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References

M. W.-L. Cheung: Synthesizing indirect effects in mediation models with meta-analytic methods **Cheung-2021**

Mike W.-L. Cheung. "Synthesizing indirect effects in mediation models with meta-analytic methods". In: *Alcohol and Alcoholism* 57.1 (June 2021), pp. 5–15. DOI: 10.1093/alcalc/agab044.

Abstract: Aims A mediator is a variable that explains the underlying mechanism between an independent variable and a dependent variable. The indirect effect indicates the effect from the predictor to the outcome variable via the mediator. In contrast, the direct effect represents the predictor's effort on the outcome variable after controlling for the mediator. Methods A single study rarely provides enough evidence to answer research questions in a particular domain. Replications are generally recommended as the gold standard to conduct scientific research. When a sufficient number of studies have been conducted addressing similar research questions, a meta-analysis can be used to synthesize those studies' findings. Results The main objective of this paper is to introduce two frameworks to integrating studies using mediation analysis. The first framework involves calculating standardized indirect effects and direct effects and conducting a multivariate meta-analysis on those effect sizes. The second one uses meta-analytic structural equation modeling to synthesize correlation matrices and fit mediation models on the average correlation matrix. We illustrate these procedures on a real dataset using the R statistical platform. Conclusion This paper closes with some further directions for future studies.

S. F. Cheung et al.: FINDOUT: Using either SPSS commands or graphical user interface to identify influential cases in structural equation modeling in AMOS

Cheung-Pesigan-2023a

Shu Fai Cheung and Ivan Jacob Agaloos Pesigan. "FINDOUT: Using either SPSS commands or graphical user interface to identify influential cases in structural equation modeling in AMOS". In: *Multivariate Behavioral Research* (Jan. 2023), pp. 1–5. DOI: 10.1080/00273171.2022.2148089.

Abstract: The results in a structural equation modeling (SEM) analysis can be influenced by just a few observations, called influential cases. Tools have been developed for users of R to identify them. However, similar tools are not available for AMOS, which is also a popular SEM software package. We introduce the FINDOUT toolset, a group of SPSS extension commands, and an AMOS plugin, to identify influential cases and examine how these cases influence the results. The SPSS commands can be used either as syntax commands or as custom dialogs from pull-down menus, and the AMOS plugin can be run from AMOS pull-down menu. We believe these tools can help researchers to examine the robustness of their findings to influential cases.

S. F. Cheung et al.: semlbci: An R package for forming likelihood-based confidence intervals for parameter estimates, correlations, indirect effects, and other derived parameters

Cheung-Pesigan-2023b

Shu Fai Cheung and Ivan Jacob Agaloos Pesigan. "semlbci: An R package for forming likelihood-based confidence intervals for parameter estimates, correlations, indirect effects, and other derived parameters". In: *Structural Equation Modeling: A Multidisciplinary Journal* (May 2023), pp. 1–15. DOI: 10.1080/10705511.2023.2183860.

Abstract: There are three common types of confidence interval (CI) in structural equation modeling (SEM): Wald-type CI, bootstrapping CI, and likelihood-based CI (LBCI). LBCI has the following advantages: (1) it has better coverage probabilities and Type I error rate compared to Wald-type CI when the sample size is finite; (2) it correctly tests the null hypothesis of a parameter based on

likelihood ratio chi-square difference test; (3) it is less computationally intensive than bootstrapping CI; and (4) it is invariant to transformations. However, LBCI is not available in many popular SEM software packages. We developed an R package, semlbci, for forming LBCI for parameters in models fitted by lavaan, a popular open-source SEM package, such that researchers have more options in forming CIs for parameters in SEM. The package supports both unstandardized and standardized estimates, derived parameters such as indirect effect, multisample models, and the robust LBCI proposed by Falk.

S. F. Cheung et al.: DIY bootstrapping: Getting the nonparametric bootstrap confidence interval in SPSS for any statistics or function of statistics (when this bootstrapping is appropriate) **Cheung-Pesigan-Vong-2022**

Shu Fai Cheung, Ivan Jacob Agaloos Pesigan, and Weng Ngai Vong. "DIY bootstrapping: Getting the nonparametric bootstrap confidence interval in SPSS for any statistics or function of statistics (when this bootstrapping is appropriate)". In: *Behavior Research Methods* 55.2 (Mar. 2022), pp. 474–490. DOI: 10.3758/s13428-022-01808-5.

Abstract: Researchers can generate bootstrap confidence intervals for some statistics in SPSS using the BOOTSTRAP command. However, this command can only be applied to selected procedures, and only to selected statistics in these procedures. We developed an extension command and prepared some sample syntax files based on existing approaches from the Internet to illustrate how researchers can (a) generate a large number of nonparametric bootstrap samples, (b) do desired analysis on all these samples, and (c) form the bootstrap confidence intervals for selected statistics using the OMS commands. We developed these tools to help researchers apply nonparametric bootstrapping to any statistics for which this method is appropriate, including statistics derived from other statistics, such as standardized effect size measures computed from the t test results. We also discussed how researchers can extend the tools for other statistics and scenarios they encounter.

Li et al.: Bayesian forecasting with a regime-switching zero-inflated multilevel poisson regression model: An application to adolescent alcohol use with spatial covariates

Li-Oravecz-Zhou-etal-2022

Yanling Li, Zita Oravecz, et al. "Bayesian forecasting with a regime-switching zero-inflated multilevel poisson regression model: An application to adolescent alcohol use with spatial covariates". In: *Psychometrika* 87.2 (Jan. 2022), pp. 376–402. DOI: 10.1007/s11336-021-09831-9.

Abstract: In this paper, we present and evaluate a novel Bayesian regime-switching zero-inflated multilevel Poisson (RS-ZIMLP) regression model for forecasting alcohol use dynamics. The model partitions individuals' data into two phases, known as regimes, with: (1) a zero-inflation regime that is used to accommodate high instances of zeros (non-drinking) and (2) a multilevel Poisson regression regime in which variations in individuals' log-transformed average rates of alcohol use are captured by means of an autoregressive process with exogenous predictors and a person-specific intercept. The times at which individuals are in each regime are unknown, but may be estimated from the data. We assume that the regime indicator follows a first-order Markov process as related to exogenous predictors of interest. The forecast performance of the proposed model was evaluated using a Monte Carlo simulation study and further demonstrated using substance use and spatial covariate data from the Colorado Online Twin Study (CoTwins). Results showed that the proposed model yielded better forecast performance compared to a baseline model which predicted all cases as non-drinking and a reduced ZIMLP model without the RS structure, as indicated by higher AUC (the area under the receiver operating characteristic (ROC) curve) scores, and lower mean absolute errors (MAEs) and root-mean-square errors (RMSEs). The improvements in forecast performance were even more pronounced when we limited the comparisons to participants who showed at least one instance of transition to drinking.

Li et al.: Fitting multilevel vector autoregressive models in Stan, JAGS, and Mplus **Li-Wood-Ji-etal-2021**

Yanling Li, Julie Wood, et al. "Fitting multilevel vector autoregressive models in Stan, JAGS, and Mplus". In: *Structural Equation Modeling: A Multidisciplinary Journal* 29.3 (Sept. 2021), pp. 452–475. DOI: 10.1080/10705511.2021.1911657.

Abstract: The influx of intensive longitudinal data creates a pressing need for complex modeling tools that help enrich our understanding of how individuals change over time. Multilevel vector autoregressive (mlVAR) models allow for simultaneous evaluations of reciprocal linkages between dynamic processes and individual differences, and have gained increased recognition in recent years. High-dimensional and other complex variations of mlVAR models, though often computationally intractable in the frequentist framework, can be readily handled using Markov chain Monte Carlo techniques in a Bayesian framework. However, researchers in social science fields may be unfamiliar with ways to capitalize on recent developments in Bayesian software programs. In this paper, we provide step-by-step illustrations and comparisons of options to fit Bayesian mlVAR models using Stan, JAGS and Mplus, supplemented with a Monte Carlo simulation study. An empirical example is used to demonstrate the utility of mlVAR models in studying intra- and inter-individual variations in affective dynamics.

McNeish et al.: Intensive longitudinal mediation in Mplus **McNeish-MacKinnon-2022**

Daniel McNeish and David P. MacKinnon. "Intensive longitudinal mediation in Mplus". In: *Psychological Methods* (Dec. 2022). DOI: 10.1037/met0000536.

Abstract: Much of the existing longitudinal mediation literature focuses on panel data where relatively few repeated measures are collected over a relatively broad timespan. However, technological advances in data collection (e.g., smartphones, wearables) have led to a proliferation of short duration, densely collected longitudinal data in behavioral research. These intensive longitudinal data

differ in structure and focus relative to traditionally collected panel data. As a result, existing methodological resources do not necessarily extend to nuances present in the recent influx of intensive longitudinal data and designs. In this tutorial, we first cover potential limitations of traditional longitudinal mediation models to accommodate unique characteristics of intensive longitudinal data. Then, we discuss how recently developed dynamic structural equation models (DSEMs) may be well-suited for mediation modeling with intensive longitudinal data and can overcome some of the limitations associated with traditional approaches. We describe four increasingly complex intensive longitudinal mediation models: (a) stationary models where the indirect effect is constant over time and people, (b) person-specific models where the indirect effect varies across people, (c) dynamic models where the indirect effect varies across time, and (d) cross-classified models where the indirect effect varies across both time and people. We apply each model to a running example featuring a mobile health intervention designed to improve health behavior of individuals with binge eating disorder. In each example, we provide annotated Mplus code and interpretation of the output to guide empirical researchers through mediation modeling with this increasingly popular type of longitudinal data.

Nüst et al.: The Rockerverse: Packages and applications for containerisation with R

Nust-Eddelbuettel-Bennett-etal-2020

Daniel Nüst et al. "The Rockerverse: Packages and applications for containerisation with R". In: *The R Journal* 12.1 (2020), p. 437. DOI: 10.32614/rj-2020-007.

Abstract: The Rocker Project provides widely used Docker images for R across different application scenarios. This article surveys downstream projects that build upon the Rocker Project images and presents the current state of R packages for managing Docker images and controlling containers. These use cases cover diverse topics such as package development, reproducible research, collaborative work, cloud-based data processing, and production deployment of services. The variety of applications demonstrates the power of the Rocker Project specifically and containerisation in general. Across the diverse ways to use containers, we identified common themes: reproducible

environments, scalability and efficiency, and portability across clouds. We conclude that the current growth and diversification of use cases is likely to continue its positive impact, but see the need for consolidating the Rockerverse ecosystem of packages, developing common practices for applications, and exploring alternative containerisation software.

Oisˊ et al.: Time to intervene: A continuous-time approach to network analysis and centrality **Ryan-Hamaker-2021**

Oisˊ and Ellen L. Hamaker. "Time to intervene: A continuous-time approach to network analysis and centrality". In: *Psychometrika* 87.1 (June 2021), pp. 214–252. DOI: 10.1007/s11336-021-09767-0.

Abstract: Network analysis of ESM data has become popular in clinical psychology. In this approach, discrete-time (DT) vector auto-regressive (VAR) models define the network structure with centrality measures used to identify intervention targets. However, VAR models suffer from time-interval dependency. Continuous-time (CT) models have been suggested as an alternative but require a conceptual shift, implying that DT-VAR parameters reflect total rather than direct effects. In this paper, we propose and illustrate a CT network approach using CT-VAR models. We define a new network representation and develop centrality measures which inform intervention targeting. This methodology is illustrated with an ESM dataset.

Pesigan et al.: SEM-based methods to form confidence intervals for indirect effect: Still applicable given nonnormality, under certain conditions **Pesigan-Cheung-2020**

Ivan Jacob Agaloos Pesigan and Shu Fai Cheung. "SEM-based methods to form confidence intervals for indirect effect: Still applicable given nonnormality, under certain conditions". In: *Frontiers in Psychology* 11 (Dec. 2020). DOI: 10.3389/fpsyg.2020.571928.

Abstract: A SEM-based approach using likelihood-based confidence interval (LBCI) has been proposed to form confidence intervals for unstandardized and standardized indirect effect in mediation

models. However, when used with the maximum likelihood estimation, this approach requires that the variables are multivariate normally distributed. This can affect the LBCIs of unstandardized and standardized effect differently. In the present study, the robustness of this approach when the predictor is not normally distributed but the error terms are conditionally normal, which does not violate the distributional assumption of ordinary least squares (OLS) estimation, is compared to four other approaches: nonparametric bootstrapping, two variants of LBCI, LBCI assuming the predictor is fixed (LBCI-Fixed-X) and LBCI based on ADF estimation (LBCI-ADF), and Monte Carlo. A simulation study was conducted using a simple mediation model and a serial mediation model, manipulating the distribution of the predictor. The Monte Carlo method performed worst among the methods. LBCI and LBCI-Fixed-X had suboptimal performance when the distributions had high kurtosis and the population indirect effects were medium to large. In some conditions, the problem was severe even when the sample size was large. LBCI-ADF and nonparametric bootstrapping had coverage probabilities close to the nominal value in nearly all conditions, although the coverage probabilities were still suboptimal for the serial mediation model when the sample size was small with respect to the model. Implications of these findings in the context of this special case of nonnormal data were discussed.

Pesigan et al.: Monte Carlo confidence intervals for the indirect effect with missing data **Pesigan-Cheung-2023**

Ivan Jacob Agaloos Pesigan and Shu Fai Cheung. "Monte Carlo confidence intervals for the indirect effect with missing data". In: *Behavior Research Methods* (Aug. 2023). DOI: 10.3758/s13428-023-02114-4.

Abstract: Missing data is a common occurrence in mediation analysis. As a result, the methods used to construct confidence intervals around the indirect effect should consider missing data. Previous research has demonstrated that, for the indirect effect in data with complete cases, the Monte Carlo method performs as well as nonparametric bootstrap confidence intervals (see MacKinnon et al., Multivariate Behavioral Research, 39(1), 99–128, 2004; Preacher & Selig, Communication

Methods and Measures, 6(2), 77–98, 2012; Tofighi & MacKinnon, Structural Equation Modeling: A Multidisciplinary Journal, 23(2), 194–205, 2015). In this manuscript, we propose a simple, fast, and accurate two-step approach for generating confidence intervals for the indirect effect, in the presence of missing data, based on the Monte Carlo method. In the first step, an appropriate method, for example, full-information maximum likelihood or multiple imputation, is used to estimate the parameters and their corresponding sampling variance-covariance matrix in a mediation model. In the second step, the sampling distribution of the indirect effect is simulated using estimates from the first step. A confidence interval is constructed from the resulting sampling distribution. A simulation study with various conditions is presented. Implications of the results for applied research are discussed.

Pesigan et al.: betaDelta and betaSandwich: Confidence intervals for standardized regression coefficients in R **Pesigan-Sun-Cheung-2023**

Ivan Jacob Agaloos Pesigan, Rong Wei Sun, and Shu Fai Cheung. "betaDelta and betaSandwich: Confidence intervals for standardized regression coefficients in R". In: *Multivariate Behavioral Research* (Apr. 2023), pp. 1–4. DOI: 10.1080/00273171.2023.2201277.

Abstract: The multivariate delta method was used by Yuan and Chan to estimate standard errors and confidence intervals for standardized regression coefficients. Jones and Waller extended the earlier work to situations where data are nonnormal by utilizing Browne's asymptotic distribution-free (ADF) theory. Furthermore, Dudgeon developed standard errors and confidence intervals, employing heteroskedasticity-consistent (HC) estimators, that are robust to nonnormality with better performance in smaller sample sizes compared to Jones and Waller's ADF technique. Despite these advancements, empirical research has been slow to adopt these methodologies. This can be a result of the dearth of user-friendly software programs to put these techniques to use. We present the betaDelta and the betaSandwich packages in the R statistical software environment in this manuscript. Both the normal-theory approach and the ADF approach put forth by Yuan and Chan and Jones and Waller are implemented by the betaDelta package. The HC approach proposed by

Dudgeon is implemented by the betaSandwich package. The use of the packages is demonstrated with an empirical example. We think the packages will enable applied researchers to accurately assess the sampling variability of standardized regression coefficients.

Rousselet et al.: The percentile bootstrap: A primer with step-by-step instructions in R **Rousselet-Pernet-Wilcox-2021**

Guillaume A. Rousselet, Cyril R. Pernet, and Rand R. Wilcox. "The percentile bootstrap: A primer with step-by-step instructions in R". In: *Advances in Methods and Practices in Psychological Science* 4.1 (Jan. 2021), pp. 1–10. DOI: 10.1177/2515245920911881.

Abstract: The percentile bootstrap is the Swiss Army knife of statistics: It is a nonparametric method based on data-driven simulations. It can be applied to many statistical problems, as a substitute to standard parametric approaches, or in situations for which parametric methods do not exist. In this Tutorial, we cover `R` code to implement the percentile bootstrap to make inferences about central tendency (e.g., means and trimmed means) and spread in a one-sample example and in an example comparing two independent groups. For each example, we explain how to derive a bootstrap distribution and how to get a confidence interval and a p value from that distribution. We also demonstrate how to run a simulation to assess the behavior of the bootstrap. For some purposes, such as making inferences about the mean, the bootstrap performs poorly. But for other purposes, it is the only known method that works well over a broad range of situations. More broadly, combining the percentile bootstrap with robust estimators (i.e., estimators that are not overly sensitive to outliers) can help users gain a deeper understanding of their data than they would using conventional methods.

Savalei et al.: Computational options for standard errors and test statistics with incomplete normal and nonnormal data in SEM **Savalei-Rosseel-2021**

Victoria Savalei and Yves Rosseel. "Computational options for standard errors and test statis-

tics with incomplete normal and nonnormal data in SEM". In: *Structural Equation Modeling: A Multidisciplinary Journal* 29.2 (Oct. 2021), pp. 163–181. DOI: 10.1080/10705511.2021.1877548.

Abstract: This article provides an overview of different computational options for inference following normal theory maximum likelihood (ML) estimation in structural equation modeling (SEM) with incomplete normal and nonnormal data. Complete data are covered as a special case. These computational options include whether the information matrix is observed or expected, whether the observed information matrix is estimated numerically or using an analytic asymptotic approximation, and whether the information matrix and the outer product matrix of the score vector are evaluated at the saturated or at the structured estimates. A variety of different standard errors and robust test statistics become possible by varying these options. We review the asymptotic properties of these computational variations, and we show how to obtain them using lavaan in R. We hope that this article will encourage methodologists to study the impact of the available computational options on the performance of standard errors and test statistics in SEM.

Tofighi et al.: Improved inference in mediation analysis: Introducing the model-based constrained optimization procedure **Tofighi-Kelley-2020**

Davood Tofighi and Ken Kelley. "Improved inference in mediation analysis: Introducing the model-based constrained optimization procedure". In: *Psychological Methods* 25 (2020), pp. 496–515. DOI: 10.1037/met0000259.

Abstract: Mediation analysis is an important approach for investigating causal pathways. One approach used in mediation analysis is the test of an indirect effect, which seeks to measure how the effect of an independent variable impacts an outcome variable through one or more mediators. However, in many situations the proposed tests of indirect effects, including popular confidence interval-based methods, tend to produce poor Type I error rates when mediation does not occur and, more generally, only allow dichotomous decisions of "not significant" or "significant" with regards to the statistical conclusion. To remedy these issues, we propose a new method, a likelihood

ratio test (LRT), that uses non-linear constraints in what we term the model-based constrained optimization (MBCO) procedure. The MBCO procedure (a) offers a more robust Type I error rate than existing methods; (b) provides a p-value, which serves as a continuous measure of compatibility of data with the hypothesized null model (not just a dichotomous reject or fail-to-reject decision rule); (c) allows simple and complex hypotheses about mediation (i.e., one or more mediators; different mediational pathways), and (d) allows the mediation model to use observed or latent variables. The MBCO procedure is based on a structural equation modeling framework (even if latent variables are not specified) with specialized fitting routines, namely with the use of non-linear constraints. We advocate using the MBCO procedure to test hypotheses about an indirect effect in addition to reporting a confidence interval to capture uncertainty about the indirect effect because this combination transcends existing methods.

Wang et al.: Investigating the impact of the time interval selection on autoregressive mediation modeling: Result interpretations, effect reporting, and temporal designs
Wang-Zhang-2020

Lijuan Wang and Qian Zhang. "Investigating the impact of the time interval selection on autoregressive mediation modeling: Result interpretations, effect reporting, and temporal designs". In: *Psychological Methods* 25.3 (June 2020), pp. 271–291. DOI: 10.1037/met0000235.

Abstract: This study investigates the impact of the time interval (the time passed between 2 consecutive measurements) selection on autoregressive mediation modeling (AMM). For a widely used autoregressive mediation model, via analytical derivations, we explained why and how the conventionally reported time-specific coefficient estimates (e.g., $\hat{a}\hat{b}$ and $\hat{c}'$) and inference results in AMM provide limited information and can arrive in even misleading conclusions about direct and indirect effects over time. Furthermore, under the stationarity assumption, we proposed an approach to calculate the overall direct and indirect effect estimates over time and the time lag lengths at which they reach maxima, using AMM results. The derivation results revealed that the overall direct and indirect effect curves are asymptotically invariant to the time interval selection, under stationarity.

With finite samples and thus sampling errors and potential computing problems, however, our simulation results revealed that the overall indirect effect curves were better recovered when the time interval is selected to be closer to half of the time lag length at which the overall indirect effect reaches its maximum. An R function and an R Shiny app were developed to obtain the overall direct and indirect effect curves over time and facilitate the time interval selection using AMM results. Our findings provide another look at the connections between AMM and continuous time mediation modeling and the connections are discussed.

Zeileis et al.: Various versatile variances: An object-oriented implementation of clustered covariances in R **Zeileis-Koll-Graham-2020**

Achim Zeileis, Susanne Köll, and Nathaniel Graham. "Various versatile variances: An object-oriented implementation of clustered covariances in R". In: *Journal of Statistical Software* 95.1 (Oct. 2020). DOI: 10.18637/jss.v095.i01.

Abstract: Clustered covariances or clustered standard errors are very widely used to account for correlated or clustered data, especially in economics, political sciences, and other social sciences. They are employed to adjust the inference following estimation of a standard least-squares regression or generalized linear model estimated by maximum likelihood. Although many publications just refer to "the" clustered standard errors, there is a surprisingly wide variety of clustered covariances, particularly due to different flavors of bias corrections. Furthermore, while the linear regression model is certainly the most important application case, the same strategies can be employed in more general models (e.g., for zero-inflated, censored, or limited responses). In R, functions for covariances in clustered or panel models have been somewhat scattered or available only for certain modeling functions, notably the (generalized) linear regression model. In contrast, an object-oriented approach to "robust"' covariance matrix estimation - applicable beyond lm() and glm() - is available in the sandwich package but has been limited to the case of cross-section or time series data. Starting with sandwich 2.4.0, this shortcoming has been corrected: Based on methods for two generic functions (estfun() and bread()), clustered and panel covariances are provided in vcovCL(), vcovPL(),

and vcovPC(). Moreover, clustered bootstrap covariances are provided in vcovBS(), using model update() on bootstrap samples. These are directly applicable to models from packages including MASS, pscl, countreg, and betareg, among many others. Some empirical illustrations are provided as well as an assessment of the methods' performance in a simulation study.