

# EXPLANATION IN CAUSAL INFERENCE

Methods for Mediation and Interaction

TYLER J. VANDERWEELE

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OXFORD

# Explanation In Causal Inference Methods For Mediation And Interaction

**Judea Pearl**



## **Explanation In Causal Inference Methods For Mediation And Interaction:**

Explanation in Causal Inference Tyler VanderWeele, 2015-02-13 The book provides an accessible but comprehensive overview of methods for mediation and interaction There has been considerable and rapid methodological development on mediation and moderation interaction analysis within the causal inference literature over the last ten years Much of this material appears in a variety of specialized journals and some of the papers are quite technical There has also been considerable interest in these developments from empirical researchers in the social and biomedical sciences However much of the material is not currently in a format that is accessible to them The book closes these gaps by providing an accessible comprehensive book length coverage of mediation The book begins with a comprehensive introduction to mediation analysis including chapters on concepts for mediation regression based methods sensitivity analysis time to event outcomes methods for multiple mediators methods for time varying mediation and longitudinal data and relations between mediation and other concepts involving intermediates such as surrogates principal stratification instrumental variables and Mendelian randomization The second part of the book concerns interaction or moderation including concepts for interaction statistical interaction confounding and interaction mechanistic interaction bias analysis for interaction interaction in genetic studies and power and sample size calculation for interaction The final part of the book provides comprehensive discussion about the relationships between mediation and interaction and unites these concepts within a single framework This final part also provides an introduction to spillover effects or social interaction concluding with a discussion of social network analyses The book is written to be accessible to anyone with a basic knowledge of statistics Comprehensive appendices provide more technical details for the interested reader Applied empirical examples from a variety of fields are given throughout Software implementation in SAS Stata SPSS and R is provided The book should be accessible to students and researchers who have completed a first year graduate sequence in quantitative methods in one of the social or biomedical sciences disciplines The book will only presuppose familiarity with linear and logistic regression and could potentially be used as an advanced undergraduate book as well

**Explanation in Causal Inference : Methods for Mediation and Interaction** Tyler J VanderWeele, 2013

Causality in Policy Studies Alessia Damonte, Fedra Negri, 2023-02-13 This volume provides a methodological toolbox for conducting policy research Recognizing that policy research spans various academic disciplines each of which takes a different view on causality the volume introduces a methodologically pluralistic approach to policy studies Each chapter clarifies the research question that each technique can answer the research design and data treatment that each technique requires for its results to be sound the validity domain of its results and the actual deployment of the technique through a replicable example Techniques covered include quasi experimental designs approaches to account for selection bias and observed imbalances directed acyclic graphs and structural equation models Qualitative Comparative Analysis Bayesian case study and process tracing and Agent Based Modelling By working through the volume readers will

understand how to learn from different techniques apply them consciously and triangulate them to make better sense of findings This volume is intended for advanced academic courses as well as scholars and practitioners in policy related fields such as political science economics sociology and public administration This is an open access book     Modern Epidemiology Timothy L. Lash, Tyler J. VanderWeele, Sebastien Haneuse, Kenneth Rothman, 2020-12-11 Now in a fully revised Fourth Edition Modern Epidemiology remains the gold standard text in this complex and evolving field This edition continues to provide comprehensive coverage of the principles and methods for the design analysis and interpretation of epidemiologic research Featuring a new format allowing space for margin notes this edition Reflects both the conceptual development of this evolving science and the increasing role that epidemiology plays in improving public health and medicine Features new coverage of methods such as agent based modeling quasi experimental designs mediation analysis and causal modeling Updates coverage of methods such as concepts of interaction bias analysis and time varying designs and analysis Continues to cover the full breadth of epidemiologic methods and concepts including epidemiologic measures of occurrence and effect study designs validity precision statistical interference field methods surveillance ecologic designs and use of secondary data sources Includes data analysis topics such as Bayesian analysis probabilistic bias analysis time to event analysis and an extensive overview of modern regression methods including logistic and survival regression splines longitudinal and cluster correlated hierarchical data analysis propensity scores and other scoring methods and marginal structural models Summarizes the history specialized aspects and future directions of topical areas including among others social epidemiology infectious disease epidemiology genetic and molecular epidemiology psychiatric epidemiology injury and violence epidemiology and pharmacoepidemiology     Insights in Life-course Epidemiology and Social Inequalities: 2021 Cyrille Delpierre, Hilde Langseth, 2022-09-05     *Health Inequalities* Johan P. Mackenbach, 2019 The world we live in is hugely unequal People in a better socioeconomic position do not only lead more comfortable lives but also longer and healthier lives Drawing on research from a wide span of disciplines this book explores the evolution of health inequalities over time in different countries and the causes behind them     Handbook of Education Policy Research Lora Cohen-Vogel, Peter Youngs, Janelle Scott, 2025-07-17 The second edition of the Handbook of Education Policy Research the largest volume published in AERA's history addresses a variety of policy and contextual issues in early childhood K 12 and postsecondary education that have received extensive empirical attention during the past 15 years With the pandemic and social turmoil as a backdrop the editors build on the breadth and depth of the first edition while expanding the scope of the project to include subjects methods theories and analyses that have contributed powerfully to the study of education policy and politics in the 2010s and 2020s The field has become more comprehensive and inclusive and the authors represent a diversity of racial ethnic and gender identities and intellectual and disciplinary orientations Most chapters come from multiple authors reflecting the multi sourced development of research in education policy since the first volume was published This

compilation consists of 70 chapters and nine commentaries that map past present and future directions of the field and richly attend to critical issues of interest to students researchers policy makers and practitioners     Developmental Psychopathology, Theory and Method Dante Cicchetti,2015-12-22 The seminal reference for the latest research in developmental psychopathology Developmental Psychopathology is a four volume compendium of the most complete and current research on every aspect of the field Volume One Theory and Method focuses on the theoretical and empirical work that has contributed to dramatic advancements in understanding of child and adult development including findings in the areas of genetics and neurobiology as well as social and contextual factors Now in its third edition this comprehensive reference has been fully updated to reflect the current state of the field and its increasingly multilevel and interdisciplinary nature and the increasing importance of translational research Contributions from expert researchers and clinicians provide insight into how multiple levels of analysis may influence individual differences the continuity or discontinuity of patterns and the pathways by which the same developmental outcomes may be achieved Advances in developmental psychopathology have burgeoned since the 2006 publication of the second edition ten years ago and keeping up on the latest findings in multiple avenues of investigation can be burdensome to the busy professional and researcher from psychology and related fields This reference solves the problem by collecting the best of the best as edited by Dante Cicchetti a recognized leader in the field into one place with a logical organization designed for easy reference Get up to date on the latest research from the field Explore new models emerging theory and innovative approaches Learn new technical analysis and research design methods Understand the impact of life stage on mental health The complexity of a field as diverse as developmental psychopathology deepens with each emerging theory and new area of study as made obvious by the exciting findings coming out of institutions and clinics around the world Developmental Psychopathology Volume One Theory and Method brings these findings together into a cohesive broad reaching reference     *Causality in a Social World* Guanglei Hong,2015-06-09 Causality in a Social World introduces innovative new statistical research and strategies for investigating moderated intervention effects mediated intervention effects and spill over effects using experimental or quasi experimental data The book uses potential outcomes to define causal effects explains and evaluates identification assumptions using application examples and compares innovative statistical strategies with conventional analysis methods Whilst highlighting the crucial role of good research design and the evaluation of assumptions required for identifying causal effects in the context of each application the author demonstrates that improved statistical procedures will greatly enhance the empirical study of causal relationship theory Applications focus on interventions designed to improve outcomes for participants who are embedded in social settings including families classrooms schools neighbourhoods and workplaces     Statistical Causal Mediation Analysis with R Anning Hu,2025-02-17 This book comprehensively covers various causal mediation analysis CMA methods developed across multiple fields organizing them into a reader friendly progression of methodological advancements Interest in the mechanisms that form

causal relationships is widespread across various fields including sociology demography economics political science psychology epidemiology public health and educational studies to name a few Compared to the well established research focusing on bivariate causality CMA the study of mediation mechanisms within the framework of causal inference requires more complex identification assumptions estimation methods and nuanced interpretations of the results Therefore to conduct CMA with rigor one must acquaint themselves with a distinct and systematic body of knowledge that is clearly separate from traditional linear regression modeling or structural equation modelling SEM Against this backdrop the objectives of the proposed book are twofold Firstly it aims to offer readers an approachable and engaging explanation of the statistical theories underpinning the diverse methods of CMA Specifically we highlight the crucial mediation identification assumptions a critical aspect frequently neglected by practitioners and educators Secondly the book intends to guide readers through detailed step by step examples of applying CMA methods in practical research contexts Through this approach readers are anticipated to gain practical skills necessary for addressing their own research or teaching challenges This book begins with traditional methods that rely on differences or products of coefficients in linear regression modeling moves on to CMA involving a single mediator and advances to more sophisticated approaches that manage parallel or sequentially ordered mediators Additionally sensitivity analysis is introduced as an important supplementary analytical step Thus the content spans from conventional CMA tools to the forefront methodologies that have emerged in recent decades The book is designed to be self sufficient characterized by a balanced and well integrated presentation of both theory and application

**Opening the Black Box: Estimation of Targeted Effects in Causal Mediation Analysis - With Applications to Global Health and Occupational Epidemiology** Aolin Wang, 2016 Recent work has considerably advanced the definition identification and estimation of different types of effects in causal mediation analysis It extended the traditional approaches for mediation analysis by using the counterfactual or potential outcome framework to allow for nonlinearities and exposure mediator interaction Despite the various estimation methods and statistical routines being developed a unified approach is lacking which incorporates recently introduced causal decompositions Also relatively few studies explored scenarios with more than one mediator In this work we used causal diagrams and potential outcome framework to contribute to the literature on causal mediation analysis We first provided a unified framework for estimating targeted effects from the most recent 4 way decomposition in the single mediator setting We demonstrated that g computation implemented via Monte Carlo simulations in standard statistical software can offer such unification and is flexible in accommodating different types of exposure mediator and outcome variables We also extended some of the existing estimation techniques to more complicated mediation settings that involve contextual exposure intermediate confounding multiple causally ordered mediators time varying mediators and time to event outcomes We applied regression based techniques g computation and inverse probability weighted IPW fitting of marginal structural model MSM to investigate mechanisms underlying the effects of human

development on individual health the health disparity in education and the effect of different physical activity domains on acute myocardial infarction The flexibility of g computation comes at a large cost it becomes computationally intensive as the number of variables and sample size grow Alternatively mediator and outcome regression based methods and IPW fitting of MSM can be applied in general linear systems and survival context respectively The use of causal inference techniques did not preclude the possibility of model misspecification and the presence of uncontrolled confounding which may bias our results Future work should explore the properties of different estimation techniques and their use in estimating targeted quantities and incorporate sensitivity analysis for uncontrolled confounding in causal mediation analysis

Sociological Abstracts Leo P. Chall, 1992 CSA Sociological Abstracts abstracts and indexes the international literature in sociology and related disciplines in the social and behavioral sciences The database provides abstracts of journal articles and citations to book reviews drawn from over 1 800 serials publications and also provides abstracts of books book chapters dissertations and conference papers

Mediation Analysis with Complex Intermediate Causal Structure Fan Xia, 2020 My doctoral research is oriented around causal inference specifically causal mediation analysis Roughly it can be divided into two parts 1 understanding and resolving conceptual issues in causal problems and 2 developing methodology for causal analysis One goal of my doctoral research is to provide a comprehensive guide to applied statisticians and epidemiologists that can help them navigate the philosophical subtleties and abundant methodology in causal inference Another goal of my doctoral research is to develop methodology for complex causal mediation structures including mediation analysis with treatment induced confounding and mediation analysis with multiple mediation pathways Clarifying Identification Assumptions in Causal Mediation Analysis One of my research projects is to clarify identification assumptions in causal mediation analysis This project provides a close examination of the definitions of the causal parameters of interest identification bounding assumptions and their connections and widely used tools and statistical methods in mediation analysis Causal Mediation Analysis with Treatment Induced Confounding Treatment induced confounding is present when some prognostic factors induced by the treatment occur before the mediator and have an effect on it Sequential ignorability assumptions that are typically used for the identification of the natural direct effect exclude treatment induced confounding Treatment induced confounding is regarded as a difficult problem in mediation analysis We provide new sets of identification assumptions including two no additional heterogeneity assumptions to identify the natural direct effect in the presence of treatment induced confounding Notably the identified expression of the natural direct effect is the same as that of the interventional direct effect We derive the semiparametric efficiency bound for the estimand and propose a multiply robust estimator that remains consistent under four types of possible misspecification To ensure model compatibility we factorize the conditional joint distribution of the mediator and the treatment induced confounder into marginal distributions and a dependence structure using copula Causal Mediation Analysis with Multiple Mediators We consider a decomposition of the total indirect

effect through multiple mediators with an unspecified causal ordering into individual components termed exit indirect effects and a remainder interaction term We provide a set of identification assumptions for estimating all components The identified expressions which are closely related to the interventional indirect effects continue to have causal interpretations when some identification assumptions are violated as long as the total indirect effect is identified We provide four moment type estimators for each decomposed effect based on different parametrisations and derive the semiparametric efficiency bounds for the effects The efficient influence functions contain conditional densities that are variation dependent which is uncommon in existing problems and we consider a reparameterization based on copulas to avoid model incompatibility and proposed a quadruply robust estimator for each of the decomposed effects that remains consistent and asymptotically normal under four types of possible misspecification and is also locally semiparametric efficient *Linguistics and Language Behavior Abstracts*, 1993 *Dissertation Abstracts International*, 2005 **Causal inference** K. J. Rothman, 1988 **Causal**

**Inference Across Populations**, 2015 This dissertation addresses the problem of when one can infer that a causal factor that has an effect in one population would have a similar effect in others For example if reducing class sizes increases educational outcomes in one neighborhood would reducing them in another raise outcomes by a similar amount This is known as the problem of extrapolation This dissertation reviews the prior literature on extrapolation explains how extrapolation relates to other forms of causal inference and presents techniques for extrapolating more reliably To model extrapolation I rely on recently developed causal modeling techniques which use graphs to represent causal relations among variables I build on the work of Judea Pearl and Elias Bareinboim who provide graphical methods for determining when it is possible to extrapolate causal quantities across populations given assumptions about how those populations differ I argue that their account explicates one type of extrapolation but that there are extrapolative inferences that go beyond their account The central positive contribution of the dissertation is that it makes precise the sense in which knowing how a cause brings about its effect facilitates extrapolation In cases where a cause influences its effect via multiple paths newly developed causal mediation techniques enable one to precisely quantify the way that the cause influences its effect via each of the paths These techniques aid extrapolation since the causal quantities identified by these techniques are invariant across a range of ways that two populations may differ Moreover the conditions across which these quantities are invariant cannot be represented within Pearl and Bareinboim's framework In discussing the problem of extrapolation I engage with several central philosophical issues First characterizing the problem requires one to elucidate the relationship between causal and statistical inference Second the causal mediation techniques I advocate shed light on recent debates about mechanistic explanation Finally the study of the conditions under which causal relationships generalize is essential for understanding the nature of causal relationships and their role in scientific theories *Causal Inference and the Problem of Estimating a Subject by Treatment Interaction* G. L. Gadbury, 1997 *An Introduction to Causal Inference* Judea Pearl, 2015 This paper



summarizes recent advances in causal inference and underscores the paradigmatic shifts that must be undertaken in moving from traditional statistical analysis to causal analysis of multivariate data. Special emphasis is placed on the assumptions that underly all causal inferences, the languages used in formulating those assumptions, the conditional nature of all causal and counterfactual claims, and the methods that have been developed for the assessment of such claims. These advances are illustrated using a general theory of causation based on the Structural Causal Model (SCM) described in Pearl (2000a), which subsumes and unifies other approaches to causation and provides a coherent mathematical foundation for the analysis of causes and counterfactuals. In particular, the paper surveys the development of mathematical tools for inferring from a combination of data and assumptions, answers to three types of causal queries: 1) queries about the effects of potential interventions, also called causal effects or policy evaluation; 2) queries about probabilities of counterfactuals, including assessment of regret, attribution, or causes of effects; and 3) queries about direct and indirect effects, also known as mediation. Finally, the paper defines the formal and conceptual relationships between the structural and potential outcome frameworks and presents tools for a symbiotic analysis that uses the strong features of both. The tools are demonstrated in the analyses of mediation, causes of effects, and probabilities of causation.

p. 1      *An Introduction to Causal Inference*, 2009

This paper summarizes recent advances in causal inference and underscores the paradigmatic shifts that must be undertaken in moving from traditional statistical analysis to causal analysis of multivariate data. Special emphasis is placed on the assumptions that underly all causal inferences, the languages used in formulating those assumptions, the conditional nature of all causal and counterfactual claims, and the methods that have been developed for the assessment of such claims. These advances are illustrated using a general theory of causation based on the Structural Causal Model (SCM) described in Pearl (2000a), which subsumes and unifies other approaches to causation and provides a coherent mathematical foundation for the analysis of causes and counterfactuals. In particular, the paper surveys the development of mathematical tools for inferring from a combination of data and assumptions, answers to three types of causal queries: 1) queries about the effects of potential interventions, also called causal effects or policy evaluation; 2) queries about probabilities of counterfactuals, including assessment of regret, attribution, or causes of effects; and 3) queries about direct and indirect effects, also known as mediation. Finally, the paper defines the formal and conceptual relationships between the structural and potential outcome frameworks and presents tools for a symbiotic analysis that uses the strong features of both.

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