Mediation: Background and Basics

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Overview

- **Background and Early History**
- **Steps**
- **Indirect Effect**
- **Broadening Mediation Analysis**
- **Taking Assumptions Seriously**
- **My Current Work**

Background and Early History

Interest in Mediation

- **Mentions of "mediation" or "mediator" in psychology abstracts:**
  - **1980: 36**
  - **1990: 122**
  - **2000: 339**
  - **2010: 1,198**

Why All the Interest in Mediation?

- **Fundamental reason: Mediation is one way to answer the question of "How?"**
- **Understand the mechanism is critically important:**
  - **theoretical concerns**
  - **cost and efficiency concerns**

Other Reasons

- **Often the key part of a causal model is the mediational piece.**
  - **Tests of a causal model are either due to mediation or due to spuriousness.**
  - **Mediation is much more theoretically interesting than spuriousness.**
- **Understand why the intervention did not work**
- **Find more proximal endpoints**
- **Tests of mediation relatively powerful**

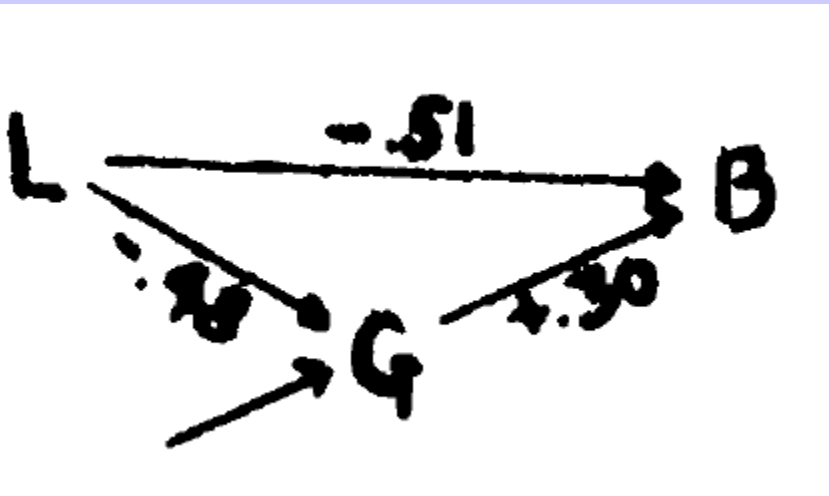
Early History of Mediation

- **Sewall Wright**
- **Ronald Fisher**
- **Herbert Hyman**

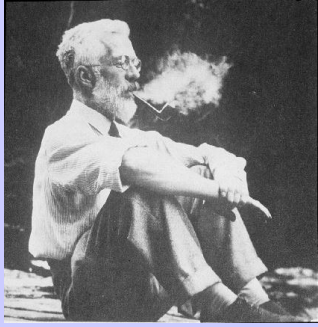
Sewall Wright

Wright, S. (1934). The method of path coefficients. *The Annals of Mathematical Statistics, 5*, 161-215.

p. 179: "The term P(BL) = -.51 can be interpreted as measuring the influence of size of litter on birth weight in all other ways than through gestation period ."



Ronald Fisher

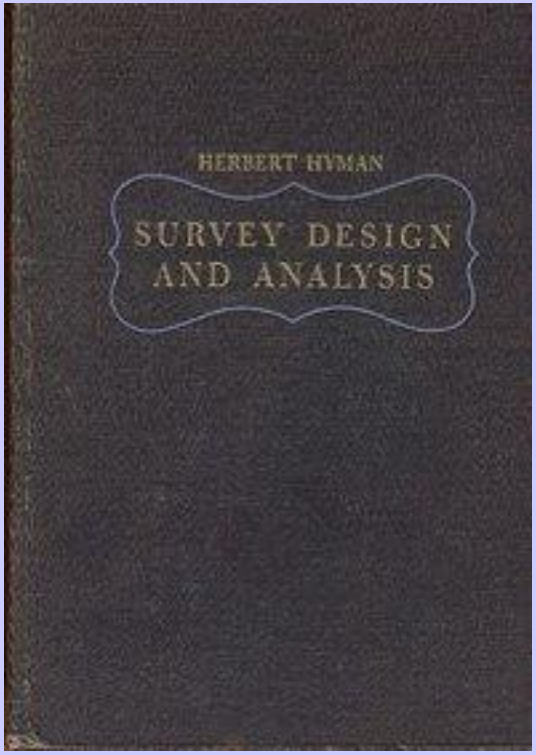


- **Analysis of covariance for mediational analysis**
- ***Design of Experiments*, 1st Ed. (1935), p. 169:**

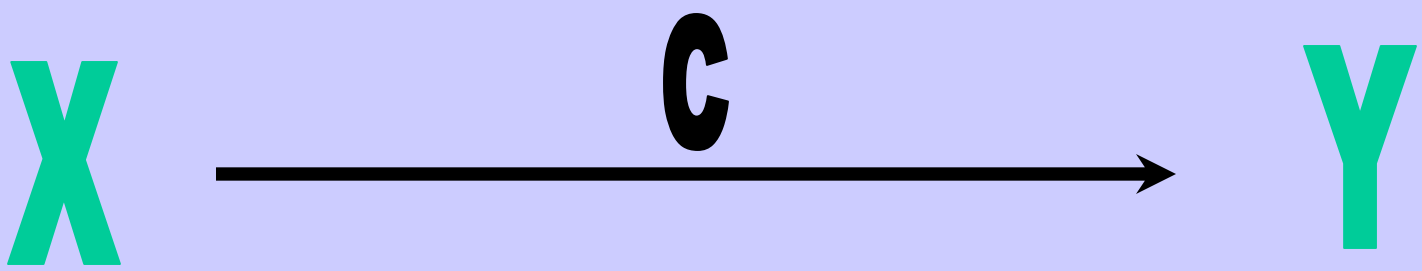
"(I)f we are willing to confine our investigation to the effects on yield, excluding such as how directly or indirectly from effects brought about by variations in plant number, then it will appear desirable to introduce into our comparisons a correction which makes allowance, at least approximately, for the variations in yield directly due to variation in plant number itself."

Herbert Hyman (and Patricia Kendall and Paul Lazarsfeld)

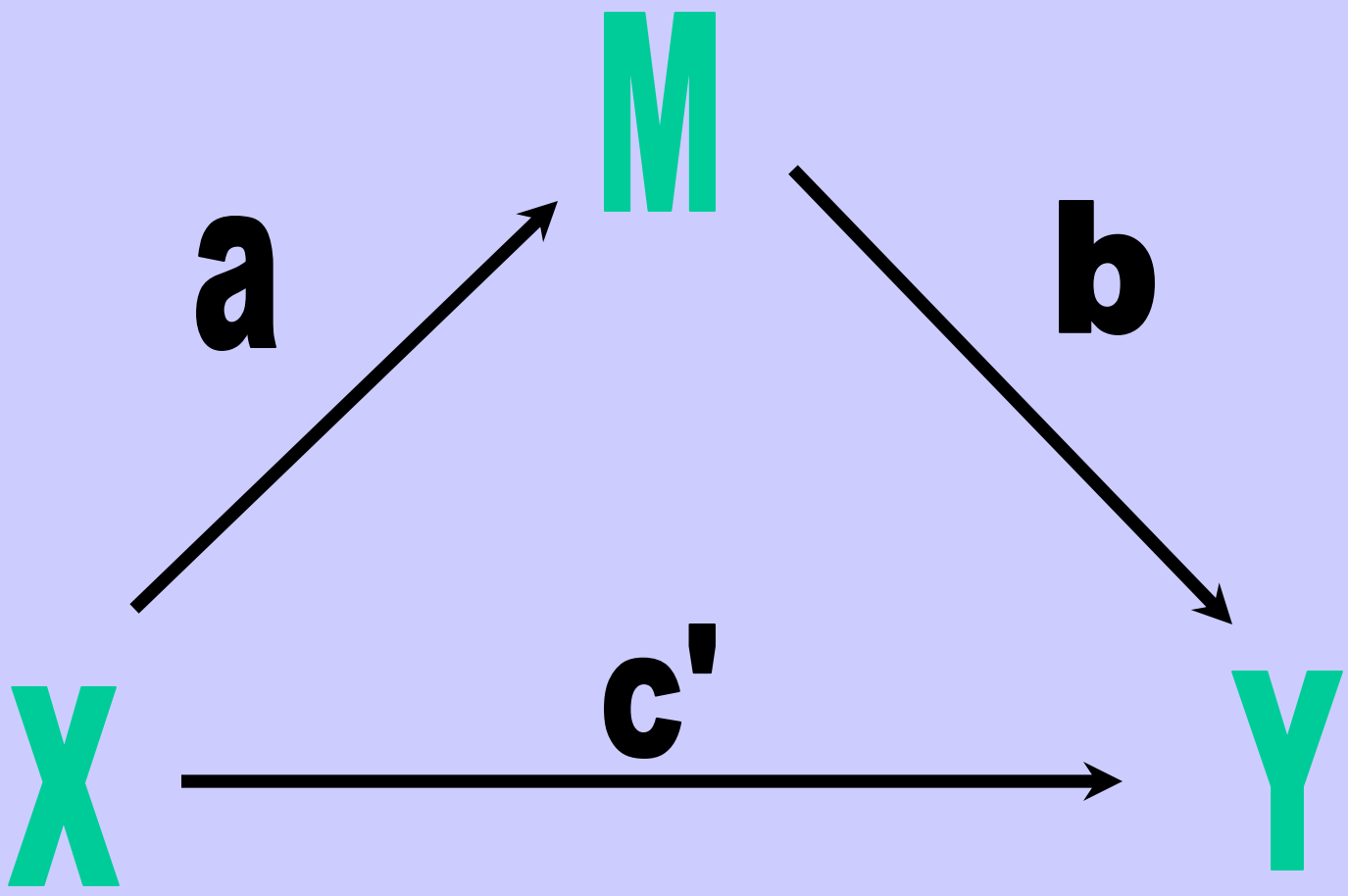
- **In *Survey Design and Analysis* (p. 280), Hyman (1955) suggested three steps to determine mediation (M type elaboration).**



The Beginning Model



The Mediational Model



The Four Paths

- **X → Y: path *c***
- **X → M: path *a***
- **M → Y (controlling for X): path *b***
- **X → Y (controlling for M): path *c′***

  (standardized or unstandardized)

Steps

In the 1980s Different Researchers Proposed a Series of Steps to Test Mediation

- **Judd & Kenny (1981)**

- **James & Brett (1984)**

- **Baron & Kenny (1986)**

Steps

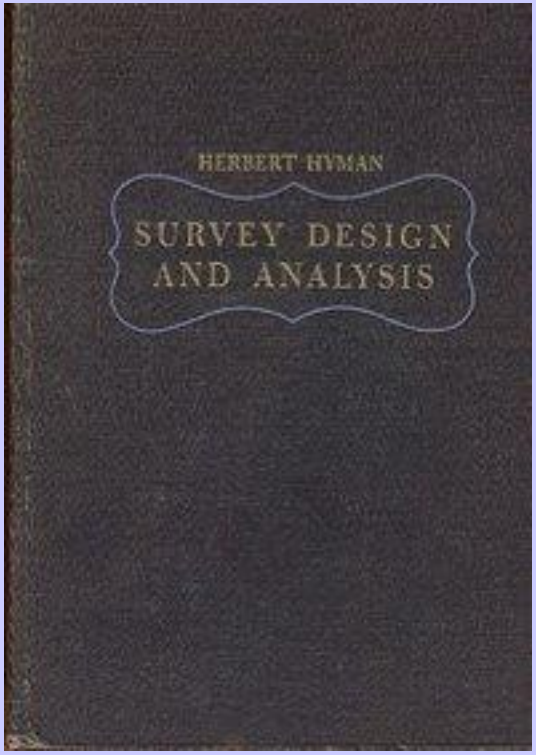
- **Step 1: X → Y (test path *c*)**
- **Step 2: X → M (test path *a*)**
- **Step 3: M (and X) → Y (test path *b*)**
- **Step 4: X (and M) → Y (test path *c′*)**

Differences in the Three Approaches

- **James & Brett estimate Step 3 without controlling for X (implicitly assuming complete mediation) whereas both Judd & Kenny and Baron & Kenny control for X.**
- **Judd & Kenny require all four steps whereas Baron & Kenny do not require Step 4.**

Hyman Steps

- **Test *c***
- **Test *a***
- **Show that *c′* is less than *c***



Steps Incredibly Popular with Practitioners

- **Suggested a straightforward way of testing mediation using a widely available estimating method.**
- **Very often lead to a successful result: Some sort of mediation was indicated.**
- **Very widely adopted and eventually the expectation was for some sort of mediational analysis.**

Dissatisfaction with the Steps Approach among Methodologists

- **Step 4 not even required in Baron and Kenny.**
- **Step 1 often failed to be satisfied and some argued was unnecessary.**
- **Meeting all the steps has low power.**
- **Steps 2 and 3 are essential. Thus, paths *a* and *b* were key. But how can those two effects be combined?**

Indirect Effect

Decomposition vs. Steps

Total Effect = Direct Effect + Indirect Effect

$$c = c' + ab$$

Note that

$$ab = c - c'$$

This equality exactly holds for multiple regression, but not necessarily for other estimation methods.

How to Measure Mediation?

Indirect Effect = *ab*

Ok, if the indirect effect is how we measure mediation, how can we statistically test whether we have any mediation?

Strategies to Test ab = 0

- **Sobel Test**
- **Distribution of the Product**
- **Monte Carlo Confidence Interval**
- **Bootstrapping**
- **Joint Significance of *a* & *b***

Broadening Mediational Analysis

Extensions

More variables

- **Multiple X, M, and Y variables**
- **Longer chains: X → M_1 → M_2 → Y**

Latent variables

- **Allowing for unreliability in X, M, and Y**

Mediation with Moderation

Multilevel Mediation

Level of Measurement of M and Y

Taking Assumptions Seriously

Worries about Causal Assumptions

- **Mediation analysis as causal analysis.**
- **The "Steps" papers did emphasize enough the causal assumptions underlying mediational analysis.**
- **Practitioners hardly ever discuss the causal assumptions.**
- **Early critics of mediational analysis argued that assumptions were hardly ever justified.**

Responses

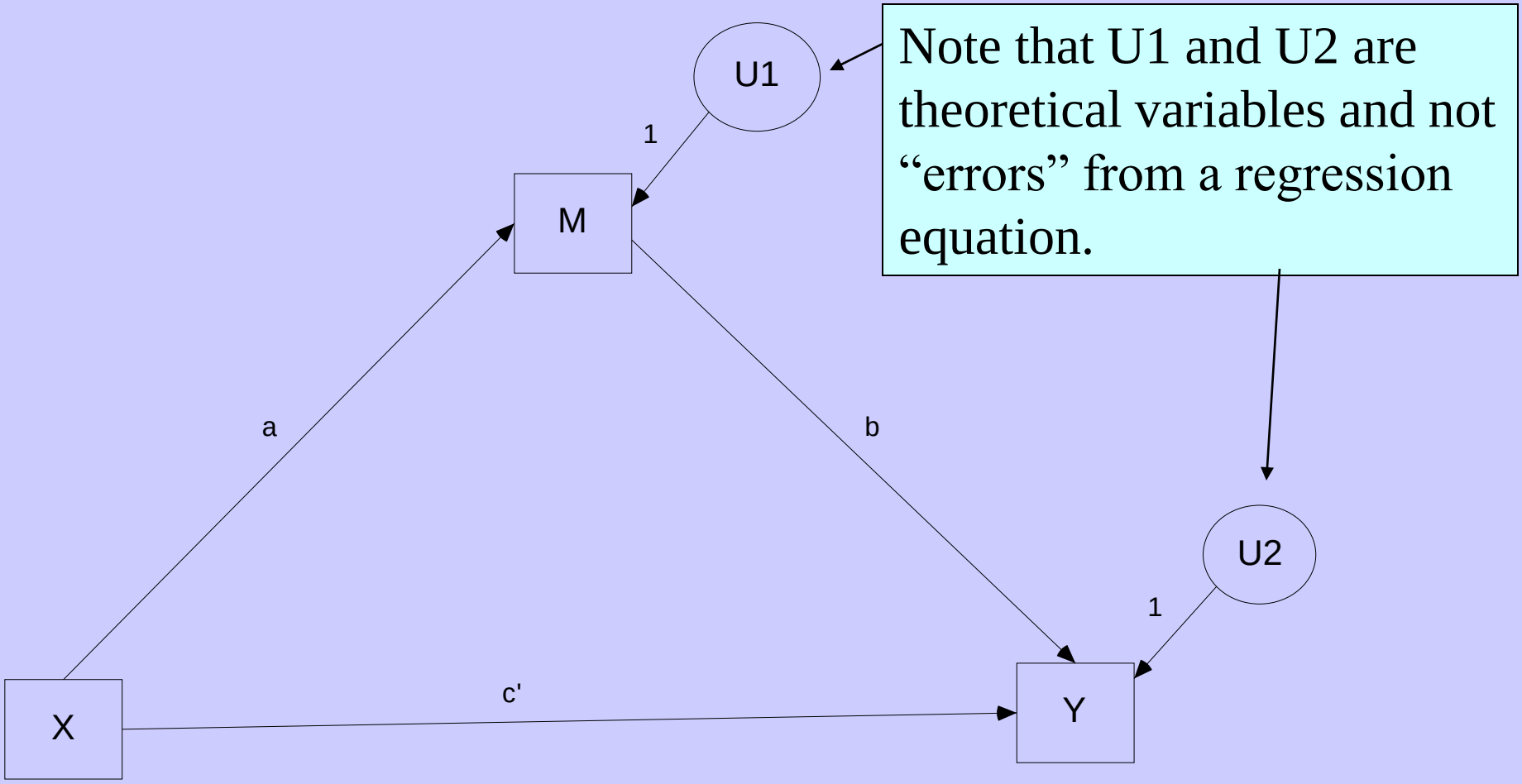
- **Several groups of researchers have developed a rationale for the *causality of mediation*.**
- **Researchers have broadened the definition of the indirect effect to allow for nonlinearities.**
- **More focus on what to do about confounders or omitted variables.**

Causal Assumptions

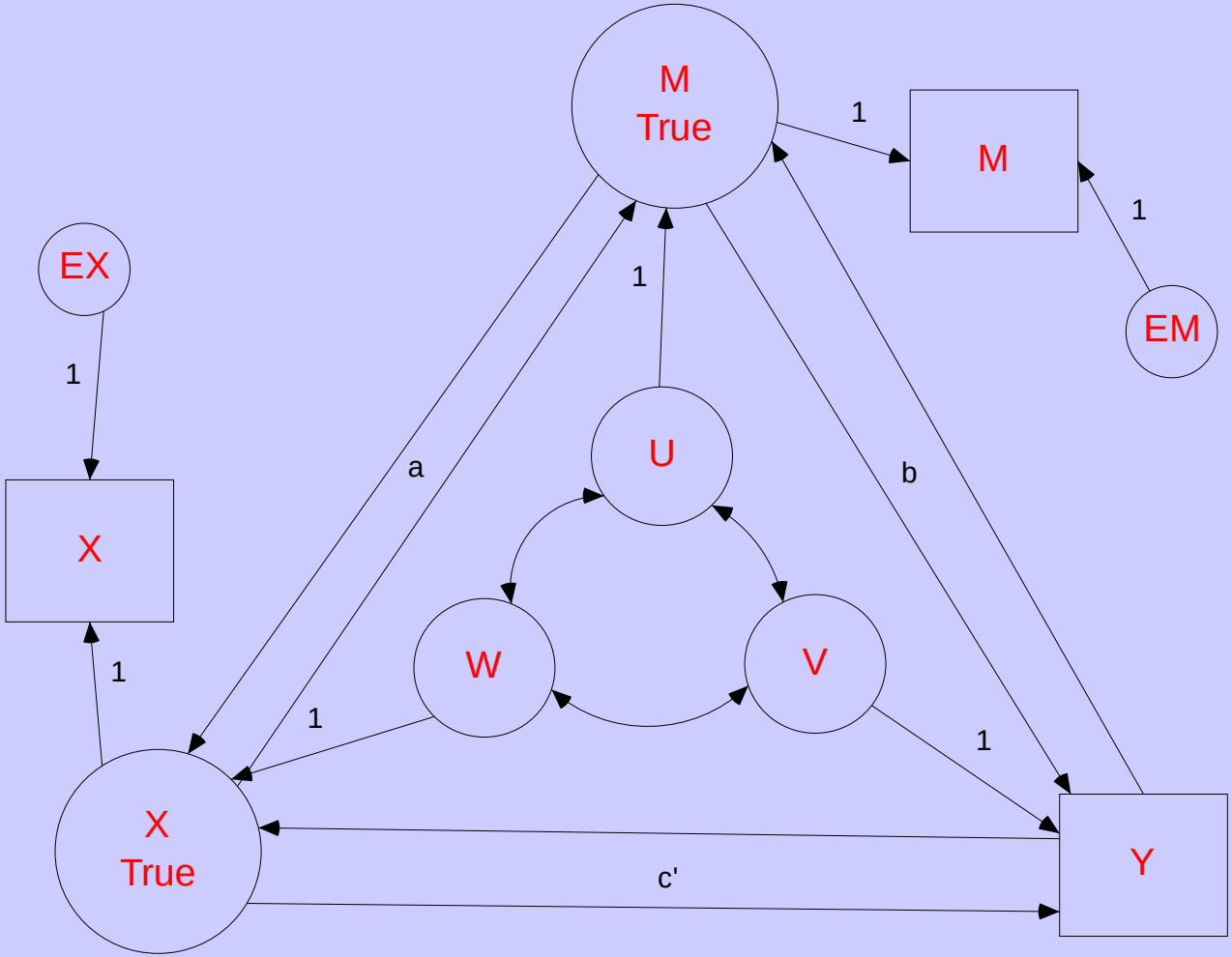
- **Perfect Reliability**
  - **for M and X**
- **No Reverse Causal Effects**
  - **Y may not cause M**
  - **M and Y not cause X**
- **No Omitted Variables (Confounders)**
  - **all common causes of M and Y, X and M, and X and Y measured and controlled**

(Guaranteed if X is manipulated.)

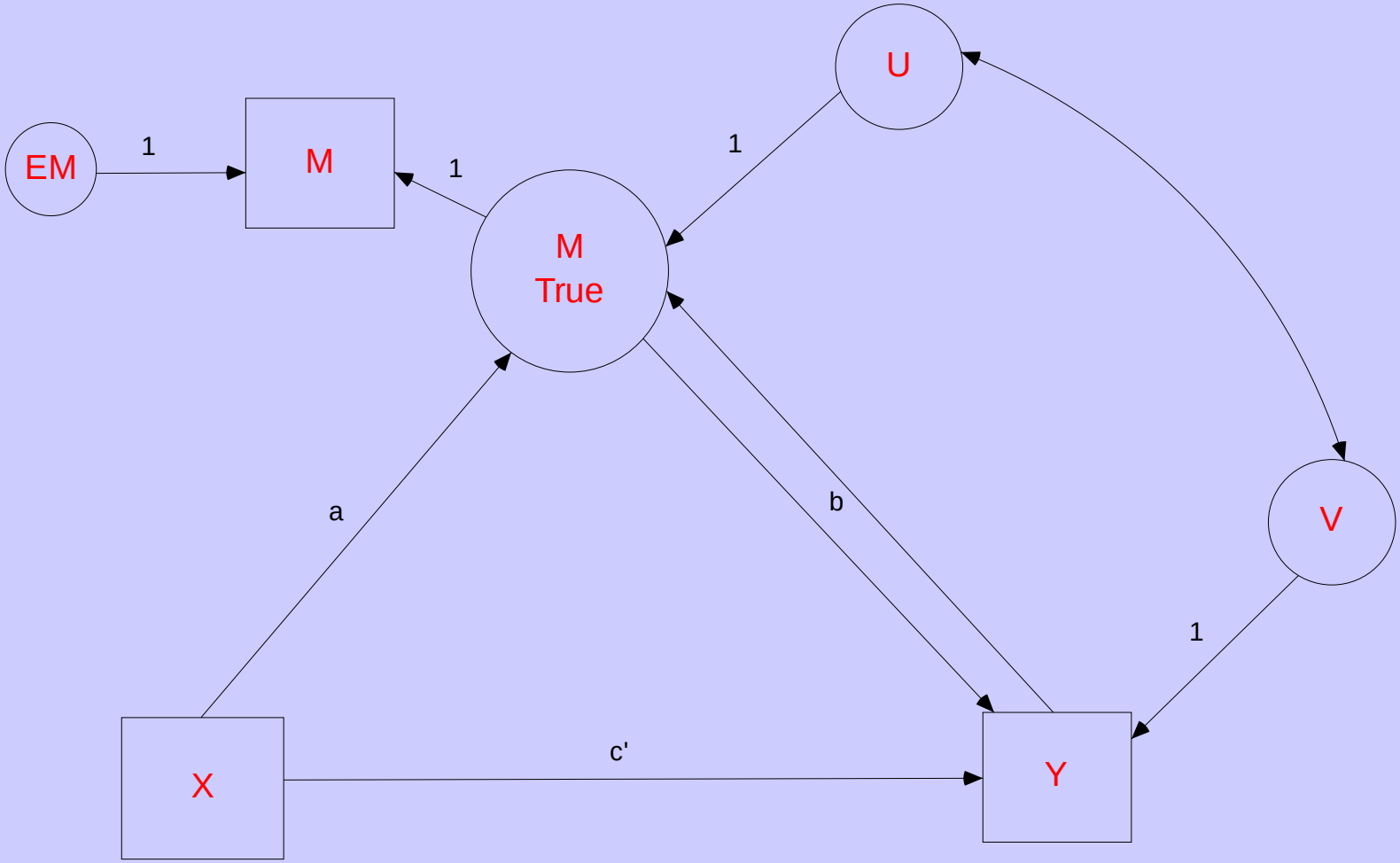
Basic Mediational Causal Model



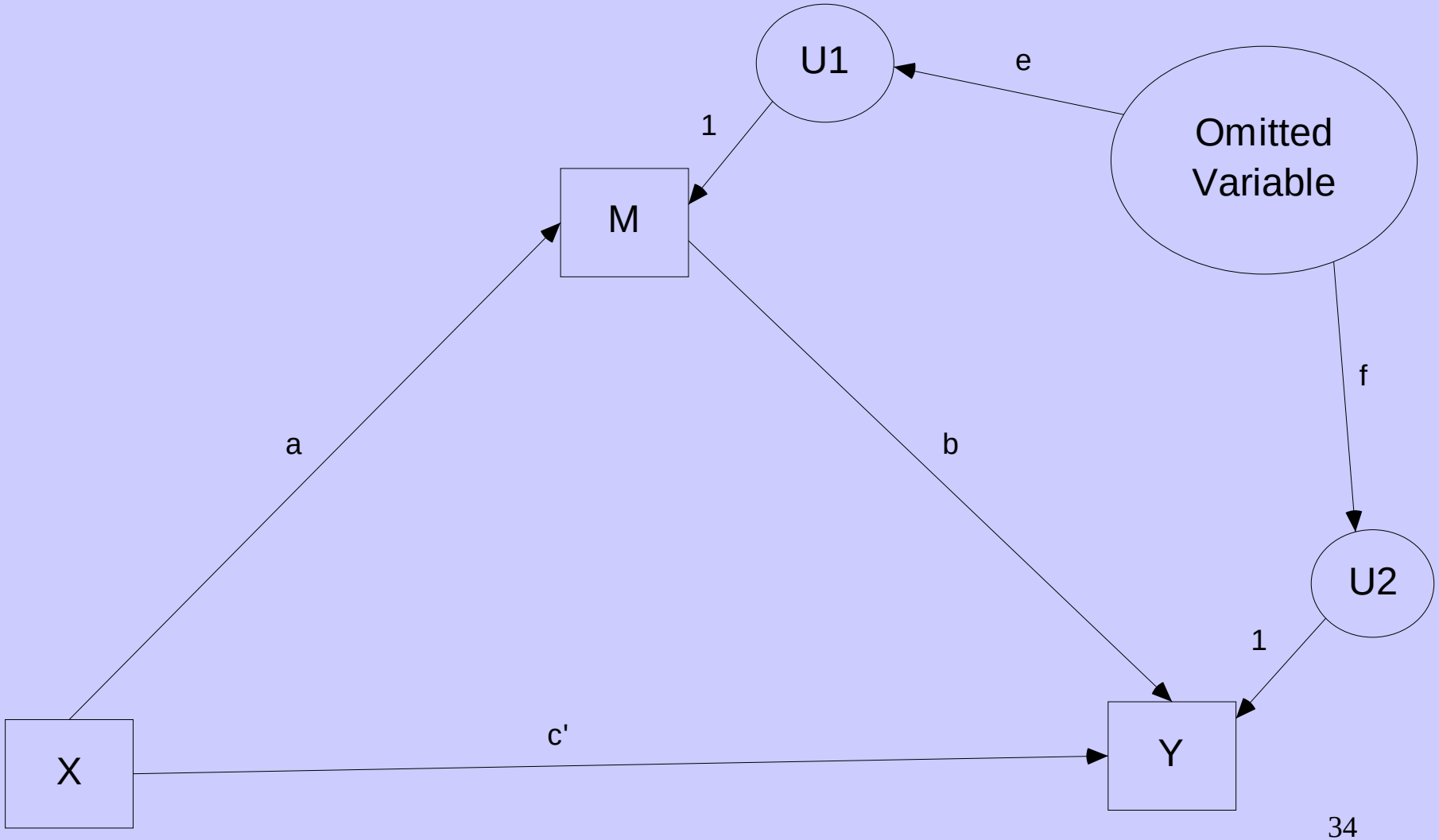
Mediation: The Full Model



Mediation: The Full Model – X Manipulated



Omitted Variables (or L Confounders)



Partial Solutions

- **Design of research**
  - **Timing of measurement**
  - **Number of measurements**
  - **Baseline measurements**
- **Statistical methods**
  - **Instrumental variable estimation**
  - **Inverse propensity weighting**
- **Single experiment approach**
- **Two experiment approach**
- **Sensitivity analyses**

My Current Work

(very briefly)

Projects

- **DataToText**
- **Power Considerations in Mediational Analysis**
- **Longitudinal Effects in Interventions**

I. DataToText

- **Macro developed to provide text, tables, and figures of a simple mediational analysis.**
  - **SPSS version: MedText**

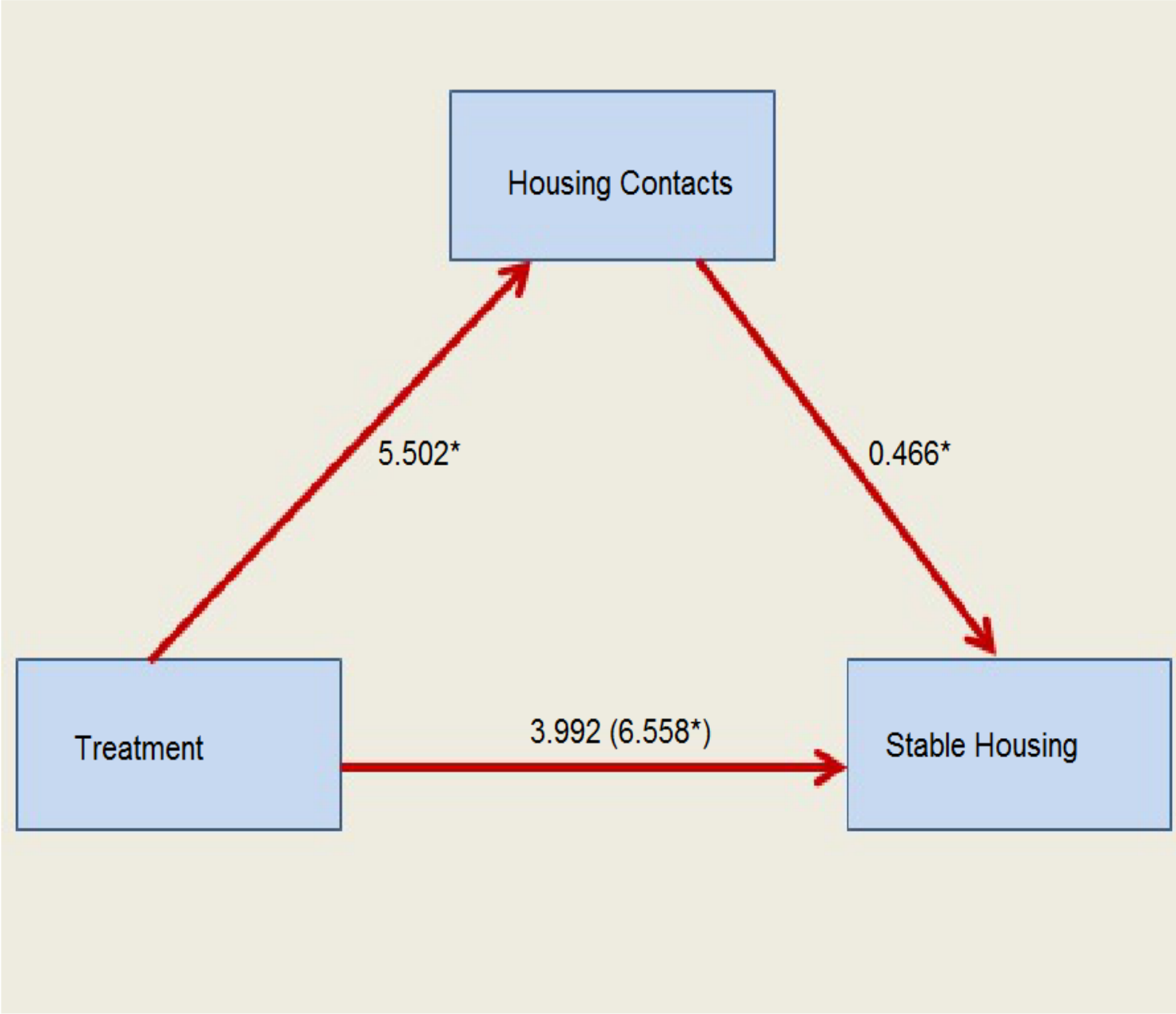
    http://davidakenny.net/dtt/mediate.htm
  - **R version: MedTextR**

    http://davidakenny.net/dtt/mediateR.htm

Advantages of DataToText

- **Does the analyses that should be done, but often are not, e.g., tests for outliers and nonlinearity.**
- **MedTextR issues up to 20 different warnings.**
- **Produces a 3 page text describing the results.**
- **Surprisingly “intelligent”**
- **Graphics**

Mediation Diagram: Unstandardized Estimates



IIa. Power of the Total Effect vs. the Indirect Effect

- **Work with C. Judd**
- **Note that if there were complete mediation ($c' = 0$), both the total and indirect effect equal *ab*.**
- **However, the power of the test of the indirect effect is much greater, sometimes (when both *a* and *b* have small effect sizes) 50 times more powerful than the test of the total effect!**

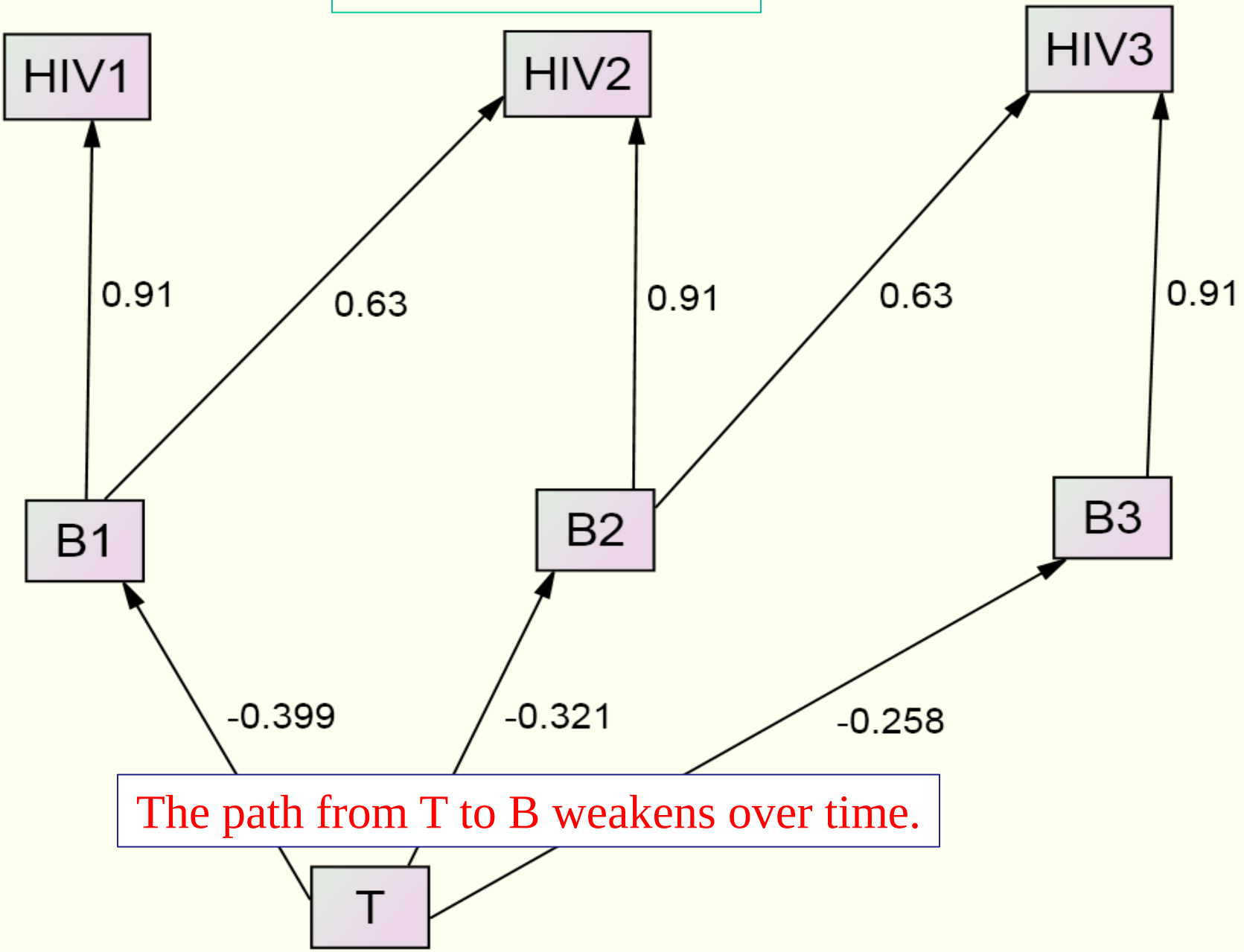
IIb. Power of the Direct Effect vs. the Indirect Effect

- **A key question in mediational analyses is the relative size of these two effects.**
- **Generally there is much more power for the test of the indirect effect.**
- **The major exception to this rule occurs for distal mediators (small *a* & large *b*) and a large indirect effect (standardized *ab* greater than .25).**

III. An Alternative Model for Longitudinal Mediation

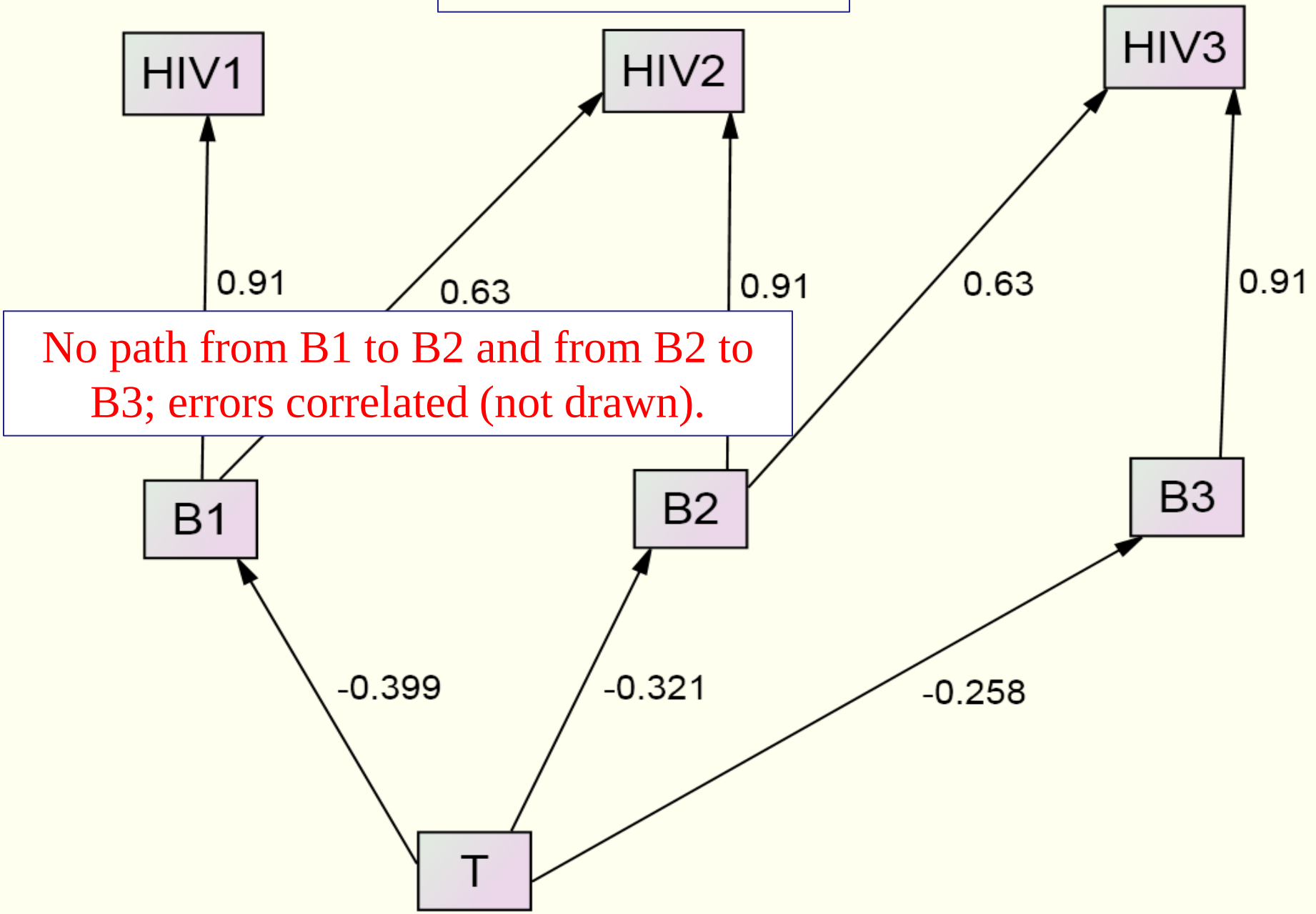
- **Focus when X is an intervention**
- **Two key features**
  - **Decay parameters**
  - **No "autoregressive" paths for M or Y**
- **Eaton et al. (in press) in *AIDS Care***
- **Calsyn et al. (in preparation)**

Eaton et al.



The path from T to B weakens over time.

Eaton et al.


HIV1
HIV2
HIV3
0.91
0.63
0.91
0.63
0.91
No path from B1 to B2 and from B2 to B3; errors correlated (not drawn).
B1
B2
B3
-0.399
-0.321
-0.258
T

Conclusion

- **Mediational analyses are very popular because they help researchers answer the questions that they want answered.**
- **Quantitative mediation researchers need to make sure their work is consumer-oriented.**
- **Hopefully, mediational analysis will remain an interdisciplinary effort.**