library(lavaan)

bootstrapN <- 500

# Data for EMM

data <- matrix( c(0.8212 , 0.6104 , 0.7951 , 0.4499 ,

0.086 , 0.5551 , -0.7836 , 0.312 ,

0.5595 , -0.6272 , 0.43 , 0.3313 ,

-0.5701 , -2.2149 , -1.604 , 0.0686 ,

0.3774 , -0.3306 , -1.5038 , -0.3149 ,

0.1768 , -0.1604 , -0.5885 , -0.1412 ,

0.1561 , -0.0746 , 0.7511 , 1.0317 ,

-0.9798 , -2.0927 , -0.31 , -0.3459 ,

-0.0274 , 1.7168 , 0.7731 , -0.5028 ,

0.0408 , -0.147 , 0.6538 , 0.7526 ,

-0.7932 , 0.6433 , -0.3829 , 0.2975 ,

0.5371 , 0.4832 , -0.5375 , -0.1992 ,

0.3947 , -0.0897 , -1.3657 , -0.4184 ,

0.3481 , 0.7184 , 0.6609 , 0.7498 ,

0.7506 , 0.7002 , -0.205 , 0.644 ,

-0.2381 , 0.2578 , 0.5142 , -0.0524 ,

0.4628 , -0.319 , 1.1025 , -5e-04 ,

-0.172 , 0.1992 , 0.4837 , 0.4123 ,

0.4597 , 0.5575 , 0.4814 , 0.1992 ,

-0.5012 , -0.7564 , -0.4886 , -0.1005 ,

-0.168 , -0.8419 , 2.3681 , 0.8349 ,

0.565 , 0.7244 , 1.2367 , 1.0107 ,

0.2153 , 1.1822 , 1.5984 , 0.3997 ,

0.1898 , 0.4246 , 1.092 , -0.1529 ,

-0.6886 , 0.7858 , -0.7477 , -0.6701 ,

0.9642 , 0.7118 , 2.4409 , 0.6771 ,

-0.1868 , 2.4265 , 0.2473 , -0.6402 ,

-0.7878 , 0.4005 , 0.4275 , -0.2306 ,

-0.1844 , -1.3268 , -0.5577 , 0.2565 ,

0.5508 , -0.4619 , -0.0672 , -0.7444 ,

-0.7335 , -1.7149 , -0.8137 , -1.1664 ,

0.8459 , 1.0565 , -0.5735 , 0.312 ,

0.0337 , -0.009 , 0.3138 , 0.2126 ,

-0.0124 , -1.5819 , -1.4 , -0.4797 ,

-0.8141 , -0.7487 , 0.5774 , -0.0948 ,

0.0933 , -0.8451 , 0.8043 , -0.5863 ,

-0.5451 , -1.955 , -0.8823 , -0.2886 ,

-0.1603 , 0.1175 , -1.232 , -0.9141 ,

0.1993 , -0.6373 , -0.8596 , -0.6002 ,

0.2728 , -0.7727 , 0.5039 , -0.0369 ,

1.5911 , 1.2235 , 0.7957 , 0.721 ,

-0.3143 , 0.5219 , -1.3132 , -0.6145 ,

-0.094 , -0.069 , -1.6032 , -0.1103 ,

-0.9997 , -0.5657 , -1.6381 , -0.7527 ,

0.5312 , 1.5862 , -1.0117 , -0.5722 ,

-0.2576 , -0.3961 , -0.007 , 0.553 ,

0.6994 , 1.7552 , 0.9293 , -0.0344 ,

-0.5776 , -0.2354 , 0.5929 , 0.7392 ,

-0.822 , -0.4842 , 0.5009 , -0.4434 ,

0.0285 , 0.0995 , -0.5985 , 0.2428 ), 50 , 4 , byrow=TRUE)

data <- as.data.frame(data)

colnames(data) <- c("Y", "X", "Z", "M")

# Lavaan Model for EMM

lavaan.model <- '

# Models Analyzed

M ~ aZ \* Z

Y ~ bM \* M + bX \* X + bXM \* X:M

# Mean of (Centered) Moderator

X ~ X.mean \* 1

# Variance of (Centered) Moderator

X ~~ X.var \* X

# Effects on Mediator conditional on moderator

ZtoM.SDlo := ( aZ )

ZtoM.SDhi := ( aZ )

# Indirect Effects Conditional on Moderator

indirect.SDlo := (bM + bXM \* (X.mean - sqrt(X.var))) \* ZtoM.SDlo

indirect.SDhi := (bM + bXM \* (X.mean + sqrt(X.var))) \* ZtoM.SDhi

# Index of Moderated Mediation (alternativ test for sign. differences among different moderator levels)

index.mod.med: = ( aZ ) \* bXM

# Covariance of Exogeneous Variables

X ~~ Z'

# Fit model to data

set.seed(300566)

lavaan.model.fit <- sem(model = lavaan.model,

data = data,

se = "bootstrap",

bootstrap = bootstrapN)

# Bootstrap confidence intervals

CI\_BS <- parameterEstimates(lavaan.model.fit,

boot.ci.type = "bca.simple",

level = .95, ci = TRUE,

standardized = FALSE)

# Display Results

CI\_BS

# Display Results EXAMPLE

# "lhs" "op" "rhs" "label" "est" "se" "z" "pvalue" "ci.lower" "ci.upper"

# "M" "~" "Z" "aZ" "0.3" "0.054" "5.535" "0" "0.202" "0.414"

# "Y" "~" "M" "bM" "0.3" "0.123" "2.437" "0.015" "0.074" "0.557"

# "Y" "~" "X" "bX" "0.3" "0.064" "4.665" "0" "0.174" "0.441"

# "Y" "~" "X:M" "bXM" "0.3" "0.154" "1.946" "0.052" "0.049" "0.631"

# "X" "~1" "" "X.mean" "0" "0.142" "0" "1" "-0.302" "0.272"

# "X" "~~" "X" "X.var" "0.98" "0.193" "5.08" "0" "0.651" "1.436"

# "Z" "~~" "X" "" "0.294" "0.133" "2.207" "0.027" "0.022" "0.539"

# "M" "~~" "M" "" "0.196" "0.029" "6.804" "0" "0.149" "0.256"

# "Y" "~~" "Y" "" "0.196" "0.031" "6.388" "0" "0.152" "0.286"

# "Z" "~~" "Z" "" "0.98" "0.174" "5.647" "0" "0.707" "1.469"

# "X:M" "~~" "X:M" "" "0.27" "0" NA NA "0.27" "0.27"

# "M" "~1" "" "" "0" "0.062" "0" "1" "-0.13" "0.122"

# "Y" "~1" "" "" "0" "0.065" "0" "1" "-0.143" "0.116"

# "Z" "~1" "" "" "0" "0.142" "0" "1" "-0.289" "0.265"

# "X:M" "~1" "" "" "0.088" "0" NA NA "0.088" "0.088"

# "ZtoM.SDlo" ":=" "(aZ)" "ZtoM.SDlo" "0.3" "0.054" "5.529" "0" "0.202" "0.414"

# "ZtoM.SDhi" ":=" "(aZ)" "ZtoM.SDhi" "0.3" "0.054" "5.529" "0" "0.202" "0.414"

# "indirect.SDlo" ":=" "(bM+bXM\*(X.mean-sqrt(X.var)))\*ZtoM.SDlo" "indirect.SDlo" "0.001" "0.057" "0.016" "0.987" "-0.148" "0.092"

# "indirect.SDhi" ":=" "(bM+bXM\*(X.mean+sqrt(X.var)))\*ZtoM.SDhi" "indirect.SDhi" "0.179" "0.066" "2.714" "0.007" "0.05" "0.312"

# "index.mod.med" ":=" "(aZ)\*bXM" "index.mod.med" "0.09" "0.049" "1.838" "0.066" "0.019" "0.218"

# NOTES

# 1) ZtoM.SDlo & ZtoM.SDhi are the direct effects from Z to M conditional on the moderator.

# 2) indirect.SDlo & indirect.SDhi are the indirect effects from Z to Y via M conditional on the moderator.

# 3) direct.SDlo & direct.SDhi are the direct effects from Z to Y conditional on the moderator (only shown of direct effects are included)

# 4) total.SDlo & total.SDhi are the total effects from Z to Y conditional on the moderator (only shown of direct effects are included).

# 5) prop.medtd.SDl & prop.medtd.SDh are the proportion of effects from Z to Y conditional on the moderator (only shown of direct effects are included).

# 6) index.mod.med is an alternative way of testing if conditional indirect effects are significantly different.

# Setup of lavaan models was inspired by Anthony N. Washburn (https://ademos.people.uic.edu/Chapter15.html#5\_moderated\_mediation\_analyses\_using\_"lavaan"\_package)