Clark Glymour, *The Mind's Arrows: Bayes Nets and Graphical Causal Models in Psychology*, MIT Press, Cambridge,MA, 2001, xv+222 pages, USD 30.00, ISBN 0-262-07220-3 (hardback).

Amongst people working in statistics, computer science, and philosophy, Bayes nets are a well-known tool to model causal structures. Besides other things this approach provides ways for obtaining causal relationships out of statistical data. The idea is that existing (conditional) dependency relations between random variables, which are reflected in statistical data, are consistent only with some causal structures between these variables (given certain axiomatic assumptions about causality, e.g., that the indirect causes of a variable are statistically screened off by its direct causes). In this manner, statistical data about a population yield inferences to (some of) the causal structure existing within that population. Alternatively, it can be evaluated under which conditions interesting causal inferences can be made at all (sometimes only if a good deal of the causally relevant variables are actually measured). The mathematical features of Bayesian networks have been already explored by Spirtes, Glymour, and Scheines (1993) and Pearl (2000), and algorithms have been designed to get causal structure out of statistical data. Now Clark Glymour offers a book dedicated to the application of this mathematical-computational framework to methodological problems in psychology.

Glymour starts out by pointing to the importance of uncovering and analyzing causal structures for all branches of psychology. For instance, learning causal relations in the world is an important aspect of individual development. This introductory part of the book includes a short and basic introduction to causal Bayes nets, their properties, and how this framework can be used. The presentation is relatively untechnical, for instance, basic notions about Bayes nets such as d-separation play virtually no role for the discussion. Then the reader is primed for Glymour's first main psychological field of application: adult judgments of causation. Judgment of causation is experimentally studied by showing several runs of a scenario with probabilistic behavior and different possible outcomes as regards the involved entities to subjects (in some setups the individuals may influence the situation). Then subjects are asked about their judgment about the causal efficacy of a certain target factor on another specific entity. Glymour discusses a psychological experiment conducted by A. G. Baker and his collaborators. The performance of the individuals in this study is in accordance with the well-known Rescorla-Wagner model of learning. However, the interpretation by Baker et al. is that in this situation the subjects behave irrationally, because their estimates systematically diverge from the (alleged) numerical value of the true causal efficacy of the target factor. Other psychologists, however, proposed different quantitative measures of the actual causal efficacy, so that there is disagreement as to how causal efficacy is to be defined at all in complex experimental setups. Glymour complains that the psychological literature does not offer an answer as to what normative standard for rational replies in experiments should be chosen, and analyzes one of Baker's experimental setups using his Bayes nets approach. The upshot is that the probability assignments are consistent with different causal scenarios, in some of which the target factor is not causally relevant, while in others the factor is an indirect cause. So doing Glymour's type of analysis reveals that it is not well-defined from the experiment what the rational answer on a scale of efficacy of the target variable ought to be. Besides this, Glymour gives a brief analysis of the Rescorla and Wagner model showing that there are actually situations where behaving in accordance with this model is actually irrational (while the corresponding claim by Baker et al. is based on a measure of efficacy that is sometimes wrong). Related to this topic are the models of assigning actual causal efficacy developed by Patricia Cheng and Laura Novick. Glymour points to the fact that their models can be considered Bayes nets with specific probability assignments and uses Bayesian

networks to generalize the model of Cheng and Novick to other cases. Glymour proposes that this generalization suggests new experimental studies. An interesting topic is the question of how individuals come to learn causal structures. Glymour gives a short discussion of the different types of approaches (updating causal hypotheses in a Bayesian fashion or assembling causal structure based on statistic patterns existing in the data), including their drawbacks. Unfortunately, this discussion is much too brief (in fact 8 pages). Glymour just states the upshot about the prospects of these different approaches instead of offering an elaborated discussion and some new developments.

The second main area of discussion is cognitive neuropsychology. This field tries to uncover human cognitive architecture by comparing the performance of normal subjects on cognitive tasks with brain-lesioned subjects. Knowledge about the malperformance on certain tasks by patients is assumed to yield information about how the mind is structured, e.g., into functional modules with specific cognitive tasks. Glymour focuses on the debate about the validity of group-data, a fundamental methodological dispute in cognitive neuropsychology. Alfonso Caramazza, a prominent figure is this debate, argues that pooling data, i.e., using group-data, cannot be used for inference because grouping subjects according to a standard (performance) syndrome amounts to considering an inhomogeneous group of people that have in fact different underlying lesions. (The dispute is somewhat messy and more issues are involved, but this is the main argument against group-data. When Caramazza talks about lesions he probably means functional lesions at particular points of the cognitive architecture. At any rate, the debate is primarily about how to infer cognitive architecture from mere performance data, the role of data about the location of lesions in the brain is not the issue.) Glymour begins his discussion by giving his introduction to cognitive neuropsychology a nice historical twist. He rightly points to striking parallels between the way of reasoning in late 19th century neuropsychology (example: Sigmund Freud on aphasia) and in late 20th century studies (example: Marta Farah's work on visual agnosia). Then the possibility of inference from data based on individual cases is discussed based on a Bayes nets framework. The box-and-arrow diagrams used to represent cognitive architecture can be understood as Bayes nets, and Glymour makes clear that standard psychological accounts are not clear about how the gating between nodes is to be understood (is the disruption of one of the pathways sufficient to bring about malperformance, or need all pathways be disrupted?). Restricted to a few examples, Glymour shows in which cases different possible causal relations between nodes can in principle be distinguished by means of data (including a brief discussion of parallel-distributed networks). Then the important issue of group-data is addressed. Glymour makes clear in which sense inference from group-data is possible and in which sense it is not. When a joint probability distribution about performance on a variety of tasks is available, then interesting inferences can be made. When only the marginal distribution of this joint distribution is available (showing just for every individual task how many subjects performed well), inference is severely limited. This latter situation is not uncommon because a single study often tests only one (or a few) cognitive tasks, so that pooling data from different studies cannot recover the joint distribution. The study of cognitive neuropsychology concludes with a brief discussion on whether a neural net approach can explain any type of possible data. Glymour shows that a lesion in an acyclic neural net brings about new probabilistic independency relations, so that a certain neural net hypothesis makes testable predictions about the lesioned situation. However, the result assumes that all nodes insides the net are measured, so that Glymour's concrete result is of limited practical application.

The last part of the book is dedicated to social psychology. Glymour uses Richard Herrnstein's and Charles Murray's "The Bell Curve" to make the underlying theme of his book particularly clear. Glymour is convinced that the hardly used Bayesian networks are the best method for inferring causal relations: "The hard issue is whether the methods of large parts of social science are bogus, phony, pseudoscience. They are. The other hard issue is whether there are better methods attempted to the important tasks of social science. There are." (p. 171) Glymour's target are two standard statistical methods: factor analysis and regression. Factor analysis, roughly a tool to estimate the (minimum) number of causes in a population, is used in the discussed context to argue for a single factor—general intelligence—as the cause of different test performances. Glymour complains that simulations and studies about the reliability of this method are rare. He offers a short simulation showing that two standard factor analysis packages show poor performance. The other important statistical tool is regression that allows for estimates about the degree of causal efficacy of certain factors in comparison to others. Glymour discusses a case where regression leads to wrong conclusions. In "The Bell Curve" this method is used to show that intelligence has a *high influence* on various social features. Glymour raises the following question: can it be answered (based on the existing data) whether IQ is *a cause* of the studied social feature *at all*? Focusing on a causal structure proposed by Herrnstein and Murray, his answer is a plain no. The reason is that a Bayes nets analysis of this causal structure reveals that it is empirically indistinguishable from other structures where IQ and the social behavior are just related by an (unobserved) common cause. So it is unclear what regression can do in this and similar cases as long as possible common causes are not measured.

"The Mind's Arrows" obviously does not offer detailed and elaborated developments of the Bayes nets approach, as Spirtes, Glymour, and Scheines (1993) or Pearl (2000) do. Rather, it offers small applications to various issues from different parts of psychology. While Glymour gives short discussions of the relevant historical background, at a few points references to the current literature are sparse. For instance his critique of standard statistics could have been connected to the literature on these methods and it could have referred to the existing tests of factor analysis and regression. Glymour's message is clear—Bayes nets and the algorithms based on this approach offer a powerful tool to discover causal relationships. However, Glymour does not discuss how in his view this general and domain-independent method relates to other and more conventional tools and methodological considerations in psychology. Even if he thinks that standard statistical tools on causal inference are to be replaced by his preferred framework, the Bayes nets approach assumes at least that the potentially relevant variables as given, so that other scientific and methodological issues need to be addressed in specific domains of application and an interplay between this mathematical-computational tool and other scientific considerations is necessary and could be discussed. In sum, Glymour gives interesting applications of the Bayes nets approach to causal inference in psychology and offers results on some important methodological issues. He makes plain that Bayesian networks should be considered a vital tool—psychology is a case in point.

REFERENCES

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