Estimating and Testing Indirect Effects in Within-Subjects Mediation Analysis:
A Path Analytic Framework

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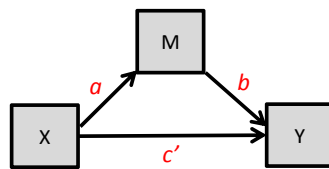
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Introduction

Mediation analysis is well-developed and widely-used in **between-subjects**, correlational or experimental designs, and primarily relies on a path-analysis approach that results In estimates of the direct (c') and indirect effects (*ab*) of causal agent X on outcome Y through mediator M, as diagrammed below.

$$Y = i_1 + cX + \epsilon_1$$

$$M = i_2 + aX + \epsilon_2$$

$$Y = i_3 + c'X + bM + \epsilon_3$$

$$c = c' + ab$$

Within-subjects experimental designs, where participants are measured in a variety of conditions or over time, are very common in psychology. Mediation analysis in these designs examines if the effect of condition (manipulated within participants, e.g. happy story, sad story) influences some measured outcome (measured in each condition; e.g., helping) through some mediator (measured in each condition; e.g., empathy).

In this research we extend the between-subjects path-analytic approach to the two-condition within-subject design, study various approaches for inference about the indirect effect, and provide a tool for SPSS and SAS to facilitate the analysis.

Judd et al's Causal Steps Approach

Judd, Kenny, and McClelland (2001, *Psychological Methods*) outlined a method for testing mediation in the two condition within-subject design. Significant effects on the first 3 steps is required to infer mediation.

STEP 1: Pairwise t-test between repeated measures of *Y*

STEP 2: Pairwise t-test between repeated measures of *M*

STEP 3: Use regression below to assess if *b* is significantly different than zero. Does *difference in M predict difference in Y*?

$$Y_1 - Y_2 = i + b(M_1 - M_2) + d\left[(M_1 + M_2) - \frac{\sum(M_1 + M_2)}{n}\right]$$

STEP 4: Is *i* in regression above significantly different than zero?

This method provides only a **yes/no decision regarding mediation**. There is **no estimate of the indirect effect** or its standard error, no confidence interval or *p*-value.

A Path Analytic Framework

We developed a path-analytic analogue of Judd et al. 2001) that yields an estimate of the **indirect effect** (the product of the *a*-path and the *b*-path) and allows for the application of inferential tests already well-established in the mediation analysis literature.
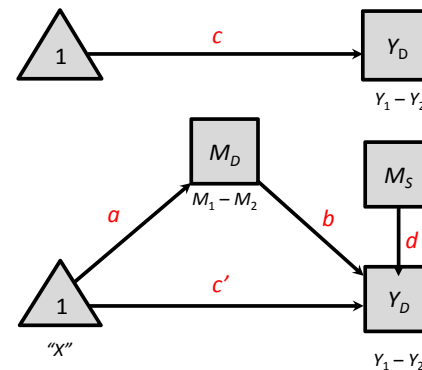
$$Y_D = c + \epsilon_1$$

$$M_D = a + \epsilon_2$$

$$Y_D = c' + bM_D + dM_S + \epsilon_3$$

$$c = c' + ab$$

$$Y_D = Y_1 - Y_2 \qquad MD = M_1 - M_2$$

$$M_S = (M_1 + M_2) \text{ mean centered}$$

Connection to Judd et al. (2001): The model above connects to the model suggested by Judd et al. by quantifying each effect in the same way. Their steps 1 – 4 are inferential tests on paths *c, a, b,* and *c'*, respectively.

Alterations: In this framework, the indirect effect is the product of *a* and *b*, just as in between-subjects analysis. Plus:

- No need to condition tests of mediation on a significant c' path (no STEP 1 in Judd et al.).
- Focus on the direct and indirect effect, rather than the individual paths in the model (no STEP 2 and STEP 3 of Judd et al. required).
- Conduct an inferential test of the indirect effect as the test of mediation.

Testing the Indirect Effect: Monte Carlo Evidence
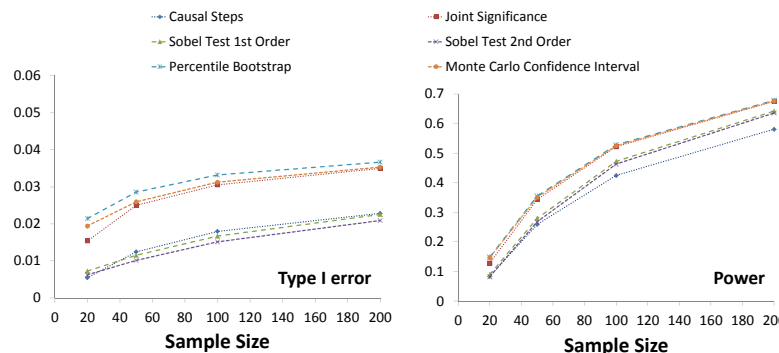
The **percentile bootstrap** confidence interval is the best performer, though only by a narrow margin. Avoid the Sobel test.

An SPSS and SAS macro: MEMORE

MEMORE is a macro for SPSS and SAS available at *afhayes.com* that will estimate the total, direct, and indirect effects of X on Y through one or more mediators in the two-condition repeated measures design.

Model Specification: After running the syntax file, a simple command can be used to run a repeated measures mediation analysis.

```
MEMORE Y = depA depB /M = medA medB
```

This command would estimate the direct and total effects of X on Y as well as the indirect effect of X on Y through M using a percentile bootstrap confidence interval based on 5,000 bootstrap samples.

Some options:
- Inferential methods for the indirect effect
  - Percentile bootstrap confidence interval
  - Bias Corrected Bootstrap confidence interval
  - Monte Carlo confidence interval
  - Normal theory tests (i.e. Sobel test)
- Confidence level
- Number of resamples
- Pairwise contrasts for indirect effects
- Save bootstrap or Monte Carlo coefficients

Discussion

This research expands methods of inference for within-subjects mediation models, much like the work done in the early 21st century for between subjects mediation.

Using a path analytic approach, the indirect effect is easily quantified, and inferential tests are available using well-established methods. No need to rely on the outdated causal steps approach. We recommend the percentile bootstrap confidence interval for inference about the indirect effect.

MEMORE makes the analysis easy for any researcher to conduct.

This path analytic is easily extended to parallel and serial mediation models as well as models that combine within-subject mediation with moderation.

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