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The Unified Theory of Meaning Emergence: A novel complexity theory of health and nursing

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Abstract

The science of complexity and its non-linear mathematics has increasingly become a basis for framing scientific questions from a new perspective. A major issue discussed in furthering the theoretical foundations of complexity science has been the validity of mathematical versus natural language descriptors. The Unified Theory of Meaning Emergence offers a novel theoretical model of health that integrates the mathematics and language of complexity science by only using the complexity concepts that can be strongly tied to an accepted mathematical process. This theory redefines health as a minimization of predictive error and proposes that predictive error is minimized through a unified, multi-level, system wide process of meaning emergence. The power of a unified platform of analysis will be shown through application in the areas of health behavior, infant and child development and health behavior change. This theory may be the basis for a greater understanding of health across all scales and a platform for new interventions in nursing and health.

Introduction

The widespread adoption of complexity science with its broad applicability and deep explanatory power has created an exciting opportunity for health science in general and nursing science especially. The natural holism of complexity science fits well with existing nursing theory and enhances interdisciplinary collaboration. Complexity Science and the mathematics of nonlinearity supports the notion that life is interdependent and in a constant state of change and for this reason provides a more authentic view of nature and health than a linear view. The Unified Theory of Meaning Emergence (UTME) is a novel complexity theory that opens new opportunities for exploration of nursing science and health. The UTME is based on two key assumptions that must be acknowledged at the outset. The first is that all of nature exhibits nonlinear characteristics and that there is nothing that is fundamentally linear or random. The second is that everything observable, including subjective phenomenon, is best understood either with the non-linear mathematics of complexity science or a reasonable qualitative proxy.

The UTME has two major theoretical components consisting of a complexity definition of health stated in both quantitative and qualitative frames and a universal process of meaning emergence based in non-linear mathematics but stated in qualitative terms. The definition of health is derived from two lines of strong evidence that a state of health is one of energy/information efficiency. The first line of evidence is that disease can be described as a decrease in complexity characterized by disruptions in effective adaptive response within and between systems Churruarín et al. (2008) and Peng et al. (1995). The second line of evidence comes from the fact that organisms maintain homeostasis and energy conservation through an efficiency of predictive response to the environment Albert and Barabási (2002) and Friston (2013). Based on these twin constraints of system coordination and energy conservation, health then would be an increase in complexity as characterized by enhanced effectiveness in adaptive response. In the parlance of complexity science, this is an effective, adaptive response within and between prediction and outcome. This perspective has been shown to be applicable across all spatiotemporal levels from cellular to environmental to human social settings Swenson (1989).

Complexity Definition of Health

The complexity definition of health according to this theory is stated here in both quantitative and qualitative frames. *Quantitative frame*: "Health is the scale-free, continuous evolutionary process for the minimization of predictive error or free energy" as defined by Friston (2007) (2012). *Qualitative frame*: "Health is the simultaneous, continuously dynamic and evolutionary search for the optimal predictive, behavioral solutions at all levels for the mutual benefit and continued existence of the whole system". The common process through which systems minimize predictive error is referred to in this theory as meaning emergence. What follows is the development of a new conceptualization of health as a minimization of predictive error actualized through a common process of meaning emergence.

The process of meaning emergence reflected in UTME is derived from three key mathematical principles seen in complex adaptive systems (CAS) at all scales and each are required for the effective minimization of predictive error at any scale. The three complexity mathematical concepts are: Bayesian predictive process, biased random walk, and quorum sensing. These principles have already been found to be useful descriptors in a variety of scientific domains such as: child development, bacterial foraging, and neural processing Gopnik and Tenenbaum (2007), Codling, Plank, & Benhamou (2008) and Knill and Pouget (2004) William (2012). While in each of these domains the names of the players and the informational interactions will differ; the theoretical conjecture is that the process of minimization of predictive error is largely the same in all systems and can be understood with these three mathematical principles.

Bayesian Predictive Process

The Bayesian statistical process starts with a best guess prediction of some future state based on the accumulated knowledge of a system. The difference detected between the initial prediction and the actual outcome is the amount of predictive error. The dynamic nature of the environment makes a perfect prediction impossible so there will always be some level of predictive error. The amount and source of the error that is detected is used to adjust the probabilities within the Bayesian predictive model and increase the accuracy of future predictions. The predictive comparison is between the pattern detected in the environment and the representation of that pattern within the CAS Kiebel, Daunizeau, and Friston (2008) Heeger D. (2017). The process of pattern matching of the Bayesian model will take on a variety of structural forms depending on the CAS. In proteins, such as immunoglobulins, the representative pattern/memory is held in the molecular shape while at the human social level it may be in shared words or memes Arganda, Pérez-Escudero, and de Polavieja (2012). The Bayesian predictive model in any CAS serves as the source of bias for the biased random walk and guides the steps of the CAS along the walk to the minimization of predictive error and health.

Biased Random Walk

A constantly changing environment provides an innumerable number of path choices for any CAS trying to find its way. The path that a CAS takes is not random but is based on the Bayesian bias that has been established by experience as to what would likely be the most successful

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3 choice among the many options. In the process of meaning emergence, each step on the path is
4 the result of a single Bayesian predictive cycle. In the UTME the steps on the path are divided
5 into two types; one of external (environment) pattern matching called a “connectedness” step
6 and one of internal (CAS) pattern matching called a “separateness” step. This division into step
7 types will hold true whether a step is a sensory prediction or an action prediction and across all
8 spatiotemporal scales. Numerous examples of this binary difference in information processing
9 have been found in nature with some examples listed in Table 1. Sources of environmental
10 energy/information are not randomly distributed but display cyclical patterns such as the
11 change of seasons, the tidal flow and migratory patterns. These patterns can be discovered
12 through external pattern matching but are represented by a corresponding pattern in the
13 internal environment of a CAS through a variety of representational forms. In humans, certain
14 retinal cells will fire when encountering vertical lines while others will fire only in the presence
15 of horizontal ones Rao (2005). One set of cells being activated will represent one thing and a
16 different set of cells will represent another. These separate retinal predictions are then
17 combined into a shared group prediction.
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23 Table 1

24 25 **Quorum Sensing**

26 Quorum sensing is the third source of prediction generation through in which a collection of
27 similar CASs creates a group prediction based on shared information. The group behavior of
28 swarming is an often cited example of quorum sensing as seen in birds flocking and in fish
29 schooling Hou (2012) Hemelrijk and Hildenbrandt (2012). Because each CAS in a group occupies
30 a different part of the environment and has a slightly different model of the environment, the
31 sharing of individual predictions generates a grouped super prediction that increases the overall
32 predictive accuracy of individual group members. The group itself takes on the characteristics of
33 a CAS as a collection of CASs creates a series of these predictions through the process of
34 quorum sensing. The grouped CASs then operates as an environmental framework that
35 individuals within that group must adapt to in order to minimize their own predictive error. For
36 humans, quorum sensing is the process through which words, memes and cultural traditions
37 arise König and Norbert (2006). Counter intuitively no group member oversees the
38 generation of these group predictions but the predictions emerge spontaneously through group
39 member interaction as in the flocking of birds.
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45 Quorum sensing is also the process through which any CAS develops predictive hierarchies that
46 generate meaning at multiple levels within the system. In this predictive hierarchy the
47 prediction at the highest level of a system is not isolated but arises from the predictive
48 processes emerging from lower levels. Consequently, every super prediction will contain
49 predictive steps within predictive steps. For example, a consciousness step on a predictive path
50 in the brain is derived from multiple shorter and more frequent steps that came before it
51 arising in the brain, muscles, eyes and other organs Meunier et al. (2011) and Wacongne et al.
52 (2011).
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55 56 **Application**

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3 Taken together these three principles outline a system wide process to maintain homeostasis
4 through the minimization of predictive error. The is a large theory and the explanatory power
5 of the theory will be explored in three key areas important to nursing and health: individual
6 health behavior, the process of child development and the process of health behavior change.
7 Each area of application was chosen to highlight the contribution of one of the three
8 mathematical principles of meaning emergence.
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11 **Individual health behavior – Bayesian modeling:**

12 Self-concept is considered the basic unit of Bayesian modeling in the individual and is the
13 guiding force in adult health behavior. Psychologists see the self-concept as a universal,
14 necessary but at the same time mentally constructed device that allows an individual to
15 operate with consistency in their environment Markus and Wurf (1987)
16 Marsh (1990) Keramati, Smittenaar, Dolan, and Dayan (2016). The UTME conceptualizes three
17 basic levels of Bayesian predictive modeling expressed through the self-concept that drive
18 health behavior at the individual level. Each of these three levels of self-concept are organized
19 around Bayesian predictive models that differ significantly in organizing principle. The level of
20 Bayesian modeling a person occupies will be reflected in the language they use in their story of
21 self and the story of their social group. As individuals evolve through the three levels, the
22 previous levels do not go away are but subsumed within the highest current level of predictive
23 modeling forming a nested hierarchy of predictive models. The higher the predictive model is
24 in the hierarchy the greater will be the predictive accuracy of the model for the minimization of
25 predictive error and hence greater health.
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31 The first level of self-concept is called the sensory level where the predictive model is organized
32 around biases that will search an environment for experiences that meet or reinforce the
33 sensory expectations that define an individual's self-concept. These sensory methods of
34 defining the self may be of many types but includes, entertainments and food. At the sensory
35 level, the self-concept or story of the self will often equate the identity of the person with the
36 sensory experience using language such as "I am a big chip eater" or "I am a smoker". Because
37 sensory experiences are by nature transitory they must be repeated frequently to maintain the
38 integrity of the self-concept so that at the most extreme end of this level there will be a
39 tendency for addictive behavior. Individuals at this level of self-concept will participate in social
40 gatherings organized to provide opportunities to engage in the experience or even to celebrate
41 the experience. The social group that shares this behavior becomes the arbiter and validator of
42 the shared sensory experience. Group membership is validated by the individual engaging in
43 the sensory experience of the group.
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48 The next level of self-concept is the referential level where the individual predictive model is
49 organized around a set of shared norms or facts that can be scientific, religious or cultural in
50 origin. The individual operating at the referential level will seek out the part of the environment
51 that supports this frame of reference and will express their individual story by referring to that
52 frame of reference such as, "I am a healthy eater" or "I am kosher". The referential bias,
53 whether it be religious, scientific or cultural, is rule based and the rules are accessed by
54 individuals through formal and informal membership organizations that codify the set of rules,
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3 both written and unwritten, that guide the group. Group membership is validated by the
4 individual following the rules of the group. Validity of the frame of reference is institutionally
5 based with identified experts and thought leaders.
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8 The last level of modeling is called the spiritual level where the self-concept is transcended and
9 is not bound to any concept or language framework. When the self-concept is transcended the
10 sensory and referential filters do not go away but remain in the background allowing a wider
11 range of information to be processed and expanding awareness. Additionally, this is the only
12 level of self-concept modeling that does not have to be validated by a social group. Leaving the
13 self-concept unbound to any defined organizational principle allows compassion to arise
14 naturally. The UTME predicts that compassion is the most efficient model for the minimization
15 of predictive error in both individuals and society.
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19 **Infant and child development – biased random walk:**

20 The reconceptualization of child development utilizing the UTME framework is a good
21 opportunity to demonstrate the emergence of meaning as a biased random walk. What is
22 remarkable about child development is that while there is not a strictly defined time frame in
23 which certain milestones are reached, there is enough similarity in the sequence of
24 achievements that historically, many child development theorists have arranged them into
25 stages that are also similar. Even though full development takes over two decades the stages of
26 development can be seen steps on a path towards greater predictive efficiency.
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30 The process of infant and child development in the UTME visualizes each stage of child
31 development as a single step on a path that follows the sequence of a connectedness step
32 (external pattern matching) followed by a separateness step (internal pattern matching). As in
33 all meaning emergence, each step also contains within it a nested hierarchy of smaller steps.
34 Within the sequence of child development steps, we find two major steps these being the
35 separateness step of initial self-concept formation in toddlers and a connectedness step in the
36 teen years where the first possibility of transcendence of the self-concept can be achieved.
37 There are seven stages of child development according to the UTME beginning at birth and
38 ending in adulthood.
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42 The first stage between birth and five months, is called “Connecting to the source” and is a
43 connectedness stage where the first pattern matching of the environment is established. The
44 major accomplishments in this stage are connecting the two major sources of predictive
45 information available with the first being the child’s own body as they learn to coordinate eye,
46 mouth, limb and finger movement. Primary caregivers are the second major source of
47 information where predictive models develop across a range of communication channels such
48 as visual and tactile connections along with language sounds and tempo.
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52 The second stage is “Naming the other” and is a separateness stage occurring between six and
53 eighteen months where the predictive capabilities have reached the point that the child can
54 begin to recognize and name, either verbally or through gesture, objects in the environment.
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3 The effective manipulation of objects directly or through others is also a key milestone at this
4 level.
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7 The third stage occurring between 18 months and three years is called “Naming the Self” and is
8 the first major stage of development and is also a separateness stage where the initial
9 organization of self-concept is accomplished. It is in this stage that gender and other types of
10 identity exploration begins. This is a difficult stage as the self-identity is not fully formed and its
11 consistency and integrity is difficult to maintain. This often leads to conflict between the newly
12 emerging self-concept and others.
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15 The fourth stage between ages three to six years is the “Social Self” and is a connectedness
16 stage where the new self-identity is explored in the environment of social interactions both real
17 and imagined. Role playing is key in this stage with the child developing often fanciful stories to
18 explain the world and its relationships. Theory of mind is formed in this stage.
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21 The fifth stage between the ages of six and twelve years is the “Competent Self”. This is a
22 separateness stage where the child incorporates the bulk of cultural and social learning takes
23 place in preparation for the child to understand and enter society as a contributing member.
24 This preparation is often school based but also will include cultural and religious education,
25 with practice in practical matters such as keeping oneself safe in the environment.
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29 The sixth stage from ages thirteen to eighteen is a connectedness stage called the “Communal
30 Self” where the child explores and solidifies peer group relationships. This also the second
31 major stage where the first possibility for the self-identity that was created in infancy to be
32 transcended.
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35 The final stage is the adult self which is a separateness stage and where the adult identity
36 begins to be defined with the beginnings of life work, long term relationships including the
37 possibility of children. This stage occurs between the ages of 19 and 26.
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39 **Health behavior change – quorum sensing:**

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41 Using the UTME to re-conceptualize the process of health behavior change illustrates the
42 complex interaction between individual and group behavior that emerges through quorum
43 sensing. The Transtheoretical model of behavior change by Prochaska and Velicer (1997) is a
44 standard for understanding behavior change that conceptualizes the process of change as
45 occurring in stages that evolve from not recognizing the need for change to implementing
46 change. The theoretical assumption of the UTME is that there are common patterns for all CAS
47 behaviors so these patterns should also be evident in the Transtheoretical model.
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51 The names of the stages of change in the Transtheoretical model are briefly pre-contemplation,
52 contemplation, preparation, action, maintenance and termination. The example of an alcohol
53 habit will be used in discussing the differences in the interpretation of the stages between the
54 original theory and the UTME. In the pre-contemplation stage, the impact of alcohol on a
55 person’s life is not recognized even if others around the person have recognized it and may
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3 have pointed it out. From the perspective of the UTME even if the habit is causing difficulty the
4 person at this stage it has a strong enough fit with the environment and the current predictive
5 model works well enough that it appears to the individual that the habit does not need to
6 change. The fact that the self-concept is able to match with the environment shows that this is
7 a connectedness stage. At some point the predictive mode of the self-concept that includes
8 alcohol does not fit with the environment and the person moves into the contemplation stage
9 where a change in behavior is first considered. This first possibility of change arises in the
10 person because the gap between the behavior and the environment has become too great and
11 the predictive error has become too big to ignore. This is a separateness stage as the internal
12 pattern matching is being examined for sources of error. Once the person has identified that
13 the predictive model is not working they move into the next stage known as preparation. This is
14 a connectedness stage where the person scans the environment looking for better predictive
15 models. This is where a person may consider stopping the behavior on their own or contacting
16 a support group such as AA. The action stage is next and is a separateness stage as the new
17 internal model that was chosen in the preparation stage has been adopted and is tested against
18 the environment. The final connectedness stage is the termination stage where the new
19 predictive model has been integrated fully into the model of environmental interaction and the
20 behavior change cycle is complete with a period of sobriety.
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26 Discussion of the maintenance stage of the Transtheoretical model was intentionally held until
27 this point because the UTME would interpret this stage as an indication of social influences on
28 the behavior of the person moderated through quorum sensing. It is the contention of this
29 theory that a person will adapt their behavior to the environment they are engaged with and
30 when they try to separate themselves from the social behavior of their peer group there is
31 pressure from that peer group not to change. During the maintenance stage the person is
32 fighting against both internal and external predictive models in other words they are literally
33 going against the herd. At this point the individual may change the social group they participate
34 in or the social group may reject them for the lack of participation in the shared behavior that
35 defines the group. This interaction between individual and social behavior may serve as a focus
36 for a new class of socially directed interventions.
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41 **Contributions and limitations**

42 This new theory is based on the rapidly maturing science of complexity and a set of complexity
43 science concepts that have already been validated and are in widespread use. The contribution
44 this theory makes is two-fold, the first is in the consolidation and restatement of already
45 successful applications of complexity theory to demonstrate commonalities in meaning
46 emergence in all systems through a unified definition of process. Having a unified theoretical
47 platform allows the application of the common process to extend current understanding and
48 potentially open whole new areas for exploration and intervention. Secondly, the theory makes
49 a significant contribution in tying together the mathematical and conceptual frameworks of
50 complexity when most papers on complexity in health separate them. In this theory, both
51 mathematics and natural language are legitimate descriptors of phenomenon subject to
52 scientific inquiry. At the same time this theory limits itself to conceptual language that can be
53 strongly connected to an underlying mathematical principle. A significant question that the
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3 theory does not answer is whether nature is fundamentally mathematical and can be explained
4 with a single complexity algorithm or if mathematics is just another language for describing
5 nature and other language systems such as concepts are also needed for more comprehensive
6 understanding.
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9 Major implications of the theory is that if one part of the system is introducing a large amount
10 of predictive error into the system, that error will propagate throughout the system decreasing
11 the overall stability and health of the system. This will cause the entire system to be
12 evolutionarily driven by the minimization of predictive error and the health of one part of the
13 system is dependent on the health of other parts and cannot be separated either
14 mathematically or conceptually. This could lead to new understandings on how the evolution of
15 human social systems progressively minimizes predictive error.
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19 Validation of the theory will come from a combination of advancements in complexity
20 mathematics and the design of qualitative studies verifying the conceptual components of the
21 theory. Any validation by traditional scientific methodologies that remove subjectivity will be
22 difficult as the theory says that human subjectivity is an inherent part of meaning emergence
23 and the evolution of health. The most interesting studies will likely be in the area of social
24 evolution and the impact of prevailing social memes such as paternalism and racism on the
25 health of individuals and social systems.
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29 This is a general theory and is being presented in a nursing journal not only because the author
30 is a nurse but because the nursing profession is well positioned to take advantage of the
31 advancements here. Nursing theory is naturally holistic and at its best considers the life story of
32 the person receiving care. This theory provides an additional conceptual framework to see how
33 individual life stories become woven together to create the group narrative. This integrated
34 conceptual framework will give the nursing profession new avenues to understand and work at
35 both individual and global levels.
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Steps on predictive path

System	Level	Connectedness External pattern	Separateness Internal representation
DNA	Molecular	Repressed inactive	Activated
Bacterial	Cellular	Roll	Run
Brain	Organ	Attention	Default network
Herd	Social organization	Search	Find

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