Medical Research Archives

ESMED European Society of Medicine

OPEN ACCESS

Published: September 30, 2022

Citation: Livneh H, Rumrill P, et al., 2022. The Concept of Entropy within the Context of Psychosocial Adaptation Following the Onset of Chronic Illness and Disability: History and Nature of Entropy and Its Psychodynamic Implications, Medical Research Archives, [online] 10(9). https://doi.org/10.18103/mra.v10i9.3017

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DOI
https://doi.org/10.18103/mra.v10i9.3017

ISSN: 2375-1924

RESEARCH ARTICLE

The Concept of Entropy within the Context of Psychosocial Adaptation Following the Onset of Chronic Illness and Disability: History and Nature of Entropy and Its Psychodynamic Implications

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ABSTRACT

The second law of thermodynamics, also known as the law of entropy, posits that all physical processes, in a closed system, will evolve over time toward a state of higher disorderliness and randomness. Isolated efforts to explore and examine the application of this law to human psychosocial processes (psychological entropy) have been undertaken only since the middle of the 20th century and have been limited in scope. In this article, the authors explore several domains where psychological entropy (PE) may be helpful in elucidating the nature, structure, and processes inherent in psychosocial adaptation to chronic illness and disability (CID). This article is devoted to providing the reader with a brief outline of the scope of the law of physical entropy through highlighting its historical milestones, and examining its relationships with such concepts as chaos, flow of time, informational systems, the dynamics underlying denial, and finally, its link to a selected group of psychodynamic and cognitive perspectives. In a companion article, we explore potential clinical applications.

Keywords: entropy, psychosocial adaptation, adjustment, disability, chronic illness

Impact

- In order to elucidate the nature, structure, and processes inherent in psychosocial adaptation to chronic illness and disability (CID), in this article we provide a brief outline of the scope of physical entropy (PE), highlight its historical milestones, and examine its relationships with concepts historically linked with psychosocial adaptation to CID.
- In this article we also discuss recent efforts to link PE to psychological entropy, a construct that has been gaining popularity in psychology and merits attention in the study of adaptation to CID.
- In a companion article, we explore potential theoretical, clinical and research applications for rehabilitation professionals relevant to the application of PE, and psychological entropy, in the context of psychosocial adaptation to CID.

It would appear, at first glance, that any attempt to apply laws and processes from the field of physics to psychological phenomena, let alone the intricate dynamics and processes that undergird psychosocial adaptation to chronic illness and disability (CID), is likely to confront daunting conceptual, empirical, and technical barriers challenges. When examining the nature of these two domains, it becomes readily apparent that one of the primary distinctions between physics, as reflective of mathematically-driven, ostensibly objective, "impersonal" sciences, and psychology, or as more pertinent to the present discussion, the psychosocial adaptation process following the onset of sudden, severe CID, as an exemplar of more phenomenology-driven, experiential, "personal" sciences, is that whereas the laws, rules, and principles that apply to the former (e.g., the three laws of thermodynamics, Kepler's three laws of planetary motion, Newton's three laws of motion), they hold only fleeting relevance to the latter.

Despite these arguably unbridgeable differences, we do not advocate the existence of dichotomous chasm between the two fields. Indeed, we believe that certain physical and chemical processes, regulations and laws, which were originally discovered in the physical world (both the microscopic and the macroscopic), possibly could, with discretion and caution, be harnessed to shed light on human cognitions, emotions, behaviors, motivation and overall functioning. Indeed, it should be noted that various forms of such integration have, in the past, produced important insights, research, and shifts in the conceptualization of various psychological processes that have led over time to greater understanding. Examples of such increased understanding in the specific context of psychosocial adaptation to CID include the application of chaos theory, conceptualizations of the grief process, perspective on energy mobilization, and diverse models of disability and human functioning, which are each discussed further in this paper.

Kurt Lewin, whose direct and indirect (through his students) contributions to the current understanding of psychosocial adaptation processes remain relevant and influential, successfully applied field theory, derived from theories previously developed in the physical sciences and concerned with the results of the interaction of multiple forces, in his analysis of human psychological and social processes (see e.g.,[1-3]). The question is whether such application is productive in terms of expanding or increasing knowledge and understanding; is generative, in terms of producing testable propositions; and is valuable, in terms of developing clinical interventions. The extent to which the present application meets these criteria is at this point unknown, but the possibilities appear tangible. We recognize that in seeking to explore any possible parallel lines between the two domains of physics and psychosocial adaptation one must not overstep the logical demarcating boundaries. Acknowledging the limitations of this pursuit is a must.

In this article, then, the first of two, the authors seek to provide the reader with a succinct yet necessary review of the second law of thermodynamics, also known as the law of entropy. Discussed herein are the concept of entropy, its historical antecedents, and its relationship to chaos theory, the perception of time flow, and information theory. In the concluding segment of the article, entropy is discussed as to its relationship with psychodynamic processes, including denial, as well as more recent efforts to view entropy, a decidedly physical-chemical construct, through the prism of its human counterpart, psychological entropy.

Entropy: Conceptual Foundations

The Nature of Entropy

No single or agreed upon definition of entropy exists, and there is a wide range of conceptualizations and measures of entropy.[4] Underlying all views on entropy, however, are several common themes, and these include disorder, information, complexity, nonlinearity, dimensionality, and self-organization. Entropy (typically regarded as a measure of a system's disorder) is also known as the Second Law of Thermodynamics[1]. It maintains that, in a closed system, all physical processes tend to evolve toward a state of higher disorderliness. The law, however, must be regarded as a statistically based law, rather than an absolute one.[5-7] Entropy is, therefore, an indicator of a system's (dis)organization, randomness, uncertainty, unpredictability, and even complexity). Generally, the higher the system's energy level, the less structure, distinction, and differentiation exist in its matter. Ultimately, increased entropy indicates the system's impending operational cessation or "death".[8,9] Entropy is intimately associated with time, in that entropy in a system, including the universe itself, was lower in the past, and gradually increases toward the future. This temporal unfolding signals a direction of time in the universe, often recognized as "the flow of time".[10] Furthermore, the past may then be equated with "cause" and certain cognitive processes (e.g., memories), whereas the future is equated with "effect" and separate cognitive processes (e.g., anticipations, predictions, hopes, uncertainties).[11,12] [2]

A distinction exists between entropy in an open system (e.g., the universe) and in a closed or isolated system (e.g., the earth, the human body). In an open system, energy, or matter, is permitted to be exchanged with the external environment. It is only the *combined* energy of both system and the external environment that is forbidden from decreasing over time.[13] The implication of this is that, in the context of suitable isolated environments, low entropy and spontaneous emergence, and maintenance of ordered complexity and self-organization, including the emergence and existence of life, are permitted by the second law.[13] Indeed, living systems, rather than aimlessly dissipate energy, self-organize themselves to create more efficient and adaptive use of energy.[14] This unfolding pattern is permitted as long as entropy is exported into the external environment to compensate for the local increase in order. Life, indeed, is organized complexity.[15,7] [3]

The exploration of complexity has lead researchers[16,17] to suggest a new construct, that of optimum variability. These researchers adopted the notion that individuals are self-organizing systems, and healthier and more adaptive self-structures are also more complex, differentiated and flexible (display less simple, rigid and overlapping parts). They, however, also recognized that greater levels of dimensionality, turbulence and, therefore, entropy, are associated with healthier and more adaptive living systems, while lower levels of entropy may suggest rigidity and stereotyped behaviors. Relatedly, overly complex systems, may created unwanted, or wasted, energy, thus yielding a lower survival value.[16] These researchers, then, reasoned that an optimal middle range of functional complexity exists, termed by them as the principle of optimum variability, or optimal complexity. This adaptive range can be envisioned as the bottom region of an inverted u-function, or a curvilinear-shaped region, that affords the greatest dynamic stability, health and SWB. Self-organized systems indicate a level of complexity that adheres to a fine balance between order and disorder, rigidity and fragmentation.[16,17] [4]

Historical Landmarks of the Entropy Construct

The evolution of the entropy construct can be traced to the contributions of three 19th century scientists. The first was Sadi Carnot (1796-1832), a French engineer and physicist, who maintained that steam engines function due to the passage of heat from hot to cold settings, thus recognizing the basic principle that undergirds the second law of thermodynamics. He further realized that, whereas mechanical energy can be converted into heat, it would be impossible for heat to be fully converted into mechanical energy, thus explicating the limits imposed on the efficiency of mechanical energy, and the implication to the existence of a certain directional preference for thermodynamic processes.

The second contributor was German physicist Rudolf Clausius (1822-1888), who expanded upon Carnot's insight by arguing that the arrow of time is linked to the concept of heat. His understanding of this relationship suggested that when we experience a difference between past and future, heat becomes an integral component of this unidirectional flow. Clausius was also responsible for introducing the term entropy (indicated by the letter S) into the physics lexicon as a measurable quantity that never decreases in value. Maximum entropy, according to him, can only be reached at a total thermodynamic equilibrium. At this static point, useful work can no longer be performed as no motion of energy is possible.

Finally, Ludwig Boltzmann (1844-1906), an Austrian biochemist, who, in his statistical kinetic model of gases, understood that it is thermal agitation that passes heat from hot to cold objects and environments. He realized that the growth of entropy (designated by him as H) [5] is a reflection of the natural process of increase in a system's disorder. The passage of time from past to future is tantamount to a naturally occurring process of a gradual decrease from specific or "special" situations to ones of greater disorder. Using his statistical model, he envisioned a system composed of numerous *microstates* that, in combination, comprise a *macrostate,* and where the larger the plausible number of possible microstates in that system, the higher the entropy value.[18,13,19,12]

Entropy and Chaos

Entropy in a non-homeostatic, dynamic, non-linear, open (that is, chaotic) system presents a complex picture since even minor changes in the external environment are capable of producing major changes in the system. Hence, a system in nonequilibrium, by definition, fosters dissipation of energy and brings "order out of chaos" throughout the living world.[14(p.287)] These dissipative structures are novel, self-organizing systems and may be regarded as islands of order in an ocean of disorder (that is, chaos), thus capable of increasing local order at the expense of larger environmental disorder.[20,14]

These self-organizing systems also include cognitive-behavioral systems of higher complexity that are responsible for creating and sustaining cognitive structures whose task is to cope with physical and interpersonal environmental challenges.[18] It was argued earlier that the second law of psychodynamics permits the emergence of low-entropy, self-organized and complex processes, in isolated (i.e., closed) systems, as long as the encompassing system's (external environment) entropy increases. In these self-organizing systems, there is a tendency to reach a critical "bifurcation point".[19,14] At this point of maximum entropy of the system's evolution, the system's behavior is no longer predictable, and two processes may emerge, often referred to as "phase transition". The system may experience an abrupt, nonlinear, leap from a state of chaotic turbulence to a novel state of greater self-organization, stability, higher order, complexity and adaptive functioning, or it may descend into chaos, instability, and maladaptive functioning.[13,8,19] Therefore, applying chaos theory to human behavior, the emergence of adaptive coping strategies serves as a unique attractor that ushers in and maintains psychic stability.[8] On the other hand, when maladaptive coping strategies prevail, chaotic functioning persists. [6]

The spread of life, indeed, represents a local decrease in entropy that is characterized by an abrupt ascent to greater complexity and self-organization. Life, then, is a localized departure from global equilibrium and can exist only in a state of nonequilibrium where continuous exchange of energy and information with its external environment (i.e., in an open system) is possible, thus yielding new ordered complexity and reintegration.[21,8] Many complex life systems, however, as they gradually become dysfunctional over time, manifest loss of complexity and increased degradation.[22] To sustain life, then, energy is imported from the environment, whereas entropy is exported out of the system. Masterpasqua and Perna, further posited that death (as well as Freud's "death instinct") is a manifestation of a biological system's inability to engage with its external surroundings, thus descending into disintegration and eventual annihilation. [7]

Entropy and the Flow of Time

The asymmetry of the direction of increased entropy (future-oriented) posits a unidirectional "flow of time". The thermodynamic arrow of time, then, indicates a progression from order (low entropy of the past) to disorder (high entropy of the future).[23] Indeed, the universe *appears* to progressively evolve into more structured, organized, elaborate and complex status, in matter and energy, thus indicating a unidirectional arrow of time.[24] This irreversible arrow of time occurs only in open systems, such as the universe itself. Time reversibility, however, is permitted in closed, isolated systems since the laws of physics do not distinguish between the two.[10,25] It has also been argued[24,26] that it is the work of gravitational energy which is responsible for the appearance of structure and organization in the universe (as a counter effect to the second law). This energy is associated with aggregations of matter and is *negative* in nature, thus indicating that the implicated gravitational field contains negative entropy. This progressive, self-gravitating tendency of a system appears to reflect a fundamental principle of nature.[24]

Indeed, the notion of the arrow of time occupies a cardinal place in many physical, medical, biochemical, and psychological fields. Smolin,[27] for example, has maintained that several arrows of time may be distinguished. They include: (a) cosmological--which is associated with the increased expansion of the universe; (b) thermodynamic—which indicates that specific slices of the universe tend to become more disordered with the passage of time; (c) electromagnetic—where light proceeds from the past to the future, and we see its position in the present; (d) gravitational—where gravitational waves (also) proceed from the past to the future; (e) biological—which traces the lives of plants, animals, and people (birth → growth → death); and (f) psychological or experiential—when people experience time flow from the past, through the present, to the future. The psychological arrow of time explains why humans remember the past but not the future. It further elucidates our unidirectional experience of flow of time.[10 8]

Entropy and Information Theory

Information theory,[28] is a mathematical theory of communication built around the paradigm of entropy, thus relying heavily on the concepts of uncertainty, probability, and randomness. In the context of information theory, entropy can also be conceived as the amount of information that is present in the structure of a system,[29] or as the degree of disorganization within an informational system.[30] In the same vein, Davies[31] claimed that information is a measure of what a person knows (knowledge) whereas entropy is a measure of a what a person does not know (ignorance). Information, from this perspective, measures the degree of events' predictability in a dynamic system, whereas entropy measures the degree of events' unpredictability in such a system.[8] As a system's disorder increases, internal coordination among its various components decreases and information production becomes diluted. Information dilution also indicates increased uncertainty as the number of possible outcomes increases.[32] Maximum entropy implies minimum, or missing, information. Similarly, as entropy increases, the number of possible outcomes for a random variable also increases.

In his mathematical model of information, Shannon[28,33] argued that increased information in a system parallels a decrease in its entropy, thus information may be viewed as the reciprocal of entropy. Put differently, it can be posited that although natural environmental processes are linked to a gradually increasing entropy, living organisms survive by continuously importing information (low entropy, highly organized matter and energy) from their environment (the earlier discussed concept of negative entropy), thus steadily reshaping themselves to remain alive and functional. Negative entropy, then, is not only the harbinger of life, but also the essence of information. [9] In order to function properly, a biological-based informational system, such as human cognition and memory, requires decreased entropy. Indeed, more organized and efficient brain and nervous system activities require that initial random connections among neurons achieve a more organized, complex, and stabilized interconnectedness level over time.[19] In this broader context of PE, increase in entropy can be viewed as an indicator of parallel losses of awareness, motivation, purpose, and meaning of life, as one's world view (both spatial and temporal) drastically shrinks and becomes narrowly fixated on certain themes, activities, and settings.

Psychodynamic Perspectives on Entropy

Among early psychodynamic theorizing on the nature of entropy in the context of biopsychological organizations, Klein[34] commented that the degree of entropy of a physical system is not equivalent to the degree of organization of a system used by biologists and psychologists. Similarly, Burgers[35] argued that humans are capable of distinguishing and acting upon certain states in a way that cannot be explained by physical and chemical reactions alone, thus implying that the link between entropy and both biological life and psychological functioning is inherently confounded and must be considered with caution. Finally, Szasz[36,37] maintained that the concept of entropy in the context of biological, psychological, and informational growth is unsupported. He argued that since increase in chemical complexity is equated with a decrease in entropy of a life system, an increase in psychological organization (both intrapersonal and interpersonal) should be paralleled by a decrease in its entropy. However, whereas the process of biological metabolism is characterized by a reciprocal change in the biological complexity of living organisms (increase) and the consumption of food products (decrease), such a unidirectional change cannot be assumed for processes inherent in psychological growth. In the context of the interpersonal (dyadic) context, Szasz[36] surmised that both interacting individuals can experience a simultaneous growth in psychological organization.

Among more recent efforts to address the concept and veracity of psychological entropy, two stand out. [10] First, Dishion et al.,[38] approached the topic from an experimental cognitive-interpersonal perspective. These authors employed a longitudinal research design to investigate the dyadic friendships/relationships between the degree of entropy and future, adult behavior, among two groups of adolescent boys, one of which exhibited antisocial behaviors, while the other manifested well-adjusted behavior. Entropy, in this context, was defined as the amount of information in a message, as measured by the logarithm of the number of possible equivalent interactive messages. In other words, low entropy scores reflect an organized and predictable dialogue (and, therefore, required less information to predict reactions), while high entropy scores indicated a disorganized and unpredictable pattern of dyadic interactions, thus requiring more information to predict reactions. From their findings, Dishion and his colleagues concluded that low levels of adolescent entropy were suggestive of organized and more predictable interactions between individuals in dyadic relationships, and that high levels of entropy (i.e., higher disorganization of dyadic interactions) were more prevalent among antisocial behaviors in both adolescence and adulthood. Yet, longitudinal findings further indicated the existence of an interaction effect between adolescent entropy and dialogues centering around deviant content, such that adolescents with low entropy (well-organized) scores, but with higher levels of deviant dyadic content, were more likely to exhibit antisocial behaviors during adulthood. In a later paper, Dishion et al.[39] expanded upon their earlier research in which low entropy was viewed as reflecting an organized and predictable interaction pattern, while high entropy indicated a more chaotic, uncertain and disorganized patterns. In this study, future antisocial behavior among adolescents was examined based on reports from the youths and their parents two years earlier. Both entropy and conflict resolution were assessed. Findings showed an interactive effect among the two predictors, on future antisocial behavior, such that adolescents from families with high levels of problem solving (higher resolution, better organized, more peaceful) and lower entropy, were less likely to increase antisocial behavior in the following two years. The authors speculate that since resolution of interpersonal conflicts requires appreciable degree of emotional regulation, while at the same time low entropy requires energy, families with poor emotional regulation and depleted energy resources (high entropy), are more likely to fail in solving their problems and subsequently spiral into increased negative behaviors. [11]

A different perspective on psychological entropy was offered by Hirsh et al.[18] These authors, influenced by Shannon's and Weiner's information theories, sought to investigate the nature of uncertainty which, they maintain, springs from the notion that the more microstates exist in a system, the more uncertain (in humans, experienced as anxiety) its functioning becomes (in humans, manifested as inability to successfully perform work). The model is anchored in four tenets: (a) uncertainty, manifested by perceptual and behavioral ambiguities, creates both psychological discomfort and adaptation challenge, and therefore, prompts the individual to successfully manage the situation; (b) uncertainty and psychological entropy emanate from conflicting perceptual and behavioral possibilities (termed, by the authors, "affordances")[12], and increase as the number of barriers to reaching personal goals become more prominent; (c) uncertainty can be constrained by adopting appropriate goals and beliefs, since competing possibilities are reduced (goals operate as attractors in a self-organizing behavioral system); and (d) chronic uncertainty is subjectively experienced as anxiety (manifested as heightened noradrenalin release), and uncertainty-triggering events (e.g., traumatic experiences) that threaten central life goals and belief systems result in greater anxiety. In sum, then, psychological entropy is inversely associated with one's adaptation level in the world and is manifested in the (in)ability to perform useful work and pursue goal-oriented rewards and behaviors.

An extension of Hirsh's[18] entropy model of uncertainty was offered by DeYoung,[40] who also incorporated notions from the field of cybernetics (people are goal-directed, self-regulatory systems),[41] and neurophysiology (dopamine levels exert an influence on higher order personality factors, such as openness to experience, thus rewarding uncertainty). In DeYoung's model, PE is viewed as both aversive (anxiety-producing), as well as rewarding. More specifically, unpredictable events trigger uncertainty and anxiety about achieving a goal, thus increasing PE, but, concurrently, inherent attributes such as extraversion and openness to experience, which are linked to dopaminergic functioning, also act to transform the innate treat of uncertainty into incentive reward. Finally, an innovative perspective on the role PE may play in attitudinal research was advanced by Dalege et al.[42] The authors proposed several postulates to explain their model, including: (a) attitudinal instability and inconsistency are a natural (neutral, ambivalent) state of attitudes and, therefore, represent attitudinal entropy; (b) localized attitudinal energy can be used to evaluate the attitude's global entropy; and (c) applying force to a system, that is, directing attention and thought to an attitudinal referent reduces the attitudinal representations' energy level, and thus reduces attitudinal energy. Put differently, applying such (logic-driven, attention-focusing) force to a referent, results in obtaining attitudinal consistency, predictability, and stability toward that referent, and thus lowering entropy by avoiding psychological discomfort (high entropy). [13]

The energy-exchange quality of entropy also brings to mind the Conservation of Resources Theory (CRT).[43] Research has clarified the multiple ways in which the onset of CID constitutes a significant life stressor. The presence of a disability has the potential to affect an individual's health, cognitive and psychological functioning, personal relationships, long-term vocational outcomes, life outlook, and overall quality of life.[44,45] The experience of coping with a significant disability result in considerable psychological stress, which can serve to compromise one's medical treatment, exacerbate his or her disabling condition, and affect performance in a wide range of social roles.[46] The stress that is often inherent in coping with CID is a real and present threat to assets or resources that enable the individual to maintain a fulfilling life. This threat of loss or actual loss of resources causes individuals to conclude that CID will have multiple negative and uncontrollable (i.e., stressful) effects on their lives, a conclusion that only serves to further exacerbate the impact of disability on people's lives.[47]

The motive to create and preserve resources is central to the CRT.[48] Individuals are motivated to enhance their resources and to counter any events that might cause their diminution. Applied with respect to adaptation to CID, the CRT principles and corollaries maintain that people appraise the illness or injury condition as a severe and chronic stressor because its effects can lead to losses in four categories: personal, condition, object, and energy resources. Personal resources refer to characteristics of the person such as age, gender, racial/ethnic status, and educational level; psychological characteristics such as self-esteem, self-efficacy, sense of coherence, and resilience; and health characteristics such as the presence, severity, duration, and type of illness or injury symptoms. Condition resources pertain to the life statuses and roles available to the person in terms of social relationships that promote independence and quality of life (e.g., married, divorced), employment (e.g., fulfilling or unfulfilling work), and social support (e.g., supportive or unsupportive). Object resources refer to those tangible attributes of the person's environment such as housing (e.g., accessible or not) and transportation (e.g., sufficient or not). On the other hand, energy resources are tangible and intangible entities such as money, time, motivation, and effort that can be exchanged to acquire and build resources in the other three categories. Because resources exist in aggregate and can generate each other (e.g., employment provides income, condition and energy resources; good health increases personal and condition resources; income makes adequate housing and transportation more achievable, energy and object resources), any threat to one is a threat to all, with the cumulative outcome being drained resources, increased stress level and reduced quality of life for people with CID.[49,50] Effective adaptation, on the other hand, occurs when the person can either marshal existing resources in these categories or develop additional resources that add to his or her cumulative coping capacities.

Entropy and Denial

Although, at first glance, entropy (regarded as a physical-chemical concept) and denial (viewed as a psychodynamic construct) appear to have very little in common, closer scrutiny of their properties suggests otherwise. Undergirding both entropy and denial, one can find common elements such as: (a) information processing, (b) awareness (or lack thereof), (c) distortion (of order or reality), (d) homeostasis-seeking processes (between person and external environment), and (e) restriction of one's worldview as the energy level required to scan both internal and external environments is diminished and becomes scattered. These commonalities are dynamically intertwined and help to shed light on the intricately linked interaction between entropy and denial. [14]

Before addressing parallels between entropy and denial, it is necessary to briefly highlight the psychodynamics of denial. Denial has been traditionally regarded as a, mostly, unconscious defensive process (e.g., mechanism, strategy, mode) aiming to thwart threatening information through reality distortion.[51-55] Denial requires energy expenditure, even if it is unconscious, and the continuous employment of energy and its exportation into the external world suggests increased PE. Further, denial serves to increase experienced ambiguity and feelings of uncertainty as the ambiguity, which to Breznitz implied "conflicting bits of information",[51(p.101)] only increases the need for denial-like processes. In his oft-cited treatise on the seven types of denial, Breznitz[51] described the sizeable amounts of psychic energy required in distorting, or filtering out, objective reality. Others, including Hamilton,[53] Horowitz,[56,57] and Lazarus[58,59] have also explored the dynamics and psychological expense of denial. More recent reviews of denial (i.e.,[54,55,60,61]) echo these earlier interpretations of the link among the work of denial, reduced awareness, perceptual minimization, diminished information processing, disorganized psychic activity (in the form of overwhelmed cognitions and emotions), and reality distortion, thus lending further credence to the perceived association between denial and increased PE.

Entropy: Further Thoughts

As argued throughout this paper, both physical and psychological entropies are complex, and if left unattended, unidirectional processes in which disorder, disorganization and chaotic reactions increase. However, whereas physical entropy only applies to closed or isolated systems, such that no energy or matter can enter or exit them, the existence of such natural systems is a rather scarce occurrence. Indeed, even the universe as a whole may not adhere to a strict definition of a closed system.[62,5] Human functioning, and life in general, hardly ever experience the confounds of a closed system. PE as reflected following the onset of a sudden, as well as gradual, life-threatening event, including CID, obeys a different set of rules and operations.

More specifically, it could be argued that there are several telltale imprints left from the recent onset of a traumatic experience such as CID, that serve as indicators of increased PE. These include, but are not restricted to, the following: (a) *unpredictability* of cognitive processes and behaviors; (b) *disorganized (disordered)* thoughts, experienced emotions, and interpersonal communication; (c) increased *uncertainty* about the present and future (and the concomitant *feelings of anxiety*); (d) increased levels of generalized *anxiety;* (e) reduced ability to engage in *useful work* activities and community participation; (f) diminished levels of *informational assimilation and processing;* (g) reduced capacity for *self- and other-awareness*; (h) *emotional flooding* and intrusiveness of traumatic memories; (i) reduced capability to set *life goals and* pursue *plans* to implement them; and (j) shrinking or shattering of *purpose* and *meaning in life*, as well as *world views*. Undergirding all these indicators of entropy are two broad themes, namely, distorted time perceptions (slowed down, speeded up, truncated, or irregular perception of time flow; difficulty predicting future events, uncertainty about present and future occurrences), and reduced psychosocial adaptiveness across a number of life domains (cognitive and emotional disorganization, blunted awareness, poor social communication, inefficient information assimilation, poor work productivity, reduced community involvement, increased anxiety and emotional distress, decreased social capital, diminished ability to find meaning in life, shattered world view(s) (see summary in Table 1).

Table 1: *Summary of Suggested indicators and Correlates of Physical and Psychological Entropies*

General (Physical) Indicators of Increased Entropy
Disorganization
Disorganized information
System's inability to perform useful work
Unpredictability
Uncertain outcomes
Unidirectional flow of time (future-oriented)
General (Physical) Indicators of Decreased Entropy
Close proximity to a gravitational field (signaling negative entropy)
Increased organization and structure
Increased amount of available information
Higher level of data comprehensibility

Table 1 (continued): *Summary of Suggested indicators and Correlates of Physical and Psychological Entropies*

Psychological Indicators of Increased Entropy
Threated life goals and belief system
Decreased purpose of and meaning in life
Anxiety
Heightened uncertainty
Cognitive disorganization
Poor ability to assimilate and process information
Emotional flooding
Intrusive traumatic memories
Psychosocial maladaptation
Unpredictable interpersonal interactions
Diminished awareness
Defensive denial
Inability to perform useful work
Mental rigidity and shrinkage of world view
Distorted time perceptions

Psychological Indicators of Decreased Entropy
Greater awareness
Increased purpose of and meaning in life
Cognitive flexibility and openness of world view
Increased psychological organization
Psychosocial adaptiveness
Capacity for assimilating and processing information
Capacity for performing useful work
Successful pursual of life goals and plans to implement them

Conclusion

Most often considered a construct that is the sole purview of thermodynamics in particular and the physical sciences in general, the time-and-space movement of heat and energy known as entropy has been applied to numerous environmental, medical, and psychosocial fields including geography, ecology, economy, and marketing,[63] to psychotherapeutic change processes,[64,65] and also to a wide range of complex bio-pathological medical conditions, such as type 2 diabetes, infectious diseases, neurodegenerative impairments, epileptic seizures, and psychiatric disorders.[66,67,22] Indeed, several subspecialties within medicine have relied on entropic algorithms to facilitate understanding of medical diagnoses and procedures. These include tumor growth analysis,[68] EEG signal detection,[69,70] fMRI brain activity,[71] consciousness status and related neurodynamic functioning,[72] and the application of entropy indices to monitoring depth of anesthesia status.[73] It stands to reason, then, that entropy, can play a useful role in furthering our understanding of human behavior, medical conditions, and the experience of traumatic events, more specifically. The natural inclination of physical phenomena to move toward chaos over time, especially without intervention, has the potential to inform our understanding of the dynamic, energy intensive process of psychosocial adaptation to CID. Entropy's natural progression toward disorganization and dysfunction has a parallel in the maladaptive psychological responses of anxiety and denial within the psychodynamic paradigm.

Psychological entropy, as a conceptual extension of physical entropy, can be viewed as an indicator of the degree of psychosocial adaptiveness manifested by the individual.[38,39,18] It is, therefore, a reflection of the congruence among the individual's perception of the world around him or her, the activities undertaken to plan ahead, reduce anxiety and uncertainty, and successfully function in the world, the external social and cultural standards and rules, as well as the available resources imposed by society and the physical environment. In the words of the evolutional bio-psychologist La Cerra, "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".[74(p.445)] This article has attempted to introduce entropy as a useful framework for conceptualizing psychosocial adaptation to CID. We provided an overview of the history of thermodynamic and entropy theory, examined chaos as a natural though not inevitable outgrowth of entropy and applied an analysis of parallels between physical entropy, psychological entropy and the psychodynamic processes of anxiety and denial, which are commonly experienced by people who have acquired CIDs. In the second article of this series, we explore potential clinical and rehabilitation applications based on the framework we have established here.

Ethical Compliance Section

No funding was secured for this paper. The authors, therefore, have no funding to disclose.

No human participants were used for this paper. Compliance with Ethical standards is, therefore, not applicable.

The authors declare they have no conflict of interest.

No human participants were used for this paper. Informed consent is, therefore, not applicable for this paper.

References

1. Lewin K. The conflict between Aristotelian and Galilean modes of thought in contemporary psychology. *J Gen Psychol*. 1931;5(2):141–177.
2. Lewin K. *A Dynamic Theory Of Personality*. New York, NY: McGraw-Hill; 1935.
3. Marrow AJ. *The Practical Theorist: The Life and Work Of Kurt Lewin*. Basic Books; 1969.
4. Guastello SJ. (2010). Entropy. In: Guastello SJ, Gregson RA, eds. *Nonlinear Dynamical Systems Analysis for The Behavioral Sciences Using Real Data*. Taylor & Francis; 2010:213-230.
5. Clegg B. *The Reality Frame*. UK: Icon Books; 2017.
6. Greene B. *The Fabric Of The Cosmos: Space, Time, and The Texture Of Reality*. Vintage Books; 2004.
7. Greene B. *Until the End of Time*. Alfred Knopf; 2020.
8. Masterpasqua F, Perna PA, eds. *The Psychological Meaning of Chaos: Translating Theory Into Practice*. American Psychological Association; 1997.
9. Williams N. *The Concept of Psychological Entropy*. The Negative Psychologist. https://thenegativepsychologist.com/the-concept-of-psychological-entropy/. Published September 7, 2011.
10. Carroll S. *From Eternity to Here: The Quest for the Ultimate Theory Of Time*. Plume; 2010.
11. Carroll S. *The Big Picture: On the Origins of Life, Meaning, and the Universe Itself*. Dutton; 2016.
12. Rovelli C. *The Order of Time*. Riverhead Books; 2017.
13. Lockwood M. *The Labyrinth of Time: Introducing the Universe*. Oxford University Press; 2005.
14. Prigogine I, Strengers I. *Order Out of Chaos: Man's New Dialogue with Nature*. Bantam Books; 1984.
15. Davis P. *The fifth miracle: The Search for The Origin and Meaning of Life*. Simon & Schuster; 1999.
16. Guastello SJ. The complexity of the psychological self and the principle of optimum variability. *Nonlinear Dyn Psychol Life Sci*. 2015;19(4):511-527.
17. Schuldberg D. What is optimum variability? *Nonlinear Dyn Psychol Life Sci*. 2015;19(4):553-568.
18. Hirsh JB, Mar RA, Peterson JB. Psychological entropy: A framework for understanding uncertainty-related anxiety. *Psychol Rev*. 2012;119(2):304-320.
19. Muller RA. *Now: The Physics of Time*. W. W. Norton; 2016.
20. Capra F. *The Web of Life*. Anchor Books; 1996.
21. Krauss LM. *The Greatest Story Ever Told-So Far*. Atria; 2017.
22. Vargas B, Cuesta-Frau D, Ruiz-Esteban R, Cirugeda E, Varela M. What can biosignal entropy tell us about health and disease? Applications in some clinical fields. *Nonlinear Dyn Psychol Life Sci*. 2015;19(4):419-436.
23. Falk D. *In Search of Time: The History, Physics, and Philosophy Of Time*. Thomas Dunne Books; 2008.
24. Davis P. *The Cosmic Blueprint*. Templeton Foundation Press; 1988.
25. Gribbin J. *Deep Simplicity: Bringing Order to Chaos and Complexity*. Random House; 2004.
26. Gribbin J. *In Search of the Multiverse*. John Wiley & Sons; 2009.
27. Smolin L. *Time Reborn*. Mariner Books; 2013.
28. Shannon CE. A mathematical theory of communication. *Bell Syst Tech J*. 1948;27(3):379-423:623-656.
29. Susskind L. *The Black Hole War*. Back Bay Books; 2008.
30. Wiener N. *Cybernetics: Or Control and Communication in the Animal and the Machine*. 2nd ed. MIT Press; 1961.
31. Davies P. *The Demon in The Machine: How Hidden Webs of Information Are Solving the Mystery of Life*. UK: Penguin; 2019.
32. Kuang, K. Reconceptualizing uncertainty in illness: Commonalities, variations, and the multidimensional nature of uncertainty. *Ann Int Commun Assoc*. 2018;42(3):181-206.
33. Shannon CE, Weaver W. *The Mathematical Theory of Information*. University of Illinois Press; 1949.
34. Klein MJ. Order, organization and entropy. *Br J Philos Sci*. 1953;4(14):158-160.
35. Burgers JM. (1954). Entropy and disorder. *Br J Philos Sci*. 1954;5(17):70-71.
36. Szasz TS. Entropy, organization and the problem of the economy of human relations. *Int J Psychoanal*. 1955;36(4-5):289-297.
37. Szasz TS. Is the concept of entropy relevant to psychology and psychiatry? *Psychiatry*, 1956;19(2):199-202.
38. Dishion TJ, Nelson SE, Winter CE, Bullock BM. Adolescent friendship as a dynamic system: Entropy and deviance in the etiology and course of male antisocial behavior. *J Abnorm Child Psychol*. 2004;32(6):651-663.

39. Dishion TJ, Forgatch M, Van Ryzin M, Winter C. The nonlinear dynamics of family problem solving is adolescence: The predictive validity of a peaceful resolution attractor. *Nonlinear Dyn Psychol Life Sci*. 2012;16(3):331-352.
40. DeYoung CG. The neuromodulator of exploration: A unifying theory of the role of dopamine in personality. *Front Hum Neurosci*. 2013;7:762.
41. Carver CS, Scheier MF. *On the Self-Regulation of Behavior*. Cambridge University Press; 1998.
42. Dalege J, Borsboom D, van Harreveld F, van der Maas HL. The attitudinal entropy (AE) framework as a general theory of individual attitudes. *Psychol Inq*. 2018;29(4):175-193.
43. Hobfoll S. Conservation of resources and disaster in cultural context: The caravans and passageways of resources. *Psychiatry*. 2012;75:227-232.
44. Kosciulek J. The social context of coping. In: Martz E, Livneh H, eds. *Coping with Chronic Illness and Disability*. Springer; 2007:29-48.
45. Martz E, Livneh H, eds. *Coping with Chronic Illness and Disability*. Springer; 2007.
46. Marini I, Stebnicki MA, eds. *The Psychological and Social Impact of Illness and Disability*. 6th ed. Springer; 2012.
47. Mohr D, Hart S, Julian L, Cox D, Pelletier D. Association between stressful life events and exacerbation in multiple sclerosis: A meta-analysis. *BMJ*. 2004;328(7442):731.
48. Hobfoll S. Conservation of resource caravans and engaged settings. *J Occup Organ Psychol*. 2011;84:116-122.
49. Brummelhuis L, Bakker A. A resource perspective on the work-home interface. *Am Psychol*. 2012;67:545-556.
50. Strauser D. *Career Development, Employment and Disability in Rehabilitation: From Theory to Practice*. Springer; 2014.
51. Breznitz, S. The seven kinds of denial. In S. Breznitz (Ed.), *The Denial of Stress*. International Universities Press; 1983:257-280.
52. Goldbeck R. Denial in physical illness. *J Psychosom Res*. 1987;43(6):575-593.
53. Hamilton V. Information-processing aspects of denial: Some tentative formulations. In: Breznitz S, ed. *The Denial of Stress*. International Universities Press; 1983:167-195.
54. Kortte KB, Wegener ST. Denial of illness in medical rehabilitation populations: Theory, research, and definition. *Rehabil Psychol*. 2004;49(3):187-199.
55. Livneh H. Denial of chronic illness and disability: Part I. Theoretical, functional, and dynamic perspectives. *Rehabil Couns Bull*. 2009;52(4):225-236.
56. Horowitz MJ. Stress response syndromes and their treatment. In: Goldberger L, Breznitz S, eds. *Handbook of stress: Theoretical and clinical aspects*. The Free Press; 1983:711-732.
57. Horowitz MJ. *Stress Response Syndromes*. 2nd ed. Jason Aronson; 1986.
58. Lazarus RS. The costs and benefits of denial. In: Breznitz S, ed. *The Denial of Stress*. New York, NY: International Universities Press; 1983:1-30.
59. Lazarus RS, Folkman D. *Stress, Appraisal, and Coping*. Springer; 1984.
60. Vandereycken W. Denial of illness: A concept in search of refinement. *Adv Psychol Res*. 2005;37:63-95.
61. Wheeler S, Lord L. Denial: A conceptual analysis. *Arch Psychiatr Nurs*. 1999;13(6):311-320.
62. Carroll S. *Something Deeply Hidden: Quantum Worlds and The Emergence of Spacetime*. Dutton; 2019.
63. Haynes KE, Phillips F, Yu MC. Recent applications of entropy in social and environmental sciences. In: Reggiani A, ed. *Handbook on Entropy, Complexity and Spatial Dynamics: A Rebirth of Theory?* UK: Edward Elgar; 2021:32-45.
64. Cerf R. Pathway to psychological change from the structural stability theory. *Nonlinear Dyn Psychol Life Sci*. 2015;19(1):13-39.
65. Schöller H, Viol K, Goditsch H, Aichhorn W, Hütt MT, & Schiepek G. A nonlinear dynamic systems model of psychotherapy: First steps toward validation and the role of external input. *Nonlinear Dyn Psychol Life Sci*. 2019;23(1):79-112.
66. Cutler CD, Neufeld RW. Nonlinear indices with applications to schizophrenia and bipolar disorder. *Nonlinear Dyn Psychol Life Sci*. 2019;23(1):17-56.
67. Guastello SJ. Modelling illness and recovery with nonlinear dynamics. In: Sturmberg JP, Martin CM, eds. *Handbook of Systems and Complexity in Health*. Springer; 2013:147-156.
68. Gatenby RA, Frieden BR. Application of information theory and extreme physical information to carcinogenesis. *Cancer Res*. 2002;62(13):3675-3684.
69. Jiang GJA, Fan SZ, Abbod MF, et al. Sample entropy analysis of EEG signals via artificial neural networks to model patients' consciousness level based on anesthesiologists

experience. *Biomed Res Int.* 2015;2015:343478.
70. Srinivasan V, Eswaran C, Sriraam N. Approximate entropy-based epileptic EEG detection using artificial neural networks. *IEEE Trans Inf Technol Biomed*. 2007;11(3):288-295.
71. Yao Y, Lu WL, Xu B, et al. The increase of the functional entropy of the human brain with age. *Sci Rep*. 2013;3(1):1-8
72. Carhart-Harris R, Leech R, Hellyer PJ, et al. The entropic brain: a theory of conscious states informed by neuroimaging research with psychedelic drugs. *Front Hum Neurosci*. 2014.
73. Liang Z, Wang Y, Sun X, et al. EEG entropy measures in anesthesia. *Front Comput Neurosci*. 2015.
74. La Cerra P. 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. *The Human Nature Review*. 2003;3:440-447.
75. Pincus D, Cadsky O, Berardi V, Asuncion CM, Wann K. Fractal self-structure and psychological resilience. *Nonlinear Dyn Psychol Life Sci*. 2019;23(1):57-78.
76. Haan N. *Coping and Defending: Processes of Self-Environment Organization*. Academic Press; 1977.
77. Guevara Erra R, Mateos DM, Wennberg R, Perez Velazquez JL. Towards a statistical mechanics of consciousness: Maximization of number of connections is associated with conscious awareness. *Phys Rev E*, 2016;94(5):1-18.
78. Mateos DM, Guevara Erra R, Wennberg R, Perez Velazquez JL. Measures of entropy and complexity in altered states of consciousness. *Cogn Neurodyn*. 2018;12(1):73-84.
79. Jach HK, Smillie LD. The fear of fly to the unknown: Tolerance of ambiguity and big five personality traits. *J Res Pers*. 2019;79:67-78.
80. Gibson JJ. The theory of affordances. In: Shaw, RE, Bransford J, eds. *Perceiving, Acting and Knowing*. Erlbaum; 1977:56-60.
81. Hartson HR. Cognitive, physical, sensory and functional affordances in interaction design. *Behav Inf Technol*. 2003;22(5):315-338.
82. Jenkins HS. Gibson's "Affordances": Evolution of a pivotal concept. *J Sci Psychol*. 2008;12(2008):34-45.
83. Brehm JW, Wright RA, Solomon S, Silka L, Greenberg J. (1983). Perceived difficulty, energization, and the magnitude of goal valence. *J Exp Soc Psychol*. 1983;19(1):21-48.
84. Baumeister RF, Faber JE, Wallace HM. Coping and ego depletion: Recovery after the coping process. In: Snyder CR, ed. *Coping: The Psychology of What Works*. Oxford University Press; 1999:50-69.
85. Ryan RM, Deci EL. From ego depletion to vitality: Theory and findings concerning the facilitation of energy available to self. *Soc Personal Psychol Compass*. 2008;2(2):702-717.

Author's notes

[1] the 1st and 3rd Laws of psychodynamics are the law of conservation of Energy (1st Law) and the law of a system at absolute zero having zero entropy (3rd Law) respectively.

[2] in more technical terms, entropy is viewed as a measure of a system's thermal or molecular activity, per unit of temperature that is *unavailable* for the production of useful work.[20,13] As the entropy of the universe increases with time, a progressively larger volume of energy becomes unavailable for useful work purposes. This evolutionary process ultimately reaches a state of maximum entropy, or maximum equilibrium, when heat energy is no longer available for work.[24]

[3] the relationship between entropy and complexity, however, is not simple. As Carroll[10,11] argued, whereas entropy, in an open system, typically increases in a gradual manner (or at least, temporarily remains the same), complexity presents an altogether different picture. Complexity, in an open system, tends to advance in a curvilinear (U-shaped) fashion, thus portraying a trajectory whose initial unfolding appears to manifest low complexity (e.g., the beginning of the evolution of the universe; life events such as infantile mobility and functioning). The earlier low complexity, however, gradually gives rise to more complex patterns (e.g., current status of the universe, approximately 13.75 billion years in the making; life events such as adult mobility and functioning), and eventually, after reaching a certain peak in complexity, the trend reverses course and complexity gradually decreases (e.g., death heat of the universe, life events such as old age mobility and functioning). To wit, living organisms are capable of decreasing the progression of entropy by importing energy from the external environment, and achieving more complex forms of functioning, while exporting entropy to the outside world, thus sustaining order and the functionality of their own biochemical systems.

[4] in a similar vein, Pincus et al.,[75] expanded on the role of complexity and rigidity within the organizing self-structure, arguing that more complex people possess richer and more diverse traits and are, therefore, more multifaceted and adaptive. Based on findings drawn from MMPI profiles the researchers reported that MMPI scales (traits) indicating psychopathology were positively linked to self-structure rigidity, but also suggesting that scales denoting over-flexibility may be reflective of dysfunctional tendencies. The authors concluded, adopting the optimum variability concept, that individuals with more flexible, yet reasonably well-integrated, trait-structure, may be best suited to recover from traumatic events, through the adoption of a greater, and more fluid, variety of cognitive and affective coping resources.

[5] Technically speaking, Boltzmann's H, as a quality of enclosed gas, is a function of the overall distribution of velocities at a designated time (H, then, starts at $H > 0$, and then approaches $H = 0$ at a future time. H is a measure of the difference between the actual measured entropy of the gas and its maximum possible entropy. Therefore, as H decreases in value, S (the actual entropy) increases at a similar rate, finally reaching a maximum value at $H = 0$. In an equation form, S (entropy) $= k \log W$ [so also engraved on Boltzmann's tomb], where $k =$ Boltzmann's constant, and $\log W =$ log of the number microscopic arrangements in a system, or the logarithm of the number of quantum states (volume of the phase space) accessible to a system.[10,19]

[6] an indirect, yet psychologically and clinically relevant reference to these chaotic processes may be found in the models of Haan[76] and Horowitz.[57] In these models, Haan's fragmentation-oriented ego processes and Horowitz's succumbing to stress responses, both of which signal chaotic reactions exemplified by decompensation, emotional flooding, confusion, sense of meaninglessness and extreme anxiety, all indicators of what has been described earlier as increased psychological entropy.

[7] chaotic systems, according to Capra[20] and Prigogine,[14] evolve into complex dynamic systems with the following features: (a) a large number of independent components, (b) a dynamic motion of component readjustment, (c) adaptation to novel situations in order to ensure survival and advantageous reorganization, (d) spontaneous order and self-organization, (e) local rules that govern each set of components, and (f) hierarchical progression of the rules of components evolution and emergence of novel and more complex order.

[8] a somewhat different conjecture is offered by Rovelli.[12] He argues that the flow of time is an inclusively human experience, an experience that stems from our partial and blurred vision of the world. He posits that this experienced flow depends on our unique interaction with the rest of the universe in such a way that entropy is lower in a preferred, single direction and increases only in relation to human's thermal time.

[9] Shannon[28] defined entropy as the measure of the average information content that is missing from a set of data for an unknown random variable, or,

alternatively, the amount of uncertainty linked to a random variable.[18] Based on Shannon's model, entropy is associated with the average number of bits (or amount of storage) required to communicate a signal or a unit of information. Entropy, then, indicates the degree of information flow in communication, or comprehensibility of a set of data.

[10] other views on psychological/cognitive entropy and its relationships to the unconscious-unconscious spectrum may be found, for example, in more recent efforts by Williams[9] and Guevara Erra, Mateos, Wennberg and Perez Velazquez[77] (see also,[78]). The former, argues that the concepts of consciousness and unconsciousness indicate nothing more than a state of psychological entropy, such that consciousness defines a state of zero psychological entropy, or a state of perfect cognitive symmetry, while unconsciousness indicates a state of high psychological entropy, noted by higher levels of irrationality, ignorance, diffusion, and unawareness. The latter researchers, analyzing several types of brain signals and related neurophysiological recordings in individuals under different states of consciousness (wakefulness, sleep stages, epileptic seizures), concluded that the entropy and complexity (i.e., larger information content) of these signals tend to be lower in states of diminished awareness (consciousness) and rise in states of full alertness. These findings, therefore, suggest that consciousness, as exemplified by larger information content and complexity, could be the end product of information optimization processing.

[11] supportive empirical evidence to DeYoung's model, using traits drawn from the big five personality framework, was more recently provided by Jach and Smillie.[79] These authors reported that, in their sample of respondents, tolerance of ambiguity was positively correlated with extraversion and openness to experience (as an indicator of low-level PE), and negatively associated with neuroticism (reflecting anxiety, depression, and volatility, or higher-level PE).

[12] the term Affordance[80-82] has been typically employed to convey the nature of organism-environment interaction. It attempts to catalog the behaviors (action possibilities) that the organism is capable of performing. Affordances, in the context of ecological psychology, are viewed as a dynamic reciprocity of the perceived opportunities and constraints afforded by the environment. They may be, further, analyzed as to their physical, cognitive, sensory and functional properties.

[13] several theories were proposed that explored the relationships between psychosocial functioning, energy, energy conservation and depletion, and energy mobilization, which included passing, even if not always direct, references to the concept of psychological entropy. These include: (a) the energization and motivation theory[83] which postulates that motivation varies with increased energy mobilization, the magnitude of goal valence, the actual exerted efforts, and the difficulty of the coping efforts employed; (b) the self-regulation theory[84] which maintains that both self-control and self-regulation deficiencies are linked to a host of behavioral problems, including chronic diseases, and that overuse of these efforts of self-control (including coping efforts directed at stressful and traumatic events) leads to gradual exhaustion of one's reservoir of energy, resulting in what the authors termed ego depletion; (c) the self-determination theory[85] which posits that energy and vitality are enhanced when the essential psychological needs of autonomy (the perception of personal volition), competence (the perception of personal effectiveness), and relatedness (the perception of being connected to others) are being realized. All three theories share the common beliefs that energy level (e.g., goal-directedness, vitality, motivation level), is a prime promoter of human behavior, physical and mental functioning, and that once energy is exhausted or depleted (i.e., psychological entropy increases), the ability to carry out useful work and maintain functional physical, emotional and cognitive performance is greatly compromised.

[14] as indicated earlier, entropy is an indicator of the amount of available ordered or useful information in a system (e.g., physical, biochemical). Put differently, for a system to function adaptively, information must be imported from the environment (thus increasing the system's negative entropy). This results in an adaptive equilibrium between person and environment, assuring lower PE. However, when this equilibrium is threatened, that is, when the supply of externally imported negative entropy is reduced at the expense of increased internally driven disorder, chaos ensues and maladaptive functioning increases. This contrast between physical and psychological forms of entropy is often overlooked, indeed misinterpreted, since a state of physical systems equilibrium is typically indicative of higher physical entropy, while it does suggest lower PE. This clinical interpretation stems from the fact that lower PE (i.e., adaptive cognitive-emotional homeostasis between person and the environment) suggests a functional balance between internal and external informational processes, higher level of personal awareness, increased certainty regarding one's goals and plans, and the capacity to perform useful work activities.