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Original Article

The First Law of Psychology is the Second Law of Thermodynamics: The Energetic Evolutionary Model of the Mind and the Generation of Human Psychological Phenomena

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Abstract

Entropy is the primary adaptive problem that life forms must solve; consequently, evolutionary processes have crafted intelligence systems that are fundamentally designed to acquire, manage and direct energetic resources toward the maintenance of life processes and the attainment of life-stage specific goals. The behavioral intelligence systems of animals function primarily as predictive bioenergetic cost/benefit analysis systems so as to ensure that the energetic costs and risks of behavior do not, on average, exceed the adaptive benefits behavior confers. In humans, the planning of energetically viable behavior is accomplished by 'the mind', the neurocognitive component of the behavioral intelligence system. The energetic evolutionary (EN) model of the mind, briefly reviewed herein, reflects this line of reasoning.

The EN model was developed in accordance with the laws of thermodynamics and evolution, and constructed in alignment with contemporary neuroscientific findings. It provides a powerful explanatory framework for robust phenomena across the various subdisciplines of psychology and related fields of social science; moreover, the EN model reflects a neurocognitive architectural design that is in phylogenetic alignment with our animal ancestry, extending back to the appearance of bacteria. It embodies a predictive cost/benefit problem-solving logic that solves the constraints imposed by entropy in an ongoing and life stage-specific manner.

A critical design feature of the EN model, the adaptive representational network (ARN), conceptualizes the functional complexing in neocortical representational networks of the essential information required to facilitate adaptive behavior in evolutionarily recurrent as well as novel environments: internal state, environmental, behavioral, and outcome information. The configuration of this informational complex is similar to that which has been shown to support adaptive behavior in animals as evolutionarily ancient as bees; within the EN framework, the same energetic behavioral problem-solving logic and elemental information configuration is assumed to have been phylogenetically retained throughout human evolutionary history, and is proposed to have the capacity to support human psychological and behavioral intelligence.

ARN are considered to be essential units of intelligence, with each unit intrinsically encoding behavioral energetic cost/benefit information, and 'causality' -- temporal contiguity of a bioenergetically-meaningful interaction between the individual and its physical and social environment). On the basis of the known hierarchical and associative properties of representational networks in the human neocortex, and the informational structure of the proposed ARN complex, the EN model provides an explanatory framework for a vast range of psychological phenomena, and concerted physiological, psychological and behavioral phenomena, within a principled energetic framework. It is proposed that this physically-principled model of the mind serves as a first step toward reconciling the disparate knowledge bases within the psychological sciences, and vertically integrating the social sciences, humanities and arts with the life and physical sciences.

[Note: This paper presents a review of the energetic (EN) model of the mind, which has been previously described in two publications: A preliminary scientific exposition of the model appeared in the *Proceedings of the National Academy of Sciences, USA, (Evolution)*, La Cerra and Bingham, 1998 (therein referred to as "an alternative" evolutionary model); and a description of the entropically-driven evolved design of life intelligence systems, with primary emphasis on the human intelligence system and neurocognitive architecture, appeared in *The Origin of Minds* (La Cerra and Bingham, 2002). Written for a general and interdisciplinary readership, *The Origin of Minds* provides a more detailed explanation of how entropy drove the design of the human mind, and why the second law of thermodynamics is the first law of psychology.]

A biological explanation should invoke no factors other than the laws of physical science, natural selection, and the contingencies of history.

George Williams
Adaptation and Natural Selection, 1966

… the mind arises from an evolved intelligence system that was designed to be responsive to any number of adaptive problems (including those yet to emerge in the evolutionary future). But the fundamental problem it was designed to solve – the problem that drove the elemental logic inherent in all intelligence systems on earth—was one imposed by the universe at large, by the physical laws of energy.

La Cerra and Bingham
The Origin of Minds, 2002

Introduction

"In the distant future I see open fields for far more important researches. Psychology will be based on a new foundation, that of the necessary acquirement of each mental power and capacity by gradation."- *The Origin of Species, 1859.*

Darwin accurately predicted that his theory of evolution by natural selection would someday transform the study of psychology, but his belief that each mental power and capacity was necessarily acquired by gradation was incorrect. Darwin's research focused on the process by which nature crafted somatic adaptations – bodily tools that facilitate the performance of specific adaptive tasks. In transposing his remarkable insights about natural selection to psychological phenomena, Darwin conjured up for many sociobiologists an image of a mind stocked with 'mental power' modules – so called 'domain-specific adaptations', an image that persists today in the form of the implausible Evolutionary Psychology (EP) model of the mind (cf. Cosmides and Tooby, 1987, 1992; Tooby and Cosmides, 1995, 1996; see La Cerra and Bingham, 1998, for a refutation of the EP model and the EP research methodology employed to garner evidence for it; see Quartz and Sejnowski, 2002, and Sherman and Reeve, 1997, for additional relevant criticisms). The mind arises from innumerous adaptations, but none of them are 'mental-power' specific (as Darwin thought almost 150 years ago and Evolutionary Psychologists continue to believe today). The key to understanding the evolved nature of the human neurocognitive architecture has been to take an historically deeper, energetically-principled view of life intelligence systems, and to consider first the most important adaptive problem our ancestors had to solve -- the problem all life forms must continually solve: Entropy (La Cerra and Bingham, 2002).

Entropy is the Primary Adaptive Problem - Energetic Management is the Primary Adaptive Solution

Life forms are highly-organized physical systems that do work. In order to counter entropy – the tendency toward randomness in physical systems – the energetic input must exceed, on average, the energetic output; if it does not, life stops. As such, all life forms have evolved mechanisms designed to solve the adaptive problem imposed by the second law of thermodynamics; this is evident at every level of organization, from the cellular (e.g., the free energy harnessed in the process of cellular respiration; Campbell, Mitchell and Reece, 1999) to the system level; and it is perhaps most clearly evident at the level of the behavioral intelligence system that gives rise to the human mind (La Cerra and Bingham, 2002).

Ongoing energy management – its acquisition, storage, allocation, distribution and utilization for all life processes—was the most critical adaptive problem that ancestral life forms had to solve, and this priority is reflected in the evolved design of both plant and animal intelligence systems (La Cerra and Bingham, 2002; also see Allman, 1999). The human intelligence system is hugely complex, and while it consists of innumerous neural adaptations, all of them are, in their origins, augmentations of the life history regulatory system (LHRS). This system, which is present in one form or another in all life forms, manages bioenergy, in the moment and over the life span, and -- guided by information coming in from the environment and internal milieu -- regulates the unfolding of life history stages (La Cerra and Bingham, 2002; also see Finch and Rose, 1995, for a comprehensive comparative review of the physiological architecture supporting life history regulation). [1] Amongst these adaptive neural appendages to the LHRS is a complex set of adaptations that comprise the behavioral intelligence system -- the component of the human intelligence system that generates psychological and behavioral phenomena.

The Catch 22 of Behavior: Why Animalian Behavioral Intelligence Systems are Predictive Bioenergetic Cost/Benefit Analysis Systems

Plants are autotrophs, self-nourishing life forms. They use chlorophyll, light, carbon dioxide, and water to photosynthesize carbohydrates in order to solve the problem of energy acquisition. In plants, energy is managed and distributed for life-stage appropriate tasks by an integrated hormonal life history regulatory system (Finch and Rose, 1995). Because they are stationary, the resources plants require for photosynthesis must be available locally. Animals, on the other hand, are heterotrophs, life forms that depend on the consumption of plants, animals or both in order to meet their bioenergetic requirements. Evolution has conferred upon animals the adaptive advantage of behavior -- which enables them to forage for resources that are not locally available, to find shelter in order to conserve heat, and to otherwise manage energy in an efficient manner. But there is a cost for this benefit: behavior itself requires energy. Consequently, animals have evolved intelligence systems that function, first and foremost, as predictive bioenergetic cost/benefit analysis systems (La Cerra and Bingham, 1998, 2002).

The Design of Animalian Behavioral Intelligence Systems in Phylogenetic Perspective

The hallmark of animalian intelligence systems is the capacity to predict the likely costs and benefits of alternative paths of behavior. (La Cerra and Bingham, 1998, 2002). This logic is evident in our most ancient ancestors, bacteria.

Prototypical Centralized Behavioral Intelligence Systems: E. Coli is a single-cell organism with a single molecule of DNA. This simplest of animals exhibits a prototypical centralized intelligence system (see Allman, 1999), a system that has the same essential design characteristics and problem-solving logic as is evident in all animalian intelligence systems, including humans (La Cerra and Bingham, 1998, 2002). The bacterium's cell membrane is covered with receptors for sensing different environmental stimuli – different types of toxins and nutrients. The rate of change in receptor occupancy (toxin vs. nutrient) is calculated by a central information processor – an integrated protein circuit that serves as a 4-second 'memory representation'; this protein circuit directs the flagellum, the bacterium's motor component, to move the organism toward the region where it most recently detected the lowest cost/benefit (toxin/nutrient) ratio (La Cerra and Bingham, 1998, 2002; Berg and Brown, 1972; Koshland, 1977; also see Allman, 1999). These three components – environmental sensors, central processor, and motor effector, act in service the LHRS. In a very real sense, the central component of the bacterial intelligence system is instantiating a 'representation' -- a neural activation vector that conveys information -- of the costs and benefits of a recent behavior, and then utilizing this stored information to direct its optimal behavioral course into the future (see Churchland and Sejnowski, 1993, and Quartz and Sejnowski, 1997 for discussions of the nature and functional characteristics of representations).

Simple Centralized Behavioral Intelligence Systems: The predictive capacity of the centralized intelligence systems of animals has been enhanced by various evolved design features, but the most important of these is an adaptation found in even the simplest centralized nervous systems: a region of highly functionally plastic tissue specialized for the purpose of instantiating representations. In the honeybee brain, the mushroom bodies and protocerebral lobe serve this function. This substrate, acting in concert with the integrated intelligence system in which it is situated, allows for the retention of essential information about the probabilistic relationships between (1) the internal state of the organism, (2) specific sensory inputs, (3) behavioral responses, and (4) the registered adaptive value of the outcomes of these behaviors. Future foraging is guided by these networks, which are updated as a function of experience in the environment (i.e., new outcome information).[2] [See La Cerra and Bingham, 1998, for a detailed description of the neuroanatomical substrates that support the experientially-induced instantiation of neural network representations in the honeybee brain, and a conditioning description of the functional operation of this mechanism. See Real 1991,1994; Hammer and Menzel, 1995; Hammer, 1997; Hammer and Menzel, 1995; Hammer, 1997; Moller, 1995, for the original studies upon which this argument is based. Also, see La Cerra Bingham, 2002, especially pp. 9-10, 15-16, 48-53, 124, and 192, for a version of this argument written for general and interdisciplinary audiences).]

Note that this simplistic centralized behavioral intelligence system is a network construction system, composed of neural adaptations that have reduced the behavioral problem-solving space, eliminating the so-called 'frame problem'. Bootstraping off of a core instinctual mechanism and yoking information from sensory systems, behavioral motor systems, and the life history regulatory system (which establishes both the initial internal state of diminished glucose levels, and the post-behavioral outcome state of resumed glucostatic equilibrium), this simple behavioral intelligence system constructs ARN for foraging in the bee's prototypical 'cortex'. A direct analogy exists between the construction of ARN in the functionally plastic mushroom bodies and protocerebral lobes of bees and the construction of ARN in the neocortex of mammals.

Complex Behavioral Intelligence Systems and the Human Mind: The mammalian behavioral intelligence system is significantly more complex than the bee's, but the general neurocognitive architectural design is strikingly similar and the core bioenergetic problem-solving logic is identical (see La Cerra and Bingham, 1998 for a concise description of the neuroanatomic circuitries that instantiate and utilize ARN, or La Cerra and Bingham, 2002, for a description for general and interdisciplinary readership). ARN functionally complex representational information about 1) the internal state of the individual – physiological and/or emotional, 2) the external environment – physical and/or social, 3) behavior and/or 'thought', an internal representation of behavior, and 4) the registered outcome of the behavior or thought. Given the known associative properties of representational networks, ARN units form a relational database of information that has an intrinsic integrative circuitry, as well as a behavioral generation component: a particular internal state or an environmental stimulus situation associatively 'selects' for a matching ARN; the ARN activated has an intrinsically associated, activationally-linked behavioral component which has produced the desired outcome in the past. If there is no appropriate 'match', the activation results in forebrain 'modeling' of alternative potential paths of behavior; the associated cost/benefit information 'selects' for the optimal option (experientially, the predicted outcomes of the alternatives may be felt as 'gut level feelings' that one choice is better than another).

Bootstrapping off of a small set of infantile instincts, the human behavioral intelligence system can construct and modify ARN that have the capacity to support an adult repertoire of behavior – one that solves evolutionarily recurrent behavioral problems, yet is completely customized to the individual on the basis of his or her unique life experience. Moreover, given the hierarchical and associative properties of networks, ARN, functioning within the greater behavioral intelligence system that constructs and utilizes them, have the capacity to serve as the building blocks of a vast range of psychological and behavioral characteristics and capacities. These include the formation of prototypes, self representations, self variants, self-estimators' (e.g., self esteem values), personality configurations, inferential circuitries – including the so-called 'Theory of Other Minds Modules'. [Descriptions of the way in which this system functions to give rise to these capacities can be found in La Cerra and Bingham, 2002.] This ARN-behavioral intelligence system also provides an explanatory mechanism for the acquisition and generation of language (see La Cerra and Bingham, 2002, Ch. 3).

At every level of the human behavioral intelligence system there are design features that act to counter entropy and mitigate the energetic constraints on life, from cellular respiration in neurons, to reuptake mechanisms in synapses, to a functionally plastic neocortex that can instantiate and modify a set of adaptive networks that precisely mesh with the unique life of an individual. At the level of the general behavioral intelligence system there appears to be an overarching energetic viability monitoring mechanism that has the capacity to completely dampen behavioral motivation and effectively prevent the generation of overt behavior when there has been a nonviable energetic cost/benefit accounting over a significant period of time. Sequential ARN encode ongoing experience, forming the episodic memory record of an individual's life. Because ARN are encoding the history of an individual's behavioral successes and failures, the episodic memory record is also an accounting of the relative energetic costs and benefits of the experiential trajectory of his or her life. The basal gangliar system, which constructs and utilizes ARN in the generation of thought and behavior, has the functional capacity to access and assess temporal sequences of these ARN – to perform an energetic cost/benefit analysis of the efficacy of a behavioral path over time. Consequently, global recalibrations of the behavioral intelligence system, such as those seen in individuals suffering from depression, are likely to be adaptive responses, preventing the individual from suffering the energetic depletion likely to result from the ongoing pursuit of a nonviable life path. [For a detailed discussion of anxiety, depression and mania within the framework of the EN model, and electroconvulsive therapy findings that support this hypothesis, see La Cerra and Bingham, 2002, Ch. 6.]

In Conclusion

The second law of thermodynamics has crafted the functional design of the human intelligence system, and the psychological, behavioral and cultural products of the human mind faithfully reflect its influence. The architectural design and underlying problem-solving logic of the human behavioral intelligence system is phylogenetically ancient in its origins, a tried and true solution to the constraints on life imposed by entropy.

Darwin's belief that each human mental power and capacity was acquired by gradation was a reasonable assumption to make a century before scientists began unveiling the nature and design of the mammalian behavioral intelligence system. At this point in the history of collective science, however, it is time for students of nature – and particularly Evolutionary Psychologists – to *think again* about the probable evolved design of the human neurocognitive architecture. Evolutionary Psychologists have acknowledged that the human mind probably includes 'one or a few general mechanisms' ; likewise, they have acknowledged the necessity for an 'integrative circuitry' that would arbitrate between the hypothesized inherited domain-specific modules that populate their conceptual model of the mind. By excluding these hypothesized mechanisms from their research efforts and model testing, however, they have led the search for a physically-principled understanding of the human mind down a blind alley.

The entropically-crafted design features and problem-solving logic that characterize the EN model of the mind are apparent in the behavioral intelligence systems of all of mammalian species that have been investigated in the course of research on the biological basis of learning. And they are apparent in the psychological, behavioral and cultural products of the human mind. Scientific psychology is on the cusp of a seismic shift into this energetic framework, and in the foreseeable future, the social sciences will be rectified with the physical laws of energy. It is only a matter of time before students of human nature consensually agree that the first law of psychology is the second law of thermodynamics.

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Notes

1. In mammals, the LHRS includes the endocrine system, primarily the hypothalamic-pituitary-adrenal-gonadal axis, brain areas including the median eminence, and genes.
2. Neural informational representations of both the internal physiological state of the honeybee

and the outcome of its behavior on its internal state are established by LHRS components. This core system manages bioenergy and regulates both the organism's immediate internal physiological state requirements, as well as life-stage specific requirements (e.g., development, reproduction, etc.).

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