Medical Sociology and Case-Based Complexity Science: A User's Guide

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Abstract

In this chapter, our goal is to provide readers with the first formal overview of and introduction to case-based complexity science and its related set of techniques, known as case-based modelling. Case-based modelling, championed largely by 1 (1), constitutes a fifth major methodology for modelling complex systems, offering itself as an alternative to (and also integration of) agent (rule-based) modelling, dynamical (equation-based) modelling, qualitative (idiographic) modelling, and statistical (aggregate-based) modelling. For us, as medical sociologists, case-based modelling makes sense because, fundamentally, medicine is about the case. In terms of case-based modelling, we employ the *SACS Toolkit*. The SACS Toolkit is a new, computationally grounded, case-based method we created for modelling complex social systems as a set of cases (2,3). By the end of our review, interested readers should have enough knowledge of case-based complexity science, case-based modelling and the SACS Toolkit to determine their viability for their own research.

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1 Introduction

In this chapter, we provide readers with the first formal overview of case-based complexity science and its related methodology, case-based modelling. **Case-based modelling**, championed largely by 1 (1), constitutes a fifth major method for modelling complex systems, offering itself as an alternative to (and also integration of) agent (rule-based) modelling, dynamical (equation-based) modelling, qualitative (idiographic) modelling, and statistical (aggregate-based) modelling. For us, as medical sociologists, case-based modelling makes sense because, fundamentally, medicine is about the case. Case-based modelling also resonates with our particular practice of a **case-based complexity science**, which can be defined as a generalist approach, grounded in the epistemological perspectives of Byrne's complex realism—which we explain later.

In terms of case-based modelling, we employ the **SACS Toolkit**. The SACS Toolkit is a new, computationally grounded, case-based method we created for modelling complex social systems as a set of cases (2,3). In terms of health, we use the SACS Toolkit to study communities, school systems and stress and coping issues as different types of complex systems (4,5); and, in terms of health care, we use it to study the complexities of medical professionalism and medical education (6,7). By the end of our review, interested readers should have enough knowledge of case-based modelling and the SACS Toolkit to determine its viability for their own research.

Our chapter is organized as follows. We begin with an overview of case-based method, providing a quick history of how case-based complexity science and, more specifically, case-based modelling emerged and how we position our approach relative to other ways of modelling complex systems. From here we turn to the SACS Toolkit, providing a quick overview of how it models complex systems. Detailed reviews of the SACS Toolkit currently exist—one qualitative in focus (2) and the other mathematical (3). However, a few advances are made in the current chapter, as it is (1) our first attempt to clarify the SACS Toolkit's explicit links to case-based complexity science and (2) our first effort to integrate our two previous versions into a new, updated version. To help readers grasp a basic understanding of the SACS Toolkit, our review will draw on some examples from our research in medical sociology.

2 Case-Based Complexity Science: An Overview

Over the last several years, Professor David Byrne of *Durham University, UK* has emerged as a leading international figure in what most scholars see as two highly promising but distinct fields of study: (1) case-based method and (2) the sociological study of complex systems. An example of the former is Byrne's *Sage Handbook of Case-Based Methods* (1)—which he co-edited with Charles Ragin, the most prominent figure in case-based method. An example of the latter is his widely read *Complexity Theory and the Social Sciences* (8). What scholars (including the current authors) are only beginning to grasp, however, is the provocative premise upon which Byrne's work in these two fields is based. His premise, while simple enough, is ground-breaking:

> Cases are the methodological equivalent of complex systems; or, alternatively, complex systems are cases and therefore should be studied as such.

With this premise, Byrne adds to the complexity science literature an entirely new approach to modelling complex systems, alongside the current repertoire of agent (rule-based) modelling, dynamical (equation-based) modelling, statistical (variable-based) modelling, network (relational) modelling, and qualitative (meaning-based) method.

Working independently of and yet in tandem with Byrne, we have used his premise to develop a case-based, computationally-grounded, mixed-methods technique called the SACS Toolkit (2,3). However, because it is designed for studying both small-database and large-database complex systems, the SACS Toolkit makes a slight variation on Byrne's premise: it models a complex system as a *set* of cases, ranging from, at minimum, 1 case to any large number of cases. In the language of matrix algebra, these cases are *k* dimensional vectors (See 3 for complete mathematical overview). The goal of the SACS Toolkit is to compare and contrast, and then condense and cluster databases comprised of a large number of cases to create a low-dimensional model of a complex system's structure and dynamics across time/space. To create these models, the SACS Toolkit employs a variety of computational techniques—including cluster analysis, network analysis, agent-based modelling and artificial neural nets—as well as statistics, historiography and qualitative method.

Before we can overview the SACS Toolkit, however, it is necessary to situate it within the larger fields of case-based method and complexity science. We begin with case-based method.

2.1 Case-Based Method

Case-based method is an umbrella term for a somewhat varied set of techniques that have a long history in the social sciences and others fields such as biology, history, archaeology and medicine (1).

Case-based methods, whatever the type, can be explanatory or descriptive. They can be static or longitudinal, retrospective or prospective. Despite differences, the goal of these methods is to study a case or set of cases more holistically, systematically, and ideographically. The simplest example of a case-based method is the **case study**, which is an in-depth investigation of a single case. Most approaches, however, tend to study a set of cases, engaging in what is called **case-comparative method**.

The most popular version of case-comparative method is Ragin's **qualitative comparative analysis** (QCA) (9). Over the last decade, QCA has developed into a set of comparative techniques that allow case comparative methods to move beyond the limitations of traditional qualitative method. While case comparison is implicitly the purpose of such statistical techniques such as cluster analysis and discriminatory analysis, it is rarely couched in such terms. As such, most case-comparative methods are grounded in a qualitative tradition, focusing on a small number of cases. QCA pushes case-comparative method into a mixed-methods frame, allowing researchers to capitalize on the strengths of both qualitative and quantitative analysis, insomuch as it uses Boolean algebra and its matrices to search for patterns and to make generalizations with larger datasets (1). As a side note, Boolean algebra is a variant of algebra that works only with 1s and 0s, as truth values: cases either do or do not belong to a dominant profile identified—for example, sick or not sick patients. Ragin has also developed a fuzzy-set version of QCA which overcomes the limitations of Boolean algebra and its crisp sets to allow cases to have "degrees of membership" in the main profiles identified by a study—think, for example, of a study that allows people to be, in varying degrees, both healthy and sick (9,10).

Regardless of the case-based method used, a **case** can be a person, event, place, concept, etc. Whatever studied, the case is the focus of the study, not the individual variables or attributes of which it is comprised. Case-based researchers would not, for example, study the impact gender has on the professional behaviour of physicians. Instead, they would study how the different profiles of physicians explain their dissimilar professional behaviours, with gender being one of the key attributes examined. Case-based methods also treat the cases they study as **composites**, viewing them as comprised of an interdependent, interconnected set of variables, factors or attributes that form some type of emergent configuration, such that the whole is more than the sum of its part. Each variable, therefore, is not an isolated factor impacting the case of study; instead, it is part of a larger, context-specific set of factors which collectively define the case of study, usually in rather nonlinear ways. For example, in Ragin's QCA, variables are treated as sets (10). A case profile, therefore, tells us which sets (a.k.a variables) a case belongs to and in what manner or degree.

Case-based methods do, however, differ from one another in the degree to which they seek to **generalize** their findings. Byrne (11,12) for example—the leading figure in case-based complexity science—advocates contextualized and limited forms of case-based generalization. Despite these differences, all case-based methods treat cases as particular instances, examples, occurrences or types of some larger population.

It is its **configuration approach** to variables, however, that ultimately makes case-based method a radical departure from normative, variable-based inquiry, as defined by the majority of statistical methods used in the social sciences and, more specifically medical sociology—think here of **conventional method**. Variable-based statistics has no interest in cases or any in-depth understanding of how a set of variables collectively define or impact these cases. Instead, variable-based inquiry seeks to understand the relationship variables have with each other, and usually in the most parsimonious, reductionist, nomothetic, linear, unidirectional manner possible. To illustrate, let us go back to our example of physician professionalism. A variable-based study might examine which factor (amongst some set of supposedly independent variables) best explains the different professional behaviours of physicians. For example, which variable is more important for later misconduct? Is it the networks students hang out in or the number of times they were cited for unethical behaviour? In contrast, a case-based approach would examine how the different variable-based configurations of some set of physicians (cases) account for differences in professional misconduct. For example, one may find that male students, specializing in surgery, who attended schools that failed to really punish their misconduct, and who socialized in student networks that approved of their 'bad' behaviour went on to practice in similar ways later in life: that is, they engaged in misconduct while working at hospitals that did little about their behaviour, and they worked in physician networks that approved of their behaviour.

2.2 Case-Based Complexity Science

As Byrne recognized in his research (1,8,11,12), not only is case-based method a radical departure from variable-based inquiry, it has strong affinity with complexity science. Going even further, it also, in some very useful ways, advances the study of complex systems.

Based on Byrne, we wish to introduce in this chapter two new terms: case-based complexity science and case-based modelling. **Case-based complexity science** is defined as scholarly activity that seeks to actively integrate case-based method with complexity science for the purpose of modelling complex systems as cases. **Case-based modelling** is defined as the set of techniques scholars use to conduct case-based complexity science.

In addition to Byrne, scholars involved in the development of case-based complexity science and case-based modelling include 2,9,10,13,14. The argument is simple enough. Cases are the methodological equivalent of complex systems. If one thinks about it, complexity scientists and case-based researchers make a similar argument: (1) variable-based inquiry is insufficient for modelling complex systems; (2) needed instead are methods that employ an idiographic approach to modelling, one grounded in the techniques of constant comparison; (3) the whole of a case or system is more than the sum of its part; (4) and yet, the study of parts and their complex interactions, from the ground-up, including the interactions these parts have with the case or system as a whole, is the basis to modelling. We can go on. Bottom line: cases are complex systems; complex systems are cases.

The above argument, however, is as far as the similarities go. Fact is, Byrne (as well as ourselves) set case-based complexity science as its own particular approach, distinct from the approach *en vogue* within complexity science today. To clarify this distinction, several comments are in order.

2.2.1 Situating Case-Based Complexity Science

In the last thirty years, Academia has witnessed the emergence of what many scholars—including Stephen Hawking—call a 'new kind of science.' The name of this new, massively interdisciplinary science is **complexity**. While young, complexity science (like many new scientific innovations of late) has captured part of the academic and public imagination—in this case with discussions of six-degrees of separation, swarm behaviour, computational intelligence and simulated societies. This popularity, however, has come with a price: confusion over the field's core terminology and the disciplinary divisions within it. As Mitchell explains in her popular work, *Complexity: A Guided Tour* (15), while it is popular to refer to complexity science in the singular, "*neither a single science of complexity nor a single complexity theory exists yet, in spite of the many articles and books that have used these terms*" (2009, p. 14).

If one follows Castellani and Hafferty (2), however, complexity science's confusion over terminology has less to do with its age, and more to do with its interdisciplinary and therefore interstitial (between things) character. Interstitial areas of thinking, no matter how novel, replicate the dominant intellectual divisions of academia, such as science versus theory or qualitative method versus statistics. Complexity science, given that it situates itself within the full range of academic inquiry—from the humanities and the social sciences to mathematics and the natural sciences—is replete with such divisions. As such, while oriented toward the study of complex systems in general, scholars in complexity science find themselves struggling with significant divisions regarding the complexity theories they use, the methods they employ, the epistemologies upon which they rely, and the definitions of a complex system they embrace. Given these divisions, a few clarifications are in order—all of which help us to understand better the goal of case-based complexity science.

1. The first clarification concerns the goals of science. As mentioned by Mitchell (15), complexity science is really the complexity sciences. To date, complexity science can be organized into several competing types, based on different combinations of the dominant distinctions in academia (16).

For Byrne (and for us), one of the most important distinctions is between what Morin (16) calls restricted versus general complexity science. **Restricted complexity science** is popular in economics and the natural sciences. It is defined as the empirical study of complex systems via the methods of rule-based, computational modelling. Its goal is quasi-reductionist, as it seeks to identify and explore the set of rules out of which complex systems emerge, so it can generate quasi-general laws about complex systems. In contrast is **general complexity science**, which is defined as the empirical study of complex systems via the methods of case-based comparative research. Its goal is more qualitative and holistic, seeking to model complex systems through a comparative analysis of cases, in order to create context-specific, grounded theoretical understandings of complex systems. **Case-based complexity science** situates itself in the latter approach.

As Klüver and Klüver make clear in their book *Social Understanding: On Hermeneutics, Geometrical Models and Artificial Intelligence* (17), most sociological phenomena are simply too complex to be reduced to the emergent consequence of rule-following. A more general approach, as Byrne explains (12), is one that that acknowledges this point: context and messiness and the mutual influence of macroscopic and microscopic structures and dynamics are crucial to understanding social systems.

2. The second clarification concerns computational modelling. A defining feature of the complexity sciences (restricted and general) is their reliance upon the latest developments in computational modelling. As Mitchell (15) explains, while the complexity sciences offer scholars a handful of new concepts (autopoiesis, self-organized criticality), their major advancement is **method**. Case in point: one can go back to the 1800s to Weber, Marx, Pareto or Spencer to find reasonably articulate theories of society as a complex system; or, one can go back to the 1950s to systems science and cybernetics (or, more recently, social network analysis in sociology) to find many of the concepts complexity scientists use today. Despite their theoretical utility—which, albeit critically received, is widespread—all the aforementioned theories ultimately stalled in terms of the study of complex systems because (amongst other reasons) they lacked a successful methodological foundation.

Computational modelling is the usage of computer-based algorithms to construct reasonably simplified models of complex systems. There are three main types of computational models used in complexity science: agent (rule-based) modelling, network (relational) modelling, and dynamical (equation-based) modelling. Different methods yield different results. Situating itself within the latest advances in computational modelling, case-based complexity science seeks to use these tools. Byrne (12) and Uprichard (14), for example, use cluster analysis; and our own work employs agent-based modelling, cluster analysis, neural nets, and network analysis (3). But, the focus is on comparing cases and searching for common case-based profiles, as concerns a particular health outcome. The consequence of this focus is the causal model built—not the techniques used. Focusing on cases is a search for profiles: context dependent assemblages of factors (k dimensional vectors) that seem to explain well different types of health outcomes. For example, one could use computational modelling to examine a set of health factors (e.g., income level, education, gender, age, and residential location) to see which case-based assemblage of these factors relate to differences in mortality rates.

3. The third clarification concerns the distinction between complexity science and complexity theory. Like complexity science, there are multiple complexity theories, which form a loosely organized set of arguments, concepts, theories and schools of thought from across the humanities and the social sciences that various scholars use in a variety of ways to address different topics.

In terms of intellectual lineage, these theories are strongly grounded in two intersecting epistemological and theoretical traditions: the one stems from systems theory, Gestalt psychology, biological systems theory, second-order cybernetics, and ecological systems theory; while the other stems from semiotics, post-structuralism, feminism, postmodernism, constructivism, constructionism and critical realism (2).

Complexity theories and their related epistemologies are also tied up in the substantive systems theories of sociology, anthropology, political science, economics, psychology and managerial studies. As such, complexity theories can differ dramatically from one another. For example, Niklas Luhmann uses complexity theory to articulate a new, *metaphorical* theory of global society (a grand theory with no agents, only a communicating society); while John Holland uses complexity theory to build a bottom-up, agent-based *computational theory* of complex emergent systems.

Perhaps the sharpest distinction between complexity theory and complexity science, however, is that neither necessarily has affinity for the other. In fact, complexity theories need not be data-driven, empirically grounded, computational or scientific. They can even be anti-data, anti-empirical, anti-computation, and anti-scientific. For example, Francois Lyotard uses early *empirical* research in complexity science (mainly chaos theory) to end grand narrative and place a limit on the conditions of science, which he called post-modernity. Meanwhile, most scholars in the managerial sciences use complexity theory in a *prescriptive* manner, with almost no empirical backing whatsoever (16). In contrast, the complexity sciences, while reliant upon key concepts from complexity theory, such as self-organization or emergence, tend to ignore theory (Mitchell 2009). For example, most rule-based complexity science is theoretically vacuous.

Given the above distinctions, the generalist approach of case-based complexity science is grounded in a post-positivistic epistemology, albeit one that has learned from the errors and shortcomings of much of postmodernism and post-structuralism. This seasoned viewpoint is best described as complex realism, which combines Bhaskar's critical realism with Cillier's understanding that knowledge and the world are complex interdependent processes. Together, these two ideas form what Byrne calls *complex realism*. Here is an all-too-short overview of its main point. For an in-depth review, see Byrne (12). Complex realism seeks to overcome two key problems.

The first is epistemological. Why is reality so hard to comprehend? Is it because our minds cannot know reality? No, it is not because we are immured within a solipsist (simulated) mind-constructed view of the world. Complex realism explains that much of the contingency in knowing (causal modelling) is not because reality cannot be apprehended. Reality escapes us because it is fundamentally complex, both in terms of the real and the actual.

Second, in relation to this complexity, we have a methodological problem. **Quantitative modelling** (statistics) fails us because it does not know how to model complexity and is lost in a reductionist world of variables and parsimony. In turn, **qualitative modelling** limits itself because it cannot deal with generalization and often falls prey to problematic post-positivist ideas, such as postmodernism and radical post-structuralism. **Restrictive complexity** limits itself because it fails to actually address complexity, primarily in the form of context and contingency—that is, the manner in which things practiced are done so uniquely and done so in contextual frames, larger complex systems, etc. Complex systems are more than just rules. **Conventional case-comparative method** has all the methodological tools and the epistemological basis, but it does not have yet an explicit theory of complexity and complex systems. Finally, **equation-based modelling** cannot get beyond the dynamics of simple systems. So, what is the solution? Complex realism coupled with a generalist complexity theory coupled with case-comparative method—that is the solution. The link pin to this 'trifecta coupling' is the idea that cases are the methodological equivalent of complex systems. If reality and our knowledge of it is complex, then complexity is the issue to address. If complex systems are cases, then complex systems cannot be reduced to some set of rules or variables, and context has to be explicitly modelled. If cases are complex systems, then case-based researchers need a wider explicit vocabulary grounded in a wider set of methods, including computational modelling.

So, how do these clarifications help us contextualize the SACS Toolkit? The SACS Toolkit is part of the case-based complexity science agenda. It was designed to be the first explicit case-based modelling method designed for modelling complex social systems. Epistemologically speaking, it embraces a generalist complexity science and complex realism perspective, tempering this approach with an equal embrace of Michel Foucault's post-structuralism (which it uses to develop its theoretical framework) and Richard Rorty's neo-pragmatist understanding of the tool value of modelling; that is, scientific models of complex systems are true insomuch as they work, not because they gain a direct understanding of a complex system in its entirety. With these clarifications established, we turn now to a review of how the SACS Toolkit works.