A Complex Systems Science Perspective for Whole Systems of Complementary and Alternative Medicine Research

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A Complex Systems Science Perspective for Whole Systems of CAM Research

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Abstract

Whole systems complementary and alternative medicine (WS-CAM) approaches share a basic world view that embraces interconnectedness; emergent, non-linear outcomes to treatment that include both local and global changes in the human condition; a contextual view of human beings that are inseparable from and responsive to their environments; and interventions that are complex, synergistic, and interdependent. These fundamental beliefs and principles run counter to the assumptions of reductionism and conventional biomedical research methods that presuppose uni-dimensional simple causes and thus dismantle and individually test various interventions that comprise only single aspects of the WS-CAM system. This paper will demonstrate the superior fit and practical advantages of using Complex Adaptive Systems (CAS) and related modeling approaches to develop the scientific basis for WS-CAM. Furthermore, the details of these CAS models will be used to provide working hypotheses to explain clinical phenomena such as (a) persistence of changes for weeks to months between treatments and/or after cessation of treatment; (b) nonlocal and whole systems changes resulting from therapy; (c) Hering's Law; and (d) healing crises. Finally, complex systems science will be used to offer an alternative perspective on cause, beyond the simple reductionism of mainstream mechanistic ontology and more parsimonious than the historical vitalism of WS-CAM . Rather, Complex Systems Science provides a scientifically rigorous, yet essentially holistic ontological perspective with which to conceptualize and empirically explore the development of disease and illness experiences, as well as experiences of healing and wellness.

Introduction

There is a growing body of research literature in biomedicine, medical anthropology, nursing, and public health suggesting that current views of science and accompanying research methods have considerable limitations when applied to the complex and dynamical processes involved in health/illness of individual human beings, families and communities [1-2]. Whole-systems complementary and alternative medicine (WS-CAM) has been particularly vocal about these limitations, consistently suggesting that alternative world views may provide more helpful ways to conceptualize how disease/health/illness experiences manifest within individual persons and how various interventions or systems of care facilitate the process of healing and health promotion [3-7].

The National Center for Complementary and Alternative Medicine at the National Institutes for Health NIH/NCCAM defines WS-CAM as “complete systems of theory and practice that have evolved independently from or parallel to allopathic (conventional) medicine. Many are traditional systems of medicine that are practiced by individual cultures throughout the world.” (http://nccam.nih.gov/health/whatiscam/wholemedical/). WS-CAM, with hundreds to thousands of years of historical use include: classical homeopathy (Europe), traditional Chinese medicine (TCM) (China), Ayurvedic medicine (India), and naturopathy (Europe/North America), as well as many indigenous medical systems referred to as Traditional Medicine (TM) by the World Health Organization. These systems of care differ in their cultural contexts and evolution, as well as in the specific diagnostic approaches, therapeutic modalities used, and clinical goals. Nonetheless, they share variants of a vitalistic philosophy that asserts the flow of a non-material life force throughout the living person [8].

In addition, WS-CAM share a basic world view that embraces interconnectedness; emergent, non-linear outcomes to treatment that include both local and global changes in the human condition; a contextual view of the human being that is inseparable from and responsive to their environment; and interventions that are complex, synergistic, and interdependent. These fundamental beliefs and principles run counter to the assumptions of reductionism and conventional biomedical research methods that dismantle and individually test various interventions that comprise aspects of the WS-CAM system [3-7, 9-12]. Table 1 summarizes issues with the conventional scientific paradigm identified by WS-CAM researchers as well as clinicians.

We suggest that these basic conceptual and theoretical differences form the basis for calls by the CAM practice and research communities (4-7, 13-14) for greater external validity in research studies, signaling the need for new theoretical and methodological approaches that align with a world view consistent with that of WS-CAM traditions. Complex Adaptive Systems (CAS) Theory, including its attendant theories of nonlinear dynamical systems (NDS) and fractal networks offer a meta-theoretical perspective that can be used to develop the scientific basis for WS-CAM. Further, innovative research methods arising from this perspective, such as agent-based modeling, network analysis, state space analysis, and various time-series analyses for measuring complexity and patterning can be used to reconsider some of the methodological challenges facing the WS-CAM scientific community [10,15-28]. Together, this entire field has been referred to as complex systems science (CCS) [29-32].

Theoretical Tenets of Complex Systems Science

Complex systems science studies "how the parts of a system give rise to the collective behaviors of the system and how the system interacts with its environment" (http://necsi.org/guide/study.html; last accessed Oct 31st 2011) [33]. Complex adaptive systems (CAS) are open systems, exchanging information with the environments with which they are nested. These systems are inter-dependent and self-organizing wholes with emergent properties greater than the sum of the parts [34]. Moreover, a CAS exhibits nonlinear dynamics, i.e., a small change in one aspect of an open system may produce disproportionately large effects over time in remotely related systems (the butterfly effect in weather; the princess-and-the-pea effect of childhood fairytales) [32, 35]. Because of these and other complex processes of information exchange, timing plays a much more prominent role in characterizing the evolutionary dynamics of a CAS than it does in previous conceptualizations of mechanical or integrated systems [30-31, 33].

While the mathematical origins of CAS and NDS can be quite complex, six basic tenets summarize the systems properties that are directly applicable to the nascent science of WS-CAM. CAS are:

(1) **whole systems** that

(2) **change over time** [34]. They are characterized by

(3) **emergence, connectivity** [37], and **mutual causation** [38]; sufficiently complex interactions among system components lead to global order. Furthermore,

(4) **emergence is a function of the whole system and not predictable by the properties of the parts** [39]. Emergence of coherent patterns in nonlinear dynamical systems is exponential, potentially synergistic, and is driven by

(5) **self-organization** [40], whereby emergent order feeds back to the level of system components allowing a system to self-tune its levels of complexity for adaptive purposes. In this sense,

(6) **Stability and flexibility are critically paired** in emergent phenomena as systems naturally evolve to a state at the edge-of-chaos, where levels of coherence versus flexibility may shift rapidly in response to changes in flows of information among system components [37-38].

(1) CAS are wholes that operate within a context or environment of other CAS or nested wholes. Complex systems are self-sustaining entities that are comprised of nested networks of relationships [39]. Newtonian ontological and epistemological principles conceive systems as machines with subsystems of pieces and parts that are independent and externally controlled. Such a worldview is replaced in complex systems science by the view that systems are actually assemblies of other systems, emerging hierarchically across scales. Elements of the system at each scale co-create the larger CAS of which they are agents, with the increasingly global patterns emerging from these layered relationships and interactions. Cause is viewed, within such systems, as a complex mixture of bottom-up and top-down processes. As Goldberger [27] noted, the principle of superposition, a major tenet of linearity, is replaced

within complex systems science. A CAS cannot be fully understood by simply analyzing each of its constituent parts and their relationships to each other. Neither can change or response of the system be predicted by investigating individual elements of a stimulus and “adding up” their effects. The global or supra-system does not respond in a summative manner; rather, the larger system responds as an integrating whole because of the unique time sensitive exchanges of information that occur among the systemic components and within the nesting environment.

Biology can be viewed as an exemplar of complexity in action. Liebovitch et al [41] comment: “…biology is not linear, it is a network of highly nonlinear genomic and proteomic interactions. . . Everything is connected to everything else. In this beautiful and tangled complex web, any therapeutic interaction spreads throughout the entire network of interactions. There is no single effect that can be associated with a single cause. A single therapeutic intervention does not produce a single desired effect; it produces many ‘side effects’.”

(2) Change in a CAS is an inherent quality of the system and is characterized as nonlinear and unpredictable. As noted by Goldberger, once the principle of superposition fails, systems behaviors are not predictable [27]. Since CASs are nested systems rather than a system comprised of independent and modular pieces and parts, change is an emergent property of the whole. Causality is circular, without beginning or end, powered by a host of feedback loops, network configurations, and points of bifurcation or system instability. Complex systems can be identified or mapped based on a series of behavioral phases, characterized as a state space or landscape that describes how the system is functioning across various possible contexts. Attractors (fixed, spiral, periodic, strange/chaotic) represent pulls toward particular behaviors, repellors represent unlikely system states, and saddle points represent a combination of an attractor and repellor. Together, the constellation of these stable aspects of a system creates a behavioral landscape or a set of possible behaviors of a system. The intrinsic dynamics of the system, as well as its initial conditions, ultimately determine the system’s set of attractors, its potentially multi-stable state-space. Changes in the attractors occur at bifurcation points as the system is capable of adapting

toward new and innovative patterns that will lead to greater fitness and adaptability, thereby increasing global complexity and flexibility [29-33, 35, 40].

At points of bifurcation an abrupt change in dynamical patterns occurs, and a cascade of events unfolds across the system, manifesting in a whole system response that appears to have both local and global features. However, what is "local" may actually have its origins in a distant feedback loop; likewise what appears to be global may well be a whole systems response. As such, this calls into question labels such as "specific and non-specific treatment effects" and the common practice of testing for specific, predictable responses to a system change while dismissing the more global responses as "system noise". Complex adaptive systems may contain a variety of noisy outcomes, some random (i.e., white noise) and others deterministic (e.g., pink noise), each of which may play a role as the system selects from a variety of emergent outcomes involving co-evolving shifts with their environmental fields to find their "best-fit" [31-32].

(3) Change occurs across both local and global scales. Since system component effects are not additive and may lead to emergent properties, complex systems scientists anticipate change to be at both global and local levels of behavior. Further, local perturbations in the system can produce distant change. In a given ecosystem, for example, eradicating a specific insect could make it harder for the natural predator of that insect to find enough food to survive, which might lead, indirectly to reduced survival of the insect's predator. It may also lead to an overgrowth of the first insect's food source (perhaps plant material) which will eradicate competing plants.

This tenet also calls into question the concepts of "specific" and "non-specific effects". As complex webs of relationships, with infinite varieties of possible feedback loops and responses to a system perturbation, CAS can be expected to have responses across levels of scale that are unpredictable and emergent. Thus, it could be argued that all effects are specific within complex systems science [30-32]. The practical outcome of such a view is to minimize the focus on the specifics of a particular intervention, and to increase the emphasis on where and when the intervention is applied within the CAS.

(4) The CAS self-organizes, seeking greater efficiency and sustainability. A self-organizing system is one that does not require outside agents to foster adaptive change. Kauffman [42] and Guastello & Liebovitch [40] characterize self-organization as “order for free,” wherein internal systems dynamics seek the “best-fit,” the most efficient, or the optimal conditions for the system in environmental context. Distributed control within the system enables learning and adaptive strategies of the whole. Therefore, outcomes occur as a process of ongoing system re-configuration, increasingly complex relationships, and evolution information transfer within the system to maximize the changes of success. Flexibility or nimbleness signals a robust system, a system that is able to adapt to potentially abrupt changes and to learn within complex fitness landscapes [40].

(5) *Change is emergent and occurs as a function of the whole; it is not additive in nature.* Change in a CAS is emergent, a function of the entire system with all of its nested systems and complexities. Emergence and self-organization may occur through a variety of processes such as synergetics (e.g., multicomponent global coherence such as lasers), rugged landscapes (complex adaptive organization in tune with a shifting environment), multiple basin (interactive multi-stability among a variety of attractors), and the sandpile/avalanche models (complex systemic outputs in response to distributed information build-up across the system) [32, 40]. Taken together, these models focus on (a) information flow between subsystems and agents and (b) bi-directional feedback across scales, explaining how small stimuli often result in large effects and how seemingly catastrophic events can, at times, result in merely a ripple effect across the system [32, 40].

Lorenz [43] first coined the metaphorical description of the “butterfly effect” to capture how small changes in atmospheric conditions can greatly alter global weather patterns. This hypothesis demonstrates the sensitivity of dynamical systems to the timing of intervention or change. Thus, change in a CAS defies proportionality, a central principle in linear systems thinking. Output in a complex system does not necessarily occur in a linear proportion to the magnitude of the input because of the influence intrinsic dynamics have within a system co-evolving with an ever-changing context [44].

(6) Emergent, self-organizing CAS display both stability and flexibility in dynamic dance. Emergence of complex behaviors or phenomena is a product of system integration and is dependent on connectivity within the CAS. Emergence represents criticality that is not dependent on specific elements at lower levels within a system but rather the processes of their complex interactions. Therefore, emergence is a function of the whole and not reducible to parts. Adaptive, self-organization tends to occur when a system is at a complex region referred to as the edge-of-chaos [34] where there is an ideal mix of stability and flexibility. Within this complex region, a system also is poised to become either more or less coherent, depending upon adaptive demands from within or from the nesting environment. [37-38]. Table 2 summarizes complex systems science terminology.

Explanatory Power of the Complex Systems Science and NDS for WS-CAM

Theories are only as useful as their explanatory power or applicability within a particular discipline [46]. Therefore, to determine if complex systems science is useful in conceptualizing WS-CAM, we examine exemplars from clinical theories and practice observations that have historically been identified as problematic when applying the traditional science paradigm.

Constitutionally-oriented WS-CAM therapies strive to alter the whole-person process underlying susceptibility to the environmental allergens and irritants gradually over time, rather than directly preventing expression of symptoms. In classical homeopathy, for instance, contemporary homeopath Jeremy Sherr [47] has written: “The fixed verb is a constant factor in any proving or case, repeating on every level…In pathology, a person will tend to excel at performing their main verb while failing at everything else…As pathology advances it becomes progressively more static, just as all verbs flow into nouns. Nouns (arthritis, tumor, neurosis) are the end result of a pathological process that began dynamically and ended as a fixed entity…The ‘verb’ of a case or remedy is its most dynamic expression…Western physiology and pathology focuses on nouns. In homeopathy, these nouns are termed affinities. Systems of analysis such as the four elements (or Chinese five elements) focus on adjectives – color, taste, temperature, etc. Verbs run silently behind these components, lending them motion and life." Sherr [47] also notes: "This restricted verb pervades the whole organism. As a stuck repetitive action , people often express this verb as 'must', 'have to', 'should', and 'need to.'" In this analysis of Eastern versus Western languages of healing, connections to NDS are apparent in the central health-related factors of dynamical change involving rigidity versus flexibility.

Moreover, homeopaths and naturopaths assess clinical progress during treatment in terms of Hering's Law of Cure, a clinical principle that is consistent with the principles of self-organization and non-specific response to change [48-49]. Practice theory postulates that the center of gravity or deepest level of symptomatology shifts within the person from above downward (head towards toes), from inside outward (more important to less important organs, e.g., from lungs to skin), and in reverse order of time of original symptom appearance (newer symptoms resolve sooner than long-standing symptoms). Practitioners also monitor patients for global improvements such as an increased sense of overall well-being, even when specific local organ symptoms temporarily worsen [49-51]. Therefore, when treating a patient with joint pain, a WS-CAM practitioner would conclude a patient experiencing less depression and more energy but more joint pain for a few days or weeks was showing a good treatment response. By contrast, a conventional health care provider would rate the same patient as "worse".

WS-CAM practitioners utilize information about emergent person-environmental patterns as indicators of the patient's condition, their diagnosis and their requisite treatment. Thus, effects of hot or cold external temperatures, ingested foods and beverages, dryness or dampness, environmental odors, seasonal changes, and circadian times of day all make a difference in the diagnosis, treatment plan, and patient outcomes [50-56]. Interventions by practitioners of WS-CAM can be conceptualized to (a) manipulate the balance of the person as an integrated functional network (changing the interaction rules for the body parts or subsystems that comprise the person, e.g., with Traditional Chinese Medicine (TCM) or Ayurveda) or (b) alter the control parameters of the whole person, thereby driving changes of function at the global level and local subsystem levels hierarchically across levels of organizational scale (e.g., with an individualized homeopathic remedy) [59].

When observing for responses to treatment, practitioners observe and monitor emergent patterns as evidence of what the person as an indivisible system does in his/her world context over time. WS-CAM clinicians anticipate abrupt worsenings and improvements during the course of therapy. Homeopathy, TCM and Ayurveda all report healing crises (aggravations) or a worsening of both local and global symptoms in response to initiation of treatment and prior to system improvement. [51, 52, 58-60]. WS-CAM researchers have termed the sudden events as “unsticking” and the periods of transitional instability as “unstuckness” [61-62]. Each of these processes is consistent with complex systems science principles involving rigidity and flexibility as well as bi-directional transitions across scales. These “bifurcations” in dynamics can lead to transitional periods that create new patterns of adaptation that better fit the fitness landscape of the environment. Phase transitions in NDS, consistent with the periods of unsticking that have been observed following WS-CAM interventions in themselves do not necessarily result in clinically improved system dynamics; however these periods do offer opportunities for a complex system to transition into patterns that are more efficient and effective for the organism overall. Thus, a complex systems science perspective would justify improving WS-CAM clinical trials by adding better baseline measures to assess the dynamical processes underlying unique patient illnesses prior to intervention, assessment of a variety of potentially relevant clinical parameters across biopsychsosial scales during the trial, and longer trial durations [6, 28, 63-65].

Conclusions

Complex systems science offers a theory-driven perspective that maps onto observed phenomena from clinical practice. At the very least, there is face validity supporting the use of Complex Adaptive Systems (CAS) Theory, Nonlinear Dynamical Systems (NDS) theory, and Networked Systems Theory/Agent Based Modeling. More likely, such models are the only truly adequate conceptual background for WS-CAM. These models provide working hypotheses that suggest explanatory mechanisms of action for such clinical phenomena as (a) persistence of changes for weeks to months between treatments and/or after cessation of treatment; (b) nonlocal and whole systems changes resulting from therapy; (c) Hering's Law; and (d) healing crises.

Further, complex systems science offers a way to move beyond the more limited, simple causal models of both mainstream mechanistic ontology and the historical perspective of WS-CAM vitalism (Figure 1).

[INSERT FIGURE 1 HERE]

As Langton, an early leader in complex systems science observed, the "real world" involves multi-directional interactions of parts and wholes to generate emergent outcomes of increasing complexity [8]. Complex systems science provides a holistic ontological perspective with which to conceptualize the development of disease and illness experiences, as well as experiences of healing and wellness [10].

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