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Complex Systems and Human Complexity in Medicine

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Abstract
Concepts taken from complex systems theory, such as 'agents' and 'attractors', have been proposed as metaphors in medical practice. This proposal is assessed by a comparison of the notions of complex adaptive systems (CAS) and human complexity. CAS are characterized by the emergence of sophisticated output features of rule-governed non-linear systems. Human complexity is the result of higher mental capacities and human culture. Failure to understand it in such terms may result in medical failure or medical 'success' in which the wrong problem is solved. CAS concepts may thus be useful in the solution of given medical problems, while their application may lead to an undesirable reduction of complexity in cases in which the identification of the medical problem itself is part of the medical challenge.

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Introduction: Complexity and Reflexivity

Health care is increasingly perceived as a complex enterprise [1, 2]. The catalogue of medical diagnoses, diagnostic tests and curative and preventive therapies is proliferating, and so are our institutions for health care and their relationships with the rest of society. On one hand, there has been a development of public health improvement. On the other hand, the medicalization of Western culture has reached a level at which the general population has been said to trust doctors less and demand more, whereas doctors spend more time on surveying risk factors of healthy individuals and communicating with other health care workers and various bureaucratic organizations [3]. Whether this will significantly improve public health any further remains to be seen. Nevertheless, these changes in society and medical practice call for changes in our perception of what may count as relevant goals and means in medicine. The introduction of what we may call complexity science in medicine [1, 4–6] contributes to this important debate.

An important facet of complexity, in medicine as well as elsewhere, is that there can be no guarantee of a simple relationship between action and effect. Accordingly, complexity calls for *reflexivity*, that is the ability to identify and reflect upon the results of one's own actions and limitations. The purpose of this study is to contribute to medical reflexivity by clarifying the strengths and limitations of the application of concepts from complexity science in the understanding and dealing with the apparent complexity encountered in medicine. As is easily recognized, however, 'complexity science' is a diverse field, and there is no consensus on the definitions of 'complexity' and 'complex systems'. In this paper, we shall focus on the concept of 'complex adaptive systems' (CAS) as encountered e.g. in the work of Holland [7] and more generally in the research tradition often associated with the name of the Santa Fe Institute. We have made that choice in part because we hold CAS to be an important and promising concept of complex systems, and in part because it has already played a role as a metaphor of complexity in medical debate [1, 2, 4–6]. Our approach is to highlight certain aspects of CAS and compare them with what we call 'human complexity', a label for phenomena encountered in medical practice in which their complex character (in an every-day sense) seems to reside in the doctor and patient being human beings. Finally, we discuss the use of CAS as a metaphor for human complexity.

The Complexity of CAS

Holland [7] introduces the CAS concept by mentioning a variety of natural systems such as the human central nervous system, the humane immune system, ecosystems, economies and cities. He continues by defining CAS as the 'common heading' of such systems, identified by the functional property of 'coherence under change' and, apparently, the structural properties of having many and diverse components (to be called 'agents') and a large number of interactions between them. A much-used textbook [8, p. 276], however, introduces the concept in the following way: 'A complex adaptive system consists of a large number of agents, each of which behaves according to some set of rules.'

Although we have no reason to suspect that a disagreement lies behind the difference of the two quotations, they show that CAS can be defined in more than one way. Leaving aside the question as to whether functional properties of the system as a whole should form part of the definition, we turn to the issue of the rule-governed behaviour of the agents. While some include this property in the definition of CAS [8, 9], Holland [7] wrote: 'It is useful to think of an agent's behavior as determined by a collection of rules' [p. 7] and '... our intent is *not* to claim that we can locate the rules explicitly in the agents' [p. 8]. When proceeding to the description of performance systems of agents, however, he writes: '... now we take rules more seriously as a formal means of defining agents' [p. 43]. This move represents well the research practice of CAS studies: The researcher is aware that the agents of the natural system, above all human agents, may not always be known to behave in a rule-governed way; however, the actual agent-based modelling practice consists of defining transformation rules of agent states (and of rules) and studying their implications. The reason why CAS are called 'complex', then, is that some agent-based models have produced more sophisticated results than previous generations of mathematical models. Thus, the agents of a CAS may be seen to 'form groups' or otherwise evolve new 'survival strategies', or the system as a whole may show a variety of dynamical states such as regular growth patterns, steady-state, collapses, or formation of hierarchical structures. In the CAS literature, such mathematical phenomena are known as 'self-organized behaviour'. In a sense, these phenomena are 'self-organized' and 'emergent' in these models, but they emerge automatically from non-linear feedback patterns predefined by the choice and design of the computing algorithms. Indeed, the strength of the CAS approach has been to show that interesting dynamical features can emerge from quite simple model designs and in spite of random elements included in the program. It is this strength that may play a role in medicine; and conversely, the possible risk to be discussed in this paper is that of oversimplification when assuming that behaviour is rule-governed. Accordingly, in this paper we have to distinguish clearly between rule-governed systems and natural systems in which the principles of behaviour may be unknown [7, 10], and we will in the following consider agent behaviour in CAS as rule-governed by definition [8, 9].

Human Complexity in Medicine

Our main point when speaking of human complexity in medicine in contrast to CAS is that it is not evident that human behaviour is rule-governed, or can be adequately described as rule-governed. It should be noted, however, that already on the level of biology and biomedicine, challenges and limitations to the application of CAS may be noticed. Indeed, it has been argued that the causal structure of CAS (essentially limited to what can be formalized into algorithms) is too constrained to account for the properties of real cells and organisms [11]. Furthermore, complexity in the form of so-called *radical openness* and *contextuality* may be lost in the specification of a well-defined system [10].

Medical practice, however, involves encounters between human beings. Humans have a richness of mental capacities, such as self-awareness, personality development, creativity, pretending and self-deception, giving them the ability to make self-fulfilling and self-destructive prophecies. Human beings often consciously follow rules, but they can also choose to disobey or change them, and invent new ones. Historically, there have been a number of research traditions that tried to reduce this complexity by discovering lower-level, unconscious rules that humans are governed by, ranging from the psychophysics of the 19th century to the behaviourism of the 20th century; it seems fair to say, however, that none of these traditions fulfilled their ambitions. Indeed, philosophical critiques have been available for a long time, arguing that such ambitions in principle cannot be fulfilled [12, 13]. A regular feature of such critiques is that they argue that behaviourist and other research traditions have an idealized and naïve notion of objectivity and assume that there can be such a thing as a unique, correct and context-independent representation of the phenomena at hand, described by a researcher viewing 'from nowhere'. In medicine, this corresponds to the belief that patients' medical problems can be uniquely described in terms of disease. However, as witnessed by medical anthropology [14] and, more practically, in the vast research on subjective health complaints, quite a few medical phenomena simply have no determinate form until patient and doctor have shaped a medical narrative and crystallized one of the innumerable possibilities of interpreting the situation [15]. In a CAS, the state of the agent has an objective description for which some rules apply. In a medical encounter, the state of the patient is to some extent subject to negotiation where a mixture of facts, values and various pragmatic considerations is involved. On a cultural level, human complexity may even redefine diseases, as witnessed by the following quote from an editorial of the *British Medical Journal* [16]: '[A]s the years pass back pain does indeed seem to be changing from a condition thought of primarily in physical terms to one considered to be predominantly psychosocial.'

Literal and Metaphorical Use of Scientific Concepts

It has been proposed to use the vocabulary of CAS as *metaphors* in medical practice [1, 2]. To assess this proposal, one should note the following important differences between literal and metaphorical uses of scientific concepts.

Literal uses of science are justified by their *truth*. Such use takes place with patients that can be classified as (conceptually) 'simple cases' (table 1). For instance, we may isolate tubercle bacilli in a patient and treat his tuberculosis. In such a case the use of science is literal: we believe that the infectious agent actually exists and essentially caused the patient to become ill by a scientifically known mechanism. The treatment may be unsuccessful, of course, but not because scientific concepts were misused.

However, many patients are not clear-cut textbook cases [17], and in the face of uncertainty, doubt and complexity, it is human to grasp for conceptual heuristics, such as metaphors, to get a hold of the situation. Their use is problematic though. Metaphors imported from some other domain of science cannot be justified in medicine by their scientific truth, since they are not supposed to be true in the new context. The pump is a brilliant model of the heart for many purposes; however, the structure and functions of the heart are very different from those of any mechanical pump, and at some level these differences have practical consequences that are obscured if the metaphor is taken to be a literal description. Likewise, when CAS was introduced into management theory, it was not necessarily claimed that human behaviour always conforms to simple, algorithmic rules. Rather, the justification of the metaphor lies in its pragmatic utility (such as the success of the business enterprises who listened to CAS-inspired consultants).

Given the essential differences between CAS and human complexity, the introduction of CAS-based insights into medicine must be seen as a metaphorical use. What are the possible costs and benefits of using CAS metaphors? What are the criteria for the evaluation of their success? These will be the topics of the remainder of the paper.

Criteria for the Evaluation of Metaphors

Having said above that the justification of a metaphor lies in its utility, we have glossed over profound philosophical debates on the importance of metaphor in human thought. Thus, there may be deeper levels of motivation for the choice of a given metaphor, also connected to ideology and cultural identity [18]. Nevertheless, it is possible and, we believe, useful to identify more palpable utility aspects of a metaphor. For instance, we agree with Holland [19] that CAS models and metaphors may

Table 1. Medical care: extreme stereotypes of its real workings

	Simple cases (rare)	Complex cases (common)
Medical problem	Fight the disease that causes the patient's illness	Somehow help the patient towards improved health
Causality	Disease caused by a physiological imbalance or the presence of a disease agent	Partly opaque causal networks involving physiology, psyche and personal/social relationships
Therapy	Reinstates physiological normalcy; removes or counteracts disease agent	Perturbs physiology and psyche towards presumed attractors of health, or simply tries whatever might help
Effects	Therapeutic effect on the disease Adversary effects (undesired illness and/or disease)	Therapeutic effect on the disease Adversary effects Change of physiology Change of life style and personal values

be useful for scientific creativity and innovation. Furthermore, an indirect but relevant criterion is the ability of the metaphor to facilitate efficient description, 'making sense' of the phenomena. For instance, the CAS metaphor has provided an efficient and plausible description of the physiological fluctuations in diabetes patients [6].

Unlike certain other sciences, however, medicine has an ultimate purpose, namely to reduce suffering and improve health. A reflexive stance towards immediate enthusiasm over a new metaphor or a new technique accordingly implies the need to discuss its long-term potential to help medicine fulfil its purpose.

Medical Success in the Presence of Human Complexity

In some cases, the purpose of medicine is readily operationalized into quantifiable goals. For instance, one may observe the successful removal of disease or symptoms, readily measured in terms of survival, recovery, functionality and health. In such cases, the value of CAS can be estimated as any other theoretical or practical device.

In the presence of human complexity, however, the relationship between purpose and goals may be more complicated, as witnessed by the difficult debates on terminal health care, the increased focus on risk determination and preventive health care. Objective measures of medical success must be supplemented by considerations of life quality and other subjective outcome measures. Such considerations are difficult. Quality of life includes an irreducible aspect of subjectivity, but patients are often as much in want of the good answers as doctors when it comes to priority setting and choice among evils. Not only is it difficult for each and one of us to decide which life scenario (or rather set of probable scenarios) is the better. When facing the really important therapeutic crossroads, the patient also has to predict his own long-term opinions on the good life. There may even be a complex dynamic between the choice of therapy and the individual development of personality, in particular in cases of mental illness. The patient *may become* a person who will regret his prior decision. These existential considerations are profoundly difficult and lonely ones, but a doctor with professional experience and ample human understanding might help the patient to be less lonely [20].

It may be argued that CAS metaphors could facilitate such considerations better than the traditional 'machine metaphors' of medicine, as CAS-inspired thinking might be better in handling phenomena such as surprises, uncertainty and unpredictability. On the other hand, the medical problem will still be seen as a sort of imbalance (table 2), not anymore in terms of a deviation of physiological values, but as a deviation from healthy dynamics. Indeed, CAS methods are similar to traditional science in that they abstract away individual details and focus upon general properties [21]. Inside both conceptual frameworks, the goal of medicine appears to be just a matter of solving a pre-existing, uniquely given medical problem. A preliminary conclusion is accordingly that CAS may be a useful metaphor in such cases, but that the recognition of human complexity is required to acknowledge that the process towards the identification of the medical goal in itself may be a significant medical challenge. For this reason we think that human complexity should not be conflated with CAS.

There is probably no agreement on the relevance of the point just made. We would like to point to two factors. First, it has been observed that doctors often fail to discover the medical agenda of their patients [22]. Second, new developments in imaging technology indicate that any individual runs the risk of having a number of bio-

Table 2. How the perception of medical problems is shaped

	Machine metaphor	CAS metaphor	Human complexity
The medical problem …	… can be measured objectively	… can be figured out objectively	… needs to be negotiated by doctor and patient
The illness is just …	… an imbalance or a dysfunction	… system dynamics away from health	It is not obvious that illness can be reduced to a single principle
Medical events …	… are in principle deterministic	… may be only qualitatively predictable	… may even be indeterminate, i.e., a matter of post hoc reconstruction and interpretation
Uncertainty …	… is nothing but deficient knowledge	… of prognosis is inevitable and needs proper management	… may penetrate the diagnosis, the choice and evaluation of therapy, and the choice of evaluation criteria
The doctor should …	… reinstate physiological normalcy	… navigate towards attractor of health	… fight disease, or navigate towards health, or prepare for a life of illness and death, or do nothing

logical deviations from the 'normal', the health consequence of which may be very small or even profoundly unclear [23]. Biomedical investigations that are too thorough may thus reveal medical 'problems' that can be diagnosed and treated, without coinciding with the experienced problem of the patient or indeed with any significant problem at all. The result may be a medical success in the objectivist sense, but one that rather reminds us that it is often possible to fit square pegs into round holes if one applies sufficient power. Again, the introduction of dynamic concepts such as attractor patterns might result in fewer cases where physiological deviations from average values in otherwise sound bodies are considered abnormal and corrected. Reflexivity is strongly called for, however, to avoid that the doctor tries too hard to identify the patient's 'undesirable attractor pattern' rather than talking to the patient and including his perspective in the clarification of what is undesirable and what could be done about it. Indeed, Stacey [8] warned against the uncritical use of CAS metaphors because one easily traps the discourse into (1) a rule-based conception of human behaviour and (2) a way of relating to systems similar to that of the computer programmer, residing *outside* the computer and controlling it at wish. For Stacey, the question that reveals understanding of complex systems is not 'how can I govern the system into a new attractor (desired by me)?' but rather 'what is my role in this system, and how does the action of me and others affect the system?'

Conclusion: Living with Uncertainty and Complexity

Perhaps the most important insight that indirectly might be drawn from CAS or other theories of complexity is that of accepting that quite a few events are unpredictable, that some problems cannot be solved, and that some uncertainties cannot be avoided.

Within the machine metaphor (and probably also the CAS metaphor), every incurable disease and death amounts to a failure. In Western societies, this attitude has become a cultural attribute. Thus, one ought to welcome the scientific focus upon complexity, in the furtherance of which we see the contours of a science that gives more attention to the nature and the role of the subject, especially if a rich concept of human complexity can be maintained.

We would like to recommend a pragmatic attitude towards metaphors. Some medical problems are best tackled as simple cases, reinstating a normal blood value or killing an infectious agent. Other problems may call for a CAS-based approach, while those characterized by challenges posed by human complexity might be better dealt with using other concepts, such as those offered by narrative medicine or simply the experience-based traditions of general practice. Accordingly, we agree that the complexity theory may have a lot to offer, but remain critical to claims that 'complexity theory offers a broader, potentially unifying framework in which health care can be understood' [2]. Indeed, it appears quite contrary to an understanding of complexity even to look for a unifying conceptual framework of health care, and even more so to look for it within institutional science [24–26].

References

1 Plsek PE, Greenhalgh T: Complexity science: The challenge of complexity in health care. Br Med J 2001; 323: 625–628.
2 Kernick D, Sweeney K: Post-normal medicine. Fam Pract 2001; 18: 356–358.
3 Le Fanu J: The Rise and Fall of Modern Medicine. London, Little, Brown, 1999.
4 Fraser SW, Greenhalgh T: Complexity science: Coping with complexity: Educating for capability. Br Med J 2001; 323: 799–803.
5 Plsek PE, Wilson T: Complexity science: Complexity, leadership, and management in healthcare organisations. Br Med J 2001; 323: 746–749.
6 Wilson T, Holt T, Greenhalgh T: Complexity science: Complexity and clinical care. Br Med J 2001; 323: 685–688.
7 Holland JH: Hidden Order. Reading, Helix Books, 1995.
8 Stacey RD: Strategic Management and Organisational Dynamics: The Challenge of Complexity. Harlow, Financial Times/Prentice Hall, 2000.
9 Dooley K: Complex Adaptive Systems: A Nominal Definition. http://www.eas.asu.edu/kdooley/casopdef.html
10 Chu D, Strand R, Fjelland R: Theories of complexity. Complexity 2003; 8: 19–30.
11 Rosen R: Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life. New York, Columbia University Press, 1991.
12 Bergson H: Time and Free Will: An Essay on the Immediate Data of Consciousness. London, Allen & Unwin, 1910.
13 Dreyfus HS, Dreyfus SE, Athanasiou T: Mind over Machine: The Power of Human Intuition and Expertise in the Era of the Computer. New York, Free Press, 1986.
14 Good BJ: Medicine, Rationality, and Experience: An Anthropological Perspective. Cambridge, Cambridge University Press, 1994.
15 Hurwitz B, Greenhalgh T: Narrative Based Medicine: Dialogue and Discourse in Clinical Practice. London, BMJ Books, 1998.
16 Editor: Increasing complexity. Br Med J 2001; 323: 0a.
17 Malterud K: The legitimacy of clinical knowledge: Towards a medical epistemology embracing the art of medicine. Theor Med 1995; 16: 183–198.
18 Lakoff G, Johnson M: Metaphors We Live by. Chicago, University of Chicago Press, 1980.
19 Holland JH: Emergence. From Chaos to Order. Oxford, Oxford University Press, 1998.
20 Tauber AI: Confessions of a Medicine Man: An Essay in Popular Philosophy. Cambridge, MIT Press, 1999.
21 Gross D, Strand R: Can Agent-Based Models Assist Decisions on Large-Scale Practical Problems? A Philosophical Analysis. Complexity 2000; 5: 26–33.
22 Barry CA, Bradley CP, Britten N, Stevenson FA, Barber N: Patients' unvoiced agendas in general practice consultations: Qualitative study. BMJ 2000; 320: 1246–1250.
23 Fisher ES, Welch HG: Avoiding the unintended consequences of growth in medical care: How might more be worse? JAMA 1999; 281: 446–453.
24 Waltner-Toews D, Wall E: Emergent perplexity: In search of post-normal questions for community and agroecosystem health. Soc Sci Med 1997; 45: 1741–1749.
25 Waltner-Toews D: The end of medicine: The beginning of health. Futures 2000; 32: 655–667.
26 Strand R: Complexity, Ideology and Governance. Emergence 2002; 4: 164–183.