Human Systems Management xx (20xx) x–xx
DOI 10.3233/HSM-171795
IOS Press

Ontology, epistemology and the complexity of human neurobiology

Petia Sice[a,*], Edward Bentley[b] and Laurie Rauch[c]

[a]*Department of Computer and Information Sciences, Faculty of Engineering and Environment, Pandon Building, Camden Street, Northumbria University, Newcastle City Campus, Newcastle-upon-Tyne, NE2 1XE, UK*

[b]*Department of Mathematics, Physics and Electrical Enginneering, Faculty of Engineering and Environment, Ellison Building, Northumbria University, Newcastle City Campus, Newcastle-upon-Tyne, NE2 1XE, UK*

[c]*Department of Human Biology, Division of Exercise Science and Sports Medicine (ESSM), University of Cape Town, Sports Science Institute of South Africa, Boundary Road, Newlands, Cape Town, South Africa*

Abstract. Certain ontology and epistemology perspectives are most relevant to human systems' enquiry. These are derived from a synergy of insights from theories of autopoiesis, interpersonal neurobiology and complexity. Ontology has implications for our comprehension of the nature of human systems: 1/ Human systems are embodied and situated, exhibiting self-organising and emergent properties; 2/ Human experience is personal but not private, it is born in the interactions with the environment, and is validated by the human structure; 3/ Changes in human structure are necessarily subservient to conservation of autopoiesis, i.e. self-production and maintaining life. The epistemological implications deem ontology and epistemology as mutually informative in human enquiry; the thrust of this article. Our knowledge is limited by our capabilities of awareness. The quality of perception interlinks with cultivating awareness and intentionality for maintaining wellbeing, i.e. sustaining life-enhancing conditions. The concept of 'wellbeing informatics' is used to outline a tangible approach to evaluating wellbeing.

Keywords: Autopoiesis, complexity, neurobiology, ontology, epistemology

Petia Sice holds a PhD in Complexity in societal systems. She is passionate about interpreting and applying insights from complexity theory for facilitating positive transformation in individuals and organisations. She is convenor of the UK EPSRC Systems Practice and Managing Complexity network (SPMC), and Senior Associate Editor of the International Journal of Systems and Society. Petia Sice is a Reader in the Department of Computer and Information Sciences at Northumbria University, specialising in Wellbeing Informatics.

Dr Edward Bentley completed his degree in Engineering at Northumbria university followed by PhD in the use of Artificial Neural Networks (ANN) to solve a long standing problem in power systems. He then became a research assistant and subsequently a lecturer. Dr Bentley's research and scholarly interests include: analysis and interpretation of physiological data, i.e. Heart Rate Variability and ECG; Artificial Neural Networks; Analogue Research and Development.

*Corresponding author: Petia Sice, Department of Computer and Information Sciences, Faculty of Engineering and Environment, Pandon Building, Camden Street, Northumbria University, Newcastle City Campus, Newcastle-upon-Tyne, NE2 1XE, UK. E-mail: Petia.Sice@northumbria.ac.uk.

Dr Rauch is a neurobiologist. He examines the neural correlates of low intensity physical activity (based on natural movement principles) and biofeedback as a means of combatting ANS dysregulation to improve health and wellbeing. The same natural movement principles are also effective in improving performances on the sports field and in the workplace. Two crucial aspects of ANS dysregulation that needs to be optimized are: neutralizing excessive somatic sympathetic nerve activations (SNA) and enhancing vagal nerve activation of the heart and the viscera. Dr. Rauch's recent research established that heart rate and HRV are good markers of SNA and vagal activity, respectively if the measurements are done under well controlled conditions.

1. Introduction

The purpose of this article is to introduce perspectives on ontology and epistemology with relevance to enquiry, and sense making in human systems. The last few decades have seen advancements in science, and trans-disciplinary synergies have rendered a shift from a reductionist to a more holistic paradigm [21, 22]. New insights have implications for the comprehension of the nature of being human and the nature of societal systems. This, in turn, informs epistemology and knowledge creation coherent with the ontological perspective. According to the 2017 Stanford Encyclopaedia of Philosophy, ontology concerns itself with the nature of things and the study of the most general features of what there is, and how the things, that are relate to each other metaphysically. In this article it is used to describe the nature of human systems from the perspective of autopoiesis [14, 15], the theory of mindsight [24] and complexity [2, 4, 9, 12, 17, 16, 19]. Grasp of the nature of 'being human', with relevance to the physical, mental and societal domains in the theory of autopoiesis leads to epistemological perspectives that deviate from the rationalistic metaphor of knowledge as an objective representation of a world outside of the human observer [12, 32]. Systems ontology leads to considering methods of enquiry and intervention coherent with the nature of the system. Ontology and epistemology intertwine into an impacting and developing relationship, and are mutually informative in human enquiry.

2. Autopoiesis

There is a large body of literature by the Chilean biologists Humberto Maturana and Francisco Varela, usually referred to as autopoietic theory [14, 15]. The theory describes the nature of living systems and has found far wider application than may be suggested from its biological roots, thus, generating implications for epistemology, communication and societal systems theory.

Autopoietic theory proposes a generative definition of a living system, i.e. autopoietic system in the physical domain. An autopoietic system is defined as a network of processes of production of components that produces the components that through their interaction and transformations continuously regenerate the network of processes that produced them, and constitute the entity as a concrete unity in the space by specifying the topological domain of its realisation as such a network [14]. Thus, the internal dynamics of the components (neural nets, metabolic nets, etc.) generate and sustain the global processes of the autopoietic entity. At the same time, however, the global processes (behaviour, consciousness, mind) constrain and govern the interactions and the state of the individual components. This dialectic relationship between local and global levels is described in autopoietic theory as 'reciprocal' [14]. For example, in organisms with a nervous system, the rules of interactions within the neural network are in reciprocal relationship with the overall activity of the living entity. To a very large extent, behaviour is a regulator of perception [30, 31], i.e. what the organism senses is a function of how it behaves and of its state of being, and how it is and how it behaves, is a function of what it senses. 'Situated behaviour', thus, takes the form of coupling with the environment; where environmental perturbations trigger changes in the entity but do not determine them, because changes in living systems are necessarily subservient to conservation of autopoiesis [14, 15]. The observer is in a position to distinguish the structure of a living system and the structure of the environment, and, observe them both changing in their mutual interaction. The important thing is that both the system and the environment undergo transformations through the process of coupling, referred to as 'structural coupling', and these transformations are determined by the structure of the transformed entity and not only by the perturbation. In autopoietic (living) entities with a nervous system, the coupling with the environment constrains and governs the neural dynamics. Thus, it is clear that the mode of coupling with the environment has two complementary dimensions: First, the living entity

depends on its environment and defines itself through the interactions with that environment (these interactions are of the nature of macro-physical encounters such as sensory transduction or muscle movements); Second, yet no less important, coupling is only possible because these encounters are embraced from the perspective of the global processes (mind, consciousness, behaviour) produced by the internal dynamics of the autopietic system. This action appears to the observer as an ongoing cognitive activity, and the living organism exhibits the properties of a cognitive self [14].

The dialectics of living organisms are based on the necessary emergence of a meaning proper to the perspective of the cognitive self (for example one's perception), and on a coupling with the environment which refers to the necessary dependence of the self on its environment (for example socio-linguistic interactions). Consequently, the contents of human experience depend crucially on the mutual embeddedness of the neural dynamics (embedded in the overall physical and chemical dynamics), the human agent as a unity with global processes (behaviour, mind, consciousness) and the environment. Thus, human experience is personal but not private. Experience is clearly a personal event, but that does not mean it is private, in the sense of some kind of isolated subject that is parachuted down onto a pre given objective world [30]. It appears more appropriate to view personal experience as 'ripples on the common ocean'. An investigation of the structure of human experience inevitably induces a shift towards a consideration that several levels of consciousness become inextricably linked to those of others and to the phenomenal world in an emphatic mesh [31]. The irreducibility of human experience cannot be underestimated when developing research approaches or methodologies [11, 12]. Human experience represents an irreducible first-person ontology [28]. It is not sufficient to explain experience by assuming a third person or objective viewpoint. What is required is to recognise that both first-person and third person accounts, and their interplay, are necessary in order to do justice to the quality of enquiry [22, 29].

An autopoietic ontology suggests: the human experience is validated in a special way by the human structure, and this shapes the entity that arises in the description [14, 15]. This ontological perspective has impact on epistemology, i.e. it challenges the fragmented world view of an observer separate from the observed reality.

3. Linguistic interactions, language and complexity in human organisations

An organism can enter into structural coupling with other organisms, and if the interacting organisms reciprocally select in each other their respective paths of ontogenic structural changes, then they generate a domain of communicative interactions. The individual ontogenies of the participating organisms occur as part of the network of co-ontogenies that they bring about in constituting societal unities. The observer designates as communicative those behaviours which occur in societal coupling, and, as communication that behavioural co-ordination he observes as a result. This consensual domain of communicative interactions in which the behaviourally coupled organisms orient each other with modes of behaviour, whose internal determination has become specified during their coupled ontogenies, is a linguistic domain. The name 'linguistic domain' was chosen because such learned communicative behaviours constitute the basis for language, although they are not identical with it [14]. The conduct of each organism is internally determined by its autopoietic structure. However, the conduct of one organism is a source of perturbations for the others while the coupling lasts. The linguistic domain, therefore, is intrinsically non-informative, although the observer may describe it as if it were so. What determines the interaction, is the dynamics of structural coupling of the interacting organisms [14, 30].

Such a view contradicts the more traditionally established metaphor of 'the transmission of information', in which communication represents something which is generated at a certain point and carried through an information channel, or conduit, and delivered to a receiver. This metaphor is not correct, since biologically there is no transmitted information [14]. Moreover, it presupposes that what happens to the receiver (listener) is predetermined only by the perturbing agent. In actual fact, however, communication depends not only on what is transmitted, but what happens in the organism that receives it. Communication, therefore, is a matter of mutual orientation, primarily with respect to each other's behaviour, and secondarily with respect to some subject [7].

To an observer, linguistic co-ordinations of actions appear as distinctions, linguistic distinctions. They describe objects in the environment of those who operate in a linguistic domain. Thus, when an observer operates in a linguistic domain, he operates

in the domain of descriptions. Moreover, language as a phenomenon takes place in the recursion of linguistic interactions – linguistic co-ordinations of linguistic co-ordinations of actions. Therefore, the linguistic domain becomes part of the environment in which linguistic co-ordination of actions take place, and language appears to an observer as a domain of descriptions of descriptions. But what an observer does is this - he makes linguistic distinctions of linguistic distinctions, or what another observer would say are ontogenically generated descriptions of descriptions [14]. With language arises also the observer as a languaging entity; by operating in language with other observers, this entity generates the self and its circumstances as linguistic distinctions of its participation in a linguistic domain. In this way meaning arises as a relationship of linguistic distinctions [14].

Language cannot be regarded as a system of symbols that stand for things in the world, and thus reveal our 'objective' knowledge of it. Words are tokens for linguistic co-ordination of actions. Therefore, it is appropriate to discuss languaging as a venue for action rather than language as a symbolic notation. Human organisations exist, for their members, in co-creating reality where language agreements decide what is true and what is false. This is not an agreement in opinions but in form of life. The key point is that by languaging together, the behavioural co-ordination, which is language, brings forth a world. Language allows for limitless recursion in the coupling of behavioural capabilities of individuals with the changes in societal life they generate [14].

If language is used to promote the status-quo or one way or other reinforce a specific worldview, then it can lead to pathological organisational life, where the individual members are 'enslaved' to support and act in organisational processes that they have no access to change. Such organisations, deliberately or not, use language as a repressive tool to shape human experience, and because of this, the creative potential of exploring and developing human experience into alternative language and practices is lost [15].

A simple pragmatic alternative is to respect human experience. What is required is to foster an environment where awareness and attentiveness, are actively developed, and where, conversations encourage new linguistic distinctions based on new experiences, to emerge. Practices like dialogue become essential in organisational conversations. The basic requirement of dialogue is to be able to talk while suspending opinions, while neither suppressing them nor insisting upon them, not trying to convince but simply to understand, without having to say who is right or wrong [3]. This type of communication, enhances awareness of what there is to be heard, without focusing it through the lenses of preconceptions and creates a new frame of mind in which there is a common (or organisational) consciousness: a new kind of intelligence.

The dialogue process is to be seen as a core element within any human enterprise, as it creates the context for all activities, rather than (as may be suggested by more traditional communication approaches) being merely part of the chain of activities. Dialogue is about involvement, about co-creation. Thus, a generative dialogue process in organisations will enhance their ability to develop a meaningful language, a valid venue for action and continuous learning.

The phenomenal domain of human organisations is realised through the network of linguistic interactions. Stacey, in interpreting the impact of complexity theory on management paradigms, argues that such networks through local agent interactions are capable of spontaneous self-organisation, to produce emergent, evolving patterns of behaviours of the network without any prior comprehensive, system-wide blueprint for evolution [27]. The dynamics are determined by the pattern and nature of the actor's relationships and linguistic interactions, and the response to any perturbation is determined by these very dynamics. Stabilising the behaviour of the network means simply repeating the past. Dialogue allows for emergence of new meaning and destabilises the status-quo, the network conducts itself as a complex adaptive system, i.e. rapidly generating emergent behaviours in response to perturbations [21]. This is what Maturana and Varela define as learning [14]. The flexibility to learn and innovate is essential. Operating in the complex systems domain, human organisations perceive and respond to the smallest changes in the environment or, indeed, inside themselves.

4. Reductionism vs holism

Autopoietic theory resonates with the emerging paradigm of holism [23, 24]. There is now a significant body of research that supports the insight that our nervous system, mind and interactions with the environment are all interconnected [5, 11, 13, 18].

The prevailing reductionist paradigm of the twentieth century has shaped comprehension of human systems and reality through several assumptions:

Matter is the fundamental building block of the Universe; Perceptions are accurate representations of an objective reality that exists outside of the human observer; Knowledge is absolute and allows to predict and thus control nature [4]. This worldview, in turn, leads to further conceptions, some of which are: The Universe and the things comprising it (including humans), function as machines that could be understood through the study of the parts that constitute them; Humans exist as material bodies and thus are separate from each other and from nature; Genes determine biology; Language describes an 'objective' world.

These assumptions and conceptions have shaped prevailing attitudes, intentionality, beliefs, behaviours and artefacts, thus, the predominance of rational thinking, reliance on 'facts', and leaving out potential invisible influences such as the impact of the mind on the body and indeed on the world, the possibility of connection between minds, and the human tendency for cooperation [1]. This, in turn, determines the boundaries of the epistemological endeavour and the realm of possible action. It is therefore, important to explore the changes in ontological view informed by contemporary science, i.e. moving towards a holistic paradigm of the nature of reality. Insights from quantum physics, complexity theory, systems biology are informing a view of the nature of reality, which encourages profoundly different conceptions of the human potential.

Physics now suggests that energy and matter represent one 'reality' and need to be studied as part of a unified whole [4]. Energy fields exist around and within matter. They extend over space and interact with themselves and with matter. Thus, everything is connected to everything else. The quantum reality of entanglement opens the possibility of an instant nonlocal connection transcending time and space. If the fields impact physical reality, then further questions arise: How do these fields emerge and change? What is their observable impact on reality? How could we influence them?

Empirical research in contemporary evolutionary biology suggests that human systems are not separate from their environment (humans are not mere products of their genes). It is the environment, matter and energy fields that determine how genes unfold and manifest into matter [8]. Human minds, i.e. thoughts, emotions and intentions, have impact on biological embodiment and on the physical environment [8]. Minds are not simply products of brains, they are interconnected in principle everything there is.

The holistic perspective of reality informs a more complex view of the dimensions of human experience. As argued earlier, autopoiesis explores the mutual emeddedness of the nervous system, mind and interactions with the environment, thus, rendering traditional notions of representation and computation as inadequate [30]. What becomes important, in the study of human experience, is the comprehension of the complex interplay of brain/body, mental activity and world [7], i.e. how we as humans, examine what we live through, how we become aware of our own mental life. Accordingly, an aspect of exploring human experience involves developing and cultivating this basic ability through specific training. A hands-on, non-dogmatic approach can lead to progress. In Varela's work, this action of 'becoming aware' is punctuated by three 'gestures': (1) Suspension – a conscious transient suspension of beliefs about the thing being examined; (2) Redirection – turning ones own attention from the object to its source, backwards towards the arising of the thoughts themselves; and, (3) Letting go - changing one's attitude from looking for something to letting it come.

5. Awareness and mindsight

'Mindsight' is a term coined by Daniel Siegel [23, 24] to describe the human capacity to perceive the mind of the self and others.

The theory of mindsight defines the mind is an embodied and relational process emerging from the mutual interconnectedness of the physical, mental, and relational (both human and non-human) domains of reality. The mind, as an emergent property, of the body and relationships, is created within the internal neurophysiological processes and relational experiences. In other words the mind is a process that emerges from the distributed nervous system, extending throughout the entire body, and also from the communication patterns that occur within relationships [24]. To put it simply, relationships and neural linkages together shape the mind [23]. The brain (the embodied nervous system), mind and relationships are aspects of one reality and need to be considered together, where the body provides the biological structure for hosting human experience, and the mind is embodied, and relational process that regulates the information and energy flow in the embodied brain and in the relationships with others and the environment [23]. The term 'embodied brain' refers to the whole nervous system, not just the brain in the skull.

The regulation of energy and information flow is achieved through the management of intentionality and attention [24]. Intentionality determines the direction of attention. Attention acts like 'a scalpel', as the direction and scope of attention can trigger changes in the brain (neural plasticity) and in the communication space of relationships and then further influence our mental activity, brain and relationships in a continuous cycle [27]. The intentionality of 'seeing reality' more clearly and continuously enhancing awareness and reflection capability requires the integration and stabilising of attention in monitoring body sensations, mental activity and relationships.

In Western translation a heightened state of awareness is often referred to as 'mindfulness'. This terminology is widely accepted in the West, where the state of 'mindfulness' is defined as an opposite to 'mindlessness', i.e. functioning on autopilot or simply downloading mental models, assumptions and prejudices rather than witnessing present experience as it unfolds. Jon Kabat-Zinn provides an operational working definition of mindfulness as: 'The awareness that emerges through paying attention on purpose, in the present moment, and non-judgmentally to the unfolding of experience moment by moment' [10]. It is important to clarify that our comprehension of mindfulness, as paying attention to experience as it unfolds, is not only connected to present moment sensations, but to accepting and witnessing our present moment experience, that may involve some or all aspects of experience, i.e. sensations, mental activity (thoughts, feelings, memory, intentions, beliefs, attitudes, etc.) and relational experience (connectedness to others, to our planet, to nature, etc.) [24].

Daniel Siegel chooses to use the metaphor of the cameraman to explain two important aspects of awareness practices [24]. To capture a clear and accurate image, the cameraman needs to take care of: (1) opening the lens of the camera to allow for full view; and (2) stabilising the camera (using a tripod) to avoid blur in the image. Opening the lens of awareness requires attention to all aspects of experience: sensory perceptions, body awareness, awareness of mental activity such as thoughts, feelings, attitudes, beliefs, intentions, etc.; and, relational awareness of connectedness with others and with nature. However, the picture of reality will still be blurry if the observer fails to stabilise the camera of awareness. Stabilising the camera of awareness requires openness, observation and objectivity. Siegel refers to these three fundamental components as the three legs of the tripod that stabilise the awareness lens (in his work Siegel uses the word mindsight instead of awareness) [24]. When the lens of awareness is stabilised, the details come into focus with more depth and precision. Openness implies acceptance of what is, without any preconceived ideas or attitudes of how things 'should be', i.e. let go of expectations and receive things as they are. Openness allows to recognise restrictive judgements and release them from the mind. Observation allows for a larger frame of reference of self-observation, i.e. to detach from habitual responses and find a way to modify them. Objectivity recognises that awareness is separate from what the observer is aware of.

Siegel brings into focus five dimensions of awareness: 1/ Awareness of sensory input (touch, smell, sight, sound, taste); 2/ Internal body sensations of comfort or discomfort; 3/ Mental activity (images, beliefs, thoughts, feelings, attitudes); 4/ Relationship with people, nature, artefacts; 5/ Awareness of awareness. The five dimensions constitute a structure for managing awareness and attention [24].

Research from neurobiology [6, 13, 18, 25, 30, 31] provides evidence that awareness development practices are correlated with the development of the pre-frontal cortex of the brain, vertical (gut, heart and cortex) and horizontal (left, right brain hemisphere) integration of the brain and the development of qualities of: Emotional balance and modulation of fear; Response flexibility – pause before you act; Insight – linking past with present experience and future possibility; Empathy and compassion for ourselves and others; Morality – what is appropriate from the perspective of the common good; Intuition - non rational way of wisdom and knowing, and thus with wellbeing.

Siegel [23, 24] relates the concept of wellbeing with complexity. In his acronym FACES (Flexible, Adaptive, Coherent, Energised and Stable), he refers to the wellbeing of a system (in the physical, mental, and/or societal domain) as the capability to function as a complex adaptive system, i.e. exhibiting coherent emergent behaviours in relation to changes in its environment, as opposed to rigid or random responses.

6. Towards wellbeing informatics: complexity, intentionality, awareness and measurement

In science, the purpose of research is to develop insight and to predict. Science has the element of experimental falsifiability, which is lacking

from traditional disciplines, making it flexible and open ended. Scientific enquiry requires measurement as its system of validation/falsifiability. What about measurement and prediction in the human domain?

Humans and human organisations exhibit complex systems behaviour, producing emergent properties and processes (mind, culture, etc.). It is possible for a complex system to move towards an ordered system or a system exhibiting random behaviour, when constraints change. For a system, the ability to function in a complex way is needed for adaptation and innovation and provides the underlying capability for survival, sustainability and health, in both individuals and organisations. What the theory of complex systems tells us is, that the very nature of the multiple interacting and continuously changing relationships and constraints of the system, prevent precise prediction over longer periods of time, rendering the scientific approach of verification/falsification problematic. This has important implications for the measurement and comprehension of human systems. Measurement in human systems requires: describing the system in real time, both its state of being in the now and its tendency and direction of possible change [12]. As human systems are embodied and situated, measurements need to cross boundaries between the physical, mental and societal domains. What is to be measured, is the state of being of the system and the individuals comprising it, in real time, simultaneously in these different domains. Both first and third person accounts of the state of the system are important and in large human organisations a distributed ethnography approach assists insight [26]. What is important to comprehend and assess is the state of being in terms of complexity capability, i.e. capability for a coherent dynamic response to change, and the existence of an ecology capable of sustaining wellbeing.

Measuring and monitoring for wellbeing, referred to in this article, as 'wellbeing informatics', requires: An approach which prioritises description over evaluation; An enquiry that crosses the boundaries between physical, mental and societal domains; Grounding in phenomenology and the 'act of becoming aware'. Psychophysiological measurement such as Heart Rate Variability provides a valuable link between the human actor and objective physiology [11, 18]. Catalysing new knowledge requires new ways of engagement and experimentation. As Varela points out 'behaviour is to a very large extent a modulator of perception' [29].

The term 'wellbeing informatics' is important as it implies a tangible, evidence based approach to the study and evaluation of human and systemic wellbeing, using the tools provided by informatics to create a framework within which one may consider the interaction between humans and information alongside the construction of interfaces, organisations, technologies and systems.

References

[1] R.F. Baumeister and M.R. Leary, The need to belong: Desire for interpersonal attachments as a fundamental human motivation, *Psychological Bulletin* **117**(3) (1995), 497–529.

[2] D. Bohm, Thought as a System, Routledge, London; 1994.

[3] D. Bohm, On Dialogue, Routledge, London; 1999.

[4] D. Bohm and D. Peat, Science, Order and Creativity, Routledge, London; 2000.

[5] R.E. Boyatzis, A. Passarelli, K. Koenig, M. Lowe, B. Matthew, J. Stoller and M. Phillips, Examinaton of neural substrates activated in experiences with resonant and dissonant leaders, 2 ed., **23** (2012), 259–272. The Leadership Quarterly.

[6] R.J. Davidson, Well-being and affective style: Neural substrates and biobehavioural correlates. *Philosophical Transactions of the Royal Society B: Biological Sciences* **359** (1449) (2004), 1395–1411.

[7] N. Depraz, F. Varela and P. Vermersch, On Becoming Aware: A Pragmatics of Experiencing, John Benjamins Publishing Company, Amsterdam; 2003.

[8] B. Dias and K. Ressler, Parental olfactory experience influences behavior and neural structure in subsequent generations, *Nature Neuroscience* **17** (2014), 89–96.

[9] C.N. Georgantzas and E. Katsamakas, Information systems research with system dynamics, *System Dynamics Review* **24**(3) (2008), Autumn (Fall) 2008, pp. 247–264.

[10] J. Kabat-Zinn, Coming to Our Senses: Healing Ourselves and the World Through Mindfulness. Hyperion; 2006.

[11] K. Koya, P. Sice and L. Rauch, An enactive perspective on comprehending leadership: A comparative case study approach, *Human Systems Management* **35**(3) (2016), 197–212.

[12] D. Large, P. Sice, G. O'Brien, S. Mansi, R. Geyer, Complex Processes and Complex Systems: A Synergy of Perspectives, *International Journal of Systems and Society* **2**(1) (2015), 65–73.

[13] M. Malik, 'Heart Rate Variability: Standards of Measurement, Physiological Interpretation, and Clinical Use', *Circulation: American Heart Association* **93** (1996), 1043–1065.

[14] H.R. Maturana and F.J. Varela, Autopoiesis and Cognition, D Reidel, Dordrecht, Holland; 1980.

[15] H.R. Maturana and F.J. Varela, The tree of knowledge: The biological roots of human understanding. New Science Library/Shambhala Publications; 1987.

[16] E. Mosekilde, Topics in nonlinear dynamics – applications to physics, biology and economic systems. Singapore: World Scientific; 2002.

[17] G. Nicolis and I. Prigogine, Exploring complexity. New York: W.H. Freeman; 1989.

[18] S.W. Porges, 'The polyvagal theory: New insights into adaptive reactions of the autonomic nervous system', *Cleveland Clinic Journal of Medicine* **76**(2) (2009), 586–590.

[19] I. Prigogine and I. Stangers, Order out of chaos: Man's new dialogue with Nature. London: Heinemann; 1984.

[20] P. Reason and H. Bradbury, (Eds.). Sage Handbook of Action Research: Participative inquiry and practice (2nd ed.). London: Sage Publications; 2008.

[21] P. Sice, E. Mosekilde and I. French, Systems Language and Organisational Discourse: The Contribution of Generative Dialogue, *International Journal of Philosophy of Management* **6**(3) (2008), 53–63.

[22] P. Sice, K. Koya and S. Mansi, Leadership capability: An autopoietic perspective, *Human Systems Management* **32**(2) (2013), 95–103.

[23] D. Siegel, The Developing Mind: Toward a Neurobiology of Interpersonal Experience, New York: Guilford Press; 1999.

[24] D. Siegel, Mindsight: The New Science of Personal Transformation, New York: Bantam; 2009.

[25] O. Singleton, B.K. Hölzel, M. Vangel, N. Brach, J. Carmody and S.W. Lazar, Change in brainstem gray matter concentration following a mindfulness-based intervention is correlated with improvement in psychological well-being, *Frontiers in human neuroscience [Internet]* **2014** (2014), 8.

[26] D. Snowden, 'Complex Acts of Knowing: Paradox and Descriptive Self Awareness', *Journal of Knowledge Management* **6**(2) (2002), 100–111.

[27] R. Stacey, Strategic Management and Organisational Dynamics. Harlow: FT Prentice Hall; 2011.

[28] E. Thompson and F. Varela, 'Radical Embodiment: Neural Dynamics and Consciousness,' *Trends in Cognitive Science* **5**(10) (2001), 418–425.

[29] F. Varela, Neurophenomenology: A methodological remedy to the Hard Problem. Journal of Consciousness Studies, *Special Issues on the Hard Problem* (1996), 330–350.

[30] F.J. Varela, E. Thompson and E. Rosch, The Embodied Mind. Cambridge, MIT Press; 1995.

[31] F. Varela, Patterns of life: Intertwining identity and cognition, *Brain and Cognition* **34** (1997), 72–87.

[32] M. Zeleny, Human systems management: integrating knowledge, management and systems. Hackensack (NJ): World Scientific; 2005.