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INTRODUCTION

Introduction to the special issue "Causation, probability, and truth—the philosophy of Clark Glymour"

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This special issue of Synthese is in honor of Clark Glymour, who is a key figure in philosophy of science since decades. Clark's early work focused on more traditional issues in the philosophy of science such as confirmation, scientific theories, and general relativity. Later he also worked on historical topics in psychiatry and physics. Together with his student Kevin Kelly, he investigated formal learning theory as a tool for learning about formal theories. But the contribution to the philosophy of science probably most philosophers immediately associate with Clark Glymour is the causal interpretation of Bayes nets, which he developed together with his students Peter Spirtes and Richard Scheines at around 1990. The theory of causal Bayes nets carefully connects causal structure to empirical data via several axioms. This, for the first time in the history of philosophy, allowed researchers to get a grasp on causation from an empirical point of view. A whole new and revolutionary research program was born: The theory provided a framework for developing feasible algorithms for causal search under various conditions, but also for developing methods for computing the effects of interventions even if only non-experimental data is available.

This special issue partially documents the results of a two-day symposium with the title "The philosophy of Clark Glymour", which was organized at the University of Düsseldorf by Matthias Unterhuber and the guest editors of this special issue. The symposium was the peak of Clark's fellowship at the Düsseldorf Center for Logic and Philosophy of Science (DCLPS) in June 2013. It was a wonderful time for which we are very grateful. Clark is an impressive person with a formidable character. It is hard to describe the "big old guy with the hat" in a few words. Hence, we try our best in describing this special issue instead, which might be a much easier endeavor. Some of

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the authors of the articles in this issue were also participants of the Symposium "The philosophy of Clark Glymour". In particular, these authors are Frederick Eberhardt, York Hagmayer, Vera Hoffmann-Kolss, Paul Näger, Sylvia Wenmackers, and the guest editors of this special issue. In addition to these authors, we also invited Konstantin Genin, Christopher Hitchcock, Kevin Kelly, Hanti Lin, Jan-Willem Romeijn, Peter Spirtes, James Woodward, and Jiji Zhang to contribute to the special issue. We are very glad that they accepted this invitation and would like to thank them for their valuable contributions.

The articles in this issue are either directly on Clark's work, critically examine topics on which he worked, or contribute to these topics in novel ways. All in all, we think that the pieces collected in this special issue are a really nice mix reflecting some of Clark's most important contributions to the philosophy of science. The first four papers are more theoretical or methodological contributions to the theory of causal Bayes nets. The first article (Zhang and Spirtes 2016), which is written by Jiji Zhang and Peter Spirtes, is entitled "The three faces of faithfulness". It shows that assuming the full faithfulness condition comes with the following three advantages: Assuming faithfulness (i) allows for thinning out the set of causal structures compatible with a measured probability distribution, (ii) justifies the use of certain search algorithms which would have to be much slower to be reliable otherwise, and (iii) allows for reliable inferences even at smaller sample sizes. Zhang and Spirtes also investigate the question of how several weaker versions of the causal faithfulness condition behave w.r.t. points (i)–(iii).

The second article (Eberhardt 2016) is written by Frederick Eberhardt. Its title is "Green and grue causal variables". It generalizes a result from Peter Spirtes to the general framework of linear structural equation models, viz. that causal systems can always be described equivalently by more than just one set of variables. But while Spirtes suggested that there is no set of causal variables superior to its competitors when it comes to correctly representing the world's causal structure, Eberhardt argues that one should prefer variable sets whose variables can be manipulated by means of ideal interventions or give rise to simpler causal structures.

The third article in this issue (Woodward 2016) also investigates the question how causal variables should be chosen. This is also directly reflected in its title: "The problem of variable choice". In this article James Woodward discusses several possible criteria for variable choice w.r.t. a broader (and mainly an interventionist) background: (i) choose variables that are well-defined targets of ideal interventions. (ii) Choose variables whose effects on other variables are unambiguous under interventions. (iii) Choose variables such that they can be forced to take any value independently of the actual values of other variables. (iv) Prefer variables that lead to simpler causal structures. (v) Choose variables such that the cause-effect dependencies between them are deterministic or as close to deterministic as possible. (vi) Choose variables such that the resulting causal relations are stable w.r.t. changing background conditions. (vii) Choose variables such that the resulting causal graph can account for correlations and does not feature causal relations for which there is no empirical evidence or interventionist interpretation.

The fourth article (Schurz and Gebharter 2016) is written by the gust editors of this special issue. It is entitled "Causality as a theoretical concept: explanatory warrant

and empirical content of the theory of causal nets". In the first part of this article we suggest a new way to justify direct causal relations as they are characterized by the causal Markov condition and the minimality condition as ontologically real by an inference to the best available explanation of two statistical phenomena. In the second part of the paper we investigate the empirical content of several combinations of the axioms of the theory of causal Bayes nets and also how adding further assumptions influences the theory's empirical consequences. We present several theorems showing which conjunctions of axioms and assumptions are empirically testable, and which are not.

York Hagmayer's article (Hagmayer 2016), which is the fifth one in this issue, also focuses on the empirical adequacy of the theory of causal Bayes nets, but from a more empirical and less theoretical direction. Hagmayer's "Causal Bayes nets as psychological theories of causal reasoning: evidence from psychological research" gives an overview of a multitude of psychological studies concerned with the question of whether people's inferences conform to the causal Markov condition and the faithfulness condition. Several of these studies show that both conditions are regularly violated by people's inferences. These studies challenge whether causal Bayes nets as rational models are empirically descriptive. They can also be seen as evidence that causal Bayes nets are inadequate for deriving predictions for causal modeling theories of causal reasoning. However, so Hagmayer argues, causal Bayes nets can still be used as normative models for causal reasoning.

The next three articles are more application oriented. Paul Näger's "The causal problem of entanglement" (Näger 2016), which is the sixth article in this special issue, applies the causal Bayes net formalism to a typical case from the special sciences, viz. to EPR experiments in quantum physics. Näger argues that the causal Markov condition can actually be satisfied in EPR scenarios when the faithfulness condition is violated. He then identifies a new kind of violation of the faithfulness condition, which arises in certain causal chains: unfaithfulness due to internal canceling paths. He finally argues that this new kind of unfaithfulness is quite typical in EPR scenarios. Hence, the unfaithfulness of EPR scenarios can be explained and the causal Markov condition can—at least in principle—be saved.

In "Conditioning, intervening, and decision" (Hitchcock 2016), which is the seventh article in this issue, Christopher Hitchcock applies the causal Bayes net framework to a cluster of more philosophical problems. He picks up a suggestion made by Chris Meek and Clark to apply the causal Bayes net formalism to problems in causal decision theory. In particular, Hitchcock demonstrates that the distinction between observation and intervention in causal Bayes nets can be used to get the right recommendations in case of Newcomb's problem, the psychopath button scenario, and scenarios involving time travelers.

The next article, which is the eighth one is this issue, is Vera Hoffmann-Kolss' "Of brains and planets: on a causal criterion for mind-brain identities" (Hoffmann-Kolss 2016). It criticizes a suggestion made in Clark's "When is a brain like the planet" to decide whether mental properties are identical with neural properties. In that paper, Clark proposes a causal criterion to answer this question in an empirically informed way. Hoffmann-Kolss argues that Clark's suggestion does not succeed, since his causal criterion does not provide a sufficient condition for the local iden-

tity of mental properties with brain properties. In addition, so Hoffmann-Kolss argues, Clark's suggestion cannot be used to empirically test for mind-brain identity.

Until this point, all articles had either a clear focus on the causal interpretation of Bayes nets, were applications of the theory of causal Bayes nets, or were at least somehow connected to causation. The remaining two articles make a clear brake with this trend. They focus on two of the other numerous topics Clark worked on. The first one of these articles is "Realism, rhetoric and reliability" (Kelly et al. 2016), written by Kevin Kelly, Konstantin Genin, and Hanti Lin. It starts with an observation: Occam's razor is difficult to justify. Mere convergence to the truth in the limit is compatible with any conclusions in the present. Deductive inference, on the other hand, has problems in the long run, or in other words: It is infeasible for inductive problems. Kelly, Genin, and Lin then choose a middle path between these two extremes: They show that Occam's razor is necessary for approaching to the truth in the straightest way with a minimum of cycles and reversals of opinion.

The tenth and last one of the articles in this special issue is written by Sylvia Wenmackers and Jan-Willem Romeijn. It is entitled "New theory about old evidence: A framework for open-minded Bayesianism" (Wenmackers and Romeijn 2016). It focuses on the old evidence problem made famous by Clark in 1980. In this paper Wenmackers and Romeijn develop a new extension of a Bayesian account of confirmation: a hybrid version of two forms of open-minded Bayesianism. This new version of an open-minded Bayesianism can deal with the problem of old evidence: Within this framework one can use old evidence again without simultaneously violating Bayesian coherence norms.

There is also an eleventh article (Glymour 2016). In this article, Clark responses to the other contributions. As the reader may already expect, he also highlights several problems in a unique Glymourian fashion.

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