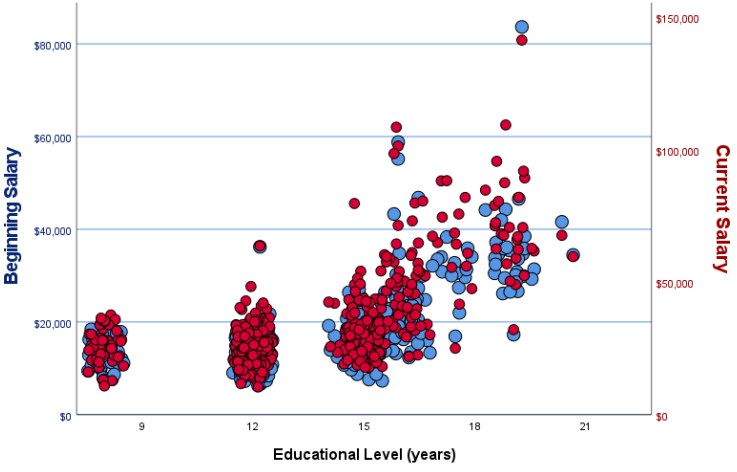
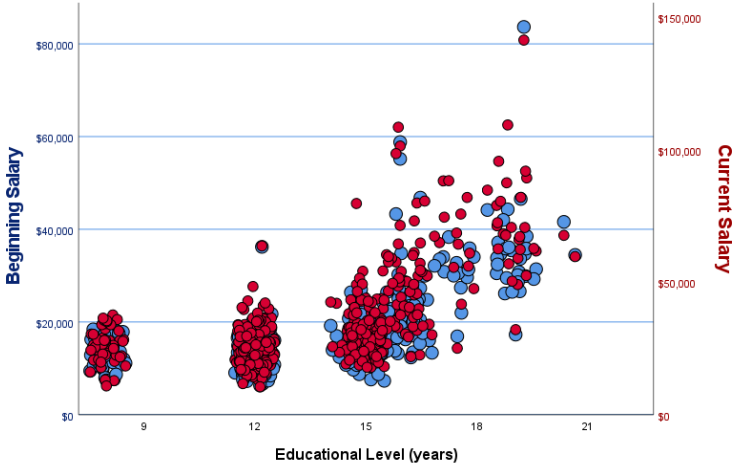


Understanding interactions and mechanisms using Moderation and Mediation Analysis

Jarlath Quinn



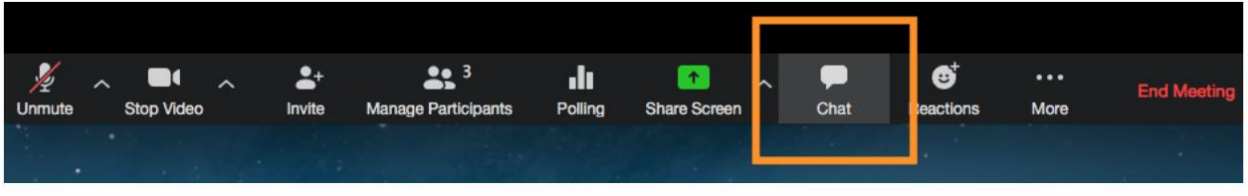
Just waiting for all attendees to join…

Understanding interactions and mechanisms using Moderation and Mediation Analysis

Jarlath Quinn

FAQ's

- Is this session being recorded? Yes
- Can I get a copy of the slides? Yes, we'll email links to download materials after the session has ended.
- Can we arrange a re-run for colleagues? Yes, just ask us.
- How can I ask questions? All lines are muted so please use the chat panel – if we run out of time we will follow up with you.

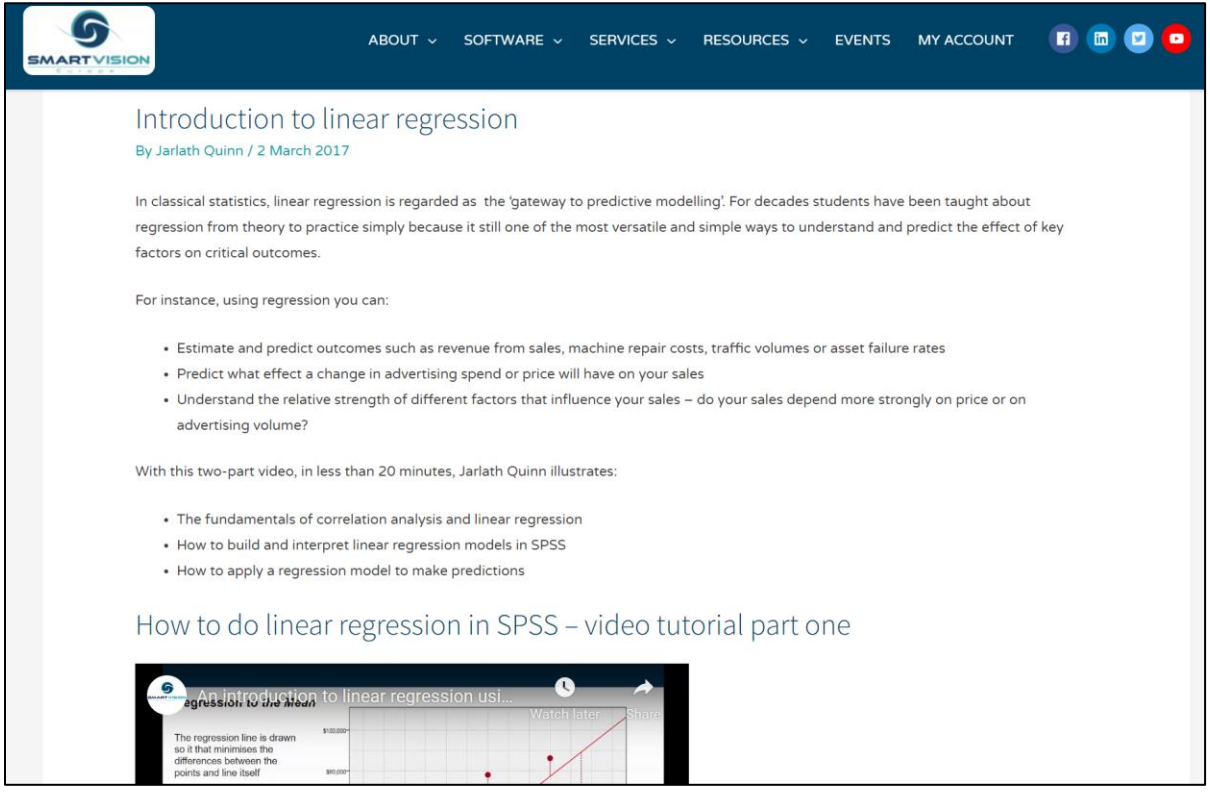


- Gold accredited partner to IBM, Predictive Solutions and DataRobot specialising in advanced analytics & AI technologies
- Work with open-source technologies (R, Python etc.)
- Team each has 15 to 30+ years of experience working in the advanced and predictive analytics industry

- Deep experience of applied advanced analytics applications across sectors
  - Retail
  - Healthcare/Pharma
  - Finance/Insurance
  - Media/Telecoms
  - Utilities
  - FMCG
  - Charity/Housing/Government

Prerequisites to this webinar: Understanding Linear Regression

- https://www.sv-europe.com/blog/introduction-to-linear-regression/



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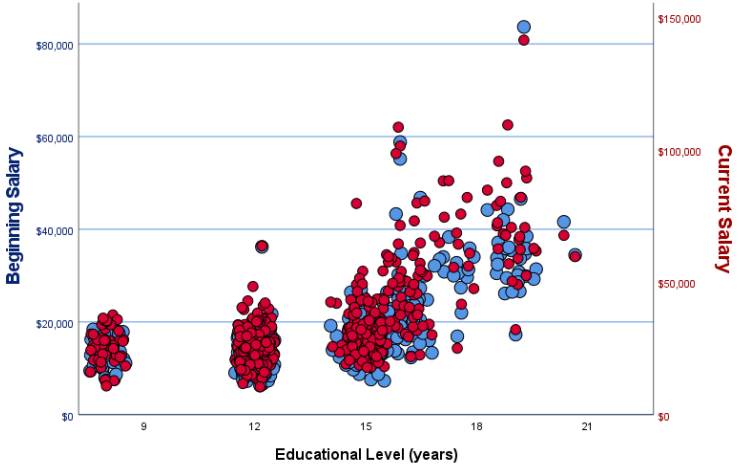

Moderation and Mediation Analysis

Why are Moderation and Mediation analyses useful?

- In multiple linear regression we are often concerned with questions like "Does X predict Y after controlling for other variables?"
- In such situations, the coefficients tell you the *average effect* of each predictor holding others constant.
- Moderation and Mediation analysis drive **deeper** insights: allowing to you to find out *when* something is related (moderation) and *how* it is related (mediation).
- **Moderation** analysis is usually multiple linear regression including an **interaction** term.
- **Mediation** analysis is akin to multiple linear regression done in steps to test a *pathway* (X → M → Y)

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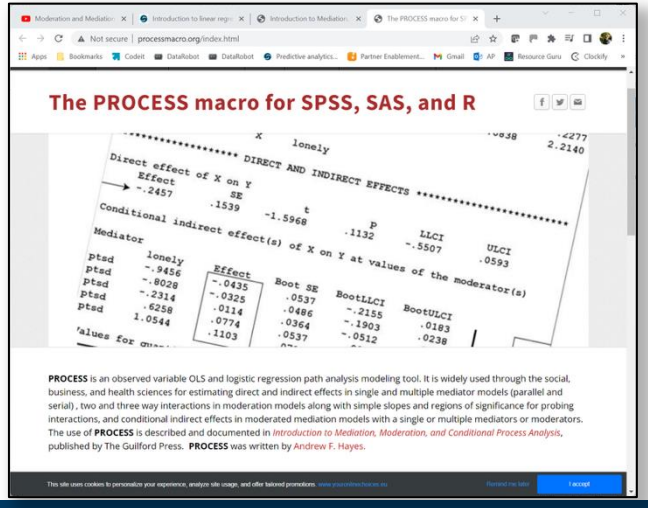


Installing Moderation and Mediation Analysis for IBM SPSS Statistics

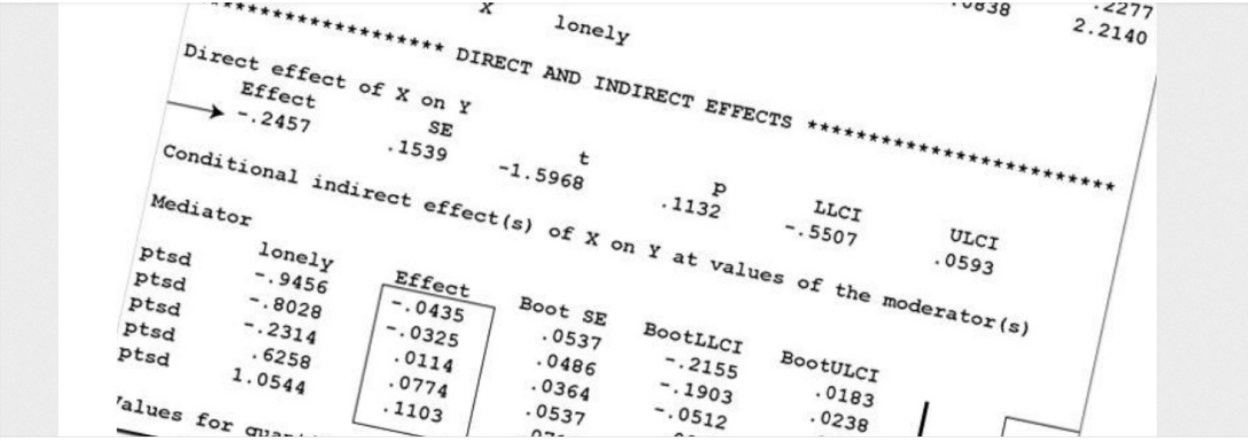
Installing Moderation and Mediation Analysis in IBM SPSS Statistics

- Moderation and Mediation Analysis is NOT available as standard functionality in SPSS Statistics.
- Fortunately, it *is* available as a free downloadable package developed by Andrew F. Hayes Ph.D.
- Dr Hayes, created a package for SPSS (and other statistical software) called PROCESS, and includes instructions on how install the software which can be found here:
- http://www.processmacro.org/

The processmacro.org website

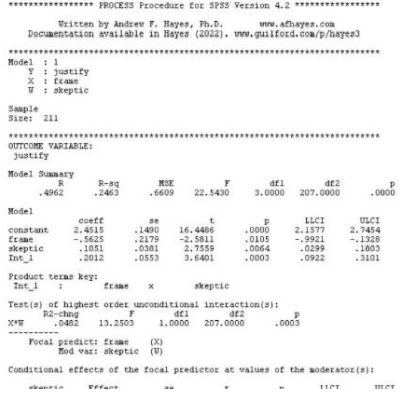
HOME | DOWNLOAD | WORKSHOPS | PAPERS | FAQ | VERSION HISTORY

The PROCESS macro for SPSS, SAS, and R



PROCESS is a regression-based modeling tool. It is widely used through the social, business, and health sciences for estimating direct and indirect effects in single and multiple mediator models (parallel and serial) , two and three way interactions in moderation models along with simple slopes and regions of significance for probing interactions, and conditional indirect effects in moderated mediation models with a single or multiple mediators or moderators. New features for ordinary regression analysis as dealing with random measurement error in

Computational Tools and Aids



```
********** PROCESS Procedure for SPSS Version 4.2 **********

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

**************************************************************************
Model  : 1
    Y  : justify
    X  : frame
    W  : skeptic

Sample
Size:  211

**************************************************************************
OUTCOME VARIABLE:
 justify

Model Summary
          R       R-sq        MSE          F        df1        df2          p
      .4962      .2463      .6609    22.5430     3.0000   207.0000      .0000

Model
              coeff         se          t          p       LLCI       ULCI
constant     2.4515      .1490    16.4486     .0000     2.1577     2.7454
frame        -.5625      .2179    -2.5811     .0105     -.9921     -.1328
skeptic       .1051      .0381     2.7559     .0064      .0299      .1803
Int_1         .2012      .0553     3.6401     .0003      .0922      .3101

Product terms key:
 Int_1    :        frame    x        skeptic

Test(s) of highest order unconditional interaction(s):
       R2-chng          F        df1        df2          p
X*W      .0482     13.2503     1.0000   207.0000      .0003
----------
    Focal predict: frame    (X)
          Mod var: skeptic  (W)

Conditional effects of the focal predictor at values of the moderator(s):
```

PROCESS macro for SPSS, SAS, and R

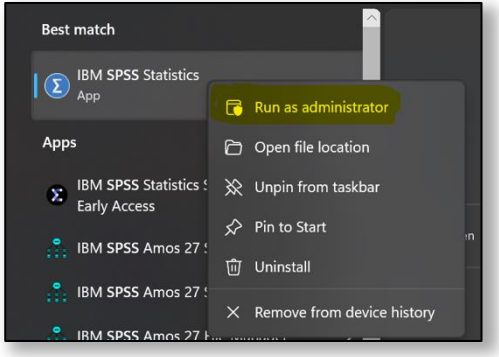
PROCESS is a computational tool invented by CCRAM expert Andrew F. Hayes. It is freely-available for SPSS, SAS, and R, and has become widely used throughout the behavioral sciences as well as in business research, medicine, and public health for easing the estimation of effects in mediation, moderation, and conditional process analysis.

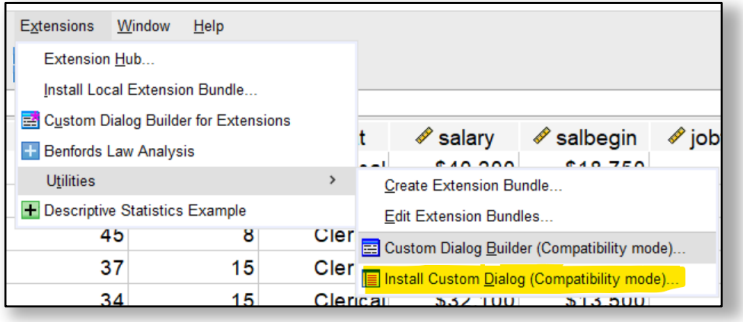
Version 5.0 is now available! The SPSS version of PROCESS v5.0 requires SPSS version 26 or later. The SPSS GUI for PROCESS v5.0 is now an extensions file (*.spe) rather than a custom dialog builder file (.spv).

Take a class on the use of PROCESS | Download PROCESS v5.0

Steps to install the PROCESS dialog

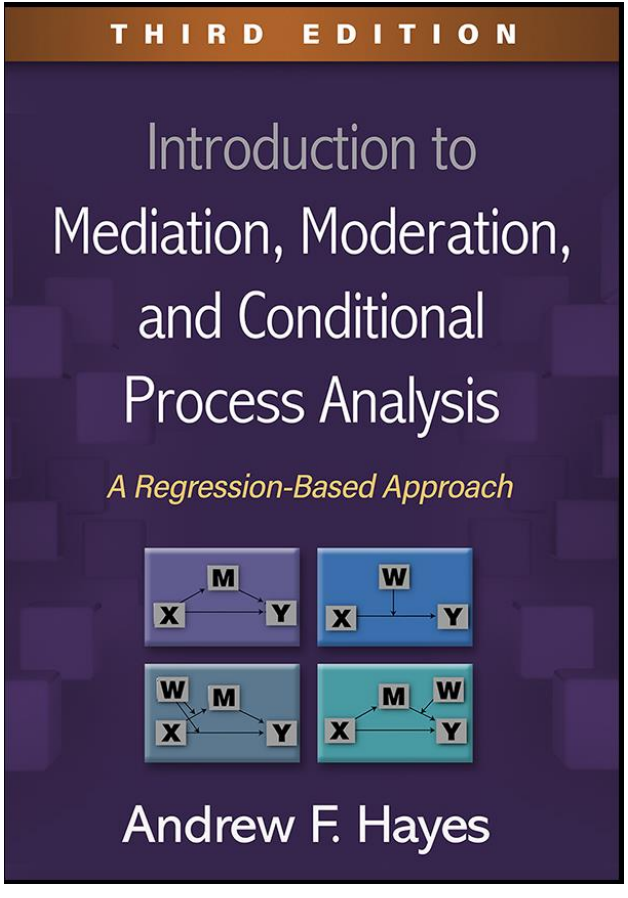
1. Download the **Process** zip file (http://www.processmacro.org)
2. Unzip the file in a location of your choice
3. Start SPSS in **Run as Administrator** mode (right-click the icon)
4. Within SPSS, go to
   - **Extensions > Utilities > Install Custom Dialog**
5. To use the new procedure, navigate to
   - **Analyze > Regression > PROCESS**





Recommended Reading

- Andrew F. Hayes illustrates each step in an analysis using diverse examples from published studies, and displays SPSS, SAS, and R code for each example.
- Procedures are outlined for estimating and interpreting direct, indirect, and conditional effects; probing and visualizing interactions; testing hypotheses about the moderation of mechanisms; and reporting different types of analyses.
- Readers gain an understanding of the link between statistics and causality, as well as what the data are telling them.



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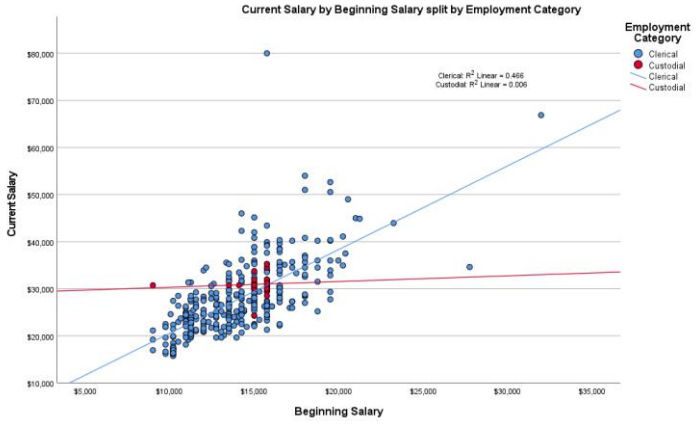
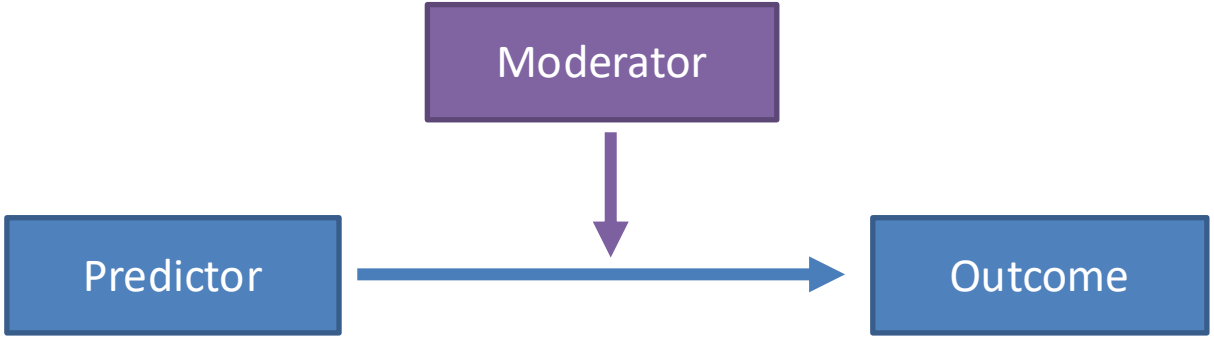


Understanding Moderation Analysis

Moderation Analysis

- A moderating variable is one that interacts with a key independent variable to **amplify** or **dampen** the relationship between the independent and dependent variables
- A moderator variable *contextualises* an effect by changing the relationship between an independent variable and a dependent variable. Moderating effects are also referred to as interaction terms.
- A moderator **is not *caused*** by an independent variable
- Examples:
  - Does time in employment affect salary progression? Is this relationship moderated by gender?
  - Does study amount affect your essay score? Is this moderated by sleep quality?
  - Does advertising spend affect sales? Is this relationship different by quarter?

Moderation Analysis - Graphical Form



Moderation Analysis - Statistical Form

- Y – Dependent Variable
- X – Independent Variable
- M – Moderator Variable
- X*M – Interaction between independent and moderator variable

Dependent Constant Independent Moderator Interaction

$$Y = b_0 + b_1X + b_2M + b_3XM$$

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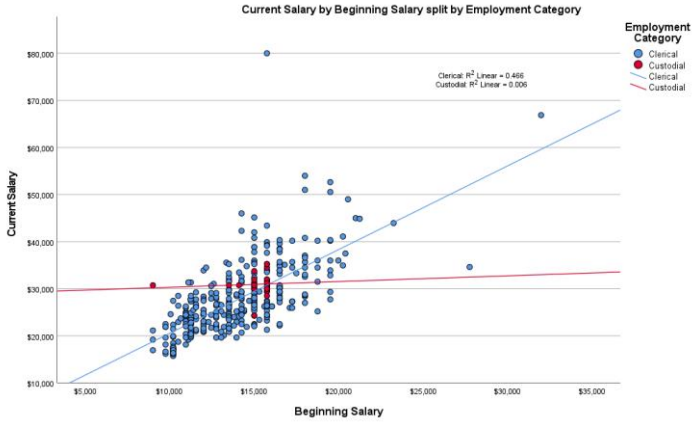
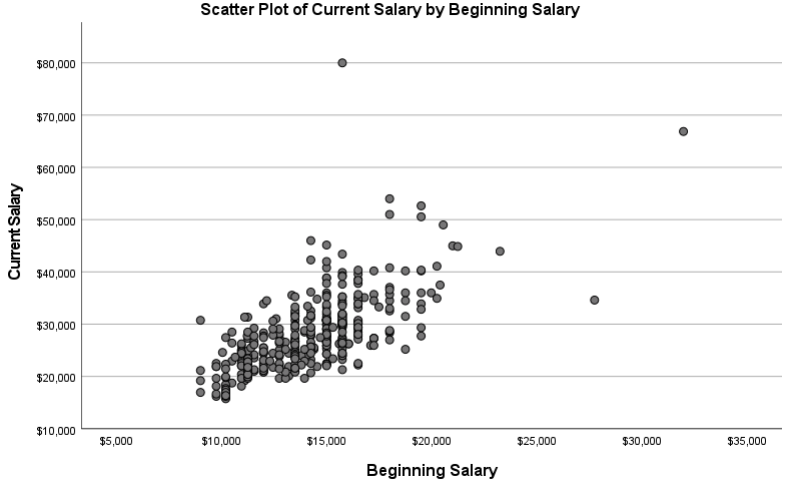


Performing Moderation Analysis in SPSS Statistics

Moderation Analysis

In the SPSS sample data file, **Employee data.sav**, there seems to be a strong relationship between starting salary and current salary



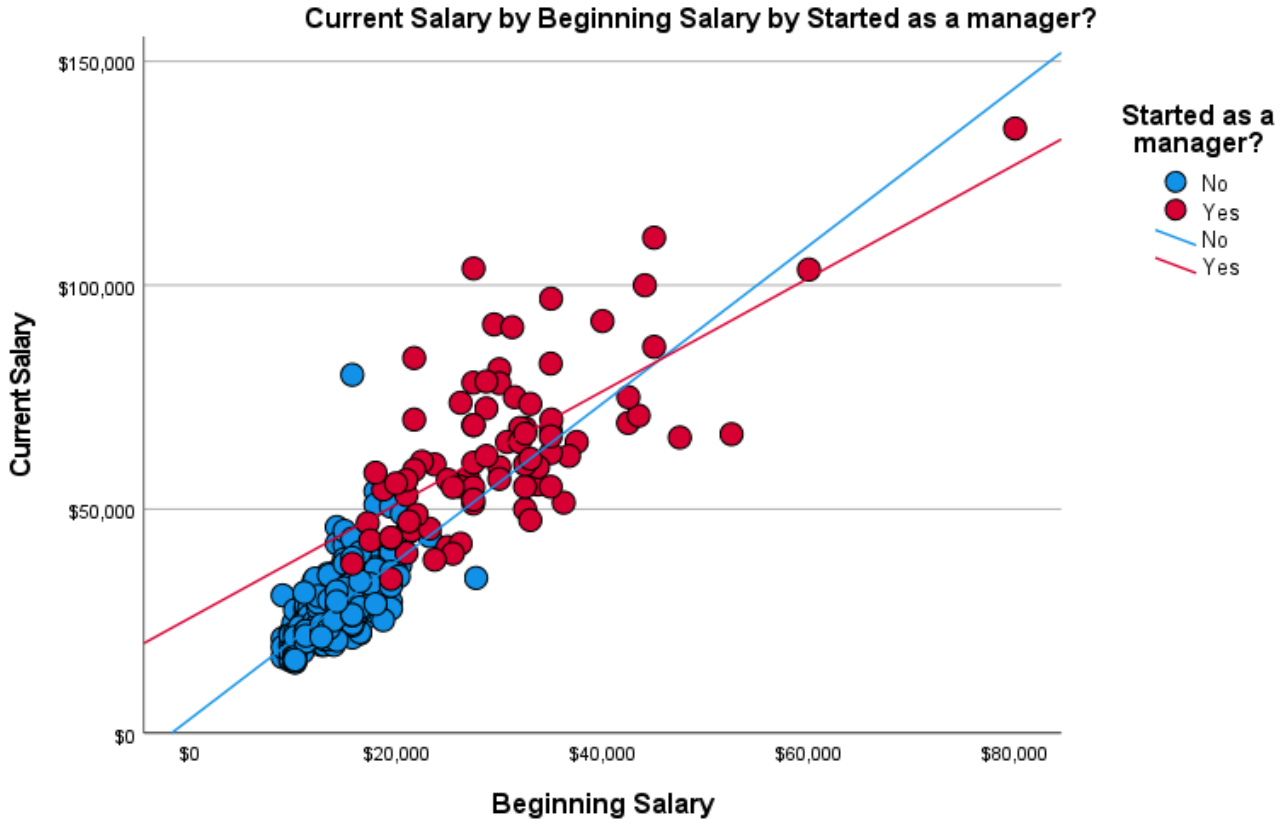
Report

Current Salary

Started as a manager?	Mean	N	Std. Deviation
No	$28,053.18	390	$7,363.358
Yes	$63,977.80	84	$18,244.776
Total	$34,419.57	474	$17,075.661

Is this relationship moderated by whether the employees started as managers or not?

Moderation Analysis



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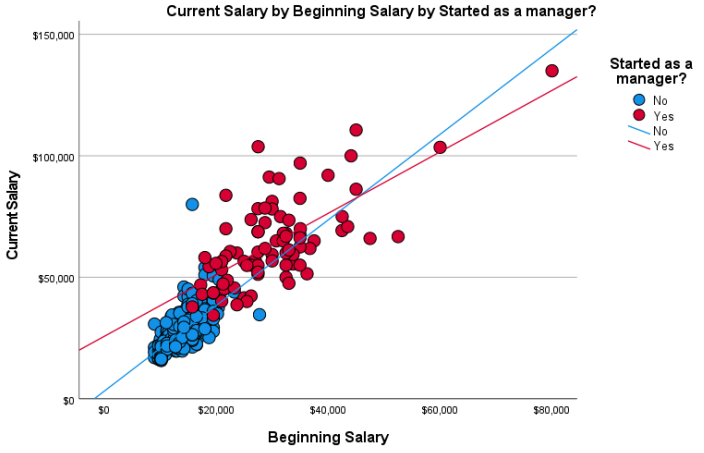
Moderation Analysis - Statistical Form

- **Current Salary** (Dependent Variable)
- **Beginning Salary** (Independent Variable)
- **Started as a manager** (Moderator Variable)
- **Beginning Salary* Started as a manager** (Interaction between independent and moderator variable)

Dependent = Constant + Independent + Moderator + Interaction

$$\text{Current Salary} = b_0 + b_1 \text{ Beginning Salary} + b_2 \text{ Started as a manager} + b_3 \text{ Beginning Salary} * \text{manager}$$



Let's take a look…

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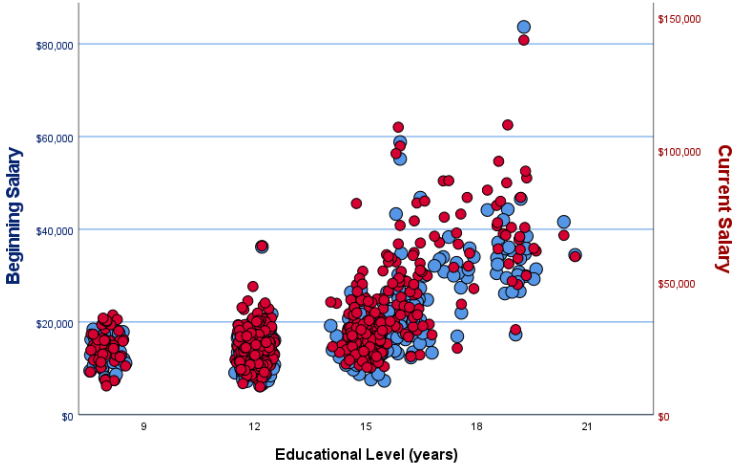


Understanding Mediation Analysis

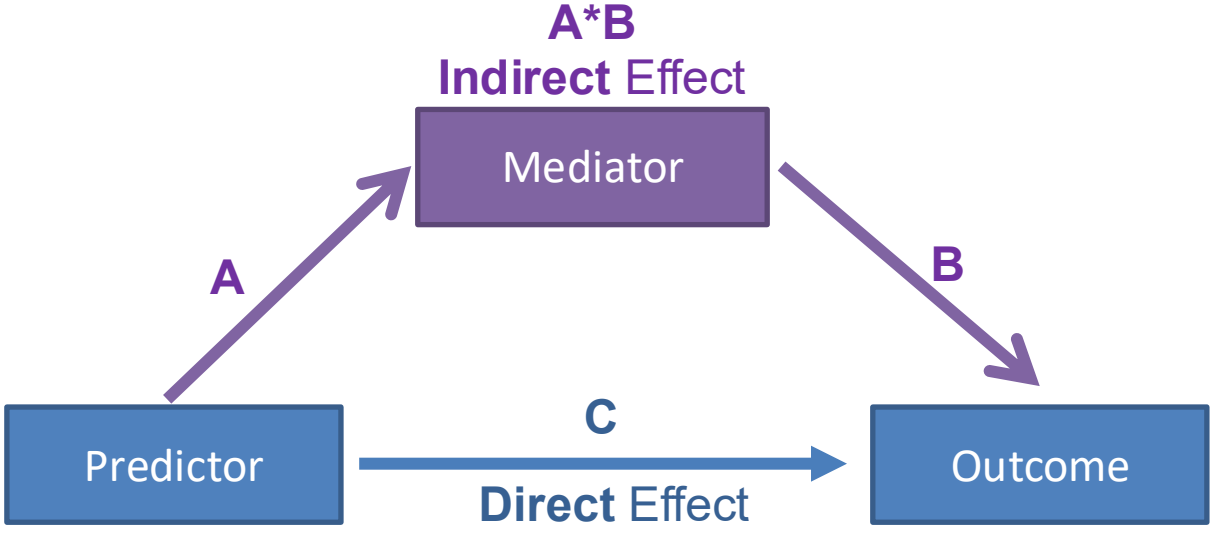
Mediation Analysis

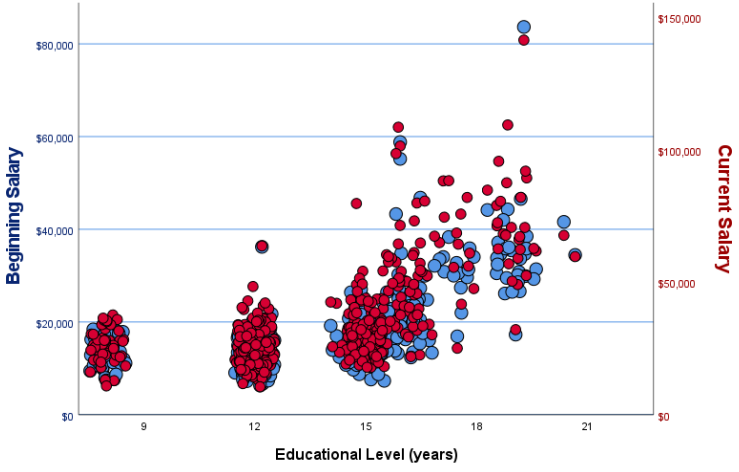
- A mediating variable is one that can be used to represent the *hidden underlying cause* of a relationship between an independent and dependent variable
- A mediator variable *explains why* a relationship exists as it provides a *reason* for the effect of a given factor upon an outcome of interest
- Most analysts regard a **mediator** as something that the independent variables ***causes.*** The mediator variable then goes on to influence the dependent variable.
- Examples:
  - A new exercise regime may be related to an increase in self-esteem. Is this relationship mediated by the degree of weight loss that exercise regime causes which in turn increases self-esteem?
  - A researcher discovers that income is related to life expectancy. Is this relationship mediated by the assumption that those with higher incomes spend more on healthcare?

Mediation Analysis - Graphical Form

No Mediator

Mediator included




Beginning Salary
$80,000
$60,000
$40,000
$20,000
$0
$150,000
$100,000
$50,000
$0
Current Salary
9
12
15
18
21
Educational Level (years)

Our example

Mediation Analysis

- Is the relationship between **education level** and **current salary** mediated by **starting salary**?
- A person's starting salary is likely to be directly related to their education level
- Therefore, the relationship between education, starting salary and current salary might look something like:

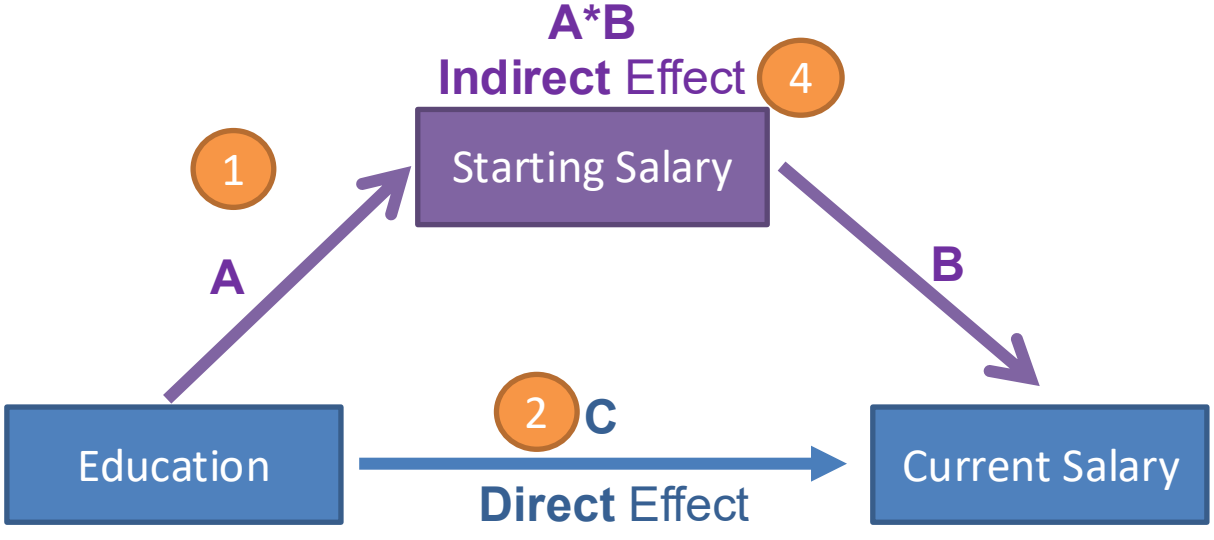
Education > Starting Salary > Current Salary

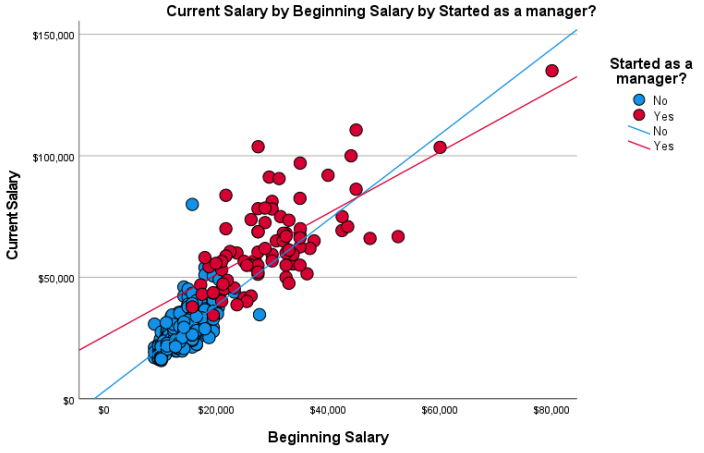
- If so, it is reasonable to assume that starting salary *may* **mediate** the relationship between education and current salary

Mediation Analysis - Graphical Form

No Mediator

Mediator included





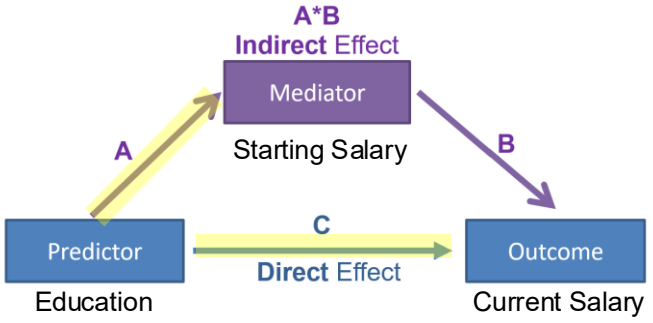
Let's take a look…

Path A – education predicts *starting* salary

```
**************************************************************************
OUTCOME VARIABLE:
 salbegin

Model Summary
          R       R-sq        MSE          F        df1        df2          p
      .6332      .4009 37188762.8   315.8967     1.0000   472.0000      .0000

Model
              coeff         se          t          p       LLCI       ULCI
constant -6290.9673  1340.9198    -4.6915     .0000 -8925.8785 -3656.0560
educ      1727.5283    97.1969    17.7735     .0000  1536.5360  1918.5206
```



1727.5283

Path C – Direct Effect – education & starting salary predict current salary

```
OUTCOME VARIABLE:
 salary

Model Summary
          R       R-sq        MSE          F        df1        df2          p
      .8902      .7924 60785788.0   898.9469     2.0000   471.0000      .0000

Model
              coeff         se          t          p       LLCI       ULCI
constant -7808.7142  1753.8605    -4.4523     .0000 -11255.074 -4362.3545
educ      1020.3901   160.5504     6.3556     .0000   704.9064  1335.8739
salbegin     1.6726     .0588    28.4234     .0000     1.5570     1.7883
```

X = 2889.516

1.6726

Indirect Effect Output

```
*************** TOTAL, DIRECT, AND INDIRECT EFFECTS OF X ON Y ***************

Total effect of X on Y
     Effect         se          t          p       LLCI       ULCI       c_cs
  3909.9067   204.5470    19.1150     .0000  3507.9712  4311.8422     .6606

Direct effect of X on Y
     Effect         se          t          p       LLCI       ULCI      c'_cs
  1020.3901   160.5504     6.3556     .0000   704.9064  1335.8739     .1724

Indirect effect(s) of X on Y:
              Effect     BootSE   BootLLCI   BootULCI
salbegin  2889.5166   228.4900  2451.4110  3353.5845
```

The confidence intervals do not contain zero…

…Beginning salary is therefore a significant mediator

Percentage of total effect that the indirect effect accounts for

```
*************** TOTAL, DIRECT, AND INDIRECT EFFECTS OF X ON Y ***************

Total effect of X on Y
     Effect         se          t          p       LLCI       ULCI       c_cs
  3909.9067   204.5470    19.1150     .0000  3507.9712  4311.8422     .6606

Direct effect of X on Y
     Effect         se          t          p       LLCI       ULCI      c'_cs
  1020.3901   160.5504     6.3556     .0000   704.9064  1335.8739     .1724

Indirect effect(s) of X on Y:
            Effect     BootSE   BootLLCI   BootULCI
salbegin  2889.5166   228.4900  2451.4110  3353.5845
```

$$\frac{2889.5166}{3909.9067} = 0.739 * 100 = \mathbf{73.9\%}$$

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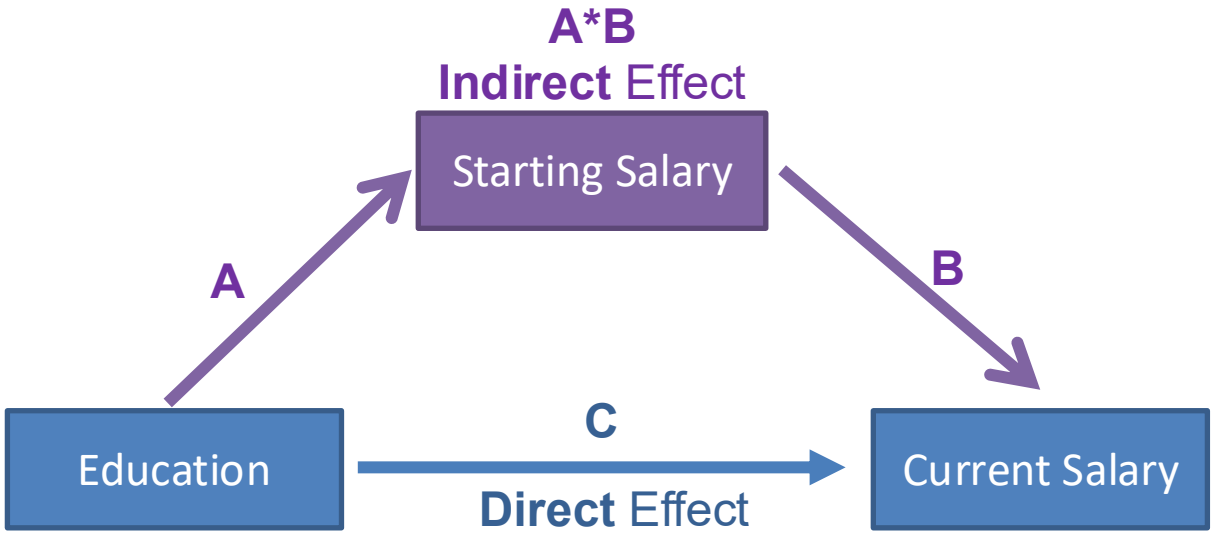
Full and Partial Mediation

- **Full** mediation – Path A*B is significant but Path C is not
- **Partial** mediation – Path A*B and Path C are significant



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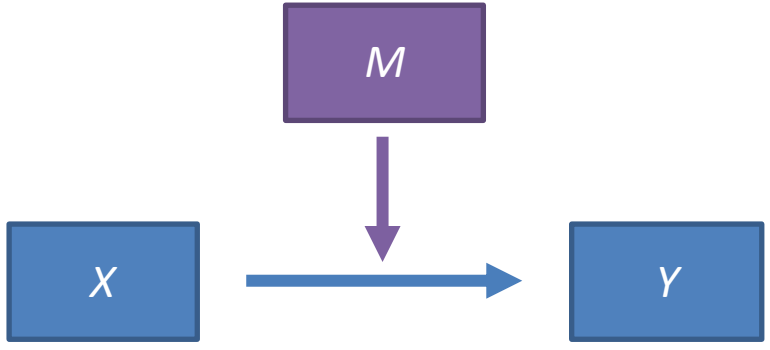
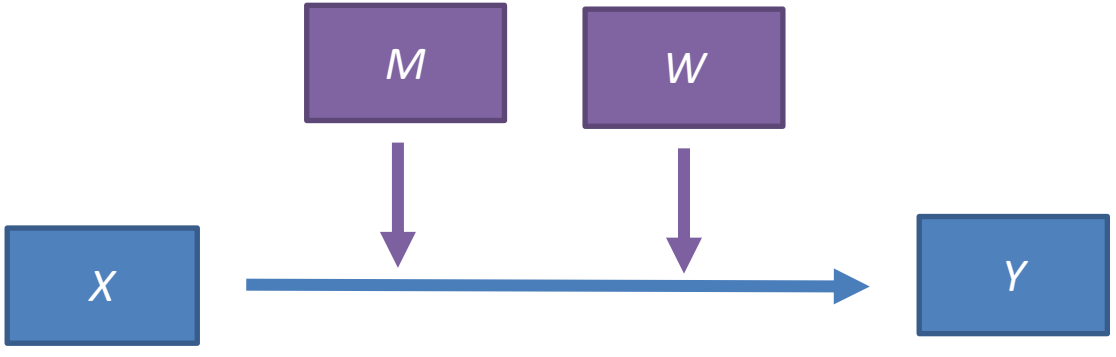
Model Types

The Process macro supports multiple model forms

Model 1



Model 2



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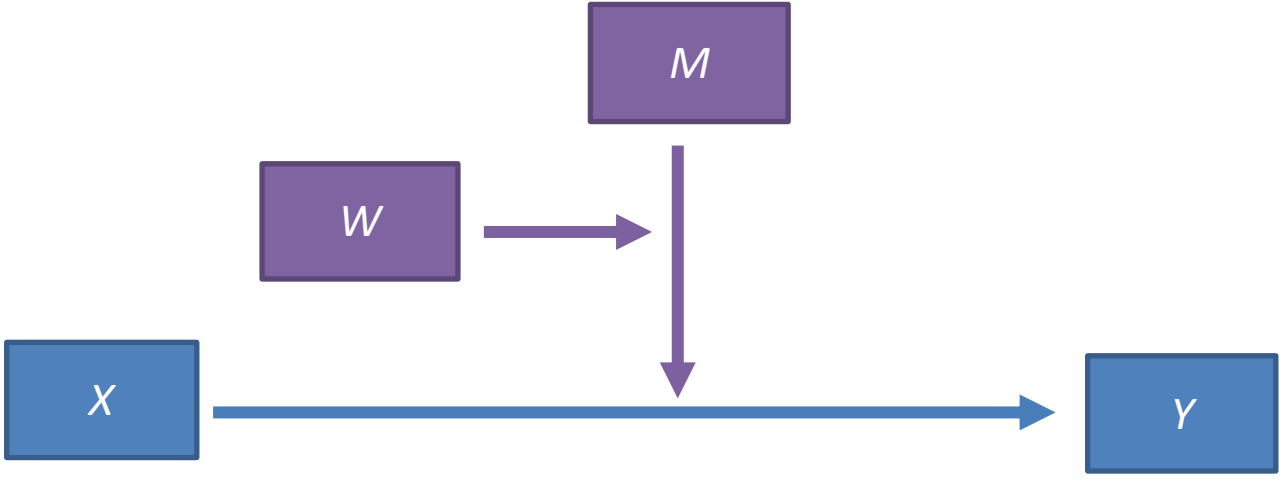
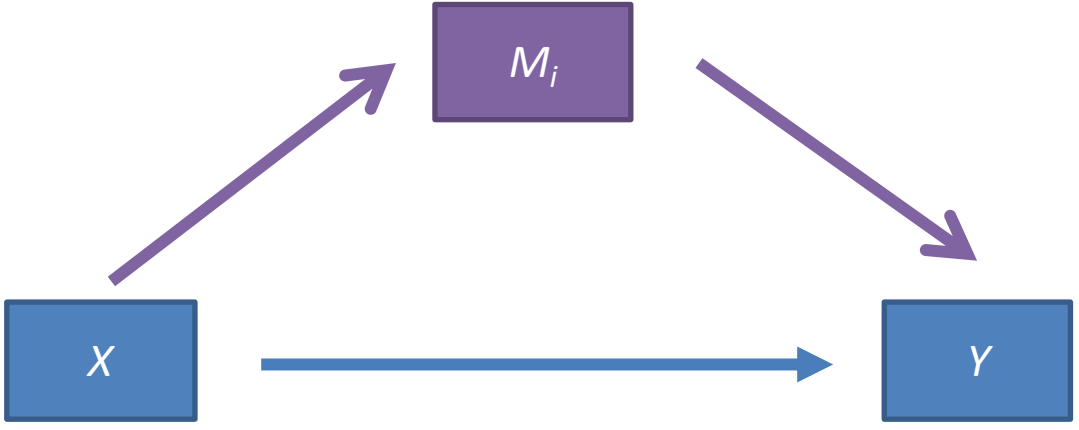
The Process macro supports multiple model forms

Model 3



The Process macro supports multiple model forms

Model 4

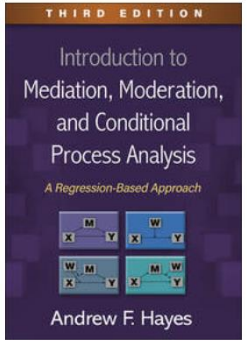


https://www.afhayes.com/

Andrew F. Hayes, Ph.D.

- Home
- My C.V.
- Workshops
- My Books
- Teaching and Speaking
- Mechanisms and Contingencies Lab
- PROCESS macro for SPSS, SAS, and R
- SPSS, SAS, and R Macros and Code
- Video
- Skeets

Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach Third Edition



Introduction to Mediation, Moderation, and Conditional Process Analysis describes the foundation of mediation and moderation analysis as well as their analytical integration in the form of "conditional process analysis", with a focus on PROCESS for SPSS SAS, and R (#processmacro) as the tool for implementing the methods discussed. Available as both an e-book and in print form, it is published by The Guilford Press.

Here are the data files and code used in this third edition of the book.
Here is the errata for the third edition.

watsonx.ai™

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https://chatspss.com

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CONVERSATIONS

- How can I remove unwanted LOG output?
  - How can I remove unwanted LOG output
  - Whats the difference between ANOVA and ANCOVA

DOCUMENT REFERENCES

- IBM_SPSS_Statistics_Core_System_User_G...
- IBM_SPSS_Statistics_Brief_Guide.pdf
- IBM_SPSS_Statistics_Base.pdf
- IBM_SPSS_Missing_Values.pdf

To remove unwanted LOG output in IBM SPSS Statistics, you can hide the log messages in the Viewer. Here's how to do it:

1. From the menus, choose:

   ```
   Edit > Options...
   ```

2. Click the **Viewer** tab.
3. Double-click the **Log** icon to hide log messages in the output.
4. Click **OK** to save your changes and close the dialog box.

This will hide the log output from the Viewer, helping to declutter your output display.

Whats the difference between ANOVA and ANCOVA?

Difference Between ANOVA and ANCOVA

ANOVA (Analysis of Variance) and ANCOVA (Analysis of Covariance) are both statistical methods used to compare the means of different groups. However, they differ in their approach and application:

- **ANOVA**: This method is used to compare the means of three or more groups to see if there are any statistically significant differences between them. It does not take into account any other variables that might influence the dependent variable.
- **ANCOVA**: This method is an extension of ANOVA that includes one or more continuous independent variables, known as covariates. ANCOVA adjusts the means of the groups based on the covariates, which can help reduce the error variance and increase the power of the test.

In summary, ANCOVA is used when you want to control for the effects of one or more continuous variables (covariates) while comparing the means of different groups, whereas ANOVA is used when you only want to compare the means without considering any other variables.

For more detailed information, please consult external sources or the official SPSS documentation.

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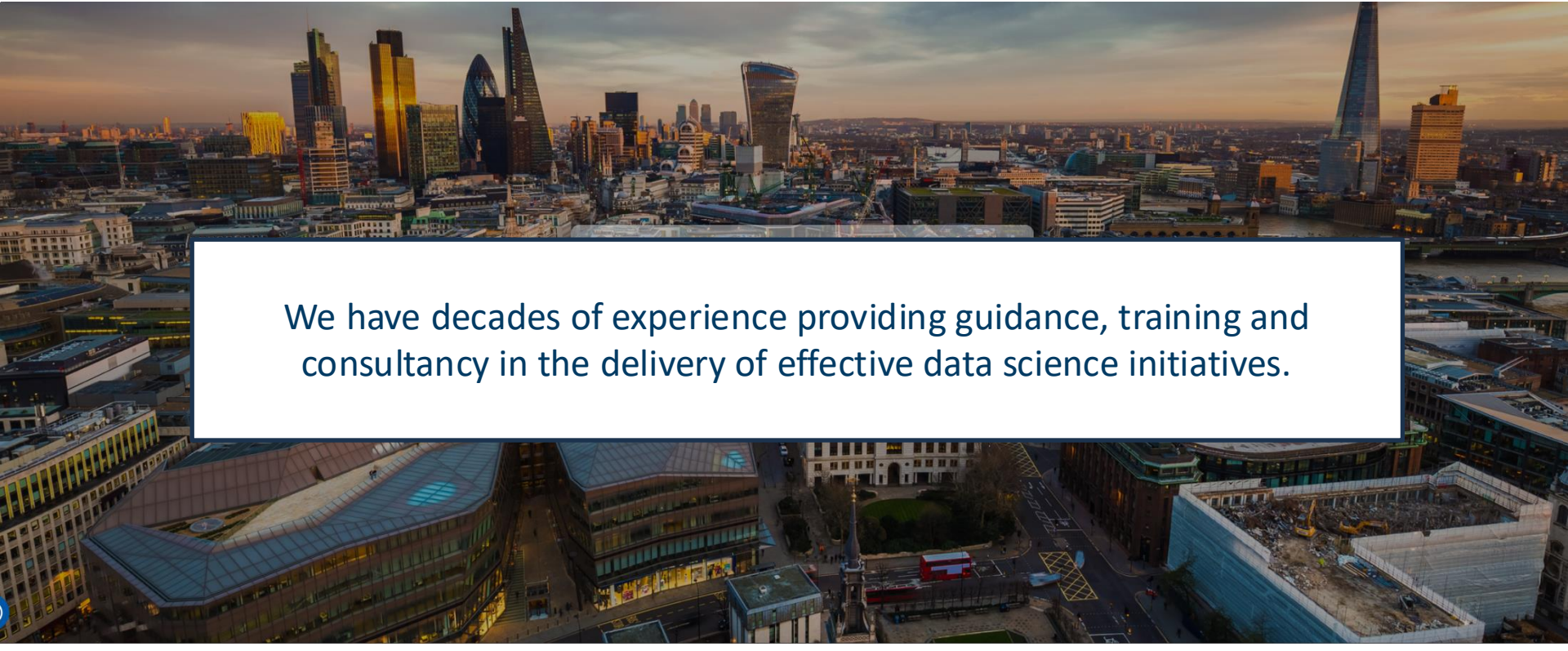

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