# Mediation and Moderation Materials

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2024-07-11

## Table of contents



```r
set.seed(10311993)
library(mediation)
library(psych)
library(tidyverse)

# Created Toy Data Set
# Variance Covariance
sigma <- rbind(c(1,-0.4,-0.3), c(-0.4,1, 0.7), c(-0.3,0.7,1))
# Variable Mean
mu <- c(7, 50, 7)
# Generate the Multivariate Normal Distribution
df <- as.data.frame(mvrnorm(n=100, mu=mu, Sigma=sigma))
df <- round(df,0)
colnames(df) <- c("mediator1","outcome","predictor")
df$condition <- rep(1:2,50)
```

## Running a Moderation Analysis in R

```r
moderation <- lm(outcome ~ condition*predictor, data = df)
summary(moderation)
```

### Line 1

Create a mediation object using the `lm()` function. The condition*predictor syntax gets you both the main effects of condition and predictor as well as the interaction effect between the two

**Line 2**

Show a summary of the moderation using the `summary()` function.

```

Call:
lm(formula = outcome ~ condition * predictor, data = df)

Residuals:
     Min       1Q   Median       3Q      Max 
-1.79555 -0.56073 -0.05061  0.55043  1.71457 

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)    
(Intercept)         44.85018    1.68125  26.677  < 2e-16 ***
condition           -0.01414    1.06533  -0.013  0.98943    
predictor            0.76026    0.23452   3.242  0.00163 ** 
condition:predictor -0.01533    0.14964  -0.102  0.91864    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.8027 on 96 degrees of freedom
Multiple R-squared:  0.5089,	Adjusted R-squared:  0.4936 
F-statistic: 33.16 on 3 and 96 DF,  p-value: 8.49e-15
```

## Running a Mediation Analysis in R

```r
#Regress M on X
outcomeM_fit <- lm(mediator1 ~ condition, data = df)
summary(outcomeM_fit)

#Regress Y on M and X
outcomeY_fit <- lm(outcome ~ mediator1 + condition, data = df)
summary(outcomeY_fit)

#Run Mediation with Bootstrap
outcome_fit <- mediation::mediate(outcomeM_fit,
                                  outcomeY_fit,
                                  treat = "condition",
                                  mediator = "mediator1",
                                  boot = TRUE,
                                  sims = 5000)
#Summary of Mediation
summary(outcome_fit)

#Path Coefficients
plot(outcome_fit)
```

**Line 2**

Run a regression of the M (mediator) on X using the `lm()` function

**Line 3**

Show output of the M on X regression using the `summary()` function

**Line 6**

Run a regression of Y on M and X using the `lm()` function

**Line 7**

Show output of the Y on M and X regression using the `summary()` function

**Lines 10-15**

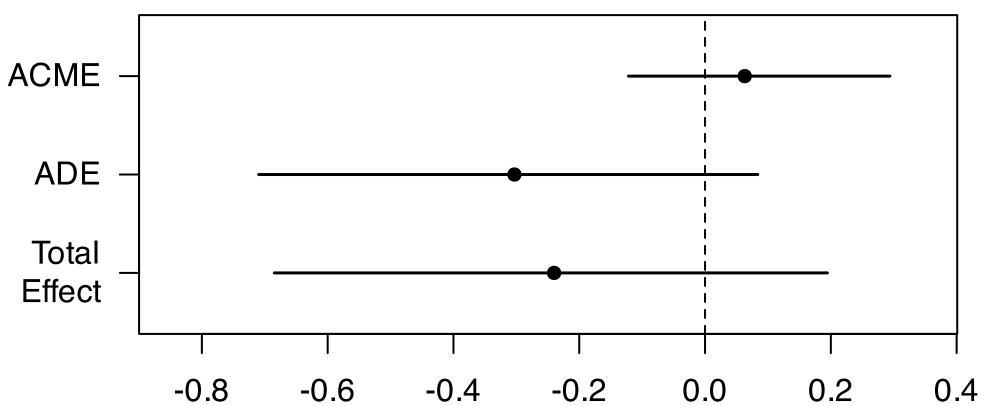
Run a mediation using the two regressions above. `treat` is the name of your X condition. `mediator` is the name of your mediating variable. Setting `boot` to `TRUE` will ensure that your mediation is bootstrapped. Lastly, the `sims` argument tells R how many samples you wish to bootstrap from. Typically you want ~ 5000 or more.

**Line 17**

For a summary of your mediation, use the `summary()` function. The indirect effect is labeled ACME

**Line 20**

The `plot()` function here will give you a graphical representation of the output above with respect to the range of the confidence interval for each metric. Please note by default this is the 95% confidence interval



```
Call:
lm(formula = mediator1 ~ condition, data = df)

Residuals:
   Min     1Q Median     3Q    Max 
-2.860 -0.755  0.140  1.140  2.280 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept)   7.0000     0.3412  20.515   <2e-16 ***
condition    -0.1400     0.2158  -0.649    0.518    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.079 on 98 degrees of freedom
Multiple R-squared:  0.004276,  Adjusted R-squared:  -0.005884 
F-statistic: 0.4209 on 1 and 98 DF,  p-value: 0.518


Call:
lm(formula = outcome ~ mediator1 + condition, data = df)

Residuals:
    Min      1Q  Median      3Q     Max 
-2.2245 -0.5522 -0.0769  0.4724  3.4724 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept) 53.53460    0.74376  71.979  < 2e-16 ***
mediator1   -0.45066    0.09569  -4.709 8.28e-06 ***
condition   -0.30309    0.20487  -1.479    0.142    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.022 on 97 degrees of freedom
Multiple R-squared:  0.1954,    Adjusted R-squared:  0.1788 
F-statistic: 11.78 on 2 and 97 DF,  p-value: 2.634e-05


Causal Mediation Analysis 

Nonparametric Bootstrap Confidence Intervals with the Percentile Method

               Estimate 95% CI Lower 95% CI Upper p-value
ACME             0.0631      -0.1217         0.29    0.52
ADE             -0.3031      -0.7098         0.08    0.12
Total Effect    -0.2400      -0.6849         0.19    0.28
```

```
Prop. Mediated  -0.2629      -6.0955         4.66    0.76

Sample Size Used: 100


Simulations: 5000
```

## Assumptions of Moderation Analyses

```
# Residual Normality
shapiro.test(residuals(moderation))

# Multicollinearity
car::vif(moderation, type = c("predictor"))

# Independence of Errors
car::durbinWatsonTest(moderation)
```

**Line 2**

Test of the residual normality of the moderation using the `shapiro.test()` function

**Line 5**

Test of the multicollinearity of the moderation analyses using the `vif()` function in the `car` package. Because there is an interaction, you must specify an additional argument of `type = c("predictor")` to properly account for the interaction effect.

**Line 8**

To test the independence of errors assumption, you can do so using the `durbinWatsonTest()` function from the `car` package.

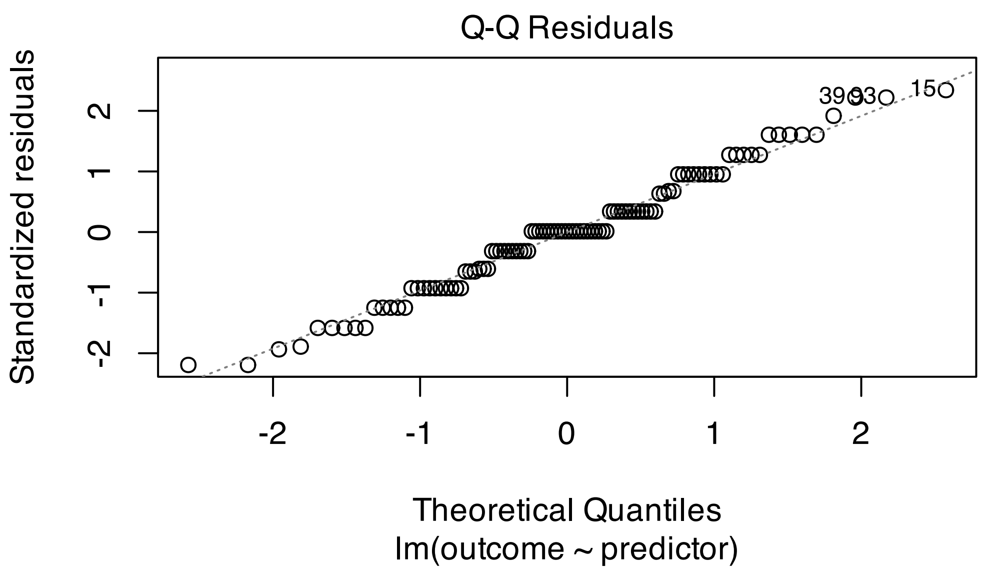
```

    Shapiro-Wilk normality test

data:  residuals(moderation)
W = 0.98684, p-value = 0.4272

          GVIF Df GVIF^(1/(2*Df)) Interacts With Other Predictors
condition    1  3               1      predictor              --
predictor    1  3               1      condition              --
 lag Autocorrelation D-W Statistic p-value
   1     -0.02268275      2.029087   0.756
 Alternative hypothesis: rho != 0
```

## Assumptions of Mediation Analyses

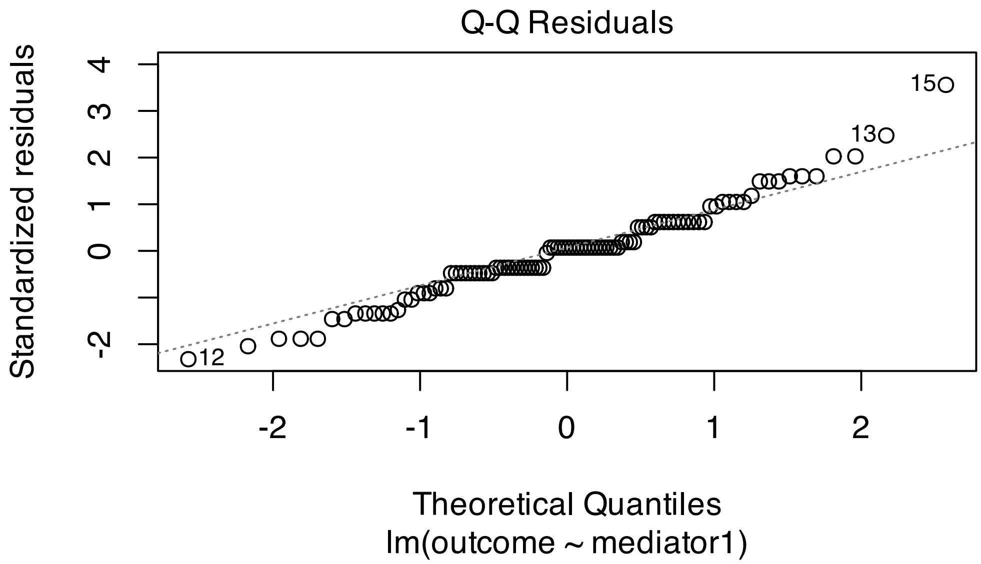
```
# Linearity
plot(lm(outcome ~ predictor, data = df),2)
```

**Line 2**

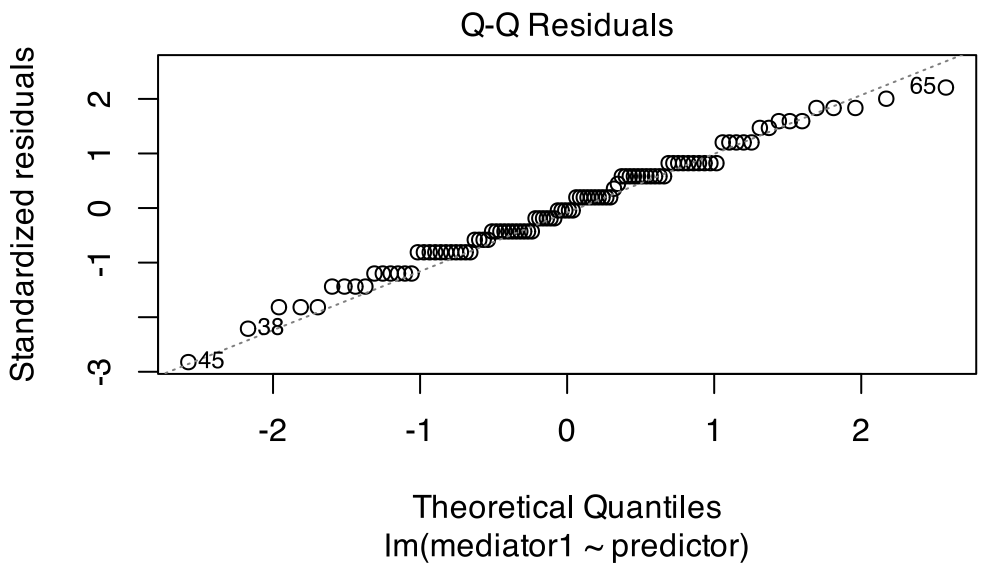
To assess multicollinearity, the best course of action is a simple correlation matrix. You can achieve this using the `cor()` function for a correlation matrix




```
plot(lm(outcome ~ mediator1, data = df),2)
```




```r
plot(lm(mediator1 ~ predictor, data = df),2)
```




```r
# Multicollinearity
cor(df)
```

```
            mediator1    outcome   predictor   condition
mediator1  1.00000000 -0.4210068 -0.38328907 -0.06539201
outcome   -0.42100683  1.0000000  0.71129322 -0.10692147
predictor -0.38328907  0.7112932  1.00000000 -0.07432941
condition -0.06539201 -0.1069215 -0.07432941  1.00000000
```

## Using Moderation and Mediation Usings Hayes PROCESS Macro (for R)

Click on the following link to download the R script for the PROCESS macro for R.

```r
source("process.R")
```

```

********************* PROCESS for R Version 4.3.1 *********************

           Written by Andrew F. Hayes, Ph.D.  www.afhayes.com
   Documentation available in Hayes (2022). www.guilford.com/p/hayes3

***********************************************************************

PROCESS is now ready for use.
Copyright 2020-2023 by Andrew F. Hayes ALL RIGHTS RESERVED
Workshop schedule at http://haskayne.ucalgary.ca/CCRAM

```

## A Moderation Example Using Hayes PROCESS Macro

```r
process(data = df,
        y = "outcome",
        x = "predictor",
        w = "mediator1",
        model = 1,
        stand = 1)
```

**Line 1**

Assign your data to the `data` argument

**Line 2**

Assign your outcome variable to the `y` argument

**Line 3**

Assign your predictor variable to the `x` argument

**Line 4**

Assign your moderator to the `w` argument

**Line 5**

Set your `model` argument to 1 for simple moderation

**Line 6**

The `stand = 1` argument standardizes your output

```
********************* PROCESS for R Version 4.3.1 *********************

           Written by Andrew F. Hayes, Ph.D.  www.afhayes.com
   Documentation available in Hayes (2022). www.guilford.com/p/hayes3

***********************************************************************

Model : 1
    Y : outcome
    X : predictor
    W : mediator1

Sample size: 100


***********************************************************************
Outcome Variable: outcome

Model Summary:
          R      R-sq       MSE         F       df1       df2         p
     0.7294    0.5320    0.6141   36.3739    3.0000   96.0000    0.0000

Model:
              coeff        se         t         p      LLCI      ULCI
constant    47.3198    3.6872   12.8336    0.0000   40.0008   54.6389
predictor    0.5567    0.5256    1.0592    0.2922   -0.4866    1.6001
mediator1   -0.2975    0.5240   -0.5676    0.5716   -1.3377    0.7427
Int_1        0.0169    0.0761    0.2222    0.8246   -0.1341    0.1679

Product terms key:
Int_1  :  predictor  x  mediator1

Test(s) of highest order unconditional interaction(s):
      R2-chng         F       df1       df2         p
X*W    0.0002    0.0494    1.0000   96.0000    0.8246

******************** ANALYSIS NOTES AND ERRORS ************************

Level of confidence for all confidence intervals in output: 95

NOTE: Standardized coefficients not available for models with moderators.
```

Tip

The Hayes PROCESS for R requires that all data is numeric in nature. As such, ensure that any potential factor variables are numeric prior to running the analyses. A failure to do so will result in PROCESS not running.

## A Mediation Example Using Hayes PROCESS Macro

```
process(data = df,
        y = "outcome",
        x = "predictor",
        m = "mediator1",
        model = 4,
        stand = 1,
        boot = 5000)
```

**Line 1**
: Assign your data to the `data` argument

**Line 2**
: Assign your outcome variable to the `y` argument

**Line 3**
: Assign your predictor variable to the `x` argument

**Line 4**
: Assign your mediator to the `m` argument

**Line 5**
: Set your `model` argument to 4 for simple mediation

**Line 6**
: The `stand = 1` argument standardizes your output

**Line 7**
: The `boot` argument specifies the number of samples you wish to bootstrap

```

********************* PROCESS for R Version 4.3.1 *********************

           Written by Andrew F. Hayes, Ph.D.  www.afhayes.com
   Documentation available in Hayes (2022). www.guilford.com/p/hayes3

***********************************************************************

Model : 4
```

```
    Y : outcome
    X : predictor
    M : mediator1

Sample size: 100

Random seed: 818206


***********************************************************************
Outcome Variable: mediator1

Model Summary:
          R      R-sq       MSE         F       df1       df2         p
     0.3833    0.1469    0.9975   16.8766    1.0000   98.0000    0.0001

Model:
              coeff        se         t         p      LLCI      ULCI
constant     9.4738    0.6609   14.3352    0.0000    8.1623   10.7852
predictor   -0.3812    0.0928   -4.1081    0.0001   -0.5654   -0.1971

Standardized coefficients:
              coeff
predictor   -0.3833

***********************************************************************
Outcome Variable: outcome

Model Summary:
          R      R-sq       MSE         F       df1       df2         p
     0.7292    0.5317    0.6081   55.0760    2.0000   97.0000    0.0000

Model:
              coeff        se         t         p      LLCI      ULCI
constant    46.5259    0.9080   51.2386    0.0000   44.7237   48.3281
predictor    0.6722    0.0784    8.5694    0.0000    0.5165    0.8279
mediator1   -0.1824    0.0789   -2.3121    0.0229   -0.3389   -0.0258

Standardized coefficients:
              coeff
predictor    0.6446
mediator1   -0.1740

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Bootstrapping progress:

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**************** DIRECT AND INDIRECT EFFECTS OF X ON Y ****************

Direct effect of X on Y:
     effect         se          t          p       LLCI       ULCI      c'_cs
     0.6722     0.0784     8.5694     0.0000     0.5165     0.8279     0.6446

Indirect effect(s) of X on Y:
             Effect     BootSE   BootLLCI   BootULCI
mediator1    0.0695     0.0353     0.0100     0.1483

Completely standardized indirect effect(s) of X on Y:
```

```
             Effect    BootSE  BootLLCI  BootULCI
mediator1    0.0667    0.0339    0.0097    0.1436

******************** ANALYSIS NOTES AND ERRORS ************************

Level of confidence for all confidence intervals in output: 95

Number of bootstraps for percentile bootstrap confidence intervals: 5000
```