Book review

Patrick Suppes, Representation and Invariance of Scientific Structures, CSLI publications, Stanford, California (distributed by Chicago University Press)

After being in preparation for many years, the latest result of Patrick Suppes’ work has come to light with the book *Representation and Invariance of Scientific Structures*, published in 2002. The book collects significant achievements of Suppes’ work, both as a practising scientist in many disciplines (from quantum mechanics to experimental psychology), and as a committed philosopher who has contributed to foundational analysis of various branches of science. Many contemporary philosophers of science cite Suppes as one of the most significant influences on the semantic view of theories, a new way of defining the nature of scientific theories, breaking with logical positivism's linguistic view of theories. As the title of the book clearly points out, *representation* and *invariance* are the concepts around which Suppes centers his analysis of science: he argues that the language of representation and invariance is the correct way to rationalize scientific theories when adopting a foundational point of view.

The first step in characterizing a scientific theory is to provide a *representation* of it. More precisely, according to Suppes’ methodology, a theory must be analyzed starting from its *structure*, represented in terms of models of the theory, i.e. the possible realizations in which the theory is satisfied. The representation of a scientific structure is achieved in terms of these models, especially the ones expressed within a set-theoretical framework. Suppes stresses in many different passages that to axiomatize a theory is to define its set-theoretical predicates, as opposed to the usual approach of adopting a syntactic characterization, where first-order logic is the formal language of description for the primitive concepts of the theory. Suppes’ preference for a set-theoretical approach mainly has the purpose of maintaining the complexity of scientific theories, avoiding the sometimes too abstract description provided by the syntactic view, where a scientific theory is considered as a logical calculus with some correspondence rules.

Suppes clearly acknowledges that set-theoretical models serve as tools for thinking about the foundations of a science, while in carrying on the same science from a practical point of view more detailed models are needed, not just for representation, but also for empirical predictions. In order to study the models by means of which to analyze the structure of a scientific theory, representation theorems have to be stated, since “the best insight into the structure of a complex theory is by seeking representations theorems for its models” (p. 51).

The framework under which the explication of a scientific theory is performed is not complete without considering the concept of *invariance*. Intuitively, invariant is what is constant in the representation of a structure, when the contextual features vary. How
invariance is connected to the explanation of scientific structures relies, again, on the process of representation. In order to axiomatize a theory, it is necessary not only to define its set-theoretical models and to prove representation theorems about the theory, but also to individuate the fundamental properties that are invariant with respect to some important transformations. Such individuation means to seek the “objective” meaning of a phenomenon, so that “objective” becomes identified with “invariant with respect to a given framework of reference”. If a representation theorem is devoted to identifying the fundamental properties of a theory and serves to isolate a significative subset among the models in order to work on such subset, the correlating invariance theorem states the uniqueness of a representation.

The book covers a great deal of material on foundational issues in science; throughout it, representation and invariance do not only play a major role for the internal (in the sense of the structure) characterization of a theory, they also function as unifying principles of Suppes’ diverse foundational investigations. It is well known that Suppes has worked in several different areas of research, proving fundamental results such as his axiomatization of classical particle mechanics, or probability theory. By means of the concepts of representation and invariance, in this book we can see these results from a more unifying point of view. For the first time in Suppes’ vast bibliography, Representation and Invariance of Scientific Structures aims at explicitly illustrating the overall perspective of Suppes’ thought on science, while discussing some of its major issues.

Still, this unified methodology in dealing with scientific theories does not entail, as it has sometimes been alleged, a unified philosophical stance towards science. Pluralism in science is one of the core concepts of Suppes’ philosophy of science, together with the idea that epistemology must be carried on in a genuine empiricist spirit. The detailed analysis of science, which derives from Suppes’ practice as an experimental scientist, plays a central role in his philosophical enterprise. In this perspective detailed has to be intended as a style for reflecting upon a scientific realm: to investigate a scientific theory is necessary to know how it is practically “implemented” in real scientific contexts, inside the real laboratories. This implies a work of reconstruction of the theory from its empirical bases that is tortuous and much less precise than the straight path of reason idealized by many philosophers.

This down to earth approach might seem to contrast with Suppes’ advocacy of formal methods in the philosophy of science; however, empirical structures are central tools of investigation as much as theoretical structures, in his view. Which approach we should adopt depends on the specific scientific problem at hand. It is appropriate to invoke both formal and informal methods when explaining scientific knowledge and the nature of some scientific concepts. In general it is useful, mainly for reasons of clarity, to embrace formal methods when possible, at least for that part of a science (i.e. foundational studies) that can benefit from them; however, with a very pragmatic
attitude (which is one of the other traits of Suppes’ thought), we should not rely too much on the rigorous nature of the formal approach as a way to reach certainty. Phenomena are, in the end, inextricably messy. But if truth or certainty are not up for grabs, this does not mean that science is absolved from its duty in leading to knowledge. And this is the reason why Suppes believes that probability is one of the best tools in practicing science.

It is not surprising, then, that the central and longest part of the book, Chapter 5, is dedicated to the discussion of the nature of probability. To represent the standard formal theory of probability, Suppes uses Kolmogorov’s axioms, based on the notion of probability space expressed in a set-theoretical notation. Starting from them, he states representation theorems for each of the important views: the classical one, the relative-frequency one, the logical one, and the subjective theories amongst the others. What is invariant is the set-theoretical notion of probability space, while an explicit formulation of the probability function is determined by each of the different theories of probability. Hence, for every probability theory it is possible to demonstrate a representation theorem stating that the models of the particular theory are also models of Kolmogorov’s axioms. Even if representation and invariance constitute the central perspective for discussing probability, Suppes is very determined to stress also the pragmatic use of probability in physics, where scientists exploit probability concepts without any concern about foundational problems.

Space-time is another concept whose representation is fundamental in many scientific areas of science. In Chapter 6, Suppes provides different ways of thinking about this representation, in so far as “different disciplines concerned with spatial and temporal phenomena pose problems that require different approaches” (p. 266). Even while stressing the plurality of approaches, nevertheless Suppes is lead to the basic assumption that both classic and relativistic structures of space-time are special cases of affine structures. In fact, analyzing the invariant properties in both approaches, Suppes underlines that many of these (such as linearity of inertial paths and conversation of their parallelism) are invariant under a general affine group of transformations, and that the Galileo transformation in classical physics and the Lorentz transformation in special relativity are both subgroups of the affine group. Once again the study of representation and invariance gives a valuable contribution to the foundations of science, in this case of physics, foundations that are too often neglected, according to Suppes, by many philosophers. In the same chapter, Suppes gives an example of how representation of space can bring insight in perceptual and psychological problems, such as the problem of establishing if visual space is Euclidean. These results are less definitive than those in foundations of physics, yet they still provide valuable heuristics for future experimentation.
Suppes delves much deeper into the foundations of physics in Chapter 7, where we find a representation in terms of vectors of a real affine space in classical mechanics, followed by invariance theorems on conservation of momentum and energy. Suppes selects this example because it is mathematically simple for the reader to grasp, while at the same time rich enough to show the importance of philosophical foundations and of systematic applications. When discussing quantum physics, Suppes demonstrates representation theorems for hidden variables, i.e. common causes; the research for common causes for a set of empirical data is a fundamental goal of every empirical science, but it is of particular interest in quantum physics, where the nonexistence of hidden variables is one of the disconcerting outcomes of the foundational efforts in the field. Suppes does not mention any invariance theorem regarding quantum physics, he offers instead other important examples of invariance in physics concerning temporal reversibility for causal chains.

The final chapter of the book, Chapter 8, illustrates different representations of language, presenting both well-known results and new research directions that show Suppes’ interests in psychology and linguistics. Representation theorems are stated to describe how grammars of a given type correspond to automata of a given strength. He follows this with a discussion of the work on machine learning of natural language, in order to evaluate whether it is possible that association and conditioning may, in principle, be adequate to give the reason for complex linguistic phenomena. In the final part of the chapter, then, we find Suppes’ latest work on language in terms of brain-wave representations: the idea is to collect data on what is going on in our heads while performing some cognitive tasks; the hope is to find invariances in these data showing useful information about internal process related to the use of language. Here no representation theorem is proved, since the work is still in progress; however, experimentally found invariances are discussed, giving evidence of some invariance in internal representations across different people. Aside from its possible consequences related to the philosophical debate on representation and associationism, this part of Suppes’ work is also very interesting from a methodological point of view. It exemplifies the interplay between experiments and theory formation, where the process of collecting and analyzing data and the formulation of a theoretical framework are shown in their tight interplay.

From a more general point of view, the very diversity of this book is highly stimulating, and it is helpful to have a single reference for the vast body of Suppes’ work. Moreover, inbetween the most technical parts of the work, large sections are dedicated to historical overviews of some of the topics (from axiomatic methods, to mental representations and the nature of the visual space). Interesting and provoking philosophical considerations, for instance about reductionism in physics, or associationism in psychology, are spread all over the book.
Unfortunately, Suppes does not seem interested in an organic presentation of these ideas, nor in a comparison with other contemporary mainstream views in philosophy: it seems clear that this would result in a refreshing analysis of these views, but is not part of the scope of this book, and we can only guess some possible conclusions from his words. Suppes is difficult to categorize in the current debates about the role of models in science, mainly for his lack of explicit discussion of them. Nevertheless, it is fair to say that his view has promoted research on the role of models in science, leading the process that has ended in the shift from the syntactic view towards the model-centered view that characterizes so much contemporary philosophy of science. Recent developments, such as Ronald Giere’s, Mary Morgan’s and Margaret Morrison’s and Paul Teller’s work¹, apparently distant from Suppes’ perspective, are in fact descendants of it, and Representation and Invariance of Scientific Structures clearly proves the milestone role of Suppes’ ideas. While on the surface he appears to offer some hope to those who value unificationist approaches in philosophy of science, his philosophy is much closer to that of someone like Nancy Cartwright or Arthur Fine. His emphasis on formal methods notwithstanding, the pragmatist streak and pluralist commitment evident in his work place him as much closer to the latter; the drive towards solving foundational issues in science, coupled with the refusal to address metaphysical issues of any kind of detail, in many ways render him a role model of Fine's NOA scientist, if not an explicit advocate.

The many technical sections of the book can be intimidating, in particular for the bulk of non-specialist readers the book deserves, especially amongst students of philosophy of science. The reader can sense a lack of homogeneity. As we have said, a level of uniformity across the different parts of the book is gained by adopting the concepts of representation and invariance as guidelines; however, even if the several representation and invariance theorems are clearly stated and summarized at the end of the volume, the conceptual contribution of these theorems inside the respective science or from a philosophical point of view are not always easily identified. For this purpose it could be useful to follow the indications provided by Suppes himself in the subsection “How to read this book”. Here Suppes indicates how to get the most out of this book without the need of committing to a cover-to-cover reading: “As in love and warfare, brief glances are important in philosophical and scientific matters. None of us have the time to look at all the details that interest us” (p. 15).

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Paul Teller, “Twilight of the perfect model model”. Erkenntnis, 55, 393-415.