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The converging paradigms of holism and complexity: An exploration of naturopathic clinical case management using complexity science principles

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Abstract

Rationale: Traditional whole systems of medicine, such as naturopathy, are founded upon holism; a philosophical paradigm consistent with contemporary complexity science. Naturopathic case management is predicated upon the understanding of an intimately interconnected internal physiological and external context of the human organism—potentially indicating a worldview aligned with a complexity perspective. In this study we investigate naturopathic clinical reasoning using a complexity lens with the aim of ascertaining the extent of correspondence between the two.

Method: Mind maps depicting case presentations were sought from Australian degree qualified naturopaths. A network mapping was undertaken, which was then analysed in accordance with a complexity science framework using exploratory data analysis and network analysis processes and tools.

Results: Naturopathic case schematics, in the form of mind maps ($n = 70$), were collected, network mapped, and analysed. A total of 739 unique elements and 2724 links were identified across the network. Integral elements across the network were: stress, fatigue, general anxiety, systemic inflammation, gut dysbiosis, and diet. A modularity algorithm detected 11 communities, the primary ones of these representing the nervous system and mood; the gastrointestinal tract, liver, and nutrition; immune function and the immune system; and diet and nutrients.

Conclusions: Naturopathic case management is holistic and based on a perspective of an integrated physiology and external context of the human organism. The traditional concept of holism, when subjected to a complexity lens, leads to the emergence of a contemporary holistic paradigm cognisant of the human organism being a complex system. The application of complexity science to investigate naturopathic case management as employed in this study, demonstrates that it is possible to investigate traditional philosophies and principles in a scientific and critical manner. A complexity science research approach may offer a suitable scientific paradigm to develop our understanding of traditional whole systems of medicine.

KEYWORDS

case management, clinical reasoning, complexity science, primary health care

1 | INTRODUCTION

Human organisms are an example of a complex system, and yet health care research and practice continue to be largely informed by a reductionist and mechanistic paradigm[1,2] which is insufficient in its scope to fully embrace this complexity.[3,4] However, some professions providing primary health care services actively identify with paradigms that are not reductionist.[5–7] The clinical reasoning processes of traditional whole systems of medicine are purported to be underpinned by holism[8,9]; a philosophical concept defined in the same manner as complexity, where 'parts of a whole are in intimate interconnection, such that they cannot exist independently of the whole, or cannot be understood without reference to the whole, which is thus regarded as greater than the sum of its parts'.[10] Clinical reasoning is a core component of all health care disciplines[11] and is a key element in assessment and treatment decision making.[12] Clinical reasoning is the cognitive and metacognitive processes[13] used to assimilate, retrieve, evaluate and discard information arising within the clinical encounter,[14] and is shaped by the philosophy of the practitioner.

Naturopathy is a traditional whole system of medicine, and is recognised by the World Health Organisation[15] on the basis of its integration of traditional and contemporary health and human system knowledge. Naturopathy is taught and practiced according to a set of globally consistent core philosophies and principles.[16] Holism and vitalism are the foundational naturopathic philosophies; holism is founded on the recognition that 'the spiritual, psychological, functional and structural aspects of an individual act interdependently and are influenced by external, environmental, social and other factors'.[17(p7)] Human health and manifestations of disease are understood by naturopathic practitioners as expressions of the close and complex interactions between a range of internal systems and external factors[18] demonstrated by the naturopathic multisystem approach.[19] Naturopathic clinical processes rely on assessment of the whole human organism as comprised of interdependent and interrelating subsystems bidirectionally influencing the external systems it is situated within.[8] A whole system treatment process is initiated as part of the naturopathic holistic clinical management process, aimed at creating global shifts across all of the subsystems of the interconnected organism, rather than focusing on a system of disease classification based on syndromic patterns and corresponding specific treatment.[6] While holism is a traditional concept with historical roots, a complexity perspective may support the evolution of traditional holism into a contemporary scientific paradigm.

Naturopathic interventions tend to be selected from a range of potential options on the basis of individualisation,[20] pattern recognition, and systems thinking.[6,8,21] It is the complete naturopathic treatment, encompassing specific and nonspecific elements, which has value for naturopathic practitioners beyond that of a single specific linear intervention.[8] The use of a complexity science perspective for investigating and understanding naturopathic case management, offers an approach aligned with the holistic nature of naturopathy and potentially provides greater insights than research focusing solely on linear and specific interventions.[22] The foundational philosophies and guiding principles of naturopathy orient practitioners to work in a manner that is complex, networked, nonlinear, minimally invasive, and cognisant and allowing for adaptive and emergent processes; a complexity perspective is ideal to encompass this. In this paper, we are proposing a complexity science informed exploration and analysis of the naturopathic clinical process to examine the extent of the possible overlap between the systems perspective of complexity science and the holistic paradigm of naturopathy.

Complexity science is the study of complex systems, including complex adaptive systems[23] such as the human organism. Complexity science seeks to understand the processes of organisation that shape collectives of elements without guidance from a central controller, to form a cohesive whole that weaves functional patterns of adaptive and evolving being.[24] Complexity science subverts the Newtonian ideology which has dominated scientific thinking for the past 300 years.[23] Newtonian principles categorise systems as machines, comprised of elements and components that act independently[25] and according to a law of cause and effect based on causal relationships.[23] Complexity science replaces this view with one where elements co-exist in multiple systems which overlap and nest—at each scale point these elements co-create the complex system which houses them—from the layered interactions of the elements global patterns emerge.[25] One such emergent behaviour of the human complex adaptive system is the individual experience and expression of health and disease. Complexity science encourages us to view disease as disturbance in the life process rather than a mechanical fault in the machine.[26] While orthodox scientific thinking has assumed a model of causality that is linear and based on cause and effect,[27] complexity science assumes emergent causality where multiple influences commingle to lead to emergent effects[28] that are multiple and not predictable in size or outcome based on knowledge of the individual inputs.

A complex system is one in which interacting components generate distinct properties, giving rise to the embodiment of the whole being greater than the sum of its parts.[6,29] The biomedical approach to managing the complexity of human organisms and their environments has been to simplify the often complex health management task through reductionism[2]—a process of divide and conquer.[30] Research is increasingly demonstrating that the human organism functions as a complex system with human health being an emergent property of this, such as the recognition of a mind-body connection as demonstrated by psychoneuroimmunology research.[31–33] The exclusive use of reductionist research methods is insufficient to fully explore this complexity.[21,25] A research framework capable of exploring the clinical reasoning that informs case management and evaluating treatment interventions while also being cognisant of the complexity of the human organism is necessary to comprehensively understand and further develop health care practices.

Complexity science has been emerging in the academic literature over the past 100 years[34,35] and has been incorporated into a number of academic disciplines including artificial intelligence, biology, business, ecology, information technology[29] and the social sciences.[36] However, a complexity science perspective has been minimally applied to health care and the case management process,[35,37,38] including naturopathy and

other traditional whole systems of medicine. Complexity science perspectives have been successfully used in other fields to address the methodological shortcomings of reductionist approaches, and although these have also been identified as particularly problematic in traditional whole systems of medicine,[39] no investigative work on this topic has been done to date. This paper seeks to address this gap by considering how complexity science may inform research into naturopathic clinical practices.

2 | METHODS

2.1 | Study design

This exploratory observational study was conducted using a network mapping and analysis process.

2.2 | Ethics approval

Ethics approval was obtained from the University of Technology, Sydney Human Research Ethics Review Committee (Approval Number: ETH20-4864).

2.3 | Participant recruitment

Naturopathic practitioners were recruited using a social media campaign, primarily using Facebook groups that related to the naturopathic profession, and the Facebook accounts of Australian professional associations representing naturopaths. Participants were required to have a minimum Bachelor's degree naturopathic qualification, currently be in naturopathic practice, and be a full practicing member of an Australian naturopathic or natural medicine association. Participants needed to routinely use mind maps as part of their case management process. Participation was voluntary and each participant received a nominal reimbursement to cover expenses. Individuals who responded to the social media campaign were provided with information and were required to sign an informed consent form before being accepted into the study.

2.4 | Data collection

Each of the participants who met the criteria were requested to randomly select 10 mind maps, each one of a different patient, from their case files. These were emailed to the research team along with a biography of each patient, which included a brief (two to three sentence) overview of each patient's presenting condition, age, and gender. All patient identifying information was to be removed from the mind maps and not be included in the biographical details before being sent to the research team. The mind maps were to be hand- or software-generated depending on the preference and standard process of the practitioner. A member of the research term entered the data contained within the mind maps into *Gephi*—an open source network mapping, exploration and analysis software.[40]

2.5 | Data visualisation

Using *Gephi* four network mappings were created: (i) a *force-based attribute layout*, (ii) a *force based physiological and external systems layout* and (iii) a *systems circular layout*, and (iv) a *modularity layout*.[41] The same data was used in each layout; however, the elements were variously assigned in the layouts to attributes (*force-based attribute layout*), physiological systems and environment (*physiological and external systems layout* and *circular layout*), or communities (*modularity layout*). Each layout consisted of nodes (elements or aspects of the case) and edges (links between the elements). The links were directional and represented a relationship or form of influence between the elements. The elements and links were identified by one or more of the participants as being relevant to one or more of the case conceptualisations depicted in their mind maps. Within the network mappings, the elements were represented by circles, and the links by lines. The direction of the links was demonstrated through being curved in a clockwise direction. The size of each element was determined by the combined number of incoming and outgoing links that it had (also called degree)—the larger the element the higher its number of links.

2.5.1 | Force based attribute layout

The *force-based attribute layout* was created using a *Gephi* algorithm which caused linked nodes to attract and non-linked nodes to repel. This resulted in the central clustering of the most connected elements, and the least connected elements being pushed to the periphery. Each element was coloured according to six different attributes, which were assigned by the research team. The attribute types were: (i) *sign, symptom, internal state*, (ii) *hypothetical risk*, (iii) *genetic, constitutional, familial predisposition*, (iv) *organ, functional subsystem*, (v) *external, environmental influence*, and (vi) *biomedical diagnosis/pathology result* (Table 1).

2.5.2 | Force based and circular physiological and external systems layout

For the *physiological and external systems layout*, 15 sub-systems relating to the human organism were identified (Table 2). These systems were not categorically distinct (e.g., low testosterone could have been assigned to the endocrine system or the reproductive system, and the lymphatic system was given the status of a unique category rather than as a sub-system of

TABLE 1 Attribute key and examples

Attribute	Colour	Examples
Sign, symptom, or internal state	Purple	Poor appetite, dermatitis
External or environmental influence	Green	Low dietary essential fatty acids, excessive laxative use
Organ or internal functional subsystem	Orange	Immune system, thyroid
Hypothetical risk	Blue	Osteoporosis risk, hepatocellular damage
Genetic/constitutional/familial predisposition	Yellow	Family history of cardiovascular disease, family history of high cholesterol
Biomedical diagnosis, laboratory or pathology result	Red	Pernicious anaemia, benign cervical lesion, Coeliac disease

TABLE 2 Physiological systems key and examples

Physiological system	Colour	Examples	Number of elements
Reproductive system	Latte	Dysmenorrhea, endometrial hyperplasia, loss of libido	105
Diet/nutrients	Lilac	Insufficient vegetable intake, diet low in magnesium, vitamin D deficiency	94
External	Red	Socially isolated, laxative use, insufficient activity	88
Gastrointestinal system	Light blue	Reflux, constipation, poor appetite	88
Nervous system	Light green	Social anxiety, insomnia, headaches	75
Immune system	Dark blue	Allergies, autoimmune processes, low white cell count	64
Integumentary system	Pink	Rosacea, hair loss, sweaty palms	47
Multisystem/systemic	Teal	Gut-brain axis, methylation issue, low vitality	44
Endocrine	Dark green	Adrenals, hypoglycaemia, insulin resistance	38
Hepatobiliary system	Dark purple	Hepatitis, Kupffer cell activity, impaired bile flow	30
Cardiovascular system	Mid blue	Heart palpitations, hypotension, varicose veins	29
Musculoskeletal	Mid green	Low muscle mass, scoliosis, neck pain	15
Respiratory system	Yellow	Asthma, sinusitis, upper respiratory tract	10
Renourinary	Orange	Nocturia, kidney stones, urinary urgency	8
Lymphatic system	Brown	Lymphatic congestion, poor lympathic drainage	4

the immune system) and were assigned by the research team. In the *circular layout*, the elements are ranged around the periphery of the mapping with the links given the primary central position; visually highlighting the extent of the connections amongst the elements.

2.5.3 | Modularity layout

A *modularity layout* was created using an algorithm within *Gephi* which decomposed the network mapping into communities (cliques) determined through linkage patterns—the more densely connected elements were clustered into groups. This representation of the data reveals underlying layers of structure within the network. In the modularity layout, elements were coloured according to the community of which they were a member, rather than by attribute.

2.6 | Data analysis

2.6.1 | Exploratory data analysis

Exploratory data analysis (EDA) is a method of viewing visual representations of a dataset to generate insights.[42] In doing so, a dataset may be explored without preconceptions allowing insights about the phenomena under consideration to arise.[43] Tukey[42(p1)] explains EDA as 'graphical detective work', and it is a process where novel information about a dataset may be gleaned. In this study, this analysis was aimed to be exploratory rather than confirmatory.

2.6.2 | Network analysis

Gephi offers various computational and mathematical algorithms which were used to analyse the network mappings. These included

node level analyses (such as degree, distance, and betweenness centrality) and network level analyses (such as network diameter, average degree, average path length, average clustering co-efficient, and modularity). Analysis of the links within the network provides information on the shortest path between any two elements (distance), the frequency an element appears on the shortest path between any other pair of elements as an indicator of an elements influence or engagement within the network (betweenness centrality), the level of interconnectedness within the network (average clustering co-efficient), and the capacity of the network to decompose into communities (modularity). The diameter of the network is the shortest path between the furthest two elements. The average path length is the average minimum distance between any two elements, a measure of the average separation between all elements. The average clustering co-efficient is a measure of the density of the network, with a possible range of nought to one. Eigenvector centrality is a measure of the importance of each element as determined by the number of links an element has, and the number of links its connections have measured across the entire network. Key network terms and measures relevant to this study are defined in Table 3. The aim of these analyses was to provide structural and functional information about the network mappings.

3 | RESULTS

Seven Australian naturopathic practitioners participated in the study (one each from New South Wales and Western Australia, two from Queensland, and three from Victoria; four from capital cities, and three from a regional or rural area). They reported between two and 11 years of clinical experience (mean: 5.43 years). Each participant contributed 10 mind maps (each mapping from a different patient), providing a total of 70 distinct mind maps representing a case overview of 70 different patients (descriptive data of each mind map is provided in Table 4).

3.1 | Exploratory data analysis

3.1.1 | Force based attribute mapping

Figure 1 is a complete combined attribute network mapping of all the elements and associations as identified by the participants across 70 distinct patients with varying presenting issues. The combined network mapping of the 70 real patient data mind maps contains a total of 739 elements and 2724 links. Degree (number of incoming or outgoing links) ranged from one, for 112 elements, to 157 (systemic inflammation). The mean average degree of the top 10 most linked elements was 84 while the mean average degree of the elements with 20 degrees of less (a total of 651 elements) was 4.85. The elements identified by the participants which were the most connected and therefore integral to the 70 cases, as identified by size and central position, were: stress, fatigue, general anxiety, systemic inflammation, gut dysbiosis, diet, impaired immune function, gastrointestinal tract, nervous system, intestinal hyperpermeability, food maldigestion and nutrient malabsorption, and compromised status of various nutrients (including iron, vitamin D, zinc, vitamin B complex). These were coloured according to six different attributes: (i) *state, sign, or symptom*, (ii) *hypothetical risk*, (iii) *genetic, constitutional, or familial predisposition*, (iv) *organ or subsystem*, (v) *external or environmental influence*, (vi) *biomedical diagnosis or pathology result* (Table 1).

3.1.2 | Physiological and external systems mappings (force based and circular)

The elements were grouped and coloured according to physiological and external systems, using a force based (Figure 2) and circular (Figure 3) mapping. There was a mean of 46.19 elements (min: 4, max: 105) for each physiological and external system (Table 2). The physiological systems with the largest number of elements included: the *reproductive system* ($n = 105$), the *gastrointestinal system* ($n = 88$), the *nervous system* ($n = 75$), and the *immune system* ($n = 64$). External factors ($n = 88$) and diet and nutrients ($n = 94$) also had a substantial number of elements, representing 25% of all identified elements. Figure 2 highlights the system groupings (see Table 2 for colour key). Every physiological system had multiple relationships identified with all other physiological systems, and the external elements, as evidenced by the linkage patterns between elements (highlighted by Figure 3).

3.1.3 | Modularity mapping

In Figure 4, a *modularity layout* is depicted where the colours of the elements signify community rather than attribute. In total, 11 communities were detected by the *Gephi* algorithm, indicating the communities of symptoms, subsystems, organs, symptoms, and environmental influences considered by the practitioners to relate most closely to one another. Using an EDA process, the largest communities identified comprised: *the nervous system and mood* (red), *gastrointestinal tract, liver, nutrition, digestive enzymes* (dark green), *immune function and immune system* (orange), *diet and nutrients* (pink), *female reproductive system and hormones* (dark blue). A more dispersed community was also identified encompassing *systemic inflammation, the integumentary system, joint issues, the lymphatic system, and physical activity* (light green).

3.2 | Network analysis

3.2.1 | Network analysis: node level measures

Within the network, each element was connected to an average of 3.815 other elements, with variation in degree between 1 and 157,

TABLE 3 Key network terms and examples

Term	Definition	Information this provides about the node or network	Significance in this network	Example(s) or value in this network
Foundational				
Node	A component or element of a network.	Identifies different elements within the system	Demonstrates a relevant aspect of the case presentation as identified by one or more of the participants	Low dietary selenium, premenstrual stress, poor wound healing, constipation
Link	A connection in a specific direction between any pair of elements.	Identifies different relationships of influence within the system	Demonstrates a relationship between two elements that is considered of relevance to the case presentation as identified by one or more of the participants	Endometrial hyperplasia à endometrial tissue compromised à recurrent uterine polyps
Path	A sequence of links and elements connecting any pair or group of elements.	Identifies a series of relationships of influence between two or more elements	Demonstrates a series of relationships between two or more elements as identified by one or more of the participants	Increased cortisol à sympathetic nervous system activation à social anxiety à excessive sweating à social anxiety
Cluster or Community	A subgroup or clique of elements that are more closely connected to each other compared with elements outside the subgroup.	Identifies well connected communities within the network, and reveals underlying network structure	Demonstrates the element groupings identified by the participants	Red cluster (e.g., nervous system, fatigue, low mood, sympathetic nervous system dominance, general anxiety, hypothalamic-pituitary-adrenal dysfunction)
Node level measures				
Degree	The number of connections (in or out) that an element has.	Identifies elements deemed most in relationship with other elements	Identifies the elements that practitioners deemed most interactive within the network	High degree: systemic inflammation Low degree: ovulation pain
Average degree	The average number of connections across all elements.	Provides the average number of connections that each element has	Provides a mid-point against which the number of connections each element has can be compared to	Average = 3.815 (with variation between one and 157)
Distance	The number of connections on the shortest path between two elements.	Detects the minimum number of steps influence needs to travel.	Demonstrates the intermediate steps for influence to spread between two elements, as determined by the participants	Excess alcohol intake à liver à reduced fat metabolism à oxidative stress
Betweenness centrality	How often an element appears on the shortest path between other pairs of elements.	Aggregates the number of paths that pass through a particular element	Demonstrates the value of each element in terms of its potential to interact with others as identified by the participants	Dysbiosis is on the shortest path between: diet & bloating with cramping; gas production & gut fermentation; toxin recycling & halitsosis. Systemic inflammation = 110106.82, Stress = 77489.13, Gut dysbiosis = 49353.82, General anxiety = 37172.48

TABLE 3 (Continued)

Term	Definition	Information this provides about the node or network	Significance in this network	Example(s) or value in this network
Clustering co-efficient	The number of connections an element has divided by the total number of possible connections. The highest possible value is 1 (where an element is connected to all other elements).	Along with the mean shortest path, the clustering co-efficient can indicate a 'small-world' effect, and signifies how embedded elements are within their neighbourhood.	Denotes the extent to which elements are connected within the network.	Average clustering co-efficient = 0.126 (therefore, on average each element is connected to 12.6% of the total of other elements)
Eigenvector centrality	Measures the value of each element, based on the number of connections it has, and the number of connections the elements it is linked to has, and so on across the network.	Measures of the influence of an element within the network	Denotes the extent to which well-connected elements are linked to other well-connected elements	Systemic inflammation (1), fatigue (0.72), general anxiety (0.67), gut dysbiosis (0.56), poor immune function (0.47).
Network level measures				
Diameter	The shortest pathway between the two most distant elements.	Provides the parameters of the network	A measure of how tightly the elements in the network are connected, as identified by the participants	Diameter = 13
Average path length	The average of the shortest path between all pairs of elements.	The average minimum number of connections between all pairs of elements	Indication of the ease with which change can ripple across the system	Average path length = 4.148
Average clustering co-efficient	The average of the clustering co-efficient for all elements.	Averaged across all elements, the proportion of elements with a direct connection to each element, divided by the total number of elements identified in the network.	A measure of how connected and clustered the network is	Average clustering co-efficient = 0.126
Modularity	A measure of the extent the network decomposes into communities.	Reveals underlying layers of structure within the network	Within communities there are denser interactional possibilities and reveals potential sub-structures as identified by the participants	11 communities detected with between nine to 112 elements each. Modularity score = 0.425

TABLE 4 Individual mind map descriptive data

Practitioner participants (pseudonyms used)	Case number	Client presentation	Client age	Client gender identification	Number of elements	Number of links	Number of physiological systems identified*	Physiological systems identified	Diet/nutrient elements identified	External elements identified
Laney	1	Fatigue, central weight gain, anxiety, depression, recurrent polyps	36	Female	69	78	7	Multisystem, nervous system, reproductive system, immune system, endocrine system, gastrointestinal system, hepatobiliary system	Y	Y
	2	Low libido, severe anxiety, dysfunctional uterine bleeding	26	Female	79	76	4	Nervous system, multisystem, reproductive system, gastrointestinal system	Y	Y
	3	Persistent acne vulgaris which flares cyclically pre-menstrually	24	Female	46	65	6	Reproductive system, integumentary system, nervous system, endocrine system, hepatobiliary system, multisystem	Y	Y
	4	Persistent chronic acne, long term use of doxycycline, digestive issues, premenstrual syndrome, anxiety	25	Female	53	52	6	Endocrine, gastrointestinal system, reproductive system, nervous system, immune system, integumentary system	Y	Y
	5	Chronic acne, premenstrual syndrome	24	Female	54	51	6	Integumentary system, reproductive system, hepatobiliary system, renourinary system, nervous system, endocrine system	Y	Y
	6	Vulvodynia, severe premenstrual syndrome, irritable bowel syndrome, fatigue, anxiety, panic attacks	37	Female	86	96	7	Immune system, reproductive system, multisystem, nervous system, gastrointestinal system, hepatobiliary system, endocrine system	Y	Y
	7	Papulopustular rosacea, irritable bowel syndrome, chronic stress	44	Female	82	110	9	Integumentary system, gastrointestinal system, nervous system, reproductive system, multisystem, immune system, lymphatic system, hepatobiliary system, respiratory system	Y	Y
	8	Chronic acne, digestive issues, reactive skin	22	Female	52	64	7	Integumentary system, gastrointestinal system, nervous system, renourinary system, hepatobiliary system, reproductive system, multisystem	Y	y
	9	Chronic bacterial vaginosis, poor sleep quality, food intolerances, bloating, chronic diarrhoea	32	Female	49	63	6	Reproductive system, multisystem, immune system, gastrointestinal system, nervous system, lymphatic system	Y	Y
	10	Chronic eczema, allergic rhinitis, asthma	26	Male	47	51	6	Integumentary system, immune system, nervous system, hepatobiliary system, respiratory system, multisystem	Y	Y

TABLE 4 (Continued)

Practitioner participants (pseudonyms used)	Case number	Client presentation	Client age	Client gender identification	Number of elements	Number of links	Number of physiological systems identified*	Physiological systems identified	Diet/nutrient elements identified	External elements identified
Shay	1	Fertility issues, irregular menstrual cycles, hypothyroidism	37	Female	40	51	7	Integumentary system, immune system, hepatobiliary system, gastrointestinal system, reproductive system, endocrine system, multisystem	Y	Y
	2	Psoriasis, recurrent miscarriage	22	Female	37	43	4	Integumentary system, reproductive system, nervous system, multisystem	Y	Y
	3	Poly cystic ovarian syndrome, chronic acne, irregular cycle, low mood	26	Female	45	57	6	Reproductive system, integumentary system, nervous system, endocrine system, gastrointestinal system, hepatobiliary system	Y	Y
	4	Hypertension, chronic stress	51	Female	40	52	5	Cardiovascular system, nervous system, hepatobiliary system, gastrointestinal system, multisystem	Y	Y
	5	Poly cystic ovarian syndrome, irregular cycle, chronic acne	29	Female	53	65	7	Reproductive system, endocrine system, integumentary system, nervous system, gastrointestinal system, hepatobiliary system, multisystem	Y	Y
	6	Depression, constipated	16	Female	33	48	4	Gastrointestinal system, nervous system, reproductive system, multisystem	Y	Y
	7	Constipation, fatigue, anxiety	21	Female	29	44	5	Gastrointestinal system, nervous system, reproductive system, hepatobiliary system, multisystem	Y	Y
	8	Anxiety, bloating	27	Female	40	54	3	Nervous system, gastrointestinal system, multisystem	Y	Y
	9	Immune insufficiency, fatigue, stress	28	Female	26	43	5	Immune system, nervous system, multisystem, endocrine system, lymphatic system	Y	Y
	10	Fertility issues, chronic stress, poor sleep quality	38	Female	29	46	4	Reproductive system, nervous system, multisystem, endocrine system, cardiovascular system	Y	Y
Kerrie	1	Fatigue, low mood, dysbiosis, mood reactivity, allergic rhinitis, chronic stress	41	Female	87	110	7	Multisystem, nervous system, gastrointestinal system, immune system, hepatobiliary system, endocrine system, respiratory system	Y	Y
	2	Eczema, allergic rhinitis, asthma, dysbiosis	40	Female	49	60	8	Integumentary system, immune system, gastrointestinal system, nervous system,	Y	Y

(Continues)

TABLE 4 (Continued)

Practitioner participants (pseudonyms used)	Case number	Client presentation	Client age	Client gender identification	Number of elements	Number of links	Number of physiological systems identified*	Physiological systems identified	Diet/nutrient elements identified	External elements identified
								reproductive system, endocrine system, hepatobiliary system, respiratory system		
	3	Cystic acne, irregular cycle	30	Female	52	63	7	Integumentary system, reproductive system, nervous system, endocrine system, multisystem, gastrointestinal system, hepatobiliary system	Y	Y
	4	Severe nausea, fatigue, chronic stress	48	Female	74	102	6	Multisystem, gastrointestinal system, reproductive system, hepatobiliary system, endocrine system, renourinary system	Y	Y
	5	Severe cystic acne, unwelcome weight gain	27	Female	54	98	7	Integumentary system, multisystem, reproductive system, immune system, endocrine system, gastrointestinal system, hepatobiliary system	Y	Y
	6	Severe eczema, poor diet, dysbiosis	40	Female	41	75	6	Integumentary system, gastrointestinal system, immune system, hepatobiliary system, nervous system, respiratory system	Y	Y
	7	Poor sleep quality, back injury, unwelcome weight gain	43	Female	41	52	5	Reproductive system, multisystem, hepatobiliary system, musculoskeletal system, immune system	Y	Y
	8	Anaemia, poor sleep quality, chronic acne, chronic stress	39	Female	40	47	5	Multisystem, nervous system, integumentary system, reproductive system, hepatobiliary system	Y	Y
	9	Fatigue, low mood, dysbiosis, mood reactivity, allergic rhinitis	41	Female	50	59	7	Multisystem, nervous system, gastrointestinal system, immune system, reproductive system, hepatobiliary system, respiratory system	Y	Y
	10	Depression, grief, alcohol use issues	72	Female	28	61	5	Nervous system, cardiovascular system, hepatobiliary system, gastrointestinal system, multisystem	Y	Y
Maggie	1	Eczema, stress, food intolerances, goitre	35	Male	31	48	7	Integumentary system, nervous system, endocrine system, immune system, multisystem, hepatobiliary system, gastrointestinal system	Y	Y
	2	Severe chronic stress, brain fog, chronic back pain, irritable bladder	53	Male	15	25	7	Nervous system, musculoskeletal system, renourinary system, gastrointestinal system, multisystem, immune system, endocrine system	N	Y

TABLE 4 (Continued)

Practitioner participants (pseudonyms used)	Case number	Client presentation	Client age	Client gender identification	Number of elements	Number of links	Number of physiological systems identified*	Physiological systems identified	Diet/nutrient elements identified	External elements identified
	3	Irritable bowel syndrome, insomnia, fatigue, poor diet	34	Female	26	45	4	Gastrointestinal system, nervous system, multisystem, integumentary system	Y	Y
	4	Reflux, bloating, low appetite, chronic headaches	43	Male	31	39	6	Gastrointestinal system, nervous system, hepatobiliary system, nervous system, integumentary system, renourinary system	Y	Y
	5	Full body rash, severe stress	54	Female	15	21	4	Immune system, nervous system, multisystem, integumentary system	Y	Y
	6	Chronic cystic acne, amenorrhoea, anxiety, irritable bowel syndrome	24	Female	20	38	5	Integumentary system, reproductive system, gastrointestinal system, nervous system, multisystem	Y	Y
	7	Eczema, food allergies, food intolerances, autism, anxiety	16	Female	14	18	5	Nervous system, integumentary system, immune system, gastrointestinal system, multisystem	Y	Y
	8	Cystic acne, poor wound healing, overweight, social anxiety	15	Male	29	38	8	Integumentary system, multisystem, nervous system, gastrointestinal system, reproductive system, endocrine system, hepatobiliary system, lymphatic system	Y	N
	9	Anxiety, irregular cycle, dysbiosis	28	Female	28	30	7	Nervous system, reproductive system, gastrointestinal system, respiratory system, multisystem, hepatobiliary system, immune system	Y	Y
	10	Recurrent bronchitis, poor immune function, asthma, recurrent upper respiratory tract infections	62	Female	14	31	4	Respiratory system, immune system, gastrointestinal system	Y	Y
Charlie	1	Psoriasis, stress, anxiety, dysbiosis	26	Female	41	49	5	Integumentary system, nervous system, gastrointestinal system, multisystem, immune system	Y	Y
	2	Perimenopause, unwelcome weight gain, central adiposity, low mood	50	Female	46	57	4	Reproductive system, multisystem, nervous system, endocrine system	Y	N
	3	Dysbiosis, food intolerances, chronic stress	33	Female	41	62	4	Gastrointestinal system, nervous system, immune system, multisystem	Y	Y

(Continues)

TABLE 4 (Continued)

Practitioner participants (pseudonyms used)	Case number	Client presentation	Client age	Client gender identification	Number of elements	Number of links	Number of physiological systems identified*	Physiological systems identified	Diet/nutrient elements identified	External elements identified
	4	Acne, chronic stress, blood sugar irregularities	23	Female	50	66	6	Nervous system, integumentary system, endocrine system, reproductive system, hepatobiliary system, multisystem	Y	Y
	5	Chronic atopic dermatitis, dysbiosis	24	Female	34	47	4	Integumentary system, immune system, gastrointestinal system, hepatobiliary system	Y	Y
	6	Insomnia, low immune function, chronic stress	32	Female	33	39	4	Respiratory system, immune system, nervous system, multisystem	Y	Y
	7	Allergic rhinitis, poly cystic ovarian syndrome, unwelcome weight gain	33	Female	50	74	7	Respiratory system, reproductive system, immune system, nervous system, gastrointestinal system, multisystem, endocrine system	Y	Y
	8	Chronic back pain, low mood	34	Male	38	53	4	Musculoskeletal system, nervous system, immune system, multisystem	Y	N
	9	Fatigue, insomnia, constipation	61	Female	62	87	5	Nervous system, gastrointestinal system, endocrine system, hepatobiliary system, reproductive system, multisystem	Y	Y
	10	Fatigue, depression, dysbiosis	28	Male	43	61	4	Multisystem, nervous system, gastrointestinal system, immune system	Y	Y
Gemma	1	Dysbiosis, poor immune function, stress	9	Female	31	31	5	Gastrointestinal system, immune system, nervous system, reproductive system, multisystem	Y	Y
	2	Reflux, dysbiosis, food intolerances, anxiety	19	Female	42	54	5	Gastrointestinal system, nervous system, immune system, hepatobiliary system, multisystem	Y	Y
	3	Acne, poor sleep quality	23	Female	37	42	5	Integumentary system, nervous system, multisystem, reproductive system, immune system	Y	Y
	4	Acne, viral rhinitis, poor immune function	25	Female	20	28	6	Integumentary system, immune system, respiratory system, endocrine system, nervous system, lymphatic system	N	Y
	5	Depression, chronic headaches, unwelcome weight gain	25	Female	32	66	6	Nervous system, multisystem, hepatobiliary system, gastrointestinal system, respiratory system, immune system	Y	Y
	6	Raynaud's syndrome, joint pain and stiffness	26	Male	12	16	5	Multisystem, immune system, musculoskeletal system, cardiovascular system, nervous system	N	Y

TABLE 4 (Continued)

Practitioner participants (pseudonyms used)	Case number	Client presentation	Client age	Client gender identification	Number of elements	Number of links	Number of physiological systems identified*	Physiological systems identified	Diet/nutrient elements identified	External elements identified
	7	Insufficient lactation, anxiety, stress, fatigue	29	Female	17	20	4	Multisystem, nervous system, reproductive system, cardiovascular system	Y	Y
	8	Irregular cycle, menorrhagia, constipation, depression	36	Female	45	73	8	Reproductive system, gastrointestinal system, nervous system, integumentary system, hepatobiliary system, multisystem, endocrine system, immune system	Y	Y
	9	Perimenopause, fatigue, anxiety, panic attacks	51	Female	22	35	5	Reproductive system, multisystem, nervous system, musculoskeletal system, cardiovascular system	Y	Y
	10	Chronic stress, fatigue, poor memory	54	Female	15	26	6	Nervous system, multisystem, cardiovascular system, musculoskeletal system, immune system, endocrine system	N	Y
Martine	1	Fatigue, poor sleep quality, stress, anhedonia	44	Male	48	63	8	Multisystem, nervous system, reproductive system, lymphatic system, cardiovascular system, hepatobiliary system, immune system, endocrine system	Y	Y
	2	Recurrent viral rhinitis, fatigue, poor immune function, poor diet, stress	15	Female	21	43	5	Immune system, respiratory system, nervous system, musculoskeletal system, gastrointestinal system	Y	Y
	3	Anxiety, mood swings, menopausal symptoms	61	Female	20	48	6	Multisystem, nervous system, reproductive system, renourinary system, gastrointestinal system, integumentary system	N	Y
	4	Chronic psoriasis, perimenopausal, Gilberts syndrome	53	Female	23	39	6	Integumentary system, reproductive system, multisystem, immune system, gastrointestinal system, hepatobiliary system	Y	Y
	5	Menopausal symptoms, urinary urgency, urinary tract infections, low libido	60	Female	37	55	8	Reproductive system, renourinary system, integumentary system, gastrointestinal system, nervous system, hepatobiliary system, immune system, endocrine system	Y	N
	6	Chronic sinusitis, gastroparesis, joint pain, osteoarthritis	65	Female	31	49	9	Cardiovascular system, hepatobiliary system, reproductive system, musculoskeletal system, gastrointestinal system, respiratory system, immune system, nervous system, multisystem	N	Y

(Continues)

TABLE 4 (Continued)

Practitioner participants (pseudonyms used)	Case number	Client presentation	Client age	Client gender identification	Number of elements	Number of links	Number of physiological systems identified*	Physiological systems identified	Diet/nutrient elements identified	External elements identified
	7	Perimenopausal, dysbiosis, mood swings	51	Female	34	55	8	Reproductive system, gastrointestinal system, nervous system, cardiovascular system, multisystem, hepatobiliary system, integumentary system, endocrine system	Y	N
	8	Psoriatic arthritis, dysbiosis	25	Female	32	56	6	Musculoskeletal system, integumentary system, hepatobiliary system, nervous system, immune system, gastrointestinal system	Y	Y
	9	Chronic headaches, menstrual cramps, anxiety, depression, fatigue	29	Female	34	52	3	Nervous system, reproductive system, multisystem	Y	Y
	10	Anxiety, fear, low mood, fatigue, perimenopause	48	Female	31	47	4	Reproductive system, nervous system, immune system, multisystem	Y	Y

and a degree distribution pattern skewed to the left (Supporting Information File S1). The elements with the highest degree (Table 5) included systemic inflammation (degree = 157), stress (degree = 140), gut dysbiosis (degree = 96), anxiety (degree = 92), compromised immune function (degree = 79), fatigue (degree = 76), poor sleep quality (degree = 58), diet (degree = 50). Elements with high betweenness centrality values are provided in Table 5. A total of 238 elements had zero betweenness centrality, 190 elements had between 0.50 and 500 betweenness centrality, and 147 elements had between 501 and 1500 betweenness centrality. 139 elements had more than 1501 betweenness centrality. See Supporting Information File S2 for distribution of eigenvector centrality, and Table 5 for the elements with high eigenvector centrality. The elements with the highest eigenvector centrality values were systemic inflammation, fatigue, and general anxiety.

3.2.2 | Network analysis: network level measures

The network analysis found the diameter of the network was 13, and the average path length was 4.148. The average clustering co-efficient was 0.126 indicating that each element in this network is linked on average to 12.6% of other elements. When subjected to the Gephi modularity algorithm, 11 communities in total were detected with a size distribution of each community ranging from eight to 115 elements. The modularity score of the network was high at 0.425, indicating a well-connected internal structure with a high density of internal connections within the identified communities, as measured against the connections between communities.

4 | DISCUSSION

In this study, network mappings of the naturopathic clinical reasoning process were created and analysed to explore primary health care using a complexity science lens. This research offers a preliminary insight into the use of a complexity science perspective to explore the manifestation of the holistic philosophy expressed by naturopathic practitioners through their clinical reasoning processes.

Overall, a vast range of elements and their multiple relationships were considered across the 70 clinical cases included in this study. The high modularity score of this dataset highlights its highly connected nature as perceived by the naturopathic practitioners; physiological systems and individual organs were not considered by the practitioners as discrete entities, but rather to be in intricate and emmeshed relationships. The naturopathic process for diagnosis and treatment of complex and chronic conditions is through an integrative physiological approach,[19] an approach that is an intrinsic component of naturopathic education globally.[44] Steel et al.[19] found that naturopathic practitioners incorporated at least two physiological patient systems within case management regardless of the presenting issue, and this holistic perspective is evidenced here. This integrated approach to clinical reasoning may be a result of the

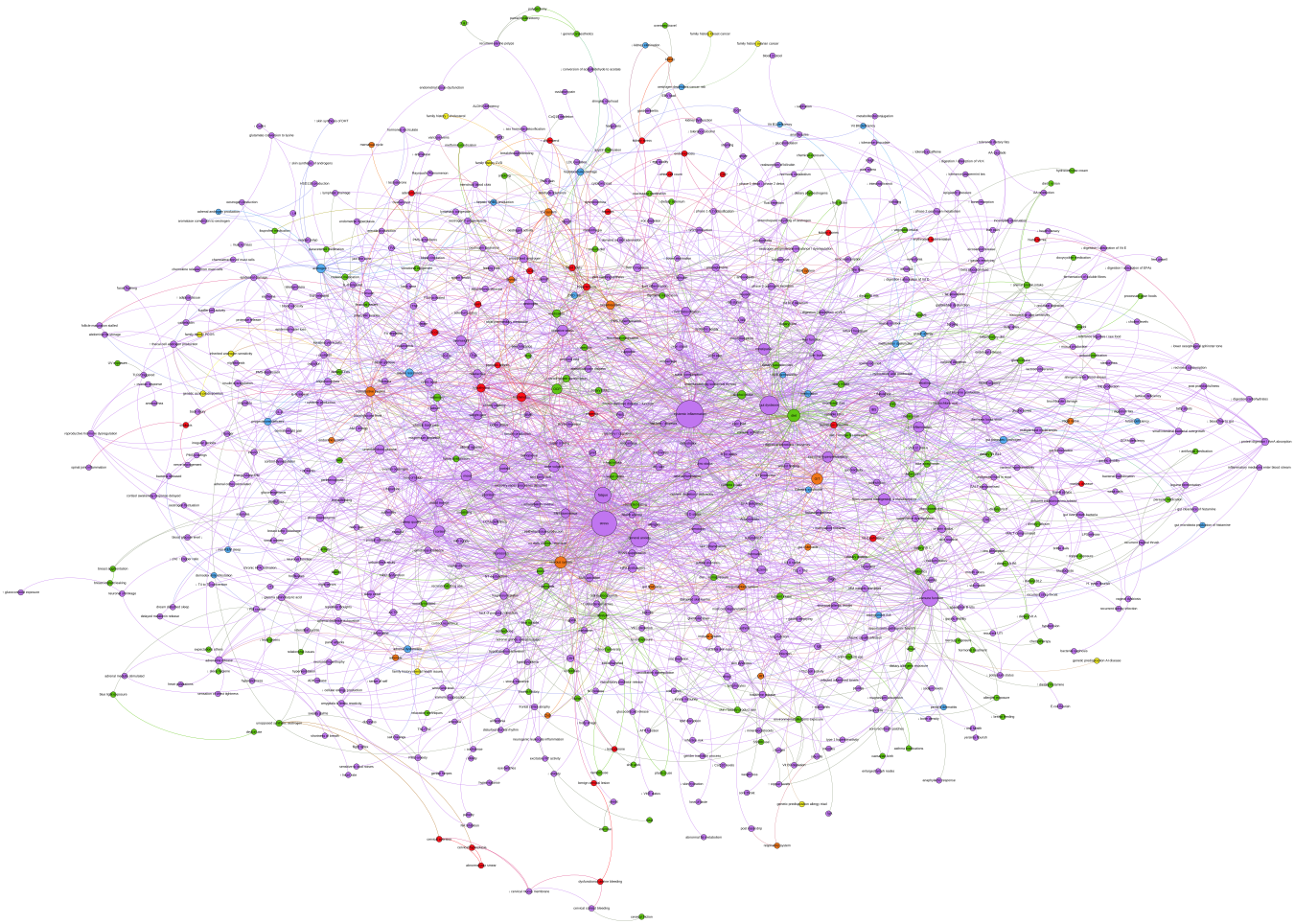

FIGURE 1 Force based attribute network mapping

complex nature of chronic conditions which constitute 75% of naturopathic practitioners' total case load.[45] Chronic disease tends to be complex and multifactorial, which favours complexity cognisant approaches rather than ones encompassing simple causal inferences and linear treatments.[46–48] Myers and Vigar[49] found positive evidence for naturopathic treatment for a range of complex and chronic conditions, and having a chronic illness has been found to be significantly associated with patients seeking naturopathic clinical services.[50] It is unknown the extent to which this integrated and complexity cognisant approach by naturopathic practitioners is enacted when they are managing patients presenting with acute conditions, and how this holistic approach might compare to the case management and clinical reasoning processes of practitioners from other professions. Future research into the clinical reasoning processes of practitioners from various professions in the management of various patient presentations may increase knowledge of primary health care practices while facilitating improvements in efficiency, efficacy, and safety.

Several elements were identified in this study as playing key roles in the clinical process, based on how many links they had to other elements, how often they were positioned in intermediary roles between other elements, and how frequently they were integral components of structural communities. These keystone elements included systemic inflammation, fatigue, anxiety and stress, depression, immune function, sleep quality, gut dysbiosis and bowel function, and diet. McIntyre et al.,[50] found that mental health disorders were most frequently reported by those who sought naturopathic clinical services, while Steel et al.,[19] found endocrine and digestive factors were critical to naturopathic practitioners' clinical reasoning. The reasons why these aspects of human health are the most prevalent in these naturopathic case considerations are not examined in this study. It is possible that these truly are vital aspects of health, potentially indicating beneficial treatment leverage points and targets for disease prevention in a salutogenic model of care, or it may be that these elements have some affinity with naturopathic clinical reasoning and so are given priority in case management in specific circumstances. Either or both possibilities indicate possible valuable areas of future research.

While links in the mappings in this study are denser within specific physiological systems, external systems, and community cliques, they were liberally present between all subsystems of the human organism and with the external context. This finding suggests naturopathic practitioners are not only applying a holistic perspective by considering each of the subsystems and their

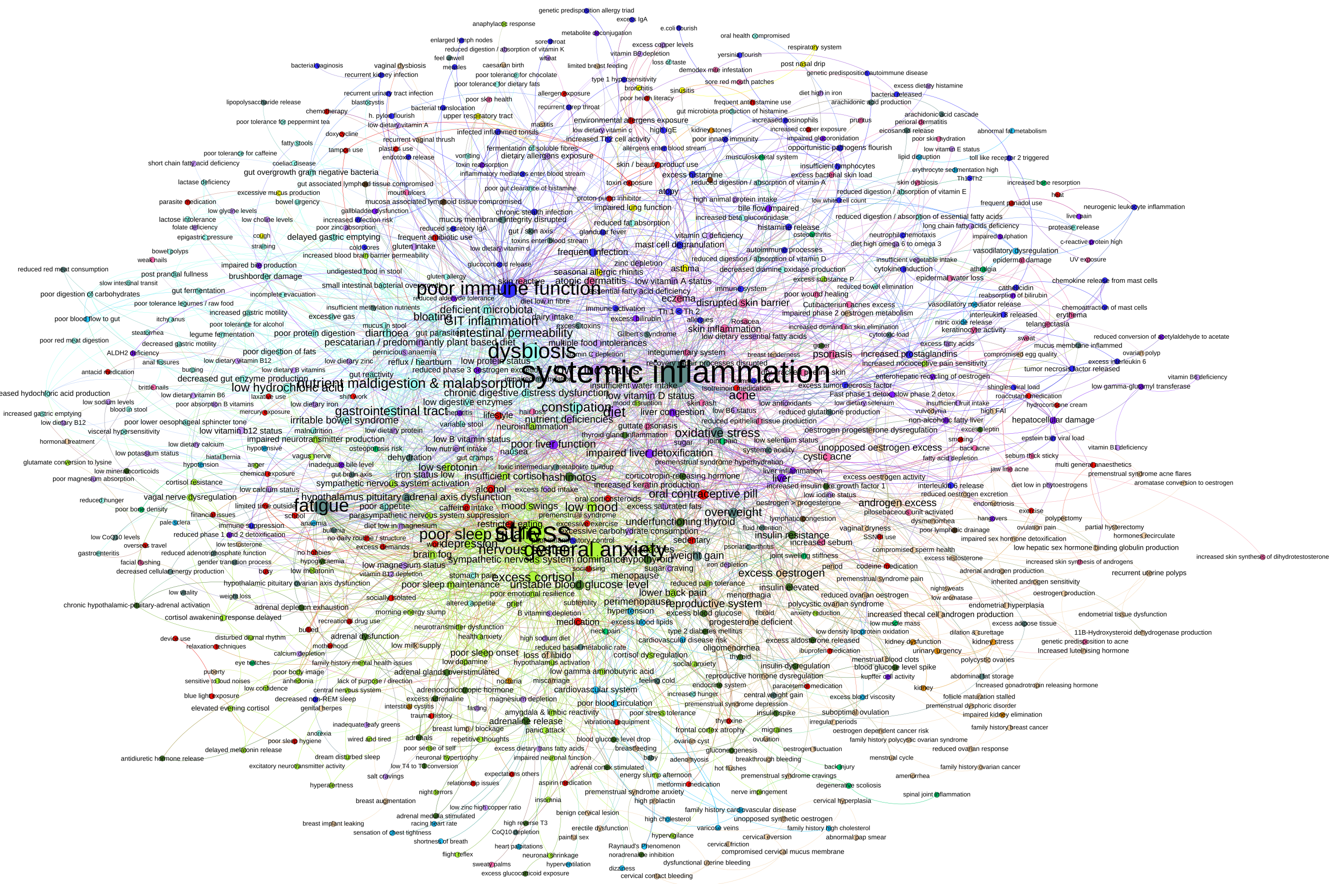

FIGURE 2 Force based system network mapping

constituent elements within a network, they are also deliberating on how elements across this holistic network interrelate and interact with each other. There is a growing body of research identifying links between different organs and systems within the body. For example, patients with hepatic encephalopathy (in itself a nervous system disorder caused by severe liver dysfunction) have been found to have higher levels of cognitive impairment, systemic inflammation, and dysbiosis than controls[51]; inflammation, commonly linked with gut dysbiosis, has been identified as playing a role in the aetiology of a number of psychiatric conditions, particularly depression[52]; psychological stress is associated with cardiovascular morbidity,[53–55] and the immune system and nervous system are linked via a bidirectional pathway.[31,56] Researchers are recognising elements of the complex structure of the human organism through the development of fields such as psychoneuroimmunology,[31] the microbiota-gut-brain axis,[52,56,57] the hypothalamic-pituitary-adrenal axis,[53] psychodermatology,[58] and the stress-response system (involving the endocrine, nervous, and immune systems)[59] indicating a trend away from a reductionist mindset towards one of connection and complexity. Further research from clinical practice—in naturopathy as well as other systems of medicine—could help identify further important complex clinical inter-relationships. Embedding a complexity science perspective into clinical practice, through integrating biological, biographical, and contextual elements,[48] could revolutionise primary health care.

Within the mappings in this study, a quarter of all elements identified across the 70 patients were external and environmental, with the remaining 75% comprising internal states, organs, symptoms, and physiological systems. As part of their case management process, naturopathic practitioners routinely consider an interrelated web of internal physiological systems and external influences —both as elements and as a collection of relationships. The treatment response to this pattern is a complete and whole response plan designed to work in a dynamic and whole manner[25] by addressing the environmental context and whole person disturbance. Naturopathy addresses both the unique external context of the individual (e.g., diet, lifestyle, social interactions, natural and built environment) and their whole person disturbance as determined through the presenting signs and symptoms pattern.[25] While the specifics of such an approach may be unique to naturopathic medicine, there is an evidence based imperative for external factors to be considered within primary health care—for example, the link between diet, lifestyle, and wellbeing has long been recognised,[60,61] placebo research has established a link between expectations, conditioning, context, and treatment outcomes,[62–64] and an association between positive social connection and health and longevity has been demonstrated.[65–67] Managing a patient's health needs without addressing contextual considerations risks overlooking

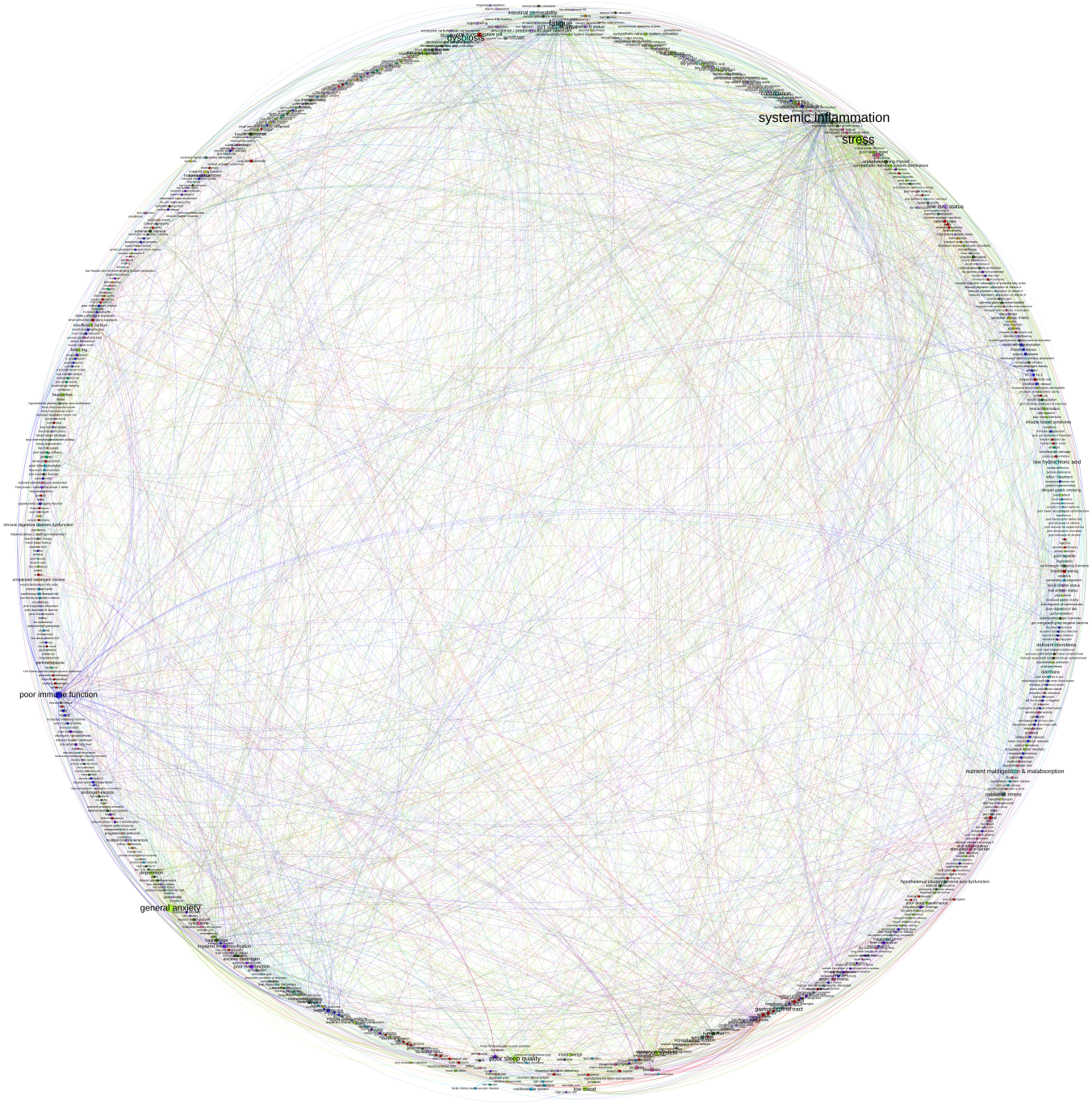

FIGURE 3 Circular system network mapping

precipitating and perpetuating elements that treatment success depends upon.

This study is not without its limitations. The small number of participants (seven in total) increases the risk of skewed data. The small sample also means that this study cannot be considered an exemplar of the use of a complexity science research framework for the naturopathic case management process but is rather a preliminary exploration of this approach within this context. Also, the research team discretionally allocated the element attributes in the force-based mapping and the assignment of elements to subsystems in the physiological and external systems mapping. This is not ideal, and in future studies of this type, the preference would be to gain a consensus regarding these allocations within the profession being investigated. Nevertheless, this exploratory study does highlight the potential of complexity science in analysing clinical practice and clinical relationships, as well as the feasibility of implementing such an approach within one profession. Larger, more rigorous studies using this methodology could help garner further insights and overcome the limitations of this study.

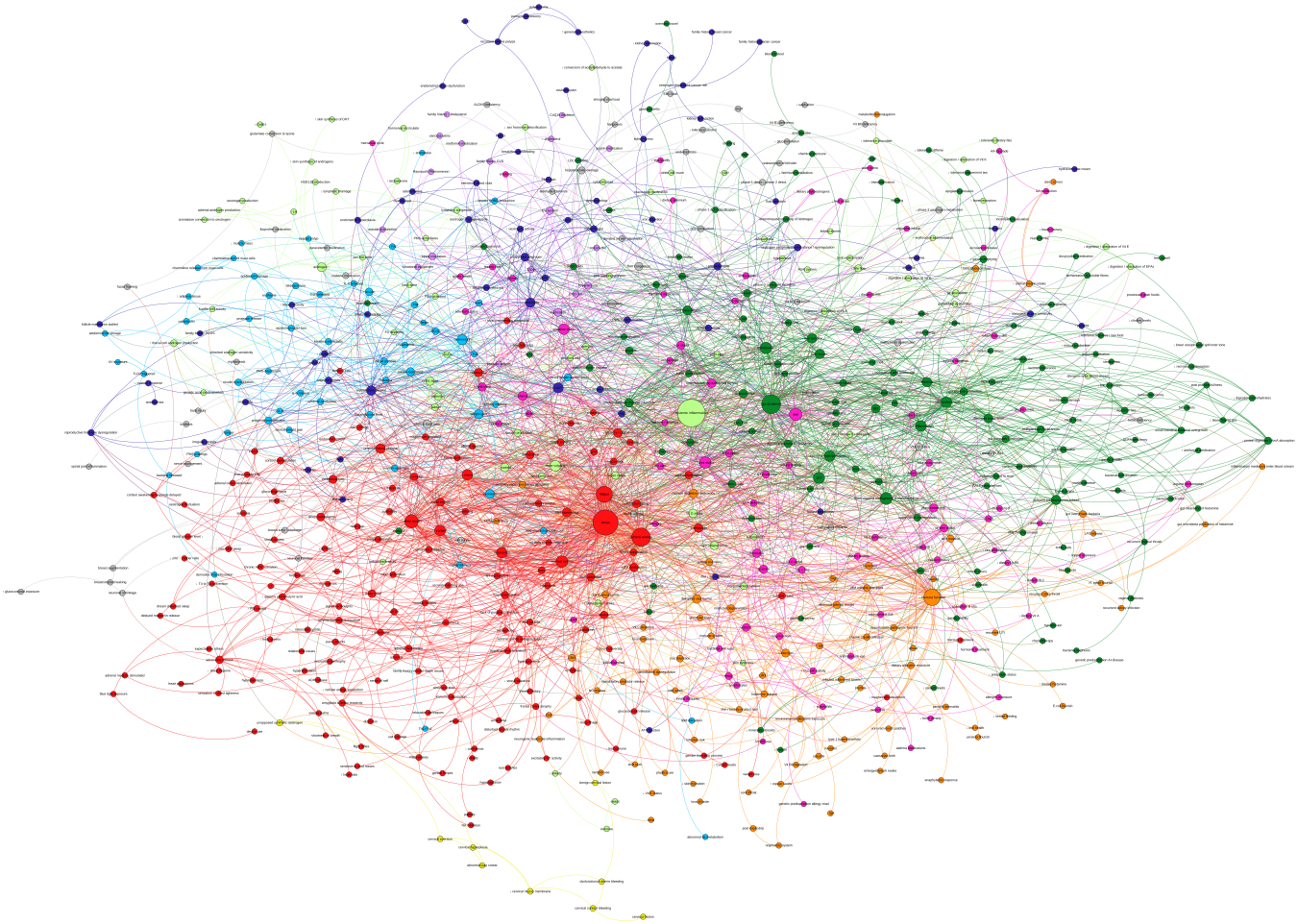

FIGURE 4 Modularity network mapping

TABLE 5 Elements with the highest degree values, betweenness centrality, and eigenvector centrality

Element	Degree	Betweenness centrality	Eigenvector centrality
Systemic inflammation	157	110,106.82	1
Stress	140	77,489.13	0.47
Gut dysbiosis	96	49,353.82	0.56
Anxiety	92	37,172.48	0.67
Compromised immune function	79	35,476.28	0.47
Fatigue	76	25,313.04	0.72
Poor sleep quality	58	17,865.43	0.46
Diet	50	19,338.36	0.03
Food/nutrient maldigestion & malabsorption	47	14,659.69	0.38
Nervous system	45	12,812.73	0.26

5 | CONCLUSION

Naturopathic clinical management is holistic in its approach and based on a multisystem view, encompassing an integrated environmental context and physiology. While a reductionist and mechanistic paradigm informs most current health research, it is insufficient in its scope to fully explore and assess clinical reasoning that is not reliant on closely defined disease classification and corresponding linear treatment, but instead consists of a broad treatment approach to a whole organism assessment. Including complexity science strategies and tools to bring a complexity science perspective to clinical research, opens the possibility for our understanding of the primary health care process to better reflect practitioners' engagement with and understanding of the whole human organism in context. Naturopathy is founded upon holism, which our study indicates is consistent with systems thinking and a complexity paradigm. As demonstrated by this study, the application of a complexity research framework enables critical exploration of case management and the clinical reasoning employed within traditional whole systems of

medicine, and the philosophical foundation underpinning these. While holism is a traditional concept within health care, the progression of complexity science and incorporation of this perspective into clinical research enables the emergence of a contemporary holistic paradigm which is cognisant of the human organism as a CAS. Incorporating complexity science perspectives into clinical research may be a tool that can help to manage healthcare's increasingly complex problems more effectively.

AUTHOR CONTRIBUTIONS

Kim D. Graham: drafted the main manuscript and prepared the supporting documents. **Amie Steel and Jon Wardle**: provided supervision and feedback throughout this process and across all produced materials. All authors reviewed the manuscript and approved its submission.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on reasonable request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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