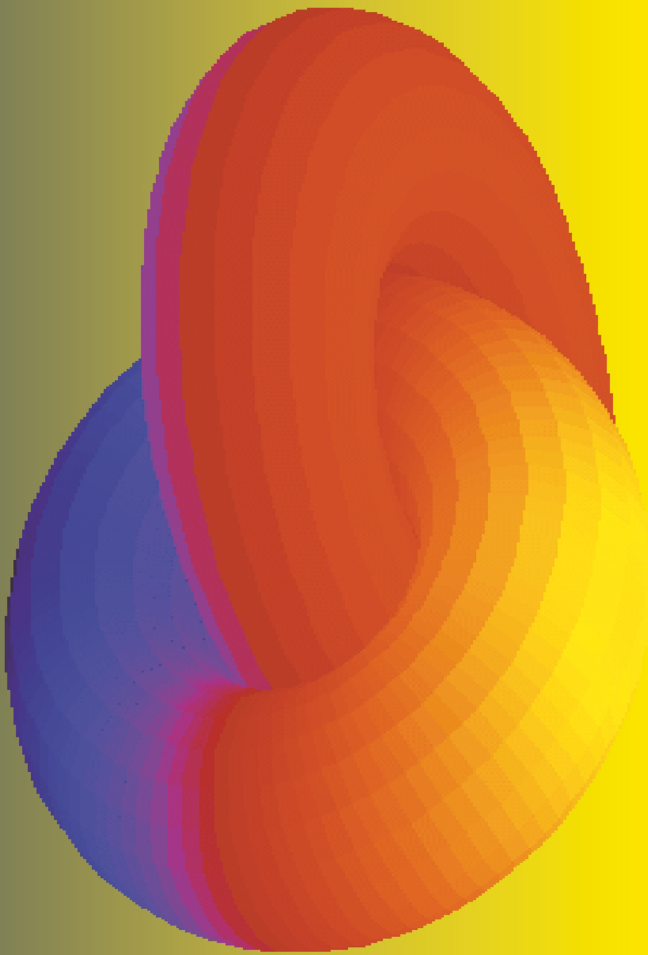
Theoriae causalitatis principia mathematica



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Dedication

To my lovely family.

Thank you.
Without your support and patience,
I would have never finished this book.

Contents

FOREWORD

"This book ... is the one in which the author elaborates on the nature of cause and effect."

Professor Dr. Marry E. Thompson

University of Waterloo, Canada
President of the Statistical Society of Canada, 2003-04
Scientific director of the Canadian Statistical Sciences Institute (CANSSI)

In:

Thompson, M. E. (2006). Reviews. Causality. New statistical methods. I. Barukčić. Short book review. International Statistical Institute, 26(1), 6.

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PREFACE

The many occasions through so many years on which I had the privilege to do some investigations on causality led step by step to the conclusion that a theory of causality must be consistent with the basic concepts of philosophy and classical logic, with probability theory, with Einstein's theory of special and general relativity and of course with quantum mechanics too. Thus far, from this point of view, a hard work had to be done. In particular, it is important to emphasize in this context that this monograph is about one of those areas that provide rich opportunities to make many mistakes.

The purpose of this monograph is to give an exact insight into the philosophical and mathematical foundations of the theory of causality to those readers who are, from a general scientific and philosophical point of view, interested in causality, causal relationships, cause and effect, but who are not conversant with the mathematical apparatus of theoretical mathematics, classical logic and philosophy. On the other hand, I have spared myself no pain in my endeavour to present the main mathematical principles of causality in the simplest and most intelligible form. Thus, on the whole, in the interest of clearness, it appeared to me inevitable that I should repeat myself frequently. For a more detailed philosophical background of causality, please look into my two publications in German from the year 1989 and 1997. The theory and mathematical methods discussed in this book will bring good help in analysing numerical data especially in medicine.

However, this book is not just another probabilistic theory of causation. Causality is an excellent book for self-study and a pragmatic help for researchers. The formal proofs, a lot of exercises and figures plus unusually detailed solutions will help the reader, especially in medical and other biosciences. This book is designed to provide both, a new mathematical methodology for making causal inferences from experimental and nonexperimental data and the underlying (philosophical) theory. This monograph will continue to be of great importance, the reader will enjoy reading this book.

Jever, the 23.04.2017 Ilija Barukčić

Book one.
The general theory of causality.

1. Definitions

1.1. INTRODUCTION

The term objective reality is of fundamental importance and in its modern usage generally relates to a reality, which is independent of a perceiving subject (normally a person), subject's perception, subject's consciousness and mind. In particular, objective reality is independent of the fact whether a perceiving subject can either perceive features of objective reality that are not part of objective reality or perceive accurately. The theory of causality itself is deeply connected with questions regarding the nature of objective reality and our understanding of objective reality as such. Causal investigations of anything, which exists as independent of any conscious awareness of it, should increase our knowledge of objective reality itself. Especially several well-known philosophers have developed a good deal of the fundamental work in the theory of causality. To avoid misunderstanding, it is necessary (at the outset) to make more precise that this monograph will not provide a detailed overview of a range of the theories of causality. To some extent, this can be found in secondary literature.

1.1.1. CAUSALITY AND PHILOSOPHY

Since centuries, causation is one of the most active fields in science and more and more literature on this topic can be seen than before. Still, despite the most extended efforts, the current state of research on causation is often incomplete; the mathematical problem of the relationship between cause and effect is not solved.

Thus far, one of the first documented attempts to present a rigorous theory of causation came from the Greek philosopher and scientist *Aristotle* (384-322 BC). Aristotle developed a theory of causality commonly referred to as the doctrine of four causes. Many aspects and general features of Aristotle's logical concept of causality are meanwhile extensively and critically debated in secondary literature. Even Aristotle himself pointed to the relationship between cause and condition. According to Aristotle, " ... *jegliches hat das Vermögen zu wirken ... ein Vermögen aber ist nicht schlechthin vorhanden, sondern nur unter gegebenen Bedingungen* ... " (Aristoteles, (1924), p. 148.)

Among other outstanding authors who worked on the problem of causality is *David Hume*, which is still present at discussions about causality. "*David Hume gilt als der 'Klassiker des Kausalproblems'.*" (Hessen (1928), p. 30) Hume's (1711-

1776) sceptical conception of causality is commonly known as the regularity theory of causation. According to Hume, "*we may define a cause to be an object, followed by another, and where all the objects similar to the first are followed by objects similar to the second. Or in other words where, if the first object had not been, the second never had existed.*" (Hume (1748 [1921]), p. 79). Consideration of specific counterexamples and objections is extremely important for discovering the previously unrecognized general issue of Hume's understanding of the nature of the causal relation itself and should not be underestimated.

COUNTEREXAMPLE 1. In other words, Hume's understanding of the nature of the causal relation is valid for the relationship between a day and a night on our planet earth too. Thus far, a day is followed by a night with the consequence that, according to Hume, a day is a cause of a night. Still, it is generally known and accepted that a day is not the cause of the night. Roughly speaking, those who endorse Hume's account of causation will have to accept the post hoc ergo propter hoc fallacy as the logical foundation of causation. In other words, "*Humes Hauptthese besagt, daß der Begriff der Kausalität nur ein zeitliches Aufeinanderfolgen von Zuständen zum Inhalt hat, nicht aber das Ausüben einer Wirkung.*" (Korch (1965), p. 82). Apart from the fundamental need to investigate causation thoroughly, Hume's reduction of the relationship between cause and effect to a time linked process where one event in time follows another event some time later is typical for Hume's restricted methodological approach to the nature of the causal relation itself. The intrinsic character of the causal relation is much more complicated than the concept of causation as provided to us by Hume. "*Typisch für Hume ist der Verzicht, in das Wesen der Dinge einzudringen und die Grundlagen ... zu klären.*" (Korch 1965, p. 74). David Hume's second remark about causation that "*… if the first object had not been, the second never had existed …*" (Hume (1748 [1921]), p. 79) is widely used as the foundation of the counterfactual analysis of causation.

Causation is often analysed in terms of counterfactual (Lewis (1973b)) conditionals too. Much of the recent writing on causation is based on the probabilistic counterfactual theories of causation. Among the counterfactual analysis of causation, *David Lewis's* theory (Lewis (1973a)) is the best-known counterfactual analysis of causation. Thus far, let *c* (a cause) cause *e* (an effect). In point of fact, according to the definition of causation in terms of counterfactuals, if "c had not occurred, e would not have occurred" (Menzies (2001)) too. In principle, the basic idea of counterfactual theories of causation is the definition of *causation ex negativo* by claiming that if a cause ${}_{i}c_{t}$ had not occurred, an effect ${}_{j}e_{t}$ would not have occurred too.

However, intense discussion over so many years has caused deep doubts on the adequacy of analysis of causation in terms of counterfactuals. In particular, the close investigation of counterexamples can give us an insight into the many deep and delicate issues surrounding a counterfactual account of causation. Nevertheless, defining causation in terms of counterfactuals raises too many various difficulties and is worthless on this account.

COUNTEREXAMPLE 2. For example, let us assume that smoking is a cause of lung cancer even if some smokers do not develop lung cancer. Thus far, suppose that Mr. Lewis smokes regularly and develops lung cancer (Menzies (2001)). In terms of counterfactuals, it is indeed true that if Mr. Lewis had not smoked he would not suffer from lung cancer. However, it is equally true if Mr. Lewis had not possessed lungs he would not suffer from lung cancer too or if Mr. Lewis had not been born, he would not suffer from lung cancer too. In other words, not being born in terms of counterfactuals is a cause of lung cancer. Only how can someone suffer from an illness if he is not alive? Consequently, analyses of causation in terms of counterfactual conditionals are generating to many absurd results and are more or less useless on this very special account. The counterfactual (Cartwright (1983)) approach to causation cannot be used as the universal principle for causal discovery.

Judea Pearl's methodological inconsistency concerning his approach to causation seems to be related to something like *the belief* (Pearl (2000), p. 2) that "there is no escape from counterfactuals" (Pearl (2000), p. 255), which stands contrary to facts. Strictly speaking, there are a couple of concerns one might have with Pearl's conception of causality. *First* and foremost, the heart of Pearl's approach to causation, Pearl's starting point, is incorrect. "The problem with *probabilistic measures* is that they cannot capture the strength of a causal connection between c [cause, author] and e [effect, author]" (Pearl (2000), p. 221). I am missing a clear proof. Consequently, Pearl is demanding that "we must go beyond probabilistic measures" (Pearl (2000), p. 221). *Secondly*, our world is determined by *quantum mechanical phenomena* too. Ironically, Pearl explicitly excludes (Pearl (2000), p. 220) quantum mechanical phenomena in his approach to causation. Pearl's concept of causality is not valid under conditions of quantum mechanics. What is the value of such a concept at all? The causal relation as such is indeed mind-independent and objective but Pearl's purely deterministic approach to causation is incorrect, a theory of causality must at the same time be consistent with quantum mechanics too. *Thirdly,* the causal *Markov condition* is another point that is problematic in this sense. Random variables are not all the time probabilistically independent of their non-effects. The causal Markov condition is not suitable as an universal principle in causal discovery. Cartwright, a philosopher of science, is right (Cartwright (2002)) on this point. *Fourthly,* Pearl introduced the *do(x) operator* as a mathematical tool which specifies what is as such free to vary and what has to be held constant in any given experiment. At the same time, Pearl himself states that "Controlling all variables in a problem is obviously a major undertaking, if not an impossibility" (Pearl (2000), p. 127). What is the methodological value of such a mathematical construct at all. In so far, Pearl is contradicting himself. Pearl's do-calculus deals only with some ideal situations and not with realistic cases. How can an experimenter make sure that all the experimental conditions approximate the requirement of Pearl's do(x) operator in practice while the world around an experimenter and the do(x) operator is changing all the time? *Fifthly,* last, but not least, to many explicit (Pearl (2000), p. 127) assumptions that are rarely satisfied in realistic cases must be made before Pearl's procedures can yield any results, if at all. In so far, contrary to expectation, Pearl has not developed long lasting algorithms for discovering causal relationships from (observational) data. Pearl's mathematical formalisation of causation ended in a revitalisation (Pearl (2000), p. 133) of a (concerning causation) useless and nebulous mathematical machinery (structural equation modelling, SEM). Due to this effort, I am missing new and fascinated insights in Pearl's contribution to philosophical reasoning about basics of causation. I am thoroughly convinced that a readable historical introduction is at the end the only viable aspect remaining in Pearl's book about causality. Peter Spirtes (Spirtes (2000)), Clark Glymour and Richard Scheines (SGS) developed a theory of statistical causal inference, difficult to understand and/or assess, that rely too much on Reverend Bayes (1763). These authors use completely abstract mathematical objects like directed acyclic graphs (DAGs) and the formalism of the Bayes networks with the focus on conditional independence including the causal Markov condition, to solve the problem of causation but without the final success. Are directed acyclic graphs (DAGs) compatible with the beginning of our world and the fundamental relation between energy, time and space?

A few other (i. e. Robins (2000)) did a good and pioneering research on causation too, but without the definite and final break through. James M. Robins himself is working on the development of analytic methods appropriate for drawing causal inferences (Robins (1999)) from data. James M. Robins developed a so called G-computational algorithm formula.

Spohn developed (Spohn (1983)) a kind of a probabilistic theory of causation while working with ranking functions instead of probability measures. Spohn's account of causation (Spohn (1988)) and the version of Lewis' account of causation are very similar. More precisely, ignoring some details, "Lewis Causation Is a Special Case of Spohn" (Huber (2011)).

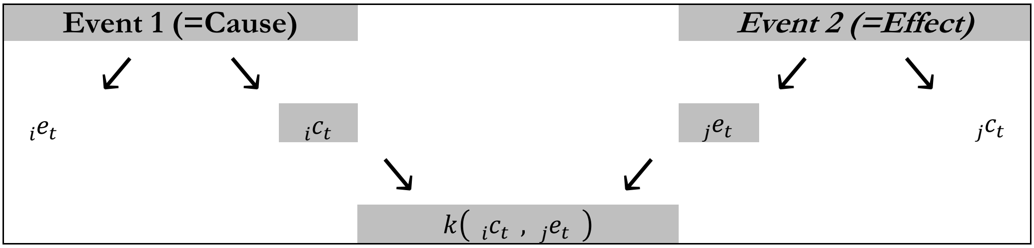
Paul-Henri Thiry, Baron d'Holbach (1723-1789), a philosopher of the French Enlightenment, notorious for his atheism and criticisms of Christianity, developed in his philosophical writings a one sided, mechanistic and deterministic theory of causality in which causality is grounded on an uninterrupted succession of causes and effects. "*L'univers, ce vaste assemblage de tout ce qui existe, ne nous offre partout que de la matière et du mouvement: son ensemble ne nous montre qu'une chaîne immense et non interrompue de causes et d'effets: quelques-unes de ces causes nous sont connues … d'autres nous sont inconnues …*" (d'Holbach, P. H. T. [par Mirabaud] (1780), p. 15). In broken English: '*The universe, that vast assemblage of everything that exists, presents only matter and motion: the whole offers to our contemplation, nothing but an immense, an uninterrupted succession of causes and effects; some of these causes are known to us, … others are unknown to us ...* ' d'Holbach links cause and effect to changes as such: "*Une cause, est un être qui e met un autre en mouvement, ou qui produit quelque changement en lui. L'effet est le changement qu'un corps produit dans un autre à l'aide du mouvement.*" (d'Holbach, P. H. T. [Par Mirabaud] (1780), p. 10). In broken English: '*A cause is a being which puts another in motion, or which produces some change in it. The effect is the change produced in one body, by the motion or presence of another.*'

The 19th Century German philosopher, *G.W.F. Hegel* (1770-1831) provided a very abstract and idealistic philosophical account of the nature of causality while relying on the dialectical method. "*Daher hat zwar die Ursache [$_{i}c_{t}$, author] eine Wirkung [$_{i}e_{t}$, author], und ist zugleich selbst Wirkung [$_{j}e_{t}$, author], und die Wirkung [$_{j}e_{t}$, author], hat nicht nur eine Ursache [$_{i}c_{t}$, author], sondern ist auch selbst Ursache [$_{j}c_{t}$, author]. Aber die Wirkung [$_{j}e_{t}$, author], welche die Ursache [$_{i}c_{t}$, author] hat, und die Wirkung [$_{i}e_{t}$, author], die sie ist - ebenso die Ursache [$_{i}c_{t}$, author], welche die Wirkung [$_{j}e_{t}$, author] hat, und die Ursache [$_{j}c_{t}$, author], die sie ist -, sind verschieden.* " (Hegel (1969 [1832-1845]), p. 233).

In broken English: '*Therefore, though the cause has an effect and is at the same time itself effect, and the effect not only has a cause but is also itself cause, yet the effect which the cause has, and the effect which the cause is, are different, as are also the cause which the effect has, and the cause which the effect is.*'

The following drawing may illustrate Hegel's account of causation in more detail.

TABLE 1. THE RELATIONSHIP BETWEEN CAUSE AND EFFECT DUE TO HEGEL



Especially authors like Reichenbach, Good, Suppes, Salmon et cetera preferred a probabilistic approach to the theory of causation.

Reichenbach in his approach to a probabilistic analysis of causality avoids any reference to time in order to leave open the possibility of analysing time itself in terms of causality. Reichenbach's approach was criticised especially by Salmon (Salmon (1980)).

Good himself (Good (1959), p. 307) published an analysis of causality in terms of a special kind of probability, a physical probability while equally avoiding a reference to time. Later Good no longer avoids a reference to time (Good (1961a), Good (1961b)) in the analysis of causality and explicitly demands that *a cause* has to be *earlier in time* than its *effec*t.

Suppes (Suppes (1970)) in his probabilistic approach to the analysis of the causal relation does not avoid a reference to time. In fact, Suppes analysis of causality did not yield any influential mathematical characterisation or mathematization of the causal relation. Suppes opinion is that causality is not entirely objective and leaves open the interpretation of probability (Suppes (1970), pp. 79–80).

Salmon (Salomon (1984), p. 190) himself advocates to some extent 'probabilistic causality'. Still, according to Salomon's view, causal relations cannot be analysed or even characterised in terms of probabilistic relations. Due to Salomon, causality is not deterministic, causality therefore is probabilistic.

Williamson himself, following Hume and Kant (Williamson (2005)) is interpreting causality as a kind of a epistemic relation, a position deeply connected with David Hume's concept of causation. Cause and effect are at the end things (Mach (1883), p. 485). Williamson's point can be put another way. According to Williamson, causality itself is a feature of how do we represent objective reality rather than a feature of objective reality itself. Williamson offers a review of some (probabilistic) theories (Salomon (1980b), Eells (1991),