

Multiple Regression: Mediation and Conditional Process Analysis

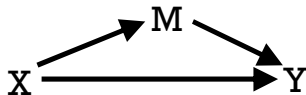
PSY 5102: Advanced Statistics for
Psychological and Behavioral Research 2

Goals

- Introduce the idea of mediation
 - Assumptions
 - Additional variables
- Introduce the idea of conditional process analysis
 - Various forms of this analysis

What is Mediation?

- Mediation is a hypothesized causal chain in which one variable (X) affects a second variable (M) which, in turn, affects a third variable (Y)



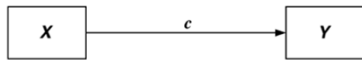
- M “mediates” the relationship between X and Y
- Mediation implies a **causal hypothesis** whereby an independent variable **causes** a mediator which, in turn, **causes** a dependent variable

Interest in Mediation

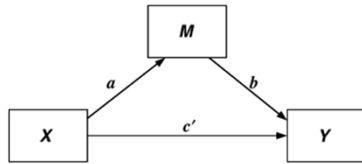
- ◉ Dramatic increase in mentions of “mediation” or “mediator” in psychology abstracts during the past few decades
- ◉ Why such interest in mediation?
 - Desire to understand the mechanisms or processes underlying behavior
 - Theoretical concerns
 - Find more proximal endpoints
 - Attempt to understand why an intervention did not work
 - Missing links
 - Compensatory processes

The Mediation Model

Panel A

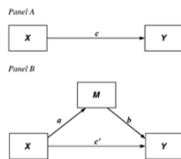


Panel B



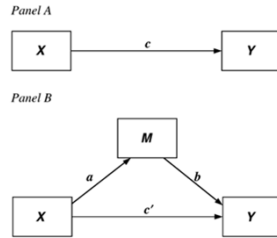
The Four Paths

- ◉ $X \rightarrow Y$: Path c
- ◉ $X \rightarrow M$: Path a
- ◉ $M \rightarrow Y$ (controlling for X): Path b
- ◉ $X \rightarrow Y$ (controlling for M): Path c'



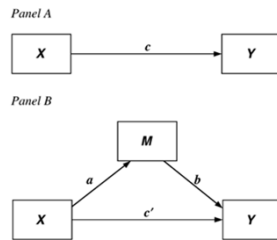
The Four Paths

Path c ($X \rightarrow Y$) is the **total effect** of X on Y



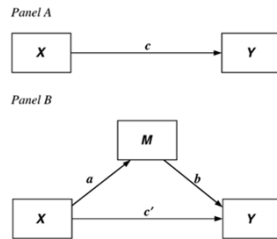
The Four Paths

Path c' ($X \rightarrow Y$) is the **direct effect** of X on Y controlling for M



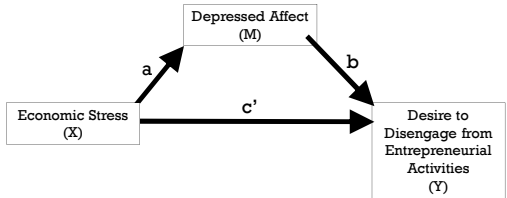
The Four Paths

The product of Path a ($X \rightarrow M$) and Path b ($M \rightarrow Y$) is the **indirect effect** of X on Y through M (i.e., $a*b$)



Example

- Pollack et al. (2012) proposed that economic stress (X) leads to a desire to disengage from entrepreneurial activities (Y) as a result of depressed affect (M)



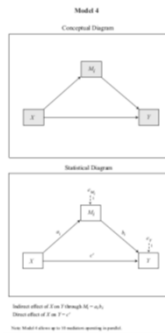
Examining Mediation Using Process

- PROCESS is a computational tool for path analysis-based moderation, mediation, and conditional process analysis (which is a combination of moderation and mediation)
- PROCESS can be downloaded from www.afhayes.com (it is free) and it can be used in conjunction with SPSS

Models from PROCESS

- PROCESS is capable of running a wide variety of analyses (there are nearly 80 models in the current version of PROCESS)

- Model 4: Simple mediation



Models from PROCESS

Model 6
(2 mediators)

Conceptual Diagram

Statistical Diagram

Indirect effect of X on Y through M1 only = a_1b_1
Indirect effect of X on Y through M1 and M2 in serial = $a_1b_1b_2$
Indirect effect of X on Y through M2 and M1 in serial = $a_2b_2b_1$
Direct effect of X on Y = c_1
Total effect of X on Y = $c_1 + a_1b_1 + a_2b_2$

Models from PROCESS

Model 6
(3 mediators)

Conceptual Diagram

Statistical Diagram

Indirect effect of X on Y through M1 only = a_1b_1
Indirect effect of X on Y through M1 and M2 in serial = $a_1b_1b_2$
Indirect effect of X on Y through M1, M2, and M3 in serial = $a_1b_1b_2b_3$
Indirect effect of X on Y through M2 and M1 in serial = $a_2b_2b_1$
Indirect effect of X on Y through M2, M3, and M1 in serial = $a_2b_2b_3b_1$
Indirect effect of X on Y through M3 and M1 in serial = $a_3b_3b_1$
Direct effect of X on Y = c_1

Models from PROCESS

Model 6
(4 mediators)

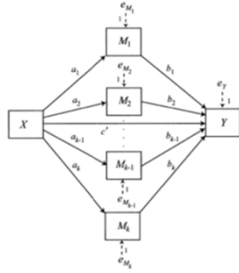
Conceptual Diagram

Statistical Diagram

Indirect effect of X on Y through M1 only = a_1b_1
Indirect effect of X on Y through M1 and M2 in serial = $a_1b_1b_2$
Indirect effect of X on Y through M1, M2, and M3 in serial = $a_1b_1b_2b_3$
Indirect effect of X on Y through M1, M2, M3, and M4 in serial = $a_1b_1b_2b_3b_4$
Indirect effect of X on Y through M2 and M1 in serial = $a_2b_2b_1$
Indirect effect of X on Y through M2, M3, and M1 in serial = $a_2b_2b_3b_1$
Indirect effect of X on Y through M3 and M1 in serial = $a_3b_3b_1$
Indirect effect of X on Y through M3, M4, and M1 in serial = $a_3b_3b_4b_1$
Indirect effect of X on Y through M4 and M1 in serial = $a_4b_4b_1$
Direct effect of X on Y = c_1

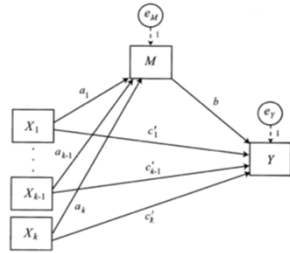
Models from PROCESS

- It is possible to run models involving multiple parallel mediators in PROCESS



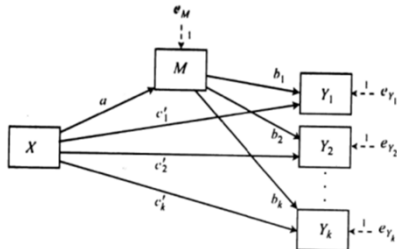
Models from PROCESS

- It is possible to run models involving multiple predictor (X) variables in PROCESS



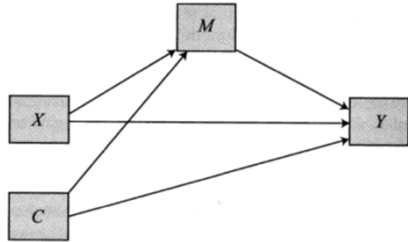
Models from PROCESS

- It is possible to run models involving multiple outcome (Y) variables in PROCESS



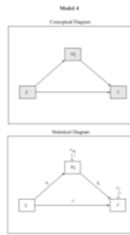
Models from PROCESS

- It is possible to run models that include one or more control (C) variables in PROCESS



Example

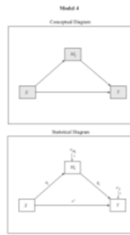
- We will start with a relatively simple example
- Model 4: Simple mediation
- Example: economic stress (X) leads to a desire to disengage from entrepreneurial activities (Y) as a result of depressed affect (M)



`process vars=stress affect withdraw/y=withdraw/x=stress/m=affect/total=1/boot=10000/normal=1/model=4`

Example

- We will start with a relatively simple example
- Model 4: Simple mediation
- Example: economic stress (X) leads to a desire to disengage from entrepreneurial activities (Y) as a result of depressed affect (M)





This part of the syntax activates PROCESS

`process vars=stress affect withdraw/y=withdraw/x=stress/m=affect/total=1/boot=10000/normal=1/model=4`

Example

- We will start with a relatively simple example
- Model 4: Simple mediation
- Example: economic stress (X) leads to a desire to disengage from entrepreneurial activities (Y) as a result of depressed affect (M)

This part of the syntax is the list of the variables that will be included in this analysis





Model 1: Conceptual Diagram
Model 4: Mediation Diagram

```
process vars=estress affect withdraw/withdraw/estress/m=affect/total=1/boot=10000/normal=1/model=4
```

Example

- We will start with a relatively simple example
- Model 4: Simple mediation
- Example: economic stress (X) leads to a desire to disengage from entrepreneurial activities (Y) as a result of depressed affect (M)

This part of the syntax identifies the outcome variable (Y)





Model 1: Conceptual Diagram
Model 4: Mediation Diagram

```
process vars=estress affect withdraw/withdraw/estress/m=affect/total=1/boot=10000/normal=1/model=4
```

Example

- We will start with a relatively simple example
- Model 4: Simple mediation
- Example: economic stress (X) leads to a desire to disengage from entrepreneurial activities (Y) as a result of depressed affect (M)

This part of the syntax identifies the predictor variable (X)

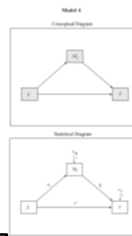


Model 1: Conceptual Diagram
Model 4: Mediation Diagram

```
process vars=estress affect withdraw/withdraw/estress/m=affect/total=1/boot=10000/normal=1/model=4
```

Example

- We will start with a relatively simple example
- Model 4: Simple mediation
- Example: economic stress (X) leads to a desire to disengage from entrepreneurial activities (Y) as a result of depressed affect (M)

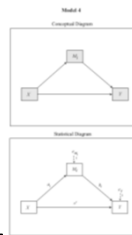


This part of the syntax identifies the mediator variable (M)

```
process vars=estress affect withdraw/y=withdraw/x=estress/m=affect/total=1/boot=10000/normal=1/model=4
```

Example

- We will start with a relatively simple example
- Model 4: Simple mediation
- Example: economic stress (X) leads to a desire to disengage from entrepreneurial activities (Y) as a result of depressed affect (M)

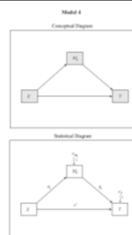


This part of the syntax requests that PROCESS generate the total effect of X on Y

```
process vars=estress affect withdraw/y=withdraw/x=estress/m=affect/total=1/boot=10000/normal=1/model=4
```

Example

- We will start with a relatively simple example
- Model 4: Simple mediation
- Example: economic stress (X) leads to a desire to disengage from entrepreneurial activities (Y) as a result of depressed affect (M)



This part of the syntax requests that PROCESS generate 10,000 bootstrap samples

```
process vars=estress affect withdraw/y=withdraw/x=estress/m=affect/total=1/boot=10000/normal=1/model=4
```

Example

- We will start with a relatively simple example
- Model 4: Simple mediation
- Example: economic stress (X) leads to a desire to disengage from entrepreneurial activities (Y) as a result of depressed affect (M)

This part of the syntax requests that PROCESS generate the normal theory-based Sobel test for the indirect effect

```
process vars=estress affect withdraw/y=withdraw/x=estress/m=affect/total=1/boot=1000(normal=1)/model=4
```

Example

- We will start with a relatively simple example
- Model 4: Simple mediation
- Example: economic stress (X) leads to a desire to disengage from entrepreneurial activities (Y) as a result of depressed affect (M)

This part of the syntax tells PROCESS to run Model 4

```
process vars=estress affect withdraw/y=withdraw/x=estress/m=affect/total=1/boot=1000(normal=1)/model=4
```

Example: Output from PROCESS

Path	Gamma	SE	p
X to M	0.5658	0.0409	<.0001
M to Y	-1.4687	0.1487	<.0001
X to Y	-0.0769	0.0534	0.0283

Sobel Test for Indirect Effect
 Indirect effect = 0.8292
 SE = 0.1824
 z = 4.5458
 p < .0001

Bootstrap CI for Indirect Effect
 Lower = 0.5457
 Upper = 1.1128
 Does not include zero

**Example:
Output from PROCESS**

This tells you which model was used

```
Model 1
1 = Outcome
2 = Mediator
3 = Predictor

Sample size: 200

----- Outcome: MEDICAL -----
Model Summary
R      0.716
F      33.808
df      1, 198
p      0.000

Coeff      SE      beta      t      p      LLCI      ULCI
Constant  0.7498  0.1433  5.2377  0.0000  0.3570  0.8824
MEDIATE1  0.1702  0.0276  6.1500  0.0000  0.1160  0.2243

Outcome: WITHDRAWAL
Model Summary
R      0.494
F      28.494
df      2, 195
p      0.000

Coeff      SE      beta      t      p      LLCI      ULCI
Constant  0.4671  0.0887  5.2625  0.0000  0.3480  0.5862
MEDIATE1  0.2465  0.0331  7.4267  0.0000  0.1840  0.3090
MEDIATE2 -0.0768  0.0324 -2.3687  0.0217 -0.1409  0.0263

----- TOTAL EFFECTS MODEL -----
Outcome: WITHDRAWAL
Model Summary
R      0.494
F      1.0714
df      1, 195
p      0.3035

Coeff      SE      beta      t      p      LLCI      ULCI
Constant  0.4671  0.0887  5.2625  0.0000  0.3480  0.5862
MEDIATE1  0.2465  0.0331  7.4267  0.0000  0.1840  0.3090
MEDIATE2  0.0561  0.0242  2.3203  0.0217 -0.0209  0.1389

----- TOTAL, DIRECT AND INDIRECT EFFECTS -----
Outcome: WITHDRAWAL
Direct effect of X on Y
Effect      SE      beta      t      p      LLCI      ULCI
MEDIATE1    0.2465  0.0331  7.4267  0.0000  0.1840  0.3090
MEDIATE2    0.0561  0.0242  2.3203  0.0217 -0.0209  0.1389

Indirect effect of X on Y
Effect      SE      beta      t      p      LLCI      ULCI
MEDIATE1    0.1702  0.0276  6.1500  0.0000  0.1160  0.2243
MEDIATE2    0.1339  0.0478  2.7943  0.0068  0.0400  0.2288

Model fit: chi-square test for indirect effect
ChiSq      df      p
MEDIATE1    0.1339  0.0478  2.7943  0.0068

----- ANALYSIS NOTES AND WARNINGS -----
Number of bootstrap samples for bias corrected bootstrap confidence intervals: 5000
Level of confidence for all confidence intervals is: alpha = 95.0000
```



**Example:
Output from PROCESS**

This tells you which variables were included in the analysis

```
Model 1
1 = Outcome
2 = Mediator
3 = Predictor

Sample size: 200

----- Outcome: MEDICAL -----
Model Summary
R      0.716
F      33.808
df      1, 198
p      0.000

Coeff      SE      beta      t      p      LLCI      ULCI
Constant  0.7498  0.1433  5.2377  0.0000  0.3570  0.8824
MEDIATE1  0.1702  0.0276  6.1500  0.0000  0.1160  0.2243

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Level of confidence for all confidence intervals is: alpha = 95.0000
```



**Example:
Output from PROCESS**

This tells you the sample size

```
Model 1
1 = Outcome
2 = Mediator
3 = Predictor

Sample size: 200

----- Outcome: MEDICAL -----
Model Summary
R      0.716
F      33.808
df      1, 198
p      0.000

Coeff      SE      beta      t      p      LLCI      ULCI
Constant  0.7498  0.1433  5.2377  0.0000  0.3570  0.8824
MEDIATE1  0.1702  0.0276  6.1500  0.0000  0.1160  0.2243

Outcome: WITHDRAWAL
Model Summary
R      0.494
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Coeff      SE      beta      t      p      LLCI      ULCI
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----- TOTAL EFFECTS MODEL -----
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Model fit: chi-square test for indirect effect
ChiSq      df      p
MEDIATE1    0.1339  0.0478  2.7943  0.0068

----- ANALYSIS NOTES AND WARNINGS -----
Number of bootstrap samples for bias corrected bootstrap confidence intervals: 5000
Level of confidence for all confidence intervals is: alpha = 95.0000
```



**Example:
Output from PROCESS**

This tells you about Path a (X → M).

Model	Path	Estimate	SE	t	p
Model Summary	R	0.176			
	R Square	0.110			
	Adjusted R Square	0.088			
Model	Constant	0.7458	0.1433	5.2077	0.0000
	ESTRESS	0.1729	0.0296	5.8308	0.0000
	AFFECT	-0.1718	0.0324	-5.2887	0.0000



**Example:
Output from PROCESS**

R² for AFFECT (M) represents the amount of variance in AFFECT (M) that is explained by ESTRESS (X). To express this value as a percentage, you should multiply this value by 100.

Model	Path	Estimate	SE	t	p
Model Summary	R	0.176			
	R Square	0.110			
	Adjusted R Square	0.088			



**Example:
Output from PROCESS**

Constant is the Y-intercept for this model.

The row for ESTRESS represents the association between ESTRESS (X) and AFFECT (M). The coefficient is .1729 with a t-value of 5.8308 and a p-value of 0.0000 which means that ESTRESS (X) has a significant positive association with AFFECT (M).

Model	Path	Estimate	SE	t	p
Model Summary	R	0.176			
	R Square	0.110			
	Adjusted R Square	0.088			
Model	Constant	0.7458	0.1433	5.2077	0.0000
	ESTRESS	0.1729	0.0296	5.8308	0.0000
	AFFECT	-0.1718	0.0324	-5.2887	0.0000



Example: Output from PROCESS

```

Model: 1
1 = WITHDRAW
2 = ESTRESS
3 = AFFECT
N = 200
Sample size: 200

-----
Outcome: WITHDRAW

Model Summary
R            F            df            SS            p
0.3402      11.748      33          288.4998      0.0000

Coefficients:
Outcome: WITHDRAW
Model: 1
Constant    0.7438      0.1433      5.2777      0.0000      0.3570      1.0884
ESTRESS    0.1752      0.0276      3.9306      0.0000      0.1189      0.2363

-----
Outcome: WITHDRAW

Model Summary
R            F            df            SS            p
0.4247      1.8294      29          238.4346      0.0000

Coefficients:
Outcome: WITHDRAW
Model: 1
Constant    0.7438      0.1433      5.2777      0.0000      0.3570      1.0884
AFFECT     -0.1752      0.0276      3.9306      0.0000      -0.1189      -0.2363

-----
Outcome: WITHDRAW

Model Summary
R            F            df            SS            p
0.5561      0.8541      1.0714      1.0000      0.3615

Coefficients:
Outcome: WITHDRAW
Model: 1
Constant    0.7438      0.1433      5.2777      0.0000      0.3570      1.0884
WITHDRAW   0.2561      0.2562      1.0303      0.3615      -0.2559      0.1499

-----
TOTAL, TOSTAT AND INDICENTY EFFECTS

Direct effect of X on Y
Effect: X
Model: 1
B          SE          CI-L         CI-U         Z          p
0.2561     0.0262     0.2033     0.3089     9.7650     0.0000

Indirect effect of X on Y
Effect: X
Model: 1
B          SE          CI-L         CI-U         Z          p
-0.2749    0.0324    -1.4667    0.1447    -8.4859    0.0000

Indirect effect of X on Y
Effect: X
Model: 1
B          SE          CI-L         CI-U         Z          p
0.1200     0.0306     0.0592     0.1808     3.9184     0.0000

Model chi-square test for indirect effect
B          SE          CI-L         CI-U         Z          p
0.1200     0.0306     0.0592     0.1808     3.9184     0.0000

-----
ANALYSIS NOTES AND WARNINGS
-----
Number of bootstrap samples for bias corrected bootstrap confidence intervals: 5000
Level of confidence for all confidence intervals is: 95.0000
    
```

This tells you about Path c' (X → Y when M is included in the model) and Path b (M → Y) which both involve WITHDRAW (Y).

Example: Output from PROCESS

```

Model: 1
1 = WITHDRAW
2 = ESTRESS
3 = AFFECT
N = 200
Sample size: 200

-----
Outcome: WITHDRAW

Model Summary
R            F            df            SS            p
0.3402      11.748      33          288.4998      0.0000

Coefficients:
Outcome: WITHDRAW
Model: 1
Constant    0.7438      0.1433      5.2777      0.0000      0.3570      1.0884
ESTRESS    0.1752      0.0276      3.9306      0.0000      0.1189      0.2363

-----
Outcome: WITHDRAW

Model Summary
R            F            df            SS            p
0.4247      1.8294      29          238.4346      0.0000

Coefficients:
Outcome: WITHDRAW
Model: 1
Constant    0.7438      0.1433      5.2777      0.0000      0.3570      1.0884
AFFECT     -0.1752      0.0276      3.9306      0.0000      -0.1189      -0.2363

-----
Outcome: WITHDRAW

Model Summary
R            F            df            SS            p
0.5561      0.8541      1.0714      1.0000      0.3615

Coefficients:
Outcome: WITHDRAW
Model: 1
Constant    0.7438      0.1433      5.2777      0.0000      0.3570      1.0884
WITHDRAW   0.2561      0.2562      1.0303      0.3615      -0.2559      0.1499

-----
TOTAL, TOSTAT AND INDICENTY EFFECTS

Direct effect of X on Y
Effect: X
Model: 1
B          SE          CI-L         CI-U         Z          p
0.2561     0.0262     0.2033     0.3089     9.7650     0.0000

Indirect effect of X on Y
Effect: X
Model: 1
B          SE          CI-L         CI-U         Z          p
-0.2749    0.0324    -1.4667    0.1447    -8.4859    0.0000

Indirect effect of X on Y
Effect: X
Model: 1
B          SE          CI-L         CI-U         Z          p
0.1200     0.0306     0.0592     0.1808     3.9184     0.0000

Model chi-square test for indirect effect
B          SE          CI-L         CI-U         Z          p
0.1200     0.0306     0.0592     0.1808     3.9184     0.0000

-----
ANALYSIS NOTES AND WARNINGS
-----
Number of bootstrap samples for bias corrected bootstrap confidence intervals: 5000
Level of confidence for all confidence intervals is: 95.0000
    
```

R² for WITHDRAW (Y) represents the amount of variance in WITHDRAW (Y) that is explained by ESTRESS (X) and AFFECT (M). To express this value as a percentage, you should multiply this value by 100.

Example: Output from PROCESS

```

Model: 1
1 = WITHDRAW
2 = ESTRESS
3 = AFFECT
N = 200
Sample size: 200

-----
Outcome: WITHDRAW

Model Summary
R            F            df            SS            p
0.3402      11.748      33          288.4998      0.0000

Coefficients:
Outcome: WITHDRAW
Model: 1
Constant    0.7438      0.1433      5.2777      0.0000      0.3570      1.0884
ESTRESS    0.1752      0.0276      3.9306      0.0000      0.1189      0.2363

-----
Outcome: WITHDRAW

Model Summary
R            F            df            SS            p
0.4247      1.8294      29          238.4346      0.0000

Coefficients:
Outcome: WITHDRAW
Model: 1
Constant    0.7438      0.1433      5.2777      0.0000      0.3570      1.0884
AFFECT     -0.1752      0.0276      3.9306      0.0000      -0.1189      -0.2363

-----
Outcome: WITHDRAW

Model Summary
R            F            df            SS            p
0.5561      0.8541      1.0714      1.0000      0.3615

Coefficients:
Outcome: WITHDRAW
Model: 1
Constant    0.7438      0.1433      5.2777      0.0000      0.3570      1.0884
WITHDRAW   0.2561      0.2562      1.0303      0.3615      -0.2559      0.1499

-----
TOTAL, TOSTAT AND INDICENTY EFFECTS

Direct effect of X on Y
Effect: X
Model: 1
B          SE          CI-L         CI-U         Z          p
0.2561     0.0262     0.2033     0.3089     9.7650     0.0000

Indirect effect of X on Y
Effect: X
Model: 1
B          SE          CI-L         CI-U         Z          p
-0.2749    0.0324    -1.4667    0.1447    -8.4859    0.0000

Indirect effect of X on Y
Effect: X
Model: 1
B          SE          CI-L         CI-U         Z          p
0.1200     0.0306     0.0592     0.1808     3.9184     0.0000

Model chi-square test for indirect effect
B          SE          CI-L         CI-U         Z          p
0.1200     0.0306     0.0592     0.1808     3.9184     0.0000

-----
ANALYSIS NOTES AND WARNINGS
-----
Number of bootstrap samples for bias corrected bootstrap confidence intervals: 5000
Level of confidence for all confidence intervals is: 95.0000
    
```

Constant is the Y-intercept for this model.

**Example:
Output from PROCESS**

The row for AFFECT represents the association between AFFECT (M) and WITHDRAW (Y). The coefficient is .7691 with a t-value of 7.4627 and a p-value of 0.0000 which means that AFFECT (M) has a significant positive association with WITHDRAW (Y).

```

Model 1
1 = WITHDRAW
2 = ESTRESS
3 = AFFECT
Sample size = 200

Outcome: AFFECT

Model Summary
R      F(1,198)    SS      MS      P
0.3601  0.1129  33.8988  33.8988  0.0000

Model
Coeff      SE      P      LLCI     ULCI
Constant  0.7938  0.1433  0.0777  0.0000  0.5170  1.0804
AFFECT    0.7691  0.0729  0.0000  0.6230  0.9150  0.9150

Outcome: WITHDRAW

Model Summary
R      F(2,196)    SS      MS      P
0.4247  0.1824  28.4246  14.2123  0.0000

Model
Coeff      SE      P      LLCI     ULCI
Constant  0.2212  0.2000  0.2820  0.0000  0.8420  0.5704
AFFECT    0.2551  0.0542  0.0000  0.1453  0.3649  0.3649
ESTRESS   -0.0768  0.0324  0.0000  -0.1409  -0.0128  0.0128

Total, Direct and Indirect Effects
Direct effect of X on Y
AFFECT    0.2551  0.0542  0.0000  0.1453  0.3649  0.3649
Indirect effect of X on Y
ESTRESS   -0.0768  0.0324  0.0000  -0.1409  -0.0128  0.0128
Total effect of X on Y
AFFECT    0.1783  0.0324  0.0000  0.1144  0.2433  0.2433

Model Change Tests for Indirect Effect
Effect      SE      P
AFFECT     0.1339  0.0076  0.0000

Number of bootstrap samples for bias corrected bootstrap confidence intervals = 5000
Level of confidence for all confidence intervals is output = 95.0000
  
```



**Example:
Output from PROCESS**

The row for ESTRESS represents the association between ESTRESS (X) and WITHDRAW (Y). The coefficient is -0.0768 with a t-value of -1.4667 and a p-value of 0.1437 which means that ESTRESS (X) does not have a significant association with WITHDRAW (Y) when AFFECT (M) is included in the model.

```

Model 1
1 = WITHDRAW
2 = ESTRESS
3 = AFFECT
Sample size = 200

Outcome: AFFECT

Model Summary
R      F(1,198)    SS      MS      P
0.3601  0.1129  33.8988  33.8988  0.0000

Model
Coeff      SE      P      LLCI     ULCI
Constant  0.7938  0.1433  0.0777  0.0000  0.5170  1.0804
AFFECT    0.7691  0.0729  0.0000  0.6230  0.9150  0.9150

Outcome: WITHDRAW

Model Summary
R      F(2,196)    SS      MS      P
0.4247  0.1824  28.4246  14.2123  0.0000

Model
Coeff      SE      P      LLCI     ULCI
Constant  0.2212  0.2000  0.2820  0.0000  0.8420  0.5704
AFFECT    0.2551  0.0542  0.0000  0.1453  0.3649  0.3649
ESTRESS   -0.0768  0.0324  0.0000  -0.1409  -0.0128  0.0128

Total, Direct and Indirect Effects
Direct effect of X on Y
ESTRESS   -0.0768  0.0324  0.0000  -0.1409  -0.0128  0.0128
Indirect effect of X on Y
AFFECT    0.1783  0.0324  0.0000  0.1144  0.2433  0.2433
Total effect of X on Y
ESTRESS   0.1015  0.0324  0.0000  0.0435  0.1591  0.1591

Model Change Tests for Indirect Effect
Effect      SE      P
ESTRESS    0.1339  0.0076  0.0000

Number of bootstrap samples for bias corrected bootstrap confidence intervals = 5000
Level of confidence for all confidence intervals is output = 95.0000
  
```



**Example:
Output from PROCESS**

This tells you about Path c (X → Y when M is not included in the model).

```

Model 1
1 = WITHDRAW
2 = ESTRESS
3 = AFFECT
Sample size = 200

Outcome: AFFECT

Model Summary
R      F(1,198)    SS      MS      P
0.3601  0.1129  33.8988  33.8988  0.0000

Model
Coeff      SE      P      LLCI     ULCI
Constant  0.7938  0.1433  0.0777  0.0000  0.5170  1.0804
AFFECT    0.7691  0.0729  0.0000  0.6230  0.9150  0.9150

Outcome: WITHDRAW

Model Summary
R      F(2,196)    SS      MS      P
0.4247  0.1824  28.4246  14.2123  0.0000

Model
Coeff      SE      P      LLCI     ULCI
Constant  0.2212  0.2000  0.2820  0.0000  0.8420  0.5704
AFFECT    0.2551  0.0542  0.0000  0.1453  0.3649  0.3649
ESTRESS   -0.0768  0.0324  0.0000  -0.1409  -0.0128  0.0128

Total, Direct and Indirect Effects
Direct effect of X on Y
ESTRESS   -0.0768  0.0324  0.0000  -0.1409  -0.0128  0.0128
Indirect effect of X on Y
AFFECT    0.1783  0.0324  0.0000  0.1144  0.2433  0.2433
Total effect of X on Y
ESTRESS   0.1015  0.0324  0.0000  0.0435  0.1591  0.1591

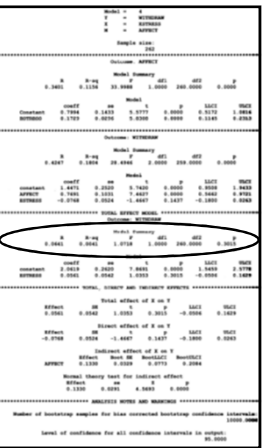
Model Change Tests for Indirect Effect
Effect      SE      P
ESTRESS    0.1339  0.0076  0.0000

Number of bootstrap samples for bias corrected bootstrap confidence intervals = 5000
Level of confidence for all confidence intervals is output = 95.0000
  
```



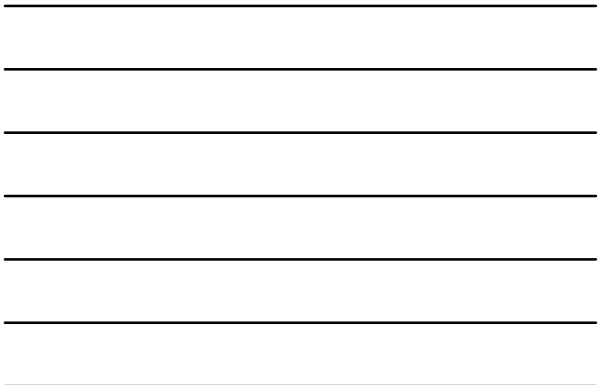
Example: Output from PROCESS

R² for the TOTAL EFFECT MODEL represents the amount of variance in WITHDRAW (Y) that is explained by ESTRESS (X) when AFFECT (M) is not included in the model. To express this value as a percentage, you should multiply this value by 100.



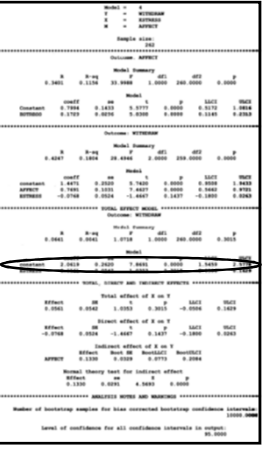
The screenshot shows the PROCESS macro output. The 'TOTAL EFFECT MODEL' section includes a table with the following data:

Model	R ²	F	df1	df2	p
1	0.061	1.138	33	2668	0.290



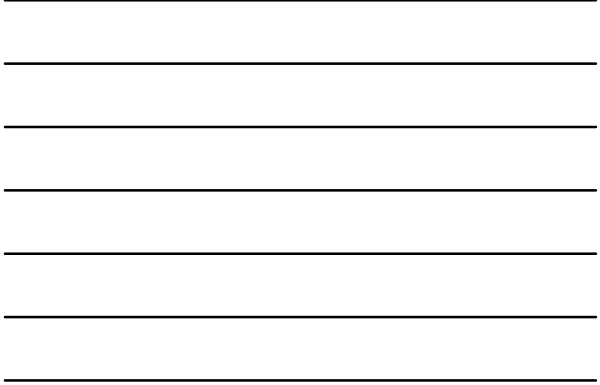
Example: Output from PROCESS

Constant is the Y-intercept for this model.



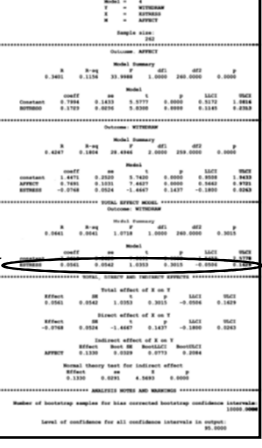
The screenshot shows the PROCESS macro output. The 'TOTAL EFFECT MODEL' section includes a table with the following data:

Model	Constant	Estress	Affect	Withdraw
1	2.192	0.056	0.000	0.301



Example: Output from PROCESS

The row for ESTRESS represents the association between ESTRESS (X) and WITHDRAW (Y). The coefficient is 0.0561 with a t-value of 1.0353 and a p-value of 0.3015 which means that ESTRESS (X) does not have a significant association with WITHDRAW (Y) even when AFFECT (M) is NOT included in the model.



The screenshot shows the PROCESS macro output. The 'TOTAL EFFECT MODEL' section includes a table with the following data:

Model	Estress	Affect	Withdraw
1	0.056	0.000	0.301



Example: Output from PROCESS

This provides a summary of the TOTAL EFFECT of X on Y (c), the DIRECT EFFECT of X on Y (c'), and the INDIRECT EFFECT of X on Y (a*b).

TOTAL EFFECT
Path c (X → Y without M in model) = .0561

DIRECT EFFECT
Path c' (X → Y with M in model) = -.0768

INDIRECT EFFECT
Path a (X → M) = .1729
Path b (M → Y) = .7691
Path a*b = (.1729)(.7691) = .1330

The INDIRECT EFFECT is significant because it has a 95% confidence interval that does not contain 0 (BootLLCI = .0773, BootULCI = .2084) which is consistent with the normal theory-based Sobel test (Z = 4.5693, p = .0000).

Model = 4
X = ENTREPRENEURIAL ACTIVITY
M = DEPRESSIVE AFFECT
Y = DESIRE TO DISENGAGE FROM ENTREPRENEURIAL ACTIVITIES
Sample size = 250

Model Summary
R = 0.196
F = 33.8088
df = 1, 248
p < .0001

Model
Coeff. SE
Constant 0.1998 0.1453 0.2377 0.0005 0.2570 0.0004
ENTREPRE 0.1729 0.0230 7.5205 0.0000 0.1489 0.0000
DEPRESSIVE -0.1729 0.0230 -7.4827 0.0000 -0.1489 0.0000

Model Summary
R = 0.497
F = 28.4545
df = 2, 248
p < .0001

Model
Coeff. SE
Constant 0.1998 0.1453 0.2377 0.0005 0.2570 0.0004
ENTREPRE 0.1729 0.0230 7.5205 0.0000 0.1489 0.0000
DEPRESSIVE -0.1729 0.0230 -7.4827 0.0000 -0.1489 0.0000

Model Summary
R = 0.494
F = 27.9718
df = 1, 248
p < .0001

Model
Coeff. SE
Constant 0.1998 0.1453 0.2377 0.0005 0.2570 0.0004
ENTREPRE 0.0431 0.0232 1.8543 0.0653 -0.0593 0.1499

TOTAL EFFECT OF X ON Y
Effect SE
Total 0.0561 0.0172 0.3252 0.0000 0.0218 0.0000

INDIRECT EFFECT OF X ON Y
Effect SE
a 0.1729 0.0230 7.5205 0.0000 0.1489 0.0000
b -0.1729 0.0230 -7.4827 0.0000 -0.1489 0.0000
a*b 0.1330 0.0308 4.3173 0.0000 0.0684 0.0000

INDIRECT EFFECT OF X ON Y
Model Summary
R = 0.494
F = 27.9718
df = 1, 248
p < .0001

Model
Coeff. SE
Constant 0.1998 0.1453 0.2377 0.0005 0.2570 0.0004
ENTREPRE 0.0431 0.0232 1.8543 0.0653 -0.0593 0.1499

Number of bootstrap samples for bias corrected bootstrap confidence intervals = 10000

Level of confidence for all confidence intervals is alpha = .05

Example: Output from PROCESS

This tells you that PROCESS used 10,000 bootstrap samples to estimate the 95% confident intervals for the indirect effect of X on Y.

Model = 4
X = ENTREPRENEURIAL ACTIVITY
M = DEPRESSIVE AFFECT
Y = DESIRE TO DISENGAGE FROM ENTREPRENEURIAL ACTIVITIES
Sample size = 250

Model Summary
R = 0.196
F = 33.8088
df = 1, 248
p < .0001

Model
Coeff. SE
Constant 0.1998 0.1453 0.2377 0.0005 0.2570 0.0004
ENTREPRE 0.1729 0.0230 7.5205 0.0000 0.1489 0.0000
DEPRESSIVE -0.1729 0.0230 -7.4827 0.0000 -0.1489 0.0000

Model Summary
R = 0.497
F = 28.4545
df = 2, 248
p < .0001

Model
Coeff. SE
Constant 0.1998 0.1453 0.2377 0.0005 0.2570 0.0004
ENTREPRE 0.1729 0.0230 7.5205 0.0000 0.1489 0.0000
DEPRESSIVE -0.1729 0.0230 -7.4827 0.0000 -0.1489 0.0000

Model Summary
R = 0.494
F = 27.9718
df = 1, 248
p < .0001

Model
Coeff. SE
Constant 0.1998 0.1453 0.2377 0.0005 0.2570 0.0004
ENTREPRE 0.0431 0.0232 1.8543 0.0653 -0.0593 0.1499

TOTAL EFFECT OF X ON Y
Effect SE
Total 0.0561 0.0172 0.3252 0.0000 0.0218 0.0000

INDIRECT EFFECT OF X ON Y
Effect SE
a 0.1729 0.0230 7.5205 0.0000 0.1489 0.0000
b -0.1729 0.0230 -7.4827 0.0000 -0.1489 0.0000
a*b 0.1330 0.0308 4.3173 0.0000 0.0684 0.0000

INDIRECT EFFECT OF X ON Y
Model Summary
R = 0.494
F = 27.9718
df = 1, 248
p < .0001

Model
Coeff. SE
Constant 0.1998 0.1453 0.2377 0.0005 0.2570 0.0004
ENTREPRE 0.0431 0.0232 1.8543 0.0653 -0.0593 0.1499

Number of bootstrap samples for bias corrected bootstrap confidence intervals = 10000

Level of confidence for all confidence intervals is alpha = .05

Reporting the Results of a Mediation Analysis

- From a simple mediation analysis conducted using ordinary least squares path analysis, economic stress indirectly influenced the desire to disengage from entrepreneurial activities through its association with depressive affect. Participants who reported higher levels of economic stress reported higher levels of depressive affect ($a = 0.17, p < .001$) and participants who experienced higher levels of depressive affect also reported a greater desire to disengage from entrepreneurial activities ($b = .77, p < .001$). A bootstrap confidence interval for the indirect effect ($ab = .13$) based on 10,000 bootstrap samples was entirely above zero (.08 to .21) which indicates that depressive affect mediated the association between economic stress and the desire to disengage from entrepreneurial activities ($Z = 4.57, p < .001$). There was no evidence that economic stress was associated with the desire to disengage from entrepreneurial activities independent of its association with depressive affect ($c' = .06, p = .30$).

Bootstrap Confidence Interval

- ◎ PROCESS uses a bootstrapping approach to estimate the confidence interval for the indirect effect
- ◎ Steps for constructing the bootstrap confidence interval
 1. Take a random sample of n cases from the original sample (sampled with replacement) where n is the size of the original sample. This is called a bootstrap sample.
 2. Estimate the indirect effect ($a*b$) in this bootstrap sample.
 3. Repeat Steps 1 and 2 a total of k times (k is usually a large number such as 10,000) saving the value of $a*b$ for each bootstrap sample.
 4. Sort the k indirect effects ($a*b$) from each bootstrap sample from low to high.
 5. Find the lower bound and upper bound of the 95% confidence interval.
 6. If the 95% confidence interval does not contain 0, then the indirect effect is significant (i.e., mediation is supported).

Previous Approaches to Mediation

- ◎ The most popular approach to mediation in the past was **the causal steps approach** which is also referred to as **the Baron and Kenny approach**
- ◎ Problems with the Baron and Kenny approach...
 1. It does not formally quantify the indirect effect nor does it require an inferential test about the indirect effect.
 2. The ability to claim that M is a mediator depends of rejecting three null hypotheses (Path c , Path a , and Path b) which makes it a relatively low power approach for detecting indirect effects.
 3. The failure to find a significant Path c ($X \rightarrow Y$) is a stopping point (i.e., this approach argues that it is impossible to mediate an association that is not significant) but this logic is flawed. There are many situations in which mediation may occur even when the total effect ($X \rightarrow Y$) appears to be 0. For example, if there are two mediators where the association through one mediator is positive and the association through the other mediator is negative, then it may lead to a situation where the total effect is 0.
 4. This approach does not quantify the indirect effect so it encourages researchers to think about indirect effects in qualitative terms (e.g., no mediation, partial mediation, full mediation).

Conditional Process Analysis

- ◎ Conditional process analysis is used when the analytical goal is to describe and understand the conditional nature of the mechanism (or mechanisms) by which a variable transmits its effect on another
 - This is a blend of **moderation** ("conditional nature") and **mediation** ("the mechanism [or mechanisms] by which a variable transmits its effect on another")
 - This has been referred to by labels such as **moderated mediation** and **mediated moderation**
- ◎ The mechanism linking X to Y can be said to be conditional if the indirect effect of X on Y through M is contingent on a moderator

Models from PROCESS

- PROCESS is capable of running a wide variety of conditional process analyses
- Model 7: Moderator of $X \rightarrow M$

Model 7

Conceptual Diagram

Statistical Diagram

Conditional indirect effect of X on Y through $M = \gamma_1 \beta_4 = \gamma_1 \beta_4 \beta_2$
 Direct effect of X on $Y = \gamma_2$

Note: Model 7 allows up to 11 moderation settings to be tested.

Models from PROCESS

- Model 8: Moderator of $X \rightarrow M$ and $X \rightarrow Y$

Model 8

Conceptual Diagram

Statistical Diagram

Conditional indirect effect of X on Y through $M = \gamma_1 \beta_4 = \gamma_1 \beta_4 \beta_2$
 Conditional direct effect of X on $Y = \gamma_2 + \gamma_1 \beta_4$

Note: Model 8 allows up to 11 moderation settings to be tested.

Models from PROCESS

- Model 9: Two moderators of $X \rightarrow M$

Model 9

Conceptual Diagram

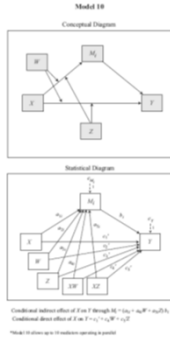
Statistical Diagram

Conditional indirect effect of X on Y through $M = \gamma_1 \beta_4 = \gamma_1 \beta_4 \beta_2$
 Direct effect of X on $Y = \gamma_2$

Note: Model 9 allows up to 11 moderation settings to be tested.

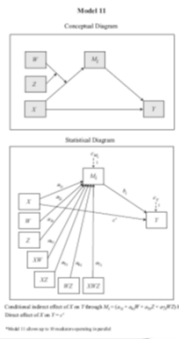
Models from PROCESS

- Model 10: Two moderators of $X \rightarrow M$ and $X \rightarrow Y$



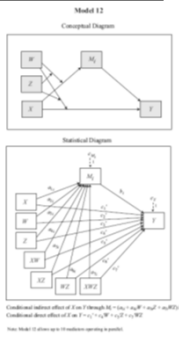
Models from PROCESS

- Model 11: Two moderators of $X \rightarrow M$ that include the three-way interaction ($X*W*Z$)



Models from PROCESS

- Model 12: Two moderators of $X \rightarrow M$ and $X \rightarrow Y$ that include the three-way interactions ($X*W*Z$)



Models from PROCESS

Model 14: Moderators of $M \rightarrow Y$

Conceptual Diagram

Statistical Diagram

Conditional indirect effect of X on Y through M : $a_1b_1 = a_1b_1$
 Direct effect of X on Y : a_2
*Model 14 allows up to 10 random opening in parallel

Models from PROCESS

Model 17: Two moderators of $M \rightarrow Y$ and $X \rightarrow Y$

Conceptual Diagram

Statistical Diagram

Conditional indirect effect of X on Y through M : $a_1b_1 = a_1b_1$
 Conditional direct effect of X on Y : $a_2 + a_2W + a_2Z$
*Model 17 allows up to 10 random opening in parallel

Models from PROCESS

Model 24: Two moderators of $X \rightarrow M$ and $X \rightarrow Y$ and a third moderator of $M \rightarrow Y$

Conceptual Diagram

Statistical Diagram

Conditional indirect effect of X on Y through M : $a_1b_1 = a_1b_1$
 Conditional direct effect of X on Y : $a_2 + a_2W + a_2Z$
*Model 24 allows up to 10 random opening in parallel

Models from PROCESS

- Model 45: Two moderators of $X \rightarrow M$ and two moderators of $M \rightarrow Y$

Model 45
Conceptual Diagram

Model 45
Statistical Diagram

Conditional indirect effect of X on Y through M: $\gamma_1 + \gamma_2 W + \gamma_3 Z$
 Conditional direct effect of X on Y: $\beta_1 + \beta_2 V + \beta_3 Q$
 Model fit statistics: $\chi^2(1) = 0.00, p = 0.96, CFI = 0.99, RMSEA = 0.00$

Models from PROCESS

- Model 57: Two moderators of $X \rightarrow M$ and $X \rightarrow Y$ that include the three-way interactions ($X*W*Z$) and two moderators of $M \rightarrow Y$ and $X \rightarrow Y$ that include the three-way interactions ($X*V*Q$)

Model 57
Conceptual Diagram

Model 57
Statistical Diagram

Conditional indirect effect of X on Y through M: $\gamma_1 + \gamma_2 W + \gamma_3 Z$
 Conditional direct effect of X on Y: $\delta_1 + \delta_2 V + \delta_3 Q$
 Model fit statistics: $\chi^2(1) = 0.00, p = 0.96, CFI = 0.99, RMSEA = 0.00$

Models from PROCESS

- Model 59: A moderator of $X \rightarrow M$, $M \rightarrow Y$, and $X \rightarrow Y$

Model 59
Conceptual Diagram

Model 59
Statistical Diagram

Conditional indirect effect of X on Y through M: $\gamma_1 + \gamma_2 W$
 Conditional direct effect of X on Y: $\delta_1 + \delta_2 W$
 Model fit statistics: $\chi^2(1) = 0.00, p = 0.96, CFI = 0.99, RMSEA = 0.00$
