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Literature review

Complexity Science as a Tool in the Health Sciences

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Abstract

Introduction: Complexity science has been described by scientists as the science of the 21st Century. It does not deny the scientific theory of the past or the huge contribution made by great scientists along history, but it looks beyond, recognizing the significance of interdependence and the context of every phenomenon. **Objective:** Complexity science and their link to the field of health. **Materials and methods:** A revision of the state of the art regarding complexity science and complex systems and their connection to health sciences was carried out. **Results:** Complexity was devised from different academic trends. It is a term coined by Edgar Morin, which consists in understanding factors influencing every decision. Regarding health sciences, it refers to complex characteristics of a phenomenon, not fully used in research. **Conclusion:** The contribution of this

paper is the description of the characteristics of the field, as well as the identification of the weaknesses of complexity science in the scope of health sciences.

Keywords: Complexity, complex systems, health sciences.

COMPLEXITY AND COMPLEX SYSTEMS

The term complexity derives from the Latin word *complexus*, form by the prefix *con*, "together", and *plectere*, that means "intertwine"; which, in its quality mode, complex, refers to being completely entangled or difficult to understand. It articulates a particular point for observing, analysing and understanding the world's phenomena, and seeks to understand a group, based on knowledge of all its singular parts that exhibit characteristics different to those they show in the context of a group[1]. Such unique parts consist of various components or agents, contained within boundaries that separate it from other systems. Thus, each system is part of a supra-system containing other subsystems, which are fed information from their environments, and provide output product[1,2]. Also, complexity has been considered a way to understand non-linearity, where causality is problematic and multifaceted and where emerging behaviors[3] are the norm[4]. The concepts used in complexity sciences promote a drive for non-linear cause-effect interactions, which are unpredictable as they develop over time, resulting in emergent situations within the system[3].

Complexity was developed from various academic trends[4], as well as from different fields of knowledge, such as the social sciences, humanities and biological sciences, making the understanding of various systems possible; since through complexity, it is possible to identify common elements, behavioral patterns in systems that may consist of different actors, which, in the case of observing biological phenomena may include people, animals, societies, species or bacteria, known also as Complex Adaptive Systems (CAS)[4,5]. Other examples of such complex systems include ecosystems, known to change from a forest state to a swampy state; or the stock market, that may suddenly collapse[6].

For Edgar Morin, quoted by Pagani[7], reality is conceived as complex and all components that constitute it are intertwined, generating understandable non-algorithmic and non-predictable behaviour. Perona in 2005, refers to a non-existent definition of complexity, based on an approach from different fields, including health sciences; this general definition of complexity can only be approximated by adding different definitions[8]. Authors like Serna in 2015, and Maldonado in 2004, propose that the emergence of complex thinking is a turning point in the progress of scientific work, with the aim of positioning its principles as a replacement for the obsolete Cartesian scientific method; however, it has not managed to consolidate as a paradigm as such[9,10].

This paradigm has been forced to adapt its composition through phenomena such as thermodynamics, chaos theory, fractal geometry, catastrophe theory and non-classical logics, etc., phenomena characterized by their instability, fluctuation, synergy, emergence, self-organization, non-linearity[3], positive or negative feedback, dynamic equilibrium, lack of symetry, and all those features close to chaos [8-11]. This means that a complex system is made up of various components [12,13] (Figure 1). Morin in 1990[14], mentions that complex thinking allows the articulation of all those isolated fragments, through a theoretical reorganisation; this rearrangement is based on seven principles as a valid tool in the global vision [15,16] (Figure 2).

	Properties of a complex system
I	Biological, psychic and social agents that have intentional or objective motives that are diverse, dynamic, with different priorities and can be contradictory.
II	Agents that by acting modify reality and are modified by it.
III	Phenomena that occur in one part of the system and that affect the entire system in a highly non-linear way.
IV	They have emergent properties, these arise from the interactions between them.
V	They present self-organization processes in all the agents.
VI	They present states of chaos and horizons of predictability.
VII	They have agents and groups that present perception, homeostasis, action, adaptation, and resilience.

Figure 1. Components that make up a complex system, with information from Aldana (2006) and Lara (2016)[12, 13].

COMPLEXITY IN THE FIELD OF HEALTH

The importance that for two decades has become evident in the area of health research with the term "complex intervention", described by Pagani in 2017, refers to a complexity, in terms of health, education, etc. Nevertheless, beyond methodological aspects, he considers that there are conceptual ambiguities about the notion of complexity, since it is not clear whether it is complex by the elements that make up the phenomenon, or by the system that may be part of it[7].

There has been controversy about the merits, or the lack of them, of qualitative studies in the medical sciences, which has highlighted the potential and the necessity of complex systems thinking in the field of health[5], since the complexity paradigm stands for a different epistemology as opposed to the prevailing one: it does not isolate, reduce or become obsolete in terms of knowledge; one that proposes new bases for a more complete understanding of physical, biological and social systems, and whose foundations are the systems theory, information technology and cybernetics[17].

A complex systems approach provides valuable alternatives to the predominant theories trying to explain health issues. In 2020, Mc Luhan stated that there are mechanisms through which scholars may use complex systems to affect, influence, change and/or even theorize phenomena related to health in a population, for example: the apposition of constructs from linear and complex systems theories, the incorporation of complexity into current linear theories,

Principle	Description
Systemic or organizational principle	Each system organizes itself, interacts and interrelates with other systems within an ecosystem.
Hologramatic principle	The whole is not reduced to the parts, but is conceived in a complementary and antagonistic way.
Retroactivity or feedback	The cause acts on the effect and the effect returns on the cause.
Recursion	Products and effects are, at the same time, causes and producers of what produces them.
Self-eco-organization	Human beings produce themselves by establishing an intricate relationship between all of their components.
Dialogic	It represents the birth of a new philosophy that facilitates the approach of the sciences of nature and man.
Of the one who knows in all knowledge	Knowledge is a reconstruction in a culture and a certain time.

Figure 2. Seven principles proposed by Morin to understand Complexity, with information from Columbie (2012) and Paiva (2004)[15, 16].

as well as questioning current theories and reframing a phenomenon[18], which in the case of medicine can move from an intuitive attitudinal approach to one that is subject to descriptors[5].

In the case of public health, they have been criticised for being too reductionist and for not providing proper evidence for decision making in the field. Authors related to complexity sciences have therefore advocated for a "complex systems approach", in order to include the complexity of the real world[3] Considering that the most urgent topics of interest in the field of public health in the world are complex issues characterized by their dynamic nonlinear intertwine cause-effect relationships, it is argued that tackling complex problems requires the involvement of diverse members and organisations at multiple levels of action [19].

Complexity sciences are a new way of doing science, researching human and social systems, not as mechanistic ones, but as interactive, dynamic and non-linear systems[13], allowing to recognise the need to have a complex vision of many phenomena, both in the field of research and in the sciences, their teaching and learning[20]. The adoption of the principles of complexity science is recognised in health systems related fields as excellent examples of complex adaptive systems due to the diversity of the agents involved (doctors, patients, nurses, consumers groups, politicians, nongovernmental organizations, etc.), and the enormous amount of interactions between them[4], as well as the possibility to understand the emergent features that cannot be explained by linear models[21]. Examples of such nonlinear include cardiac rhythm, electroencephalographic signals, fluctuations of potassium, calcium and sodium in the body,

venous structures, the nervous system networks, etc. The description and interpretation of these systems is increasingly using the concepts of chaos, fractals, bifurcations, instability, attractors, emergent structures, self-organization, etc., to characterise these systems, as well as the most advanced tools for solving non-linear equations[22].

In terms of the field of health, the human body has been considered to be an adaptive complex system because it contains different subsystems, *i.e.* organs; such subsystems of organs interact with each other through a variety of pathways, for example, neural connections, hormones, cytokines pathways, etc.[23] Also, complexity theory in the field of health research has enabled conceptual framework designs, as well as the research approach and design, allowing the conceptualisation of variables for their subsequent operationalisation; likewise in the analysis and interpretation of data, mostly qualitative, highlighting self-organisation and emergence, with the aim of being able to understand the phenomenon[24].

Different authors say there are plenty of examples of nonlinear or complex systems in the biological sciences. It is important to highlight amongst them, medicine, dentistry, nursing, etc., which, on addressing phenomena from this theory, can make clear that some consistent characteristics correlate with initial conditions, interdependent components, and an outcome not necessarily proportional to the original triggering factor [25]. In these times of global crisis, in the face of the SARS-CoV-2 (COVID-19) pandemic, the scientific community has quickly deployed advanced analysis tools to model the dynamics of disease transmission and the widespread impact of the disease at individual, community and global levels. In order to do so, it has used analysis techniques from the complex systems science. Additionally, the analytical methods of complex systems science provide tools to understand questions about the observed phenomena[26].

CONCLUSION

It is responsibility of all scientists involved in the study of complexity to demonstrate this is not only a research tool, but a science whose scope is evident in different areas such as the social sciences, humanities and biological sciences, and particularly in the health science, in order to find out a solution to a problem, from multi- inter-, and transdisciplinary points of view. In the specific case of health, and based on the characteristics of complexity, emergent behaviors, self-organization and nonlinear interaction of its components would allow the development, interpretation and use of tools focused on the diagnosis or even therapy of alterations.

BLIOBLIOGRAPHIC REFERENCES

1. Sturmberg J. Complexity and Primary Care. En: *The World Book of Family Medicine*. Turquía: Wonka; 2015. pp. 33-36.
2. Sanbonmatsu DM, Johnston WA. Redefining Science: The impact of Complexity on Theory Development in Social and Behavioral Research. *Perspect Psychol Sci*. 2019; 14(4): 672–90. DOI: 10.1177/1745691619848688
3. McGill E, Marks D, Er V, Penney T, Petticrew M, Egan M. Qualitative Process Evaluation from a Complex Systems Perspective: A Systematic Review and Framework for Public Health Evaluators. *PLoS Med*. 2020; 17(11): e1003368. DOI: 10.1371/journal.pmed.1003368

4. Churruca K, Pomare C, Ellis LA, Long JC, Braithwallte J. The Influence of Complexity: A Bibliometric Analysis of Complexity Science in Healthcare. *BMJ Open*. 2019; 9(3): e027308. DOI: 10.1136/bmjopen-2018-027308
5. Mitchell D, Sebald A, Tomsello L. Complex Systems, Part I: Why 42 is Rarely, if Ever, the Ultimate Answer. *Br J Oral Maxillofac Surg*. 2020; 58(2): 225–30. DOI: 10.1016/j.bjoms.2019.12.013
6. Kuranova A, Booij SH, Menne-Lothmann C, Decoster J, Van Winkel R, Delespaul P, *et al*. Measuring resilience prospectively as the speed of affect recovery in daily life: a complex systems perspective on mental health. *BMC Medicine*. 2020; 18(1): 36. DOI: 10.1186/s12916-020-1500-9
7. Pagani V, Kivits J, Minary L, Cambon L, Claudot F, Alla F. La complexité: concept et enjeux pour les interventions de santé publique [Complexity: Concept and Challenges for Public Health Interventions]. *Sante Publique*. 2017; 29(1): 31–9.
8. Perona E. Ciencias de la Complejidad: ¿La economía del siglo 21? [Internet]. [Fecha de consulta: 9 de julio de 2019]. Disponible en: https://www.eco.unc.edu.ar/files/comunicacion/archivos/DeptoEconomiayFinanzas/SerieDocumdeTrab/DocN%C3%82%C2%BA22.pdf
9. Serna ME. *Ciencia y Pensamiento Complejo. Desarrollo Transdisciplinar de un Paradigma*. Medellín, Antioquia: Editorial Instituto Antioqueño de Investigación; 2015.
10. Maldonado CE. Ciencias de la Complejidad: Ciencias de los cambios súbitos. *ODEON*. 2005; (2). Disponible en: https://revistas.uexternado.edu.co/index.php/odeon/article/view/2643
11. Burnes B. Kurt Lewin and Complexity Theories: Back to the Future? *J Chang Manag*. 2004; 4(4): 309–25. DOI: 10.1080/1469701042000303811
12. Columbie Puig N, La O Lobaina N. Principios del pensamiento complejo: base metodológica para la formación de una cultura medioambiental. *DELOS Desarrollo Local Sostenible Revista Desarrollo Local Sostenible Grupo Eumed.net y Red Académica Iberoamericana Local Global*. 2012; 5(13): 1–6. Disponible en: https://www.redhuertos.org/wp-content/uploads/cultura_medioambiente.pdf
13. Aldana M. Redes Complejas. 2006. Disponible en: https://docplayer.es/10141611-Redes-complejas-maximino-aldana-noviembre-2006.html
14. Paiva Cabrera AJ. Edgar Morin y el pensamiento de la complejidad. *Revista Ciencias de la Educación*. 2004; 1(23): 239–53.
15. Morin E. Introducción al Pensamiento Complejo. Argentina: Gedisa Editorial. 1990.
16. Fajardo-Ortiz G, Fernández-Ortega MA, Ortiz-Montalvo A, Olivares-Santos RA. La dimensión del paradigma de la complejidad en los sistemas de salud. *Cir Cir*. 2015; 83(1): 81–6. DOI: 10.1016/j.circir.2014.03.001
17. Goodson P. How Complex Systems Science Can Revolutionize Population Health Theory. En: Apostolopoulos Y, Hassmiller Lich K, Kenneth Lemke M (Eds). *Complex Systems and Population Health. A Primer*. Estados Unidos: Oxford University Press; 2020. pp. 73-88.
18. Hennessy E, Economos C, Hammond R. Integrating Complex Systems Methods to Advance Obesity Prevention Intervention Research. *Health Educ Behav*. 2020; 47(2): 213–23. DOI: 10.1177/1090198119898649
19. Lara-Rosano F. Las ciencias de la complejidad en la solución de problemas sociales. *RISCI*. 2016; 13(2): 43–50.
20. Roa Acosta R. Formación de profesores en el paradigma de la complejidad. *educ educ*. 2006; 9(1): 149–57.
21. North American Primary Care Research Group, Griffiths F. Complexity Science and its Relevance for Primary Health Care Research. *Ann Fam Med*. 2007; 5(4): 378–9. DOI: 10.1370/afm.727
22. Ortiz Hernández E. Complejidad, nuevo paradigma en la salud. *Innovación y Ciencia*. 2005; 12(1): 37–42.

23. Jayasinghe S. Complexity Science to Conceptualize Health and Disease: Is it Relevant to Clinical Medicine? *Mayo Clinic Proceedings*. 2012; 87(4): 314–9. DOI: 10.1016/j.mayocp.2011.11.018
24. Thompson D, Fazio X, Kustra E, Patrick L, Stanley D. Scoping Review of Complexity Theory in Health Services Research. *BMC Health Serv Res*. 2016; 16(1): 87. DOI: 10.1186/s12913-016-1343-4
25. Tuffin R. Implications of Complexity Theory for Clinical Practice and Healthcare Organization. *BJA Education*. 2016; 16(10): 349–52. DOI: 10.1093/bjaed/mkw013
26. Atkinson JA, Song YJC, Merikangas KR, Skinner A, Prodan A, Lorfino F, *et al*. The Science of Complex Systems Is Needed to Ameliorate the Impacts of COVID-19 on Mental Health. *Front Psychiatry*. 2020; 11: 606035. DOI: 10.3389/fpsyt.2020.606035