Thinking about complexity in health: A systematic review of the key systems thinking and complexity ideas in health

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Thinking About Complexity in Health: A systematic review of the use of key systems thinking and complexity ideas in healthcare

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Key Messages

- Systems Thinking and Complexity Theory, theories that acknowledge the dynamic, connected, and context dependent nature of health, are highly relevant to the post-Millennium Development Goal era yet lack consensus on their use in relation to health
- Although heterogeneous, terms and concepts like Emergence, Dynamic/Dynamical Systems, Non-linear(ity), and Interdependent/Interconnected and methods like Systems Dynamic Modeling and Agent Based Modeling that comprise Systems Thinking and Complexity Theory in the health literature are shared across an increasing number of publications within medical/healthcare disciplines
- Planners, practitioners, and theorists that can better understand these key Systems Thinking and Complexity Theory concepts will be better equipped to tackle the challenges of the upcoming development goals

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Introduction

With the Sustainable Development Goals (SDGs) already underway , stakeholders have already set the next development agenda with areas like poverty, hunger, health, education, water and sanitation, energy, economic growth, improved infrastructure, decreased inequality, climate change, and many more highlighted(1). While clearly articulating some of the uniting issues facing global development over the coming decades, these potential targets miss some of the central lessons from the Millenium Development Goals (MDGs) (2). By establishing specific areas and targets, they risk creating another bundle of unconnected, narrow, or ambiguous goals instead of a development agenda that works synergistically and dynamically toward equitable, sustainable improvements in wellbeing (3).

To address these key development areas while learning from the limitations of the past, stakeholders must look for new ways to conceptualize and address the constant, interconnected evolution of these challenges over time (4, 5).

Frameworks, including those at the core of the MDGs previously and now represented in the SDGs, have employed linear models to understand and shape the context of health (6). From testing methods that seek to minimize subject variability to statistical tools that can only detect a narrow set of associations and policies that target wide populations using narrow guidelines, approaches that inappropriately reduce variability have shown benefits but missed opportunities for synergy across complex development challenges (3, 7). Social sciences, including health practice, have adopted some of these methods as well, using logframes, participatory approaches, and stakeholder consultations in an attempt to distill complex interactions down to controllable,

input-output-outcomes (8). In both cases, the limitations of this reductionist thinking and practice are increasingly obvious when applied to the wider social determinants of health (9).

In contrast to these linear conceptions, Systems Thinking (ST) focuses on understanding the inter-relationships, interactions, engages with different perspectives, and reflects on boundaries of ~~a~~ systems (10-13). Complexity Theory (CT) emphasizes that systems reflect dynamic, often unpredictable interactions amongst diverse, constantly adapting parts(14). Combined, some elements of ST and CT may conceptualize ~~the~~ health systems as ~~a~~ Complex Adaptive Systems (CAS), a collection of interacting entities that continually change in relation to one another and their collective environment (7). The advantage of this approach is that ST/CT take into account the changing context, its key actors, and their interactions over time in understanding health, thereby allowing planners to more effectively understand and improve health (6, 7, 15). By using these ideas to guide health planning, analysis and practice, ST/CT has gained traction amongst practitioners in different fields such as international development as well as health practice offering the potential to transform modern approaches to health and well-being (2, 7, 16-20).

While there are dozens of articles in the academic health literature describing and exploring the application and potential of ST/CT approaches and methods in health (21-24), to our knowledge there is no clear consensus as to the basic components, concepts, and practices of systems thinking in health. One prior review provides an important view of the larger systems thinking literature but does not go as far in exploring the key terms, methods, or resources related to ST/CT(25). The lack of such a comprehensive review limits the ability of planners to synthesize

existing literature and apply innovative-practices to emerging development challenges such as the post-MDG agenda.

This systematic review seeks to review the frequency and nature of key terms, concepts, and methods from ST/CT in the health literature. With a clearer understanding of approaches based on ST and CT, the global health community will be better equipped to understand and address key health challenges.

Methodology

A systematic review was conducted to gain an understanding of the published literature related to systems thinking and complexity theory in health and to gather data. Systematic review has been defined as a review of the literature according to an explicit, rigorous, and transparent methodology, rather than as an exhaustive and comprehensive summary of every paper ever published on the topic(26).

The two primary researchers, aided by a small research team, collected data employing the following predetermined search terms: “systems thinkin* AND health OR complexity theor* AND health OR complex adaptive system* AND health.” Search terms and databases were determined with the help of a university librarian. The study selection was conducted in two phases: First, an initial screening of titles and abstracts against the inclusion criteria was performed to identify potentially relevant papers. Second, a screening in full was conducted for each of the papers identified as possibly relevant in the initial screening against the inclusion criteria. Articles were discarded if they did not have a health connection; did not have an English translation; or were duplicates.

The published literature was searched in mid 2016 using the search terms mentioned above and the subject headings in the databases EBSCO, BIOSIS, PROQUEST, PUBMED, and WEB OF SCIENCE from 2002 to 2016. The search resulted in 3,982 potential references. Two reviewers then reviewed the titles and abstracts independently for relevance based on broad inclusion criteria. If both reviewers agreed on inclusion or exclusion, the article was subsequently included or excluded accordingly. If they disagreed, a third reviewer reviewed the title and abstract and determined whether it should be included or not. This second screen yielded 516 articles which were included in the review. Once the articles were selected for inclusion, a team of reviewers analyzed each article independently for the relevant terms, methods, and topic area.

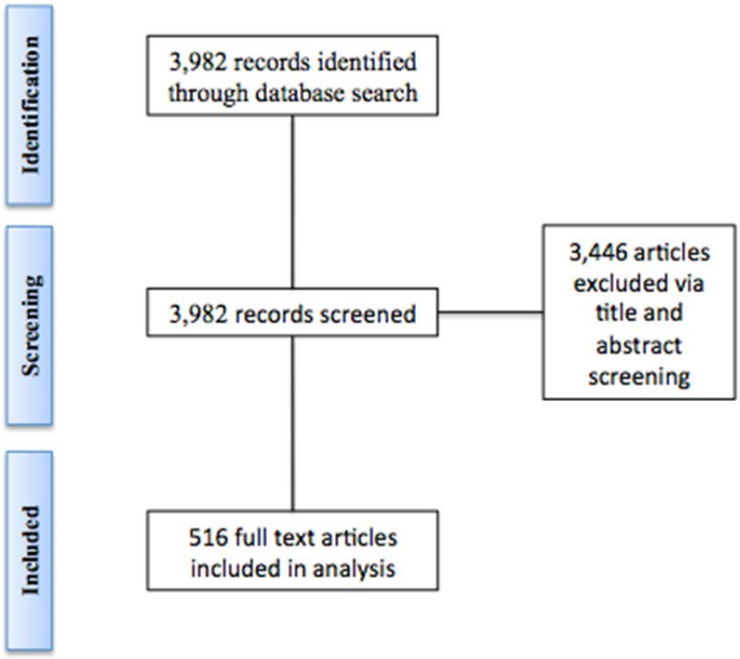

Figure 1

Analysis

Following the independent inclusion process followed by the reviewers, the texts were then reviewed and analyzed to consider the following broad research questions, as applied to the health sector:

1. What is the distribution of key terms from ST, CT, and CAS in relevant health journals?
2. What is the frequency and nature of key recurring ‘concepts’ associated with ST, CT and CAS?
3. What is the frequency and nature of key recurring ‘methods’ associated with ST, CT and CAS?

A data collection form was created through an iterative process with assistance from subject experts to aide researchers in the data collection process. This form included basic article information (title, journal, year), discipline, 21 applicable methods, 57 relevant terms, and an entry for a case study summary.

The most pervasive terms, themes, methods, and approaches from all identified documents were determined. Articles that included case studies were also summarized and included.

Results

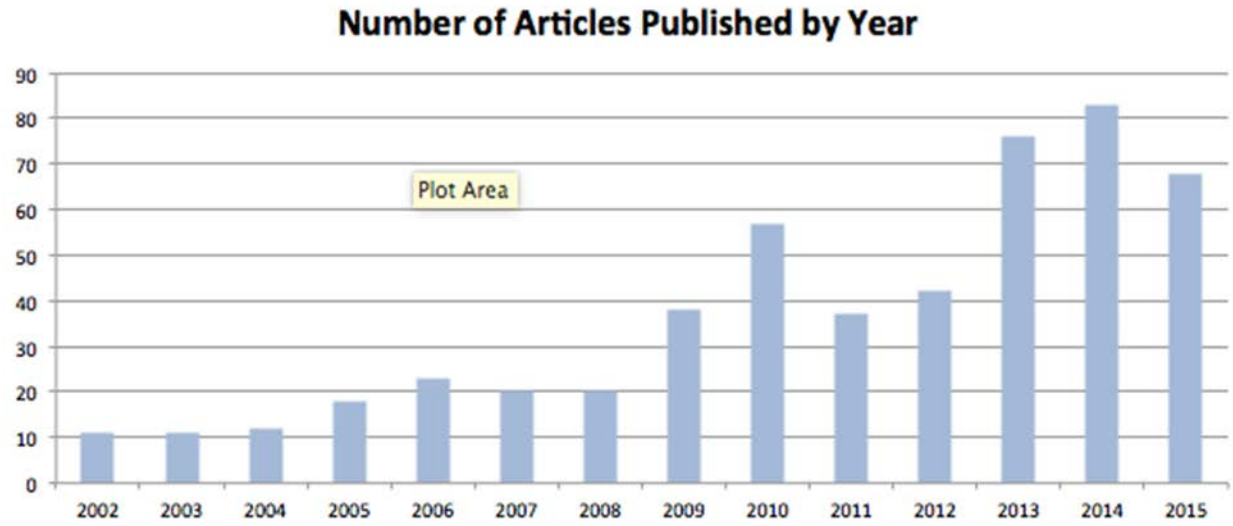

Figure 2

A total of 516 articles were identified during the review. The number of ST/CT articles increased from the first year included (2002) toward a peak in 2014 (n=83). The Journal of Evaluation in Clinical Practice published about 7%% of these articles (n=37), more than double the number of ST/CT articles published by the American Journal of Public Health (n=17), the journal with the second highest number of ST/CT articles. Along with Health Research Policy and Systems (N=15), Social Science and Medicine (n=15), the Journal of Nursing Administration (n=11), and Health Care Management Reivew (N=9), these 6 journals published just over one fifth of all reviewed articles. The remaining articles were spread across 292 other journals or dissertations. Each journal was categorized according to discipline, with any individual journal being allowed to have more than one discipline. Accordingly, there was some overlap amongst disciplines, with Medicine/Healthcare (n=265), Public Health (n=166), Health Policy (n=95), and Management/Admin (n=91) well represented among the reviewed manuscripts.

Table 1

Journal	Articles by Journal		
	Number	Percentage	Cumulative
Journal of Evaluation in Clinical Practice	37	7.2%	7.2%
American Journal of Public Health	17	3.3%	10.5%
Health Research Policy and Systems	15	2.9%	13.4%
Social Science and Medicine	15	2.9%	16.3%
Journal of Nursing Administration	11	2.1%	18.4%
Health Care Management Review	9	1.7%	20.2%
Health Policy and Planning	8	1.6%	21.7%
Annals of Family Medicine	7	1.4%	23.1%
Health Promotion International	7	1.4%	24.4%
Journal of Public Health Management and Practice	7	1.4%	25.8%

Table 2

Discipline	Articles Using Discipline	
	Number	Percentage
Medicine/Healthcare	265	51.4%
Public Health	166	32.2%
Health Policy	95	18.4%
Management/ Administration	91	17.6%
Nursing	54	10.5%
Global Health	51	9.9%
Health Education	16	3.1%
Other	12	2.3%

Several terms were explicitly mentioned, or described in the text in more than half of the articles reviewed. These included Dynamic/Dynamical Systems (n=332; 64.3%), Emergence (n=294; 57.0%), Complex Adaptive System(s) (n=270; 52.3%), and Interdependent/Interconnected (n=263; 51.0%).

Table 3

Term	Articles Using Term	
	Number	Percentage
Dynamic/Dyamical Systems	332	64.3%
Emergence	294	57.0%
CAS	270	52.3%
Interdependent/Interconnected	263	51.0%
Feedback Loops	254	49.2%
Non-linear/Non-linearity	251	48.6%
Complexity Science/Theory	225	43.6%
Adaptability/Adaptation	222	43.0%
Collaboration	213	41.3%
Capacity/ Capacity Building	211	40.9%
Linear/Linearity	185	35.9%
Self Organization	177	34.3%

Systems thinking methods were mentioned in the reviewed manuscripts 259 times, with System Dynamic Modeling (n=58), Agent Based Modeling (n=43), Causal Loop Diagram (n=43), and Social Network Analysis (n=37), and making up the majority of the methods.

Table 4

Method	Articles Using Method	
	Number	Percentage
System Dynamic Modeling	58	11.2%
Agent Based Modeling	43	8.3%
Causal Loop Diagram	43	8.3%
Social Network Analysis	37	7.2%
Concept Mapping	14	2.7%
Scenario Technique	14	2.7%
Cynefin	8	1.6%
Solution Focus	8	1.6%

The different methods have their underlying theoretical and methodological foundations, for example, *System Dynamic Modelling* adopts a holistic systems perspective and uses stocks, flows

and feedback loops to study the behavior of complex systems over time; *Agent Based Modelling* takes a bottom-up approach to modeling wherein the overall behavior of the system emerges from the underlying dynamic interaction between the agents (Mustafee, Katsaliaki and Taylor 2010). *Social Network Analysis* is the study of social relations among a set of actors or interacting units. *Causal Loop Diagrams* permit qualitative analysis of the system and soft modelling approaches such as *Qualitative System Dynamics (QSD)* rely on system representation through causal loops. The *Causal Loop Diagrams* can be transformed into *Stock and Flow Diagrams* and the resultant System Dynamic model can be used to perform a more detailed quantitative analysis. It is interesting to note that both *System Dynamics Modeling* (and by extension *Stock and Flow Diagrams*) and *Causal Loop Diagrams* are in the top-four modelling methods, and when considered together they are at the top of the list with a total of 30 occurrences. Thus it would seem that the qualitative and the quantitative forms of System Dynamics are the key modeling methods that are currently being applied in published ST/CS articles. This is hardly surprising since the latter focuses on understanding the constituents of a system and its inter-relationships, and the former realizes this by providing a structured and methodologically grounded approach for such investigation. Both the qualitative and the quantitative forms of this modelling approach help in the understanding of how even apparently simple systems display inexplicable nonlinearity. The central concept is that change to one part of a system will impact all other parts of an interrelated system.

Nearly all of the reviewed articles (n=516) were theoretical, although 108 also included case studies.

Discussion

This systematic review sought to identify the key areas of health practice where ST/CT ideas are published, along with some key concepts and methods that have recently been applied to health. We identified 516 relevant articles coming mostly from medicine- and healthcare-oriented journals, within which 4 terms and ideas appeared in more than half of the articles reviewed. While the number of ST/CT articles seemed to generally be increasing, only 108 contained case studies and only 4 methods were mentioned in 5% of the articles or more.

Several terms, particularly Dynamic/Dynamical Systems, Emergence, Complex Adaptive Systems, and Interdependent/Interconnected were very common within ST/CT manuscripts, appearing in roughly half of all manuscripts reviewed. Perhaps the fact that these four ideas were frequently encountered is not surprising, as components of ST/CT definitions often include the idea that organization in systems arises (Emergence) from the continuously evolving, yet at times unpredictable interaction amongst complex (Complex Adaptive System) parts (Dynamic/Dynamical Systems and Interdependent/Interconnected) (7, 28). With the exception of these and few other terms, most of the concepts reviewed appeared in relatively few manuscripts. The mix of these often distinct ideas under the common umbrella of ST/CT indicates that while certain concepts may be consistent across theories, others are themselves evolving as the theoretical basis is applied to new areas and practice contexts.

The absence of a core ST/CT concept has important implications for users and theorists. For those looking to teach ST/CT, a wide variety of terms and historical concepts must be covered, all of which are themselves evolving and interacting over time. Similarly, for practitioners, an understanding of the conceptual root for each method may seemingly be required.

A variety of terms may complicate the expansion of ST/CT as users seek to distill similar ideas from divergent taxonomies into guiding principles. Conversely, the existence of a rich, often

divergent theoretical and practitioner ST/CT community may not only be unavoidable but beneficial. Exploring different traditions may be the most useful way to adapt these concepts and practice to today's practice and policy context. Itself evolving and iterative, this process of aligning ideas with problems may help close the significant gap between theoretical promise and real-world implementation.

Regardless of theoretical origin or coherence, there is clearly a growing interest in ideas from ST/CT. Increasing interest in ST/CT may reflect a variety of factors. First, with results coming back from disease-specific global health initiatives like those that accompanied the MDGs, planners have been exploring new models for achieving better synergy amongst parallel programing with similar goals (3). Second, healthcare reformers, particularly in low- and middle-income countries, are seeking to expand care while providing universal coverage that reflects their unique histories and cultures (29), an undertaking that is highly complex and systems-oriented. Third, unparalleled gains in interconnectivity, such as the internet and mobile technology, have brought together actors and systems in ways that accelerate existing local and international ST/CT dynamics. Finally, some of the new evidence – particularly that coming from case studies of ST/CT – may be shifting the focus from a more conceptual basis toward realizing the promise of this tradition in practice.

While the amount of published literature is growing, only a small group of journals regularly publish ST/CT articles. This may reflect a preference amongst authors to submit to certain journals, a higher receptivity of certain journals to accept these manuscripts, different ST/CT theoretical frameworks between or even within academic traditions, and/or a scarcity of ST/CT practitioners, academic institutions or practice groups. The articles reviewed here were clustered within certain journals/academic traditions such as medicine/healthcare, public health, and

management/administration. This might suggest that groups of influential theorists within certain traditions, complemented by groups of ST/CT adopters, are applying these principles to their own theory and practice within those focus areas. Conversely, it may also represent more concerted efforts by some journals to explore ST/CT, like the American Journal of Public Health's 2005 issue on ST/CT (30) or the Journal of Evaluation in Clinical Practice's Forum on Systems and Complexity in Medicine and Healthcare (31). Further study, perhaps including a network analysis of published authors, might provide insight into this phenomena. Either way, the promise of ST/CT cannot be realized unless it is more widely promoted to leaders in development, public policy, clinical medicine, and others.

A critical gap in the ST/CT literature reviewed here, and one that may explain the limited scope of existing work in this field, is the overwhelming focus on theory as opposed to practical application. Where fields that originated ST/CT have a longer history of theory and usage, the applications in health are increasing—a fact perhaps reflected in the increasing number of related publications and the relatively few applied studies. That many ST/CT interventions require multi-sectoral involvement, are longitudinal in nature, and are to a large extent context specific, has likely inhibited the perceived generalizability of ST/CT approaches. Of the 108 cases studies identified here, most were retrospective and, if implemented and studied, relatively small; even fewer were explicitly implemented as ST/CT interventions. Evaluation has fared no better, with most studies using retrospective analysis to justify the utility of ST/CT (32, 33). To promote further investment in ST/CT, investments must also be made in studying its application.

Limitations

There were several key limitations of this review. First, this review was limited by the search terms. Although we attempted to cover relevant literature, the heterogeneity of terms we

encountered during the review along with the review methodology suggest important contributions to the study of ST/CT were likely missed. Second, we only reviewed literature covering a relatively short period of time (2002- 2015). While offering useful details on recent usages of ST/CT ideas, this review does not cover historical or more recent applications of these ideas. Third, while we tried to capture all relevant articles, it is possible that our search terms failed to capture some relevant ideas or manuscripts. The "fuzzy" boundary between ST/CT and other fields of focus like socio-ecological frameworks, network science, participatory research, quality/implementation/improvement science, health services research, team science, and realist reviews, amongst others, reflects not only a key limitation of this review but also a challenge to those in health in trying to understand and apply these ideas. Fourth, given the diverse interpretations of terms within the manuscripts reviewed, some could have been reasonably combined or dissected into distinct concepts in the analysis. Finally, the terms, methods, and usages reviewed here are constantly evolving; this review is inherently limited by the changing uses of these ideas in theory and practice.

Ways Forward

Ideas from ST and CT have variably informed many disciplines and practices ranging from education to international development, but have yet to gain much traction in health studies and practice. Several key challenges are worth highlighting. First, within the health literature there is a blurring of understanding in the use of the systems idea with concepts variously applied to a natural entity (e.g. an individual person, bacterium, or respiratory system), a mechanical artifact (e.g. a blood monitoring system) and/or as a purposeful endeavor (e.g. nursing or surgery). The blurring can exist within and between traditions of systems thinking and complexity theory.

There is little clear understanding of how ideas of systems behind ST and CT relate to each other, both now and historically(34). Results from this review confirm these diverse, evolving usages but acknowledge a lack of underlying mutual appreciation in the different use of the systems idea amongst different traditions. For practitioners, planners, students, and reviewers, this makes understanding and applying ST/CT challenging. There is an opportunity here however, for reviewing and developing a better understanding of systems ideas and the various potential applications in health studies. Given the results of this review, some terms and methods may warrant specific focus for those looking to understand some of the ideas that seem to be percolating through the many disciplines represented in the literature. Second, and related to the first challenge, there are several traditions of systems thinking in terms of purposeful systems design including viable systems method, soft systems, cognitive mapping, critical systems heuristics, amongst others (12 , 13) that have not been picked up within the systematic search. These methods themselves primarily come from within one field of ST/CT, Systems Dynamics, leaving other potentially more applicable methods from other traditions unused. Third, in the health literature ST/CT has yet to successfully transition significantly from application in theory to practice. While much has been written about practice, analyses of real-world applications of ST/CT have noticeably been limited in the literature based on this analysis and prior studies(25, 35). The 2014 series “Advancing the application of systems thinking in health “ in Health Research Policy and Systems as well as a recent review by Carey et al. represent an important step forward in understanding the application of ST/CT and could be a model for future analysis of ST/CT application. Fourth, the scope of ST/CT is perhaps larger than has been previously estimated. We found more than four times the number of articles as a prior review, dozens more examples of methods used or mentioned, and while, just as in the review, only a small

percentage of the articles included cases, we nonetheless identified a not insignificant number of real-world examples of ST/CT (25).

Finally, although categorizing ST/CT best practices is tempting, “best-practicitus” can potentially be overwhelming for busy health practitioners to grapple with, but also lends a risk of regarding such practices as fixed reified techniques and tools(2). Identifying practices that yield better practices is an approach more consistent with the inherently evolving contexts and interactions of real health systems. Accordingly, while illustrating success stories is useful, identifying the potential generic ideas behind ST/CT may actually be the most practical way to guide existing practice and administration as well as those in the Sustainable Development Goals.

Conclusion

As the global health community prepares new Sustainable Development Goals, understanding the key terms, concepts, and methods in Systems Thinking and Complexity Theory might better equip stakeholders to address complex health challenges. This systematic review found that although there is no consensus around ST/CT concepts and methods, concepts such as Emergence, Dynamic/Dynamical Systems, Nonlinear/Nonlinearity, and Interdependent/Interconnected are themes that appear frequently in the literature. These themes, while gaining credence in academic and practitioner communities, are concentrated in a few journals demonstrating the possible need for wider promotion of ST/CT principles by leaders in disciplines such as development, public policy, clinical medicine, etc. Furthermore, literature on ST/CT is largely theoretical, indicating a need for further consideration, documentation, and sharing of case studies and other applications. As our global society shifts from a theoretical to

practical approach of ST/CT, stakeholders can pursue and seize opportunities by learning from the limitations of the past while accounting for variability, and avoiding reductionist thinking. A shift toward increased systems thinking in global health might provide the theory, concepts, perspective, approaches, and common language to increase well-being, capacity, and shared learning around the globe.

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