Within-Subject Mediation Analysis for Experimental Data in Cognitive Psychology and Neuroscience

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Introduction

Statistical mediation evaluates to what extent one variable's effect on another is explained by a causal mechanism (a mediating variable).

E.g. stimuli may affect specific neural processes, which in turn may cause subsequent behavioral effects[1]: Brain processes *mediate* stimuli's effects on behavior.

Within-subject experiments present unique problems and opportunities for mediation analyses.

We developed **bmlm**, an R package for estimating, summarizing, and visualizing Bayesian multilevel mediation models for within-subject mediation analyses[2].

Learn more: https://mvuorre.github.io/bmlm/

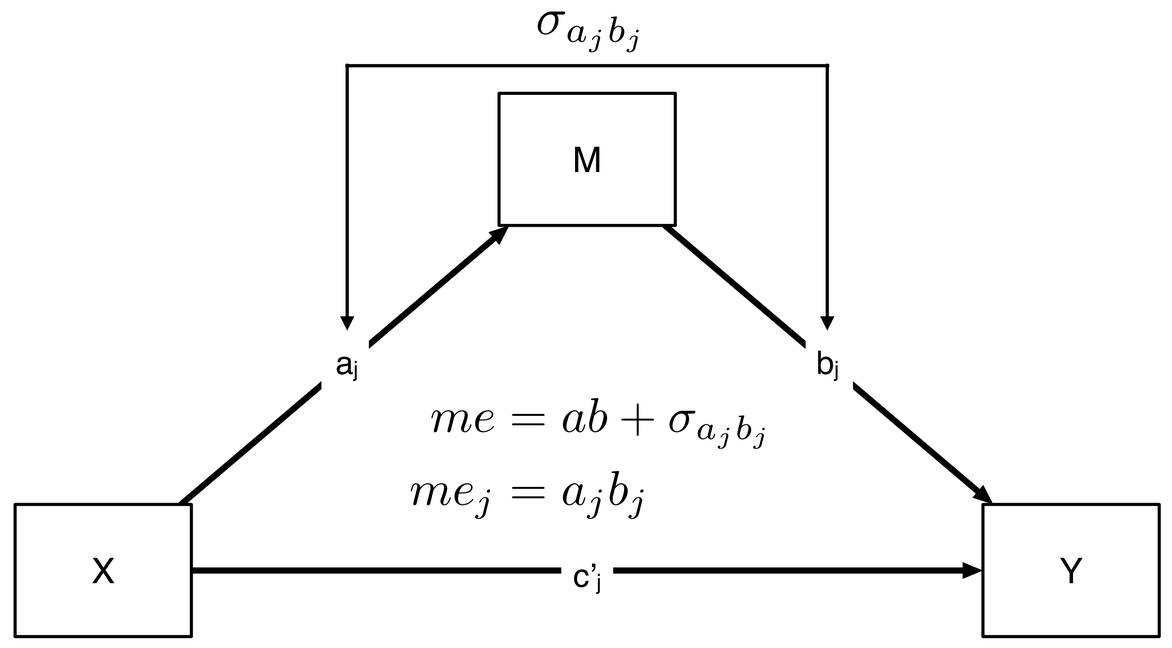

Figure 1. Path diagram of the model. Double-headed arrow indicates covariance. me = mediated effect, me_j = mediated effect for subject j.

- 3 causal paths modeled with Generalized Linear Mixed Models
  - **a**: X's (IV) effect on M (potential mediator)
  - **b**: M's effect on Y (DV), controlling for X's direct effect on Y (**c'**)
- Binary outcomes can be modeled through a logistic link function

Example: Tip-of-the-tongue, event-related potentials, and learning

Tip-of-the-tongue state (ToT) predicts increased curiosity and answer-seeking[3], and possibly **learning**.

In learning tasks, **ERP** amplitude in response to studied items (late positivity) predicts successful recall[4].

- To what extent do ToT states impact learning?
  - Parameter **c**: Total effect of ToT on Recall
- Does the ERP (late positivity) index a causal mechanism underlying the ToT—Recall relationship?
  - **me**: ToT's effect on Recall that is mediated by ERP amplitude

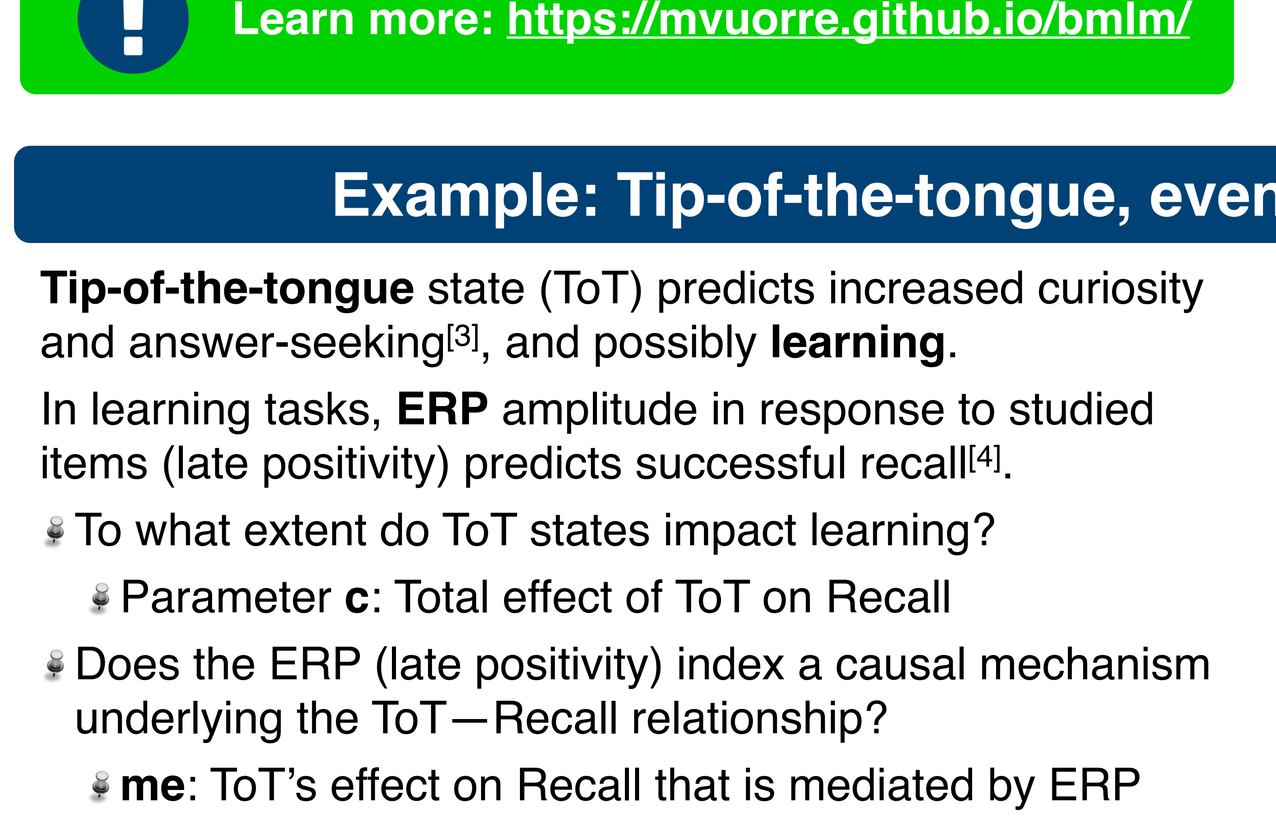

Figure 2. Model's estimated parameters. *Histograms:* Posterior samples of average parameters, and their between-subject SDs. *Caterpillar plots:* Subject-specific (blue) and average (red) parameters' posterior means and 95% credible intervals. Y is binary (recalled or not recalled) so effects on Y are in log-odds.

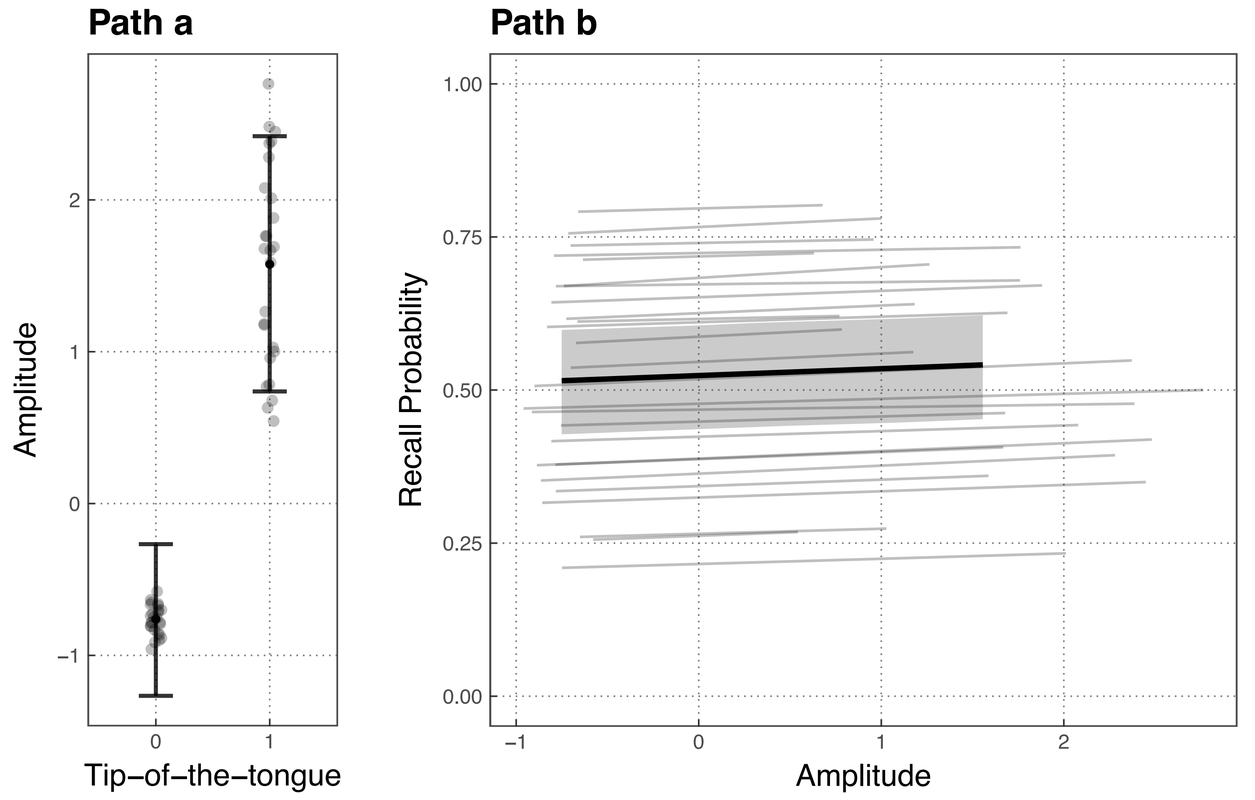

Figure 3. Model's fitted values. *Left:* Within-subject centered ERP amplitudes for no ToT (0) and ToT (1) trials. Error bars are 95% credible intervals of average amplitude. *Right:* Spaghetti plot of subject-specific (thin) and average (thick line with 95% credible interval) recall probabilities on fitted ERP amplitudes.

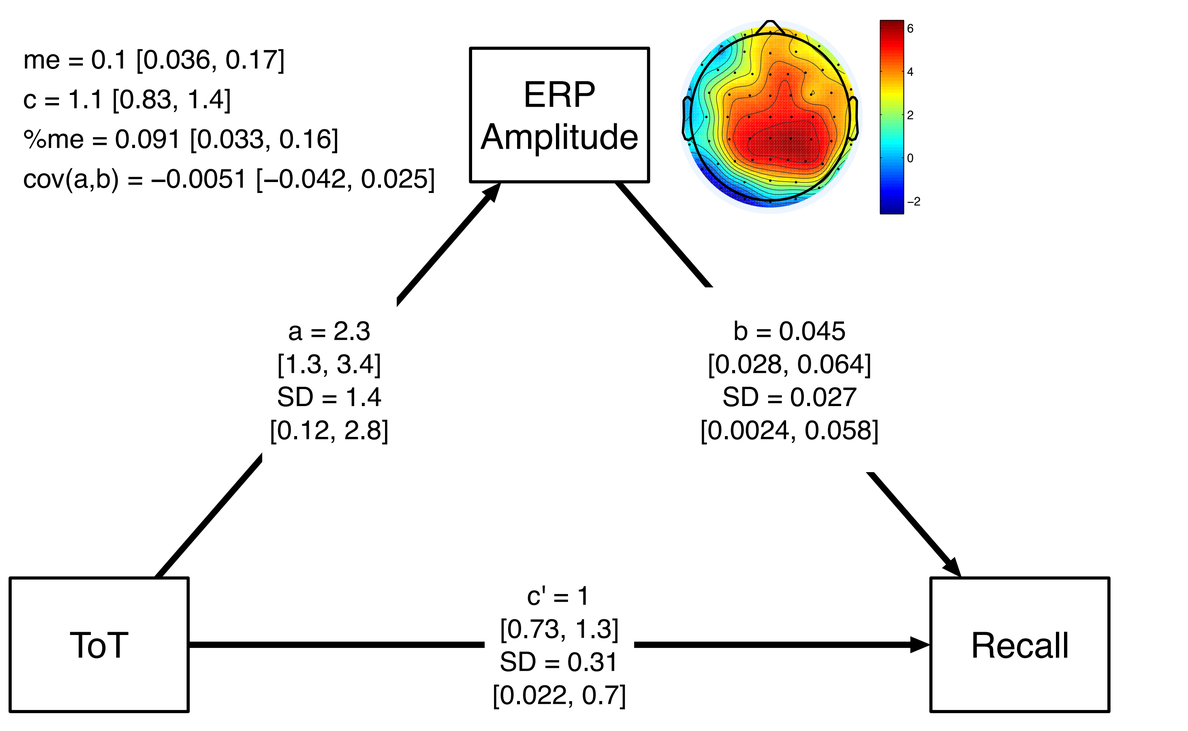

Figure 4. Path diagram of the estimated model. Each parameter is reported with a [95% credible interval]. me = mediated effect, c = total effect, %me = proportion mediated effect, cov(a, b) = covariance of subject-specific a_j and b_j).

[1] Atlas, L. Y., Bolger, N., Lindquist, M. A., & Wager, T. D. (2010). *The Journal of Neuroscience*, *30*(39). **[2]** Vuorre, M., & Bolger, N. (2017). *OSF Preprint*. **[3]** Metcalfe, J., Schwartz, B. L., & Bloom, P. A. (2017). Cognitive Research: Principles and Implications, 2(31). **[4]** Sanquist, T. F., Rohrbaugh, J. W., Syndulko, K., & Lindsley, D. B. (1980). *Psychophysiology*, *17*(6),

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