 0.86, comp. reliability = 0.74

# Plot the model
semPaths(fit_model_uni,"std",layout="circle",residuals=FALSE,sizeLat=14,sizeLat2=14,edge.color="black",
         mar=c(2.0, 2.0, 2.0, 2.0),esize=7,curvePivot = FALSE, intercepts=FALSE,thresholds = FALSE,
         nCharNodes=0,sizeMan=8, edge.label.position=0.5
         )
```




**Two Correlated Factors Model**

```
# Define the two-factor model
model_2f <- '
cog =~ i3 + i4 + i5 + i7 + i8 + i9 + i12 + i14 + i15 + i20
com =~ i1 + i2 + i6 + i10 + i11 + i13 + i16 + i17 + i18 + i19
'
# Fit the model
fit_model_2f <- cfa(model_2f, data = data, ordered = TRUE,
                    estimator = "WLSMV", std.lv=TRUE)

# Get fit measures
fitMeasures(fit_model_2f, fit.measures = c("chisq","df","cfi", "rmsea",
                                           "rmsea.ci.lower", "rmsea.ci.upper"))
```

```
##          chisq             df            cfi          rmsea rmsea.ci.lower
##        267.859        169.000          0.972          0.068          0.052
```

```
## rmsea.ci.upper
##          0.083
```

```r
# chisq(df=169) = 267.859, CFI = 0.972, RMSEA = 0.058 [0.052, 0.083]
# Model was not rejected

# Get summary
summary(fit_model_2f, fit.measures = TRUE, standardized = TRUE)
```

```
## lavaan 0.6-19 ended normally after 20 iterations
##
##   Estimator                                         DWLS
##   Optimization method                           NLMINB
##   Number of model parameters                       101
##
##                                                   Used       Total
##   Number of observations                           127         202
##
## Model Test User Model:
##                                               Standard      Scaled
##   Test Statistic                               267.859     314.998
##   Degrees of freedom                               169         169
##   P-value (Chi-square)                           0.000       0.000
##   Scaling correction factor                                  1.155
##   Shift parameter                                           83.036
##     simple second-order correction
##
## Model Test Baseline Model:
##
##   Test statistic                              3742.984    1405.901
##   Degrees of freedom                               190         190
##   P-value                                        0.000       0.000
##   Scaling correction factor                                  2.922
##
## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                    0.972       0.880
##   Tucker-Lewis Index (TLI)                       0.969       0.865
##
##   Robust Comparative Fit Index (CFI)                         0.685
##   Robust Tucker-Lewis Index (TLI)                            0.645
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.068       0.083
##   90 Percent confidence interval - lower         0.052       0.069
##   90 Percent confidence interval - upper         0.083       0.097
##   P-value H_0: RMSEA <= 0.050                    0.031       0.000
##   P-value H_0: RMSEA >= 0.080                    0.100       0.638
##
##   Robust RMSEA                                               0.130
##   90 Percent confidence interval - lower                     0.116
##   90 Percent confidence interval - upper                     0.144
##   P-value H_0: Robust RMSEA <= 0.050                         0.000
```

```
##   P-value H_0: Robust RMSEA >= 0.080                         1.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                             0.094       0.094
##
## Parameter Estimates:
##
##   Parameterization                                 Delta
##   Standard errors                            Robust.sem
##   Information                                  Expected
##   Information saturated (h1) model        Unstructured
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   cog =~
##     i3                0.476    0.073    6.522    0.000    0.476    0.476
##     i4                0.297    0.089    3.352    0.001    0.297    0.297
##     i5                0.617    0.062    9.989    0.000    0.617    0.617
##     i7                0.571    0.065    8.791    0.000    0.571    0.571
##     i8                0.323    0.085    3.794    0.000    0.323    0.323
##     i9                0.677    0.053   12.754    0.000    0.677    0.677
##     i12              -0.015    0.094   -0.159    0.874   -0.015   -0.015
##     i14               0.566    0.082    6.936    0.000    0.566    0.566
##     i15               0.762    0.045   16.933    0.000    0.762    0.762
##     i20               0.581    0.068    8.575    0.000    0.581    0.581
##   com =~
##     i1                0.417    0.071    5.857    0.000    0.417    0.417
##     i2                0.697    0.056   12.510    0.000    0.697    0.697
##     i6                0.651    0.056   11.632    0.000    0.651    0.651
##     i10               0.530    0.068    7.794    0.000    0.530    0.530
##     i11               0.570    0.061    9.285    0.000    0.570    0.570
##     i13               0.533    0.067    7.918    0.000    0.533    0.533
##     i16               0.718    0.049   14.774    0.000    0.718    0.718
##     i17               0.742    0.045   16.329    0.000    0.742    0.742
##     i18               0.782    0.043   17.982    0.000    0.782    0.782
##     i19               0.754    0.046   16.542    0.000    0.754    0.754
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   cog ~~
##     com               0.865    0.038   22.969    0.000    0.865    0.865
##
## Thresholds:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     i3|t1            -1.469    0.169   -8.712    0.000   -1.469   -1.469
##     i3|t2            -1.184    0.145   -8.149    0.000   -1.184   -1.184
##     i3|t3            -0.270    0.113   -2.384    0.017   -0.270   -0.270
##     i3|t4             0.527    0.117    4.483    0.000    0.527    0.527
##     i4|t1            -1.414    0.163   -8.654    0.000   -1.414   -1.414
##     i4|t2            -0.973    0.133   -7.306    0.000   -0.973   -0.973
##     i4|t3            -0.644    0.120   -5.344    0.000   -0.644   -0.644
##     i4|t4            -0.030    0.112   -0.265    0.791   -0.030   -0.030
##     i5|t1            -1.362    0.159   -8.577    0.000   -1.362   -1.362
```

```
##     i5|t2          -1.225    0.148   -8.270    0.000   -1.225   -1.225
##     i5|t3          -0.416    0.115   -3.613    0.000   -0.416   -0.416
##     i5|t4           0.460    0.116    3.962    0.000    0.460    0.460
##     i7|t1          -1.672    0.192   -8.720    0.000   -1.672   -1.672
##     i7|t2          -1.146    0.143   -8.021    0.000   -1.146   -1.146
##     i7|t3          -0.229    0.113   -2.031    0.042   -0.229   -0.229
##     i7|t4           0.596    0.119    5.001    0.000    0.596    0.596
##     i8|t1          -1.672    0.192   -8.720    0.000   -1.672   -1.672
##     i8|t2          -1.184    0.145   -8.149    0.000   -1.184   -1.184
##     i8|t3          -0.353    0.114   -3.087    0.002   -0.353   -0.353
##     i8|t4           0.353    0.114    3.087    0.002    0.353    0.353
##     i9|t1          -1.225    0.148   -8.270    0.000   -1.225   -1.225
##     i9|t2          -0.797    0.126   -6.351    0.000   -0.797   -0.797
##     i9|t3          -0.249    0.113   -2.207    0.027   -0.249   -0.249
##     i9|t4           0.573    0.119    4.829    0.000    0.573    0.573
##     i12|t1         -0.693    0.122   -5.683    0.000   -0.693   -0.693
##     i12|t2         -0.290    0.113   -2.560    0.010   -0.290   -0.290
##     i12|t3          0.049    0.112    0.442    0.659    0.049    0.049
##     i12|t4          0.504    0.117    4.310    0.000    0.504    0.504
##     i14|t1         -2.151    0.281   -7.657    0.000   -2.151   -2.151
##     i14|t2         -1.530    0.175   -8.748    0.000   -1.530   -1.530
##     i14|t3         -0.882    0.129   -6.837    0.000   -0.882   -0.882
##     i14|t4         -0.069    0.112   -0.619    0.536   -0.069   -0.069
##     i15|t1         -2.415    0.364   -6.629    0.000   -2.415   -2.415
##     i15|t2         -1.758    0.204   -8.632    0.000   -1.758   -1.758
##     i15|t3         -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i15|t4          0.270    0.113    2.384    0.017    0.270    0.270
##     i20|t1         -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i20|t2         -1.469    0.169   -8.712    0.000   -1.469   -1.469
##     i20|t3         -0.527    0.117   -4.483    0.000   -0.527   -0.527
##     i20|t4          0.290    0.113    2.560    0.010    0.290    0.290
##     i1|t1          -1.362    0.159   -8.577    0.000   -1.362   -1.362
##     i1|t2          -0.973    0.133   -7.306    0.000   -0.973   -0.973
##     i1|t3          -0.030    0.112   -0.265    0.791   -0.030   -0.030
##     i1|t4           0.527    0.117    4.483    0.000    0.527    0.527
##     i2|t1          -1.758    0.204   -8.632    0.000   -1.758   -1.758
##     i2|t2          -1.597    0.182   -8.754    0.000   -1.597   -1.597
##     i2|t3          -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i2|t4           0.109    0.112    0.972    0.331    0.109    0.109
##     i6|t1          -1.984    0.243   -8.172    0.000   -1.984   -1.984
##     i6|t2          -1.414    0.163   -8.654    0.000   -1.414   -1.414
##     i6|t3          -0.527    0.117   -4.483    0.000   -0.527   -0.527
##     i6|t4           0.290    0.113    2.560    0.010    0.290    0.290
##     i10|t1         -1.758    0.204   -8.632    0.000   -1.758   -1.758
##     i10|t2         -1.314    0.155   -8.486    0.000   -1.314   -1.314
##     i10|t3         -0.353    0.114   -3.087    0.002   -0.353   -0.353
##     i10|t4          0.527    0.117    4.483    0.000    0.527    0.527
##     i11|t1         -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i11|t2         -1.268    0.151   -8.383    0.000   -1.268   -1.268
##     i11|t3         -0.249    0.113   -2.207    0.027   -0.249   -0.249
##     i11|t4          0.504    0.117    4.310    0.000    0.504    0.504
##     i13|t1         -1.597    0.182   -8.754    0.000   -1.597   -1.597
##     i13|t2         -1.146    0.143   -8.021    0.000   -1.146   -1.146
##     i13|t3         -0.374    0.115   -3.262    0.001   -0.374   -0.374
```

```
##     i13|t4            0.395    0.115    3.438    0.001    0.395    0.395
##     i16|t1           -1.984    0.243   -8.172    0.000   -1.984   -1.984
##     i16|t2           -1.314    0.155   -8.486    0.000   -1.314   -1.314
##     i16|t3           -0.596    0.119   -5.001    0.000   -0.596   -0.596
##     i16|t4            0.438    0.116    3.787    0.000    0.438    0.438
##     i17|t1           -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i17|t2           -1.469    0.169   -8.712    0.000   -1.469   -1.469
##     i17|t3           -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i17|t4           -0.010    0.112   -0.088    0.930   -0.010   -0.010
##     i18|t1           -1.984    0.243   -8.172    0.000   -1.984   -1.984
##     i18|t2           -1.362    0.159   -8.577    0.000   -1.362   -1.362
##     i18|t3           -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i18|t4           -0.069    0.112   -0.619    0.536   -0.069   -0.069
##     i19|t1           -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i19|t2           -1.672    0.192   -8.720    0.000   -1.672   -1.672
##     i19|t3           -0.693    0.122   -5.683    0.000   -0.693   -0.693
##     i19|t4            0.169    0.112    1.502    0.133    0.169    0.169
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##    .i3                0.773                              0.773    0.773
##    .i4                0.912                              0.912    0.912
##    .i5                0.619                              0.619    0.619
##    .i7                0.674                              0.674    0.674
##    .i8                0.896                              0.896    0.896
##    .i9                0.541                              0.541    0.541
##    .i12               1.000                              1.000    1.000
##    .i14               0.680                              0.680    0.680
##    .i15               0.419                              0.419    0.419
##    .i20               0.663                              0.663    0.663
##    .i1                0.826                              0.826    0.826
##    .i2                0.514                              0.514    0.514
##    .i6                0.576                              0.576    0.576
##    .i10               0.720                              0.720    0.720
##    .i11               0.675                              0.675    0.675
##    .i13               0.716                              0.716    0.716
##    .i16               0.485                              0.485    0.485
##    .i17               0.450                              0.450    0.450
##    .i18               0.388                              0.388    0.388
##    .i19               0.432                              0.432    0.432
##     cog               1.000                              1.000    1.000
##     com               1.000                              1.000    1.000
```

```
# Descriptive statistics of factor loadings:
loadings_fit_model_2f <- standardizedsolution(fit_model_2f, type = "std.all")
# Selecting based on  row indices
print("Cog Factor Loadings Summary:")
```

```
## [1] "Cog Factor Loadings Summary:"
```

```
print(round(loadings_fit_model_2f[1:10, ] %>% select(est.std) %>%
        summarise(mean = mean(abs(est.std)), sd = sd(abs(est.std)),
                  min = min(abs(est.std)), max = max(abs(est.std))), 2))
```

```
##   mean   sd  min  max
## 1 0.49 0.22 0.01 0.76
```

```
# Loadings for cog: Mean = 0.49, SD = 0.16, min = 0.3 and max = 0.68

# Selecting based on row indices
print("Com Factor Loadings Summary:")
```

```
## [1] "Com Factor Loadings Summary:"
```

```
print(round(loadings_fit_model_2f[11:20, ] %>% select(est.std) %>%
        summarise(mean = mean(abs(est.std)), sd = sd(abs(est.std)),
                  min = min(abs(est.std)), max = max(abs(est.std))), 2))
```

```
##   mean   sd  min  max
## 1 0.64 0.12 0.42 0.78
```

```
#  Loadings for com: Mean = 0.53, SD = 0.22, min = 0.01 and max = 0.76

# Reliability
print(round(reliability(fit_model_2f), 2))
```

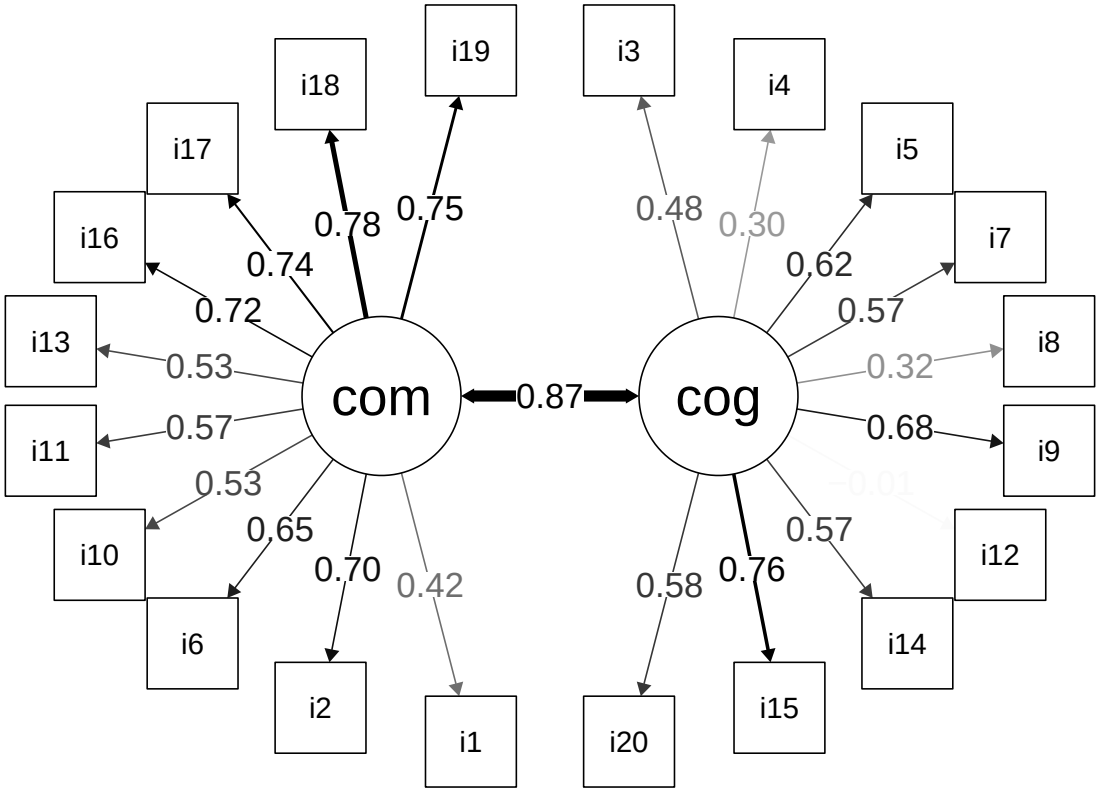
```
## For constructs with categorical indicators, Zumbo et al.‘s (2007) "ordinal alpha" is calculated in ac
```

```
##             cog  com
## alpha      0.72 0.83
## alpha.ord 0.77 0.87
## omega      0.69 0.84
## omega2     0.69 0.84
## omega3     0.65 0.85
## avevar     0.28 0.42
```

```
comp_reliability(fit_model_2f)
```

```
## # A tibble: 2 x 2
##   lhs   composite_reliability_ec
##   <chr>                    <dbl>
## 1 cog                      0.523
## 2 com                      0.702
```

```
# Cog: alpha = 0.72, alpha ord. = 0.77, omega McDonald = 0.69, comp. reliability = 0.52
# Com: alpha = 0.83, alpha ord. = 0.87, omega McDonald = 0.84, comp. reliability = 0.70

# Plot the model
semPaths(fit_model_2f,"std",layout="circle",residuals=FALSE,sizeLat=14,sizeLat2=14,edge.color="black",ed
         mar=c(2.5, 2.5, 2.5, 2.5),esize=7,curvePivot = TRUE, intercepts=FALSE,thresholds = FALSE,
         nCharNodes=0,sizeMan=8, edge.label.position=0.5
         )
```




**Bifactor Model (Orthogonal Factors)**

```
# Define the bifactor model
model_bifactor <- '
cog =~ i3 + i4 + i5 + i7 + i8 + i9 + i12 + i14 + i15 + i20
com =~ i1 + i2 + i6 + i10 + i11 + i13 + i16 + i17 + i18 + i19

general =~ i1 + i2 + i3 + i4 + i5 + i6 + i7 + i8 + i9 + i10 +
    i11 + i12 + i13 + i14 + i15 + i16 + i17 + i18 + i19 + i20
'

# Fit the bifactor model with orthogonal factors
fit_model_bifactor <- cfa(model_bifactor, data = data, ordered = TRUE, orthogonal = TRUE,
                          estimator = "WLSMV", std.lv=TRUE)


fitMeasures(fit_model_bifactor, fit.measures = c("chisq","df","cfi", "rmsea",
                                                 "rmsea.ci.lower", "rmsea.ci.upper"))
```

```
##          chisq             df            cfi          rmsea rmsea.ci.lower
##        188.811        150.000          0.989          0.045          0.020
## rmsea.ci.upper
##          0.064
```

```r
# chisq(df=150) = 188.811, CFI = 0.989, RMSEA = 0.045 [0.020, 0.064]
# Model was not rejected

# Get summary
summary(fit_model_bifactor, fit.measures = TRUE, standardized = TRUE)
```

```
## lavaan 0.6-19 ended normally after 42 iterations
##
##   Estimator                                         DWLS
##   Optimization method                           NLMINB
##   Number of model parameters                       120
##
##                                                   Used       Total
##   Number of observations                           127         202
##
## Model Test User Model:
##                                               Standard      Scaled
##   Test Statistic                               188.811     264.567
##   Degrees of freedom                               150         150
##   P-value (Chi-square)                           0.017       0.000
##   Scaling correction factor                                  0.956
##   Shift parameter                                           66.963
##     simple second-order correction
##
## Model Test Baseline Model:
##
##   Test statistic                              3742.984    1405.901
##   Degrees of freedom                               190         190
##   P-value                                        0.000       0.000
##   Scaling correction factor                                  2.922
##
## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                    0.989       0.906
##   Tucker-Lewis Index (TLI)                       0.986       0.881
##
##   Robust Comparative Fit Index (CFI)                         0.751
##   Robust Tucker-Lewis Index (TLI)                            0.684
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.045       0.078
##   90 Percent confidence interval - lower         0.020       0.062
##   90 Percent confidence interval - upper         0.064       0.093
##   P-value H_0: RMSEA <= 0.050                    0.637       0.003
##   P-value H_0: RMSEA >= 0.080                    0.001       0.421
##
##   Robust RMSEA                                               0.123
##   90 Percent confidence interval - lower                     0.108
##   90 Percent confidence interval - upper                     0.138
##   P-value H_0: Robust RMSEA <= 0.050                         0.000
##   P-value H_0: Robust RMSEA >= 0.080                         1.000
##
```

```
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.078       0.078
##
## Parameter Estimates:
##
##   Parameterization                               Delta
##   Standard errors                          Robust.sem
##   Information                                Expected
##   Information saturated (h1) model        Unstructured
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   cog =~
##     i3                0.133    0.103    1.298    0.194    0.133    0.133
##     i4                0.442    0.122    3.634    0.000    0.442    0.442
##     i5               -0.280    0.099   -2.825    0.005   -0.280   -0.280
##     i7                0.183    0.092    1.978    0.048    0.183    0.183
##     i8                0.584    0.101    5.801    0.000    0.584    0.584
##     i9                0.014    0.106    0.135    0.893    0.014    0.014
##     i12               0.467    0.125    3.738    0.000    0.467    0.467
##     i14               0.424    0.106    3.988    0.000    0.424    0.424
##     i15               0.012    0.100    0.116    0.907    0.012    0.012
##     i20               0.143    0.113    1.263    0.207    0.143    0.143
##   com =~
##     i1                0.236    0.121    1.944    0.052    0.236    0.236
##     i2               -0.010    0.113   -0.092    0.927   -0.010   -0.010
##     i6                0.198    0.110    1.800    0.072    0.198    0.198
##     i10               0.284    0.093    3.049    0.002    0.284    0.284
##     i11               0.274    0.112    2.442    0.015    0.274    0.274
##     i13               0.475    0.088    5.392    0.000    0.475    0.475
##     i16               0.363    0.077    4.715    0.000    0.363    0.363
##     i17               0.675    0.067   10.144    0.000    0.675    0.675
##     i18               0.137    0.089    1.548    0.122    0.137    0.137
##     i19               0.403    0.082    4.883    0.000    0.403    0.403
##   general =~
##     i1                0.357    0.078    4.545    0.000    0.357    0.357
##     i2                0.724    0.056   12.868    0.000    0.724    0.724
##     i3                0.464    0.071    6.527    0.000    0.464    0.464
##     i4                0.262    0.090    2.914    0.004    0.262    0.262
##     i5                0.644    0.058   11.024    0.000    0.644    0.644
##     i6                0.608    0.064    9.567    0.000    0.608    0.608
##     i7                0.553    0.066    8.375    0.000    0.553    0.553
##     i8                0.280    0.090    3.101    0.002    0.280    0.280
##     i9                0.670    0.053   12.528    0.000    0.670    0.670
##     i10               0.454    0.073    6.220    0.000    0.454    0.454
##     i11               0.500    0.072    6.895    0.000    0.500    0.500
##     i12              -0.061    0.098   -0.621    0.534   -0.061   -0.061
##     i13               0.407    0.077    5.256    0.000    0.407    0.407
##     i14               0.522    0.089    5.868    0.000    0.522    0.522
##     i15               0.760    0.046   16.568    0.000    0.760    0.760
##     i16               0.627    0.059   10.543    0.000    0.627    0.627
##     i17               0.559    0.066    8.470    0.000    0.559    0.559
##     i18               0.767    0.053   14.402    0.000    0.767    0.767
```

```
##     i19               0.640    0.063   10.102    0.000    0.640    0.640
##     i20               0.566    0.069    8.228    0.000    0.566    0.566
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   cog ~~
##     com               0.000                              0.000    0.000
##     general           0.000                              0.000    0.000
##   com ~~
##     general           0.000                              0.000    0.000
##
## Thresholds:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     i3|t1            -1.469    0.169   -8.712    0.000   -1.469   -1.469
##     i3|t2            -1.184    0.145   -8.149    0.000   -1.184   -1.184
##     i3|t3            -0.270    0.113   -2.384    0.017   -0.270   -0.270
##     i3|t4             0.527    0.117    4.483    0.000    0.527    0.527
##     i4|t1            -1.414    0.163   -8.654    0.000   -1.414   -1.414
##     i4|t2            -0.973    0.133   -7.306    0.000   -0.973   -0.973
##     i4|t3            -0.644    0.120   -5.344    0.000   -0.644   -0.644
##     i4|t4            -0.030    0.112   -0.265    0.791   -0.030   -0.030
##     i5|t1            -1.362    0.159   -8.577    0.000   -1.362   -1.362
##     i5|t2            -1.225    0.148   -8.270    0.000   -1.225   -1.225
##     i5|t3            -0.416    0.115   -3.613    0.000   -0.416   -0.416
##     i5|t4             0.460    0.116    3.962    0.000    0.460    0.460
##     i7|t1            -1.672    0.192   -8.720    0.000   -1.672   -1.672
##     i7|t2            -1.146    0.143   -8.021    0.000   -1.146   -1.146
##     i7|t3            -0.229    0.113   -2.031    0.042   -0.229   -0.229
##     i7|t4             0.596    0.119    5.001    0.000    0.596    0.596
##     i8|t1            -1.672    0.192   -8.720    0.000   -1.672   -1.672
##     i8|t2            -1.184    0.145   -8.149    0.000   -1.184   -1.184
##     i8|t3            -0.353    0.114   -3.087    0.002   -0.353   -0.353
##     i8|t4             0.353    0.114    3.087    0.002    0.353    0.353
##     i9|t1            -1.225    0.148   -8.270    0.000   -1.225   -1.225
##     i9|t2            -0.797    0.126   -6.351    0.000   -0.797   -0.797
##     i9|t3            -0.249    0.113   -2.207    0.027   -0.249   -0.249
##     i9|t4             0.573    0.119    4.829    0.000    0.573    0.573
##     i12|t1           -0.693    0.122   -5.683    0.000   -0.693   -0.693
##     i12|t2           -0.290    0.113   -2.560    0.010   -0.290   -0.290
##     i12|t3            0.049    0.112    0.442    0.659    0.049    0.049
##     i12|t4            0.504    0.117    4.310    0.000    0.504    0.504
##     i14|t1           -2.151    0.281   -7.657    0.000   -2.151   -2.151
##     i14|t2           -1.530    0.175   -8.748    0.000   -1.530   -1.530
##     i14|t3           -0.882    0.129   -6.837    0.000   -0.882   -0.882
##     i14|t4           -0.069    0.112   -0.619    0.536   -0.069   -0.069
##     i15|t1           -2.415    0.364   -6.629    0.000   -2.415   -2.415
##     i15|t2           -1.758    0.204   -8.632    0.000   -1.758   -1.758
##     i15|t3           -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i15|t4            0.270    0.113    2.384    0.017    0.270    0.270
##     i20|t1           -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i20|t2           -1.469    0.169   -8.712    0.000   -1.469   -1.469
##     i20|t3           -0.527    0.117   -4.483    0.000   -0.527   -0.527
##     i20|t4            0.290    0.113    2.560    0.010    0.290    0.290
##     i1|t1            -1.362    0.159   -8.577    0.000   -1.362   -1.362
```

```
##     i1|t2            -0.973    0.133   -7.306    0.000   -0.973   -0.973
##     i1|t3            -0.030    0.112   -0.265    0.791   -0.030   -0.030
##     i1|t4             0.527    0.117    4.483    0.000    0.527    0.527
##     i2|t1            -1.758    0.204   -8.632    0.000   -1.758   -1.758
##     i2|t2            -1.597    0.182   -8.754    0.000   -1.597   -1.597
##     i2|t3            -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i2|t4             0.109    0.112    0.972    0.331    0.109    0.109
##     i6|t1            -1.984    0.243   -8.172    0.000   -1.984   -1.984
##     i6|t2            -1.414    0.163   -8.654    0.000   -1.414   -1.414
##     i6|t3            -0.527    0.117   -4.483    0.000   -0.527   -0.527
##     i6|t4             0.290    0.113    2.560    0.010    0.290    0.290
##     i10|t1           -1.758    0.204   -8.632    0.000   -1.758   -1.758
##     i10|t2           -1.314    0.155   -8.486    0.000   -1.314   -1.314
##     i10|t3           -0.353    0.114   -3.087    0.002   -0.353   -0.353
##     i10|t4            0.527    0.117    4.483    0.000    0.527    0.527
##     i11|t1           -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i11|t2           -1.268    0.151   -8.383    0.000   -1.268   -1.268
##     i11|t3           -0.249    0.113   -2.207    0.027   -0.249   -0.249
##     i11|t4            0.504    0.117    4.310    0.000    0.504    0.504
##     i13|t1           -1.597    0.182   -8.754    0.000   -1.597   -1.597
##     i13|t2           -1.146    0.143   -8.021    0.000   -1.146   -1.146
##     i13|t3           -0.374    0.115   -3.262    0.001   -0.374   -0.374
##     i13|t4            0.395    0.115    3.438    0.001    0.395    0.395
##     i16|t1           -1.984    0.243   -8.172    0.000   -1.984   -1.984
##     i16|t2           -1.314    0.155   -8.486    0.000   -1.314   -1.314
##     i16|t3           -0.596    0.119   -5.001    0.000   -0.596   -0.596
##     i16|t4            0.438    0.116    3.787    0.000    0.438    0.438
##     i17|t1           -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i17|t2           -1.469    0.169   -8.712    0.000   -1.469   -1.469
##     i17|t3           -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i17|t4           -0.010    0.112   -0.088    0.930   -0.010   -0.010
##     i18|t1           -1.984    0.243   -8.172    0.000   -1.984   -1.984
##     i18|t2           -1.362    0.159   -8.577    0.000   -1.362   -1.362
##     i18|t3           -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i18|t4           -0.069    0.112   -0.619    0.536   -0.069   -0.069
##     i19|t1           -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i19|t2           -1.672    0.192   -8.720    0.000   -1.672   -1.672
##     i19|t3           -0.693    0.122   -5.683    0.000   -0.693   -0.693
##     i19|t4            0.169    0.112    1.502    0.133    0.169    0.169
##
## Variances:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##    .i3               0.767                              0.767    0.767
##    .i4               0.736                              0.736    0.736
##    .i5               0.506                              0.506    0.506
##    .i7               0.661                              0.661    0.661
##    .i8               0.581                              0.581    0.581
##    .i9               0.551                              0.551    0.551
##    .i12              0.778                              0.778    0.778
##    .i14              0.547                              0.547    0.547
##    .i15              0.422                              0.422    0.422
##    .i20              0.659                              0.659    0.659
##    .i1               0.817                              0.817    0.817
##    .i2               0.476                              0.476    0.476
```

```
##    .i6               0.591                              0.591    0.591
##    .i10              0.713                              0.713    0.713
##    .i11              0.675                              0.675    0.675
##    .i13              0.609                              0.609    0.609
##    .i16              0.475                              0.475    0.475
##    .i17              0.232                              0.232    0.232
##    .i18              0.392                              0.392    0.392
##    .i19              0.429                              0.429    0.429
##     cog              1.000                              1.000    1.000
##     com              1.000                              1.000    1.000
##     general          1.000                              1.000    1.000
```

```r
# Descriptive statistics of factor loadings:
loadings_fit_model_bifactor <- standardizedsolution(fit_model_bifactor, type = "std.all")

# Selecting based on row indices
print(round(loadings_fit_model_bifactor[1:10, ] %>% select(est.std) %>%
        summarise(mean = mean(abs(est.std)), sd = sd(abs(est.std)),
                  min = min(abs(est.std)), max = max(abs(est.std))), 2))
```

```
##   mean  sd  min  max
## 1 0.27 0.2 0.01 0.58
```

```r
# Loadings for cog: Mean = 0.27, SD = 0.2, min = 0.01 and max = 0.58

# Selecting based on row indices
print(round(loadings_fit_model_bifactor[11:20, ] %>% select(est.std) %>%
        summarise(mean = mean(abs(est.std)), sd = sd(abs(est.std)),
                  min = min(abs(est.std)), max = max(abs(est.std))), 2))
```

```
##   mean   sd  min  max
## 1 0.31 0.19 0.01 0.67
```

```r
# Loadings for com: Mean = 0.31, SD = 0.19, min = 0.01 and max = 0.67

# Selecting based on row indices
print(round(loadings_fit_model_bifactor[21:40, ] %>% select(est.std) %>%
        summarise(mean = mean(abs(est.std)), sd = sd(abs(est.std)),
                  min = min(abs(est.std)), max = max(abs(est.std))), 2))
```

```
##   mean   sd  min  max
## 1 0.52 0.18 0.06 0.77
```

```r
# Loadings for general: Mean = 0.52, SD = 0.18, min = 0.06 and max = 0.77

# Reliability of the latent variables in the model
print(round(reliability(fit_model_bifactor), 2))
```

```
## For constructs with categorical indicators, Zumbo et al.'s (2007) "ordinal alpha" is calculated in ac
```

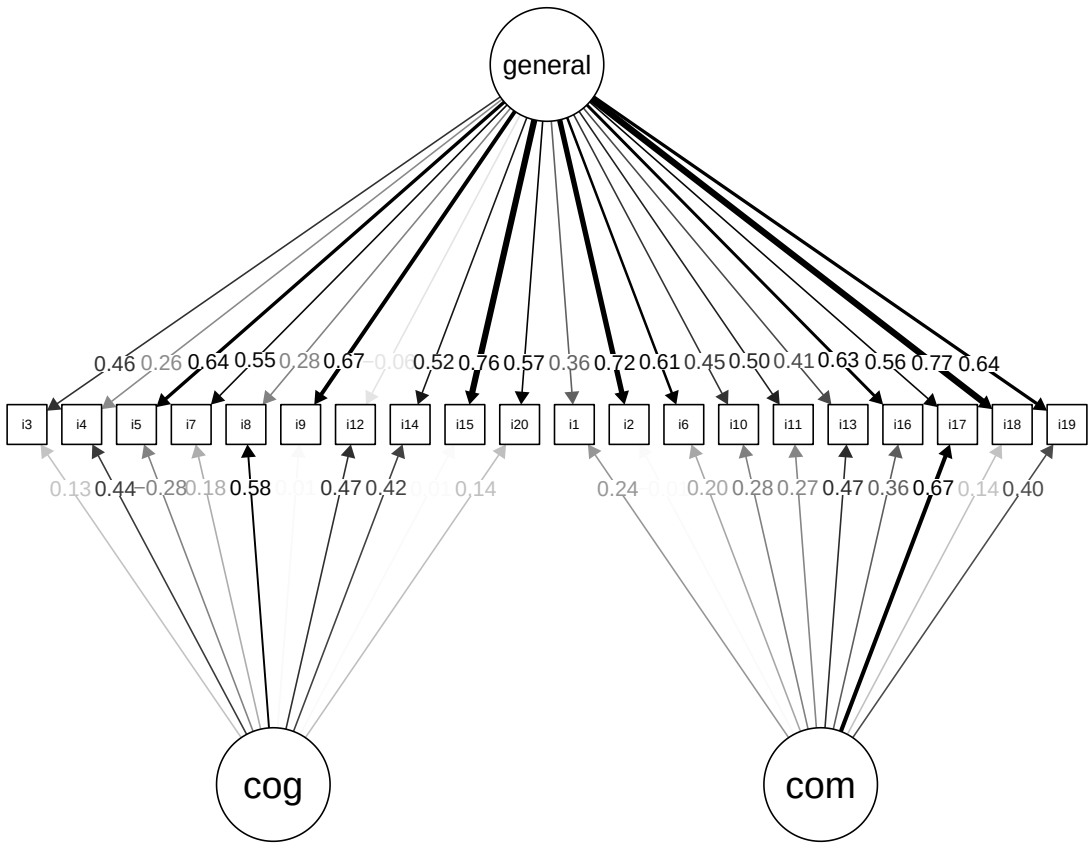
```
##            cog  com general
```

```
## alpha     0.72 0.83    0.85
## alpha.ord 0.77 0.87    0.89
## omega     0.30 0.39    0.76
## omega2    0.15 0.19    0.77
## omega3    0.15 0.19    0.78
## avevar      NA   NA      NA
```

```
comp_reliability(fit_model_bifactor)
```

```
## # A tibble: 3 x 2
##   lhs     composite_reliability
##   <chr>                   <dbl>
## 1 cog                     0.420
## 2 com                     0.630
## 3 general                 0.901
```

```
# cog: alpha = 0.72, alpha ord. = 0.77, omega McDonald = 0.15, comp. reliability = 0.42
# com: alpha = 0.83, alpha ord. = 0.87, omega McDonald = 0.19, comp. reliability = 0.63
# general: alpha = 0.87, alpha ord. = 0.90, omega McDonald = 0.78, comp. reliability = 0.90

# Plot the model
semPaths(fit_model_bifactor,"std",layout="tree2",residuals=FALSE,sizeLat=10,sizeLat2=10,edge.color="bla
         mar=c(2, 2, 2, 2),esize=4,curvePivot = FALSE, intercepts=FALSE,thresholds = FALSE,
         nCharNodes=0,sizeMan=3.5, edge.label.position=0.85, bifactor = "general") # Specify general fa
```




**Constrained Bifactor Model (Orthogonal Factors)**

```r
# Define the constrained bifactor model (fixing negative loadings to 0)
model_bifactor <- '
cog =~ i3 + i4 + 0*i5 + i7 + i8 + i9 + i12 + i14 + i15 + i20
com =~ i1 + 0*i2 + i6 + i10 + i11 + i13 + i16 + i17 + i18 + i19

general =~ i1 + i2 + i3 + i4 + i5 + i6 + i7 + i8 + i9 + i10 +
    i11 + 0*i12 + i13 + i14 + i15 + i16 + i17 + i18 + i19 + i20
'

# Fit the constrained bifactor model
fit_model_bifactor <- cfa(model_bifactor, data = data, ordered = TRUE, orthogonal = TRUE,
                                    estimator = "WLSMV", std.lv=TRUE)

# Get fit measures
fitMeasures(fit_model_bifactor, fit.measures = c("chisq","df","cfi", "rmsea",
```

```
##          chisq             df            cfi          rmsea rmsea.ci.lower
##        199.014        153.000          0.987          0.049          0.027
## rmsea.ci.upper
##          0.067
```

```r
# chisq(df=153) = 199.014, CFI = 0.987, RMSEA = 0.045 [0.020, 0.064]


# Get summary
summary(fit_model_bifactor, fit.measures = TRUE, standardized = TRUE)
```

```
## lavaan 0.6-19 ended normally after 40 iterations
##
##   Estimator                                         DWLS
##   Optimization method                           NLMINB
##   Number of model parameters                       117
##
##                                                   Used       Total
##   Number of observations                           127         202
##
## Model Test User Model:
##                                               Standard      Scaled
##   Test Statistic                               199.014     256.157
##   Degrees of freedom                               153         153
##   P-value (Chi-square)                           0.007       0.000
##   Scaling correction factor                                  1.090
##   Shift parameter                                           73.497
##     simple second-order correction
##
## Model Test Baseline Model:
##
##   Test statistic                              3742.984    1405.901
##   Degrees of freedom                               190         190
##   P-value                                        0.000       0.000
##   Scaling correction factor                                  2.922
##
```

```
## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                    0.987       0.915
##   Tucker-Lewis Index (TLI)                       0.984       0.895
##
##   Robust Comparative Fit Index (CFI)                         0.747
##   Robust Tucker-Lewis Index (TLI)                            0.685
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.049       0.073
##   90 Percent confidence interval - lower         0.027       0.057
##   90 Percent confidence interval - upper         0.067       0.089
##   P-value H_0: RMSEA <= 0.050                    0.525       0.010
##   P-value H_0: RMSEA >= 0.080                    0.001       0.242
##
##   Robust RMSEA                                               0.123
##   90 Percent confidence interval - lower                     0.108
##   90 Percent confidence interval - upper                     0.138
##   P-value H_0: Robust RMSEA <= 0.050                         0.000
##   P-value H_0: Robust RMSEA >= 0.080                         1.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.080       0.080
##
## Parameter Estimates:
##
##   Parameterization                                 Delta
##   Standard errors                            Robust.sem
##   Information                                  Expected
##   Information saturated (h1) model        Unstructured
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   cog =~
##     i3                0.141    0.107    1.321    0.187    0.141    0.141
##     i4                0.465    0.131    3.544    0.000    0.465    0.465
##     i5                0.000                              0.000    0.000
##     i7                0.155    0.096    1.609    0.108    0.155    0.155
##     i8                0.611    0.119    5.114    0.000    0.611    0.611
##     i9               -0.001    0.105   -0.005    0.996   -0.001   -0.001
##     i12               0.396    0.144    2.747    0.006    0.396    0.396
##     i14               0.413    0.109    3.769    0.000    0.413    0.413
##     i15              -0.027    0.102   -0.270    0.787   -0.027   -0.027
##     i20               0.198    0.111    1.779    0.075    0.198    0.198
##   com =~
##     i1                0.237    0.121    1.961    0.050    0.237    0.237
##     i2                0.000                              0.000    0.000
##     i6                0.193    0.109    1.771    0.077    0.193    0.193
##     i10               0.279    0.094    2.974    0.003    0.279    0.279
##     i11               0.273    0.110    2.484    0.013    0.273    0.273
##     i13               0.475    0.088    5.427    0.000    0.475    0.475
##     i16               0.349    0.079    4.411    0.000    0.349    0.349
```

```
##     i17               0.674    0.068    9.877    0.000    0.674    0.674
##     i18               0.119    0.096    1.239    0.215    0.119    0.119
##     i19               0.395    0.081    4.873    0.000    0.395    0.395
##   general =~
##     i1                0.356    0.079    4.534    0.000    0.356    0.356
##     i2                0.721    0.055   13.223    0.000    0.721    0.721
##     i3                0.460    0.071    6.458    0.000    0.460    0.460
##     i4                0.251    0.092    2.741    0.006    0.251    0.251
##     i5                0.615    0.061   10.075    0.000    0.615    0.615
##     i6                0.611    0.063    9.748    0.000    0.611    0.611
##     i7                0.552    0.066    8.320    0.000    0.552    0.552
##     i8                0.265    0.086    3.094    0.002    0.265    0.265
##     i9                0.672    0.054   12.477    0.000    0.672    0.672
##     i10               0.457    0.073    6.229    0.000    0.457    0.457
##     i11               0.502    0.072    6.967    0.000    0.502    0.502
##     i12               0.000                              0.000    0.000
##     i13               0.409    0.076    5.359    0.000    0.409    0.409
##     i14               0.515    0.087    5.934    0.000    0.515    0.515
##     i15               0.767    0.046   16.773    0.000    0.767    0.767
##     i16               0.634    0.059   10.763    0.000    0.634    0.634
##     i17               0.563    0.064    8.774    0.000    0.563    0.563
##     i18               0.776    0.054   14.462    0.000    0.776    0.776
##     i19               0.645    0.060   10.669    0.000    0.645    0.645
##     i20               0.557    0.070    7.923    0.000    0.557    0.557
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   cog ~~
##     com               0.000                              0.000    0.000
##     general           0.000                              0.000    0.000
##   com ~~
##     general           0.000                              0.000    0.000
##
## Thresholds:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     i3|t1            -1.469    0.169   -8.712    0.000   -1.469   -1.469
##     i3|t2            -1.184    0.145   -8.149    0.000   -1.184   -1.184
##     i3|t3            -0.270    0.113   -2.384    0.017   -0.270   -0.270
##     i3|t4             0.527    0.117    4.483    0.000    0.527    0.527
##     i4|t1            -1.414    0.163   -8.654    0.000   -1.414   -1.414
##     i4|t2            -0.973    0.133   -7.306    0.000   -0.973   -0.973
##     i4|t3            -0.644    0.120   -5.344    0.000   -0.644   -0.644
##     i4|t4            -0.030    0.112   -0.265    0.791   -0.030   -0.030
##     i5|t1            -1.362    0.159   -8.577    0.000   -1.362   -1.362
##     i5|t2            -1.225    0.148   -8.270    0.000   -1.225   -1.225
##     i5|t3            -0.416    0.115   -3.613    0.000   -0.416   -0.416
##     i5|t4             0.460    0.116    3.962    0.000    0.460    0.460
##     i7|t1            -1.672    0.192   -8.720    0.000   -1.672   -1.672
##     i7|t2            -1.146    0.143   -8.021    0.000   -1.146   -1.146
##     i7|t3            -0.229    0.113   -2.031    0.042   -0.229   -0.229
##     i7|t4             0.596    0.119    5.001    0.000    0.596    0.596
##     i8|t1            -1.672    0.192   -8.720    0.000   -1.672   -1.672
##     i8|t2            -1.184    0.145   -8.149    0.000   -1.184   -1.184
##     i8|t3            -0.353    0.114   -3.087    0.002   -0.353   -0.353
```

```
##     i8|t4            0.353    0.114    3.087    0.002    0.353    0.353
##     i9|t1           -1.225    0.148   -8.270    0.000   -1.225   -1.225
##     i9|t2           -0.797    0.126   -6.351    0.000   -0.797   -0.797
##     i9|t3           -0.249    0.113   -2.207    0.027   -0.249   -0.249
##     i9|t4            0.573    0.119    4.829    0.000    0.573    0.573
##     i12|t1          -0.693    0.122   -5.683    0.000   -0.693   -0.693
##     i12|t2          -0.290    0.113   -2.560    0.010   -0.290   -0.290
##     i12|t3           0.049    0.112    0.442    0.659    0.049    0.049
##     i12|t4           0.504    0.117    4.310    0.000    0.504    0.504
##     i14|t1          -2.151    0.281   -7.657    0.000   -2.151   -2.151
##     i14|t2          -1.530    0.175   -8.748    0.000   -1.530   -1.530
##     i14|t3          -0.882    0.129   -6.837    0.000   -0.882   -0.882
##     i14|t4          -0.069    0.112   -0.619    0.536   -0.069   -0.069
##     i15|t1          -2.415    0.364   -6.629    0.000   -2.415   -2.415
##     i15|t2          -1.758    0.204   -8.632    0.000   -1.758   -1.758
##     i15|t3          -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i15|t4           0.270    0.113    2.384    0.017    0.270    0.270
##     i20|t1          -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i20|t2          -1.469    0.169   -8.712    0.000   -1.469   -1.469
##     i20|t3          -0.527    0.117   -4.483    0.000   -0.527   -0.527
##     i20|t4           0.290    0.113    2.560    0.010    0.290    0.290
##     i1|t1           -1.362    0.159   -8.577    0.000   -1.362   -1.362
##     i1|t2           -0.973    0.133   -7.306    0.000   -0.973   -0.973
##     i1|t3           -0.030    0.112   -0.265    0.791   -0.030   -0.030
##     i1|t4            0.527    0.117    4.483    0.000    0.527    0.527
##     i2|t1           -1.758    0.204   -8.632    0.000   -1.758   -1.758
##     i2|t2           -1.597    0.182   -8.754    0.000   -1.597   -1.597
##     i2|t3           -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i2|t4            0.109    0.112    0.972    0.331    0.109    0.109
##     i6|t1           -1.984    0.243   -8.172    0.000   -1.984   -1.984
##     i6|t2           -1.414    0.163   -8.654    0.000   -1.414   -1.414
##     i6|t3           -0.527    0.117   -4.483    0.000   -0.527   -0.527
##     i6|t4            0.290    0.113    2.560    0.010    0.290    0.290
##     i10|t1          -1.758    0.204   -8.632    0.000   -1.758   -1.758
##     i10|t2          -1.314    0.155   -8.486    0.000   -1.314   -1.314
##     i10|t3          -0.353    0.114   -3.087    0.002   -0.353   -0.353
##     i10|t4           0.527    0.117    4.483    0.000    0.527    0.527
##     i11|t1          -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i11|t2          -1.268    0.151   -8.383    0.000   -1.268   -1.268
##     i11|t3          -0.249    0.113   -2.207    0.027   -0.249   -0.249
##     i11|t4           0.504    0.117    4.310    0.000    0.504    0.504
##     i13|t1          -1.597    0.182   -8.754    0.000   -1.597   -1.597
##     i13|t2          -1.146    0.143   -8.021    0.000   -1.146   -1.146
##     i13|t3          -0.374    0.115   -3.262    0.001   -0.374   -0.374
##     i13|t4           0.395    0.115    3.438    0.001    0.395    0.395
##     i16|t1          -1.984    0.243   -8.172    0.000   -1.984   -1.984
##     i16|t2          -1.314    0.155   -8.486    0.000   -1.314   -1.314
##     i16|t3          -0.596    0.119   -5.001    0.000   -0.596   -0.596
##     i16|t4           0.438    0.116    3.787    0.000    0.438    0.438
##     i17|t1          -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i17|t2          -1.469    0.169   -8.712    0.000   -1.469   -1.469
##     i17|t3          -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i17|t4          -0.010    0.112   -0.088    0.930   -0.010   -0.010
##     i18|t1          -1.984    0.243   -8.172    0.000   -1.984   -1.984
```

```
##     i18|t2           -1.362    0.159   -8.577    0.000   -1.362   -1.362
##     i18|t3           -0.825    0.127   -6.515    0.000   -0.825   -0.825
##     i18|t4           -0.069    0.112   -0.619    0.536   -0.069   -0.069
##     i19|t1           -1.859    0.220   -8.465    0.000   -1.859   -1.859
##     i19|t2           -1.672    0.192   -8.720    0.000   -1.672   -1.672
##     i19|t3           -0.693    0.122   -5.683    0.000   -0.693   -0.693
##     i19|t4            0.169    0.112    1.502    0.133    0.169    0.169
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##    .i3                0.768                               0.768    0.768
##    .i4                0.721                               0.721    0.721
##    .i5                0.622                               0.622    0.622
##    .i7                0.672                               0.672    0.672
##    .i8                0.557                               0.557    0.557
##    .i9                0.549                               0.549    0.549
##    .i12               0.843                               0.843    0.843
##    .i14               0.564                               0.564    0.564
##    .i15               0.411                               0.411    0.411
##    .i20               0.650                               0.650    0.650
##    .i1                0.817                               0.817    0.817
##    .i2                0.480                               0.480    0.480
##    .i6                0.590                               0.590    0.590
##    .i10               0.713                               0.713    0.713
##    .i11               0.674                               0.674    0.674
##    .i13               0.607                               0.607    0.607
##    .i16               0.477                               0.477    0.477
##    .i17               0.229                               0.229    0.229
##    .i18               0.384                               0.384    0.384
##    .i19               0.428                               0.428    0.428
##     cog               1.000                               1.000    1.000
##     com               1.000                               1.000    1.000
##     general           1.000                               1.000    1.000
```

```
# Descriptive statistics of factor loadings:
loadings_fit_model_bifactor <- standardizedsolution(fit_model_bifactor, type = "std.all")

print(round(loadings_fit_model_bifactor[1:9, ] %>% select(est.std) %>%
        summarise(mean = mean(abs(est.std)), sd = sd(abs(est.std)),
                  min = min(abs(est.std)), max = max(abs(est.std))), 2))
```

```
##   mean   sd min  max
## 1 0.25 0.23   0 0.61
```

```
# Mean = 0.27, SD = 0.2, min = 0.01 and max = 0.58

# Selecting based on row indices
print(round(loadings_fit_model_bifactor[10:18, ] %>% select(est.std) %>%
        summarise(mean = mean(abs(est.std)), sd = sd(abs(est.std)),
                  min = min(abs(est.std)), max = max(abs(est.std))), 2))
```

```
##   mean   sd min  max
## 1  0.3 0.19   0 0.67
```

```r
# Mean = 0.31, SD = 0.19, min = 0.01 and max = 0.67

# Selecting based on row indices
print(round(loadings_fit_model_bifactor[19:36, ] %>% select(est.std) %>%
        summarise(mean = mean(abs(est.std)), sd = sd(abs(est.std)),
                  min = min(abs(est.std)), max = max(abs(est.std))), 2))
```

```
##   mean   sd min  max
## 1 0.46 0.21   0 0.77
```

```r
# Mean = 0.52, SD = 0.18, min = 0.06 and max = 0.77

# Reliability
print(round(reliability(fit_model_bifactor), 2))
```

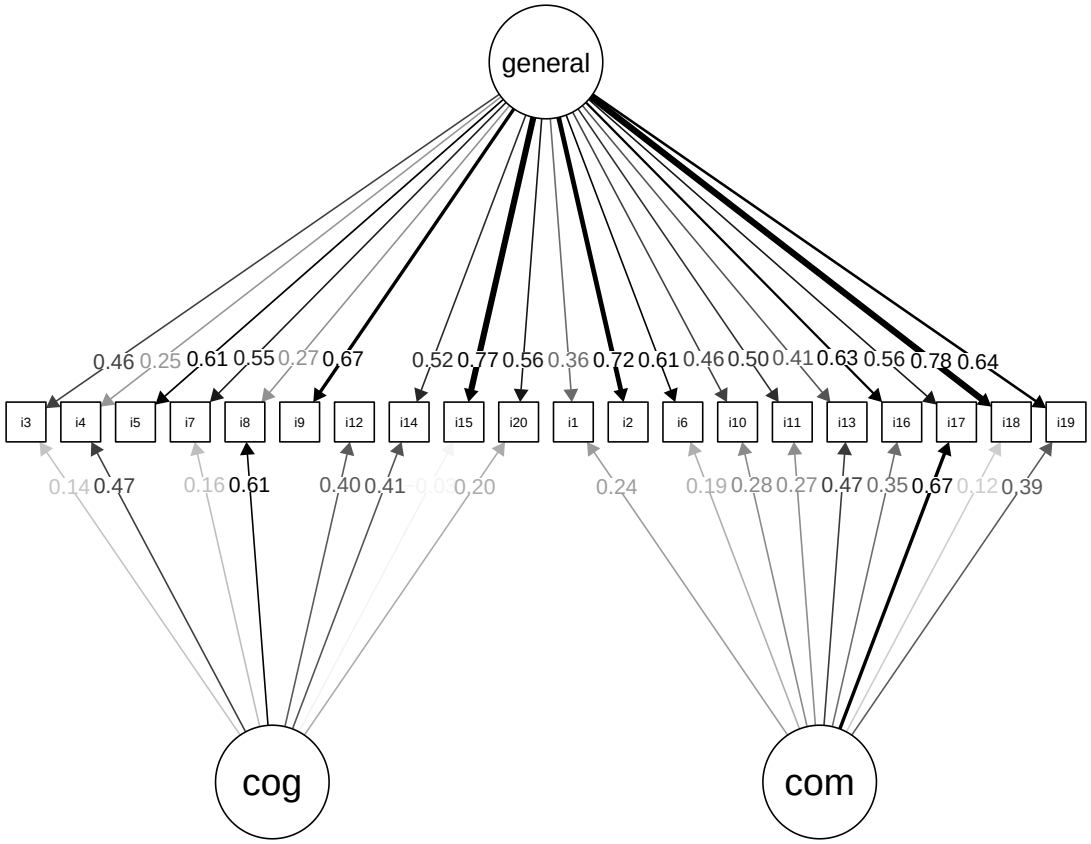
```
## For constructs with categorical indicators, Zumbo et al.'s (2007) "ordinal alpha" is calculated in ac
```

```
##             cog  com general
## alpha      0.71 0.81    0.87
## alpha.ord 0.76 0.86    0.90
## omega      0.36 0.40    0.78
## omega2     0.21 0.22    0.79
## omega3     0.21 0.22    0.80
## avevar       NA   NA      NA
```

```r
comp_reliability(fit_model_bifactor)
```

```
## # A tibble: 3 x 2
##   lhs     composite_reliability
##   <chr>                   <dbl>
## 1 cog                     0.465
## 2 com                     0.624
## 3 general                 0.901
```

```r
# cog: alpha = 0.71, alpha ord. = 0.76, omega McDonald = 0.36, comp. reliability = 0.46
# com: alpha = 0.81, alpha ord. = 0.86, omega McDonald = 0.40, comp. reliability = 0.62
# geral: alpha = 0.87, alpha ord. = 0.90, omega McDonald = 0.78, comp. reliability = 0.90

# Plot the model
semPaths(fit_model_bifactor,"std",layout="tree2",residuals=FALSE,sizeLat=10,sizeLat2=10,edge.color="bla
         mar=c(2, 2, 2, 2),esize=4,curvePivot = FALSE, intercepts=FALSE,thresholds = FALSE,
         nCharNodes=0,sizeMan=3.5, edge.label.position=0.85, bifactor = "general")
```




### Model Comparison

```
# O melhor modelo foi o bifatorial

lavTestLRT(fit_model_uni, fit_model_2f, fit_model_bifactor)
```

```
##
## Scaled Chi-Squared Difference Test (method = "satorra.2000")
##
## 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)
## fit_model_bifactor 153         199.01
## fit_model_2f       169         267.86     58.819      16  8.265e-07 ***
## fit_model_uni      170         283.29     13.562       1  0.0002308 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
sessionInfo()
```

```
## R version 4.4.2 (2024-10-31 ucrt)
## Platform: x86_64-w64-mingw32/x64
## Running under: Windows 11 x64 (build 26100)
```

```
##
## Matrix products: default
##
##
## locale:
## [1] LC_COLLATE=Portuguese_Brazil.utf8  LC_CTYPE=Portuguese_Brazil.utf8
## [3] LC_MONETARY=Portuguese_Brazil.utf8 LC_NUMERIC=C
## [5] LC_TIME=Portuguese_Brazil.utf8
##
## time zone: America/Sao_Paulo
## tzcode source: internal
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
## [1] semPlot_1.1.6  semTools_0.5-6 lavaan_0.6-19  MVN_5.9        dplyr_1.1.4
## [6] psych_2.5.3    readxl_1.4.3
##
## loaded via a namespace (and not attached):
##   [1] Rdpack_2.6.4       mnormt_2.1.1       pbapply_1.7-2
##   [4] gridExtra_2.3      fdrtool_1.2.18     sandwich_3.1-1
##   [7] rlang_1.1.5        magrittr_2.0.3     multcomp_1.4-26
##  [10] rockchalk_1.8.157  compiler_4.4.2     png_0.1-8
##  [13] vctrs_0.6.5        reshape2_1.4.4     OpenMx_2.21.13
##  [16] gsl_2.1-8          quadprog_1.5-8     stringr_1.5.1
##  [19] crayon_1.5.3       pkgconfig_2.0.3    fastmap_1.2.0
##  [22] arm_1.14-4         backports_1.5.0    energy_1.7-12
##  [25] utf8_1.2.4         pbivnorm_0.6.0     rmarkdown_2.29
##  [28] nloptr_2.2.1       xfun_0.52          kutils_1.73
##  [31] jpeg_0.1-10        parallel_4.4.2     cluster_2.1.6
##  [34] R6_2.6.1           stringi_1.8.7      car_3.1-3
##  [37] boot_1.3-31        rpart_4.1.23       cellranger_1.1.0
##  [40] estimability_1.5.1 Rcpp_1.0.14        knitr_1.50
##  [43] zoo_1.8-14         base64enc_0.1-3    Matrix_1.7-1
##  [46] splines_4.4.2      nnet_7.3-19        igraph_2.1.4
##  [49] tidyselect_1.2.1   rstudioapi_0.17.1  abind_1.4-8
##  [52] yaml_2.3.10        codetools_0.2-20   qgraph_1.9.8
##  [55] lattice_0.22-6     tibble_3.2.1       plyr_1.8.9
##  [58] withr_3.0.2        coda_0.19-4.1      evaluate_1.0.3
##  [61] moments_0.14.1     foreign_0.8-87     survival_3.7-0
##  [64] RcppParallel_5.1.9 zip_2.3.1          pillar_1.10.2
##  [67] carData_3.0-5      checkmate_2.3.2    nortest_1.0-4
##  [70] stats4_4.4.2       reformulas_0.4.0   generics_0.1.3
##  [73] ggplot2_3.5.2      munsell_0.5.1      scales_1.3.0
##  [76] minqa_1.2.8        gtools_3.9.5       xtable_1.8-4
##  [79] glue_1.8.0         mi_1.1             emmeans_1.10.6
##  [82] Hmisc_5.2-3        tools_4.4.2        data.table_1.17.0
##  [85] lme4_1.1-37        openxlsx_4.2.7.1   mvtnorm_1.3-3
##  [88] XML_3.99-0.18      grid_4.4.2         sem_3.1-16
##  [91] rbibutils_2.3      colorspace_2.1-1   nlme_3.1-166
##  [94] htmlTable_2.4.3    Formula_1.2-5      cli_3.6.4
##  [97] glasso_1.11        corpcor_1.6.10     gtable_0.3.6
## [100] digest_0.6.37      TH.data_1.1-3      htmlwidgets_1.6.4
```

```
## [103] htmltools_0.5.8.1  lifecycle_1.0.4    lisrelToR_0.3
## [106] MASS_7.3-61
```