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Scholar's Paper

Complex Thinking and Big Data

Ljiljana Trtica Majnarić

Faculty of Medicine, Department of Internal Medicine, Family Medicine and the History of Medicine and Faculty of Dental Medicine and Health, Department of Public Health, University of Osijek, Croatia

[*]**Correspondence to:** Dr. Ljiljana Trtica Majnarić, Faculty of Medicine, Department of Internal Medicine, Family Medicine and the History of Medicine and Faculty of Dental Medicine and Health, Department of Public Health, University of Osijek, Croatia.

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Abstract

Increased knowledge in many areas begins to destabilise the background way of thinking of the classical science - the reductionist thinking. Changing the paradigm towards the science of complexity and complex thinking is difficult, as our systems of research and education are not prepared for these changes, although complex thinking seems to be inherent to the mankind. Big data analytics, from computer science, may provide the methodological framework for practicing the science of complexity and help us to change our way of thinking.

Reductionism

Scientific knowledge of the modern societies is mostly built on reductionism, the paradigm that natural phenomena can be explained by universal laws and the strict causality, which are formulated by a limited number of static mathematical models [1]. This paradigm has its roots in scientific achievements of the 17th and 18th centuries, including the Newton`s laws of motion and Cartesian mathematics, as the cornestones. There was a notion that the system can be understood if it is broken down to its components, which are then analysed separately [2]. In scientific reasoning, there is no place for any contradictions or uncertainties. Scientific reasoning, according to this paradigm, should rely on the strong logic, including the principles of induction, deduction and identity (relationships of similarities and dissimilarities between objects) [3]. In line with Descartes philosophy of dualism, the physical world has its inherent, objective laws, which are independent of consideration of an observer [1]. One of the consequences of reductionism, in life science research, is that research design must include the clearly defined hypothesis, which should result in unambiguous (absolute) proofs. Life sciences use the scientific, quantitative methods, and are distinct from social sciences and art, which are in a great part subjective (depend on the consideration of an observer) and intuitive representation of reality [1].

Complexity

In contrast to reductionism, complexity is a broad concept which can be considered as a view about the world, the way of thinking or an approach to research [2]. The idea of complexity is older than that of reductionism, its history dating back to the ancient Greek philosopher Aristotle [4]. Nevertheless, it has been revitalised yet recently, in the end of the 20th century, arising from the emerging theories, evolutionary biology, cybernetics and the theory of deterministic chaos, for which the classical science could not provide the appropriate framework [1]. The science of complexity states that biological systems show behaviours as complex systems [5]. In complex systems, components interact with each other within the physiological networks, producing a function or a phenotype. That is, the properties of the system emerge from self-organisation of its components. Continuous interplay between components and networks creates fluctuating processes, which are far from being in a steady-state condition, which was the classical definition of homeostasis. This dynamic behaviour of the complex system corresponds with its high adaptability to internal and external challenges. Decline in the level of complexity, on the contrary, leads to the appearance of diseases, disability and frailty, as it is the case in aging diseases [6,7]. At the points of destabilisation (bifurcations), the system can rapidly turn into self-destruction, such as the case in some acute illnesses.

Complex Thinking

The view of the world from the perspectives of the science of complexity changes our way of thinking. Complex thinking takes into account multiple elements and contexts, uses terms "chance" and "probability", rather than "causality" and "determination" [1,2,8]. Contradictions may not be exclusive, but complementary to each other in creating new solutions and new possibilities. Complex thinking (and research approaches, as well) is playing at the edge of uncertainty, when searching for deterministic solutions. It allows for creativity to blow up, but at the same time, is oriented towards problem-solving and searching for practically relevant solutions. In striving to these aims, pieces of different theories, mixed methodologies and interdisciplinary approaches, can be used together [1]. This choice may be in a great part dependent on the knowledge and the intellectual makeup of a researcher (an observer). Since the methodological tools for practicing the concept of complexity have been missing for a long time, many of the observed phenomena in the nature and society have maintained non understood [1,9].

Complex thinking is inherent to the human beings, as already Aristotle has described [4]:

First, the instinct of imitation is implanted in men from childhood, one difference between him and other animals being that he is the most imitative of living creatures, and through imitations learns his earliest lessons; and nor less universal is the plesure felt in things imitated.

We have evidence of this in the facts of experience. Objects which in themselves we view with pain, we delight to, contemplate when reproduced with minute fidelity.

Or, as Edgar Morin, a leader of the theory of complex thinking, stated [8]:

We need a kind of thinking that reconnects that which is disjointed and compartmentalized, that respects diversity as it recognizes unity and that tries to discern interdependencies. We need a radical thinking (which gets to the root of problems), a multidimensional thinking and an organizational or systemic thinking.

Methodological Framework of the Science of Complexity

New models are needed, to cope with complex systems behaviours, but to be applicable to the real world situations. One of the first models, in medicine, were those that included time-dependent analysis (time-series) of measurable biological signals [5]. Other models would be those that are to correspond with multiple interacting components, non-linear dynamics and uncertain (more or less probable) outcomes [1]. The aim is to find the points (or elements) of the system`s destabilisation, to imitate the fluctuating and unpredictable nature of processes and to identify typical patterns in component organisation [5]. The models of complexity have been found appropriate equally in life sciences and humanistic and applied sciences, including, e.g., economy, traffic, banking systems and different technological systems [1].

Big data approaches, in computer science, and their emerging analytical tools, notably a variety of data mining and machine learning algorithms, are likely to provide this methodological framework that would be able to allow the complexity science to come to its realisation [10]. These methods enable detection of non-linear relationships and patterns in large volumes of data. Often, in solving the problem, combinations of methods or models that are not specified in advance, but are learning on data, have to be used. Or, as some theoreticians stated: “In classical science, research methods drive the hypothesis of a research; in complex science, the problem that has to be solved governs the research methods” [1].

Conclusion

Changing the paradigm from reductionist to complex thinking might have far reaching consequences on scientific developments, organisation of many areas of human activities, social relationships and the ethical principles. Big data anaytics and computer science is likely to provide the framework for changing this paradigm.

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