The Quantum Character of Perception: The Probabilistic and Reversible Thermodynamic Cycle can Produce Spin-like Attitudes, Thinking, and Behavior

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Abstract

One of the most puzzling questions in neuroscience is the nature of emotions and their role in consciousness. The sensory system's energy/information exchange revolves around a stable resting state. Therefore, cognitive perception represents information-energy exchange with the environment, giving rise to a closed thermodynamic cycle, which can be modeled by the reversible Carnot engine. The brain's significant energy investment in maintaining the resting state indicates its essential role as the ground state of consciousness, the source of our sense of self. Perception forms either an endothermic or exothermic cycle. The first represents high entropy resting state with irreversible activations, generating novelty and intellect. In the second case, low entropy and reversible resting state cause past focus, regret, and remorse. The reversible thermodynamic cycle, a classical system, takes on quantum characteristics. The cycle's direction generates an orthogonal force or torque, manifested as psychological spin. The endothermic cycle produces up-spin, whereas the exothermic cycle is called down-spin. The quantum and classical natures represent a particle-like duality between continuous and discrete states explained by the fermionic hypothesis. Therefore, emotions are the brain's homeostatic master regulators. They maintain particle-like stability manifested by cognitive comfort by utilizing physiological and hormonal regulation.

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Highlights

Energy information exchange with the environment is based on the resting-state

Perception is a reversible thermodynamic cycle representing psychological spin

High entropy and irreversible activations form up spin, inspiring future orientation

Low entropy with reversible activations and past focus acts as a down spin

Emotions are cognitive master regulators, the fundamental forces of motivation

Keywords: Quantum cognition, spinor, psychological spin, thermodynamics, positive psychology, emotion regulation.

*Social temperature or arousal:*Like temperature, which indexes internal energy, social temperature measures the intensity of emotions, arousal (Escobar et al., 2021; O'Neill & Schoth, 2022: Deli and Kisvarday, 2020; Deli et al., 2021). For example, low arousal stabilizes focus, but high arousal causes oscillating information processing, leading to erratic and arbitrary behavior. The physiological signals of high social temperature are increased breath, heart rate, skin conductance, hot or cold chills, shouting, aggravation, aggression, and risky behavior.

Introduction

> *"Who would believe that so small a space could contain the images of the whole universe?" — LEONARDO DA VINCI*

The relationship between cognition and physics has deep philosophical and scientific roots. Sensory abilities lend environmental insights even to the most primitive animals. For example, visual projections onto the optic nerve produce a holographic memory representation (Tomasi et al., 2017), which remains stable despite the constantly changing environment (Makey et al., 2019), allowing past experiences to inform present behavior and response. Therefore, memory and learning (Dabaghian, 2019) engender a stable temporal orientation (Fingelkurts & Fingelkurts, 2014; Herzog et al., 2020).

Material systems follow trajectories that have the least action when moving in space. In biological systems, predictive behavior optimizes action performance. For example, a precise computation adjusts muscle strength throughout the execution of the simplest movements, such as negotiating a cup's path to the lips (Manto et al., 2012).

The neural system is a memory-based predictive system. Despite our experience being primarily spatial, we think in temporal relationships, the future, and the past. Therefore, cognitive computation is an optimization based on memories and goals (food and security), analog to temporal least action (Deli, 2020a; Wissner-Gross/Freer, 2013). Moreover, the endothermic cycle increases future freedom of action, manifested as cognitive flexibility, associative representations, and creativity.

Spontaneous meaning generation and abstract task structure representations (Witkowski et al., 2022), the fundamental character of intellect, are based on the organizing principle of space (Singer, 2021; Deli et al., 2018; Tsao et al., 2018). Cognitive experience feeds on sensory information, reflecting spatial relationships. The experience of gravity lends itself to mental abstraction, projecting physical qualities, such as weight, size, and others, into mental concepts. For example, difficulties and misery impose a psychological heaviness, stress manifests pressure, and happiness and joy are light and airy.

As the settling of chaotic matter, mental chaos can resolve into cognitive order. In turn, mental balance represents a symmetric and stable condition inspired by understanding physical balance. Further, sequential thought steps resembling a chain link are considered logical. Finally, because we see further from higher ground, "standing on the shoulder of giants" implies the predecessors' constructive contribution to current thought. However, attraction is an example borrowed from the understanding of electromagnetism. Therefore, cognition utilizes the insights of the organizing principles of space to formulate mental concepts and understanding.

Human decision-making and behavior show quantum mechanics. For example, the brain's ability for parallel and ultrafast evaluation of the relations between probabilistic variables resembles quantum systems. Superposition, interference, and entanglement can emerge from the brain's classical sensory cycle; context clues can dramatically modify what we hear, see, or perceive (Xu & Schwarz, 2018). As "quantum" resists classical description, context turns the potentials of the memory and perception into actual properties (Dennett, 2018), discrete thoughts, and decisions. Cognition shows a point-like (discrete) or wavelike character, i.e., complementarity.

Mental Homeostasis

The physical world obeys the laws of thermodynamics, but life secures a low entropy internal stability against external conditions. Homeostasis seems to be a fundamental requirement of life from the lowest to the highest level. Cells keep their internal structure, pH, salt concentration, and membrane potential constant. In vertebrates, the heart and the kidneys keep the body's internal parameters within a very tight range. In mammals and birds, the brain is a central regulator responsible for thought, memory, emotion, touch, motor skills, vision, breathing, temperature, hunger, and bodily processes.

Neuronal processes also transpire on many scales (Stringer et al., 2019), microscopic membrane potentials and neurotransmitter fluctuations give rise to large-scale functional magnetic resonance signals. Although stimulus rapidly collapses the high-dimensional resting state into a lower-dimensional substrate (Bányai et al., 2019; Singer, 2021), a tightly controlled emotional integration (Rosenzweig et al., 2009; Tomasi, 2013) always restores the resting, neutral position (Northoff, & Tumati, 2019; Schoeller & Perlovsky, 2016).

Therefore, cognitive stability is connected to the resting state. First, the resting state's non-computable, subjective, and often ungovernable thought processes enable a subjective, transcendental, and privileged first-person experience (Kolvoort et al., 2020). Second, it personifies the sense of self (Wolff et al., 2019), i.e., a mental comfort point. Third, as a cognitive ground state, it ensures a mental constancy from birth to death. Furthermore, the correlation structure is susceptible to experience and learning-dependent modifications throughout life.

Cognitive perception is the unified, subjective and conscious experience of stimulus, which by definition modifies the synaptic connection map (Figure 1). Stimulus can be external or internal, such as a memory, perception can be conscious or unconscious, and response can be mental or produce behavioral actions. Therefore, although cognition is a highly abstract and flexible state (Nes et al., 2021), it shows a systematic relationship with perception (Montemayor & Haladjian, 2017).

The autonomic stress pathway connects the corticolimbic stress circuits to the hypothalamus (Kataoka et al., 2020) by activating the sweat glands and controlling blood pressure and blood vessel dilation to the muscles, the so-called "fight-or-flight" reaction (Fadok et al., 2017). Parental care behaviors, like endothermy, are also predicated on thermoregulation (Farmer, 2020; Seebacher, 2020). The interconnection between emotion and temperature regulatory pathways in the ventral striatum (VS) and middle insula (MI) (Grigg et al., 2021; Kataoka et al., 2020; Inagaki & Eisenberger, 2013; Inagaki et al., 2019) indicates their shared origin in energy regulation (Deli and Kisvarday, 2020).

Cortical fluctuations reflect the priors in the network architecture, stored in the anatomical layout and the synaptic weights of recurrent synaptic connections (Singer, 2021). Like the specific range of endothermic body temperature, emotion regulation keeps cognitive comfort within an individually, culturally prescribed range, immensely influencing our physiology (Ellard et al., 2017). Inversely, our physiology and electric brain stimulation have a remarkable ability to regulate emotions (Caruana et al., 2018), indicating their energy nature. Therefore, emotions are the forces of motivation with the ability to completely rule thinking (Babaev et al., 2018; Bechler et al., 2019). Emotions' powerful physiological regulatory function indicates their role at the top of the homeostatic hierarchy.

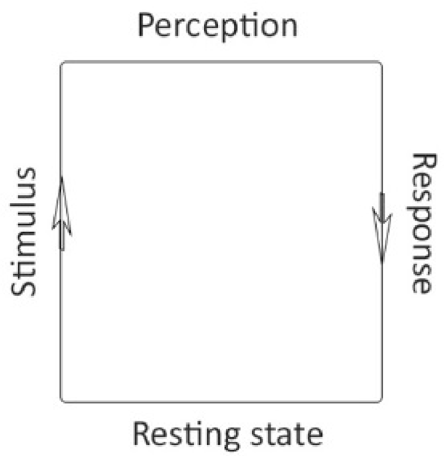

Figure 1. The cognitive perception cycle The cycle is centered on the resting state, the recurring phase. Stimulus (which can be external or internal) starts the cycle. Activation initially often unconscious but at a certain threshold perception becomes conscious. Finally, response, which can be mental process

or behavioral action, recovers the resting state. The cycle by definition changes the synaptic map. However, emotions have a constant presence in both conscious and unconscious mental states.

Quantum Cognition

People intuitively could tell within just 100 milliseconds whether a tower of blocks was unstable and about to fall over (Firestone & Scholl, 2015) and various physics frameworks can explain enigmas in cognitive sciences (Deli, 2015; Deli, 2020a,b; Goldenberg et al., 2018; Jiang et al., 2016; Khrennikov, 2015; Peters & Kashima, 2015). A prime example, quantum cognition, is based on the idea that chaotic and noisy brain activations give rise to quantum characteristics (Table I). For example, complementarity in psychology implies that the context generated by the first measure can influence subsequent ones, producing order effects (Hopkins et al., 1997). Furthermore, the superposed psychological states cannot be defined precisely; instead, all possible values within the superposition have some potential for expression (Busemeyer and Wang, 2015).

Various physics frameworks can explain enigmas in cognitive sciences (Deli, 2015; Deli, 2020a,b; Goldenberg et al., 2018; Jiang et al., 2016; Khrennikov, 2015; Peters & Kashima, 2015). A prime example, quantum cognition, is based on the idea that chaotic and noisy brain activations give rise to quantum characteristics (Table I). For example, complementarity in psychology implies that the context generated by the first measure can influence subsequent ones, producing order effects (Hopkins et al., 1997). Furthermore, the superposed psychological states cannot be defined precisely; instead, all possible values within the superposition have some potential for expression (Busemeyer and Wang, 2015).

Unlike classical systems, quantum systems are probabilistic, lacking the ability to predict the actual outcome of a measurement. Similarly, decision-making and social behaviors are probabilistic, based on the squares of the probability amplitudes (Landé, 1971; Lubashevsky, 2018; Luck et al., 2021; Selesnick & Piccinini, 2018). Superposition between network nodes bears similarities to the simultaneous and probabilistic spontaneous activity priors' evaluation (Singer, 2021). Cortical fluctuations can anticipate events and the consequences of actions (Hughes et al., 2013; Kok et al., 2017), such as the global coordination of muscle tone by the evoked potential in motor cortices (Uithol and Schurger, 2016).

Analogous to the Born rule, which expresses the probability density of finding a particle at a given point, the medial prefrontal cortex (PFC) efficiently represents hierarchically related choice-outcome associations (Witkowski et al., 2022), corresponding to the "position" of latent association. Like waves on a pond, thoughts move with considerable liberty; the brain's wavelike electric activities (Basieva et al., 2019; Chang et al., 2019) are challenging to govern and almost impossible to retrace. They represent the neural underpinning of response (Friston et al., 2020). Therefore, mental history is just as crucial in determining the quality of neuronal activation as the stimulus itself (Piscopo et al., 2018). Thus, in analogy to the Shannon understanding of entropy, the stimulus's information value and the degree and quality of comprehension depend on the observer (Tomasi et al., 2017).

Cognition alternates between a fluid charge flow versus thermodynamic balance, continuous unconscious processing, versus discrete conscious percepts and beliefs (Herzog et al., 2020), reminiscent of the quantum and classical divide. Therefore, analogous to the wave-particle duality, the brain's probabilistic temporal rhythms (Table I) formulate discrete processing (Herzog et al., 2020). Now we turn to the consequences of quantum cognition.

Quantum mechanics also shows that decoherence changes the wave function, leading to discrete and quantized energy transformations. Similarly, beliefs, decisions, and cognitive change represent discrete conditions (Libet, 1983, 1985; McCraty and Atkinson, 2014) (Table I). Analogous to a quantum system, cognitive perception's unified, and subjective experience modifies the synaptic connection map.

Table I. Analysis of quantum cognition in comparison to fermionic characteristics

Quantum mechanics		**Classical behavior**
Fermions	Quantum cognition	Decisions and beliefs
Wave function	The brain's thermodynamic cycle	The neuronal connection map
Spin (antisymmetric wave functions)	The opposite directions of the Carnot cycle represent spin-like states	Does not apply
Pauli exclusion principle	Stress triggers critical tendency and aggravation, analog to down spin.	Does not apply
Complementarity: the context generated by the first measure can influence responses to the next one	Complementary questions need to be examined sequentially, and the answer to the first question produces a context that changes the response to the next one.	Classical probability
In free regimes, energy is continuous and quantum-like	Thinking is probabilistic, fluid, continuous, and unpredictable	Predictable and well-defined
Reversible	Reversible	Irreversible
The high dimensional wave function, wave-particle duality	High-dimensional activations collapse into discrete decisions	Predictive
Heisenberg uncertainty principle	Individual action is probabilistic	Group behavior is predictable

Mental Unity

The mind, representing the smallest unit of intellect, is only meaningful in its unity (Deli, 2020b). Conscious perception is never fractured (Bayne, 2009); ambiguity forces a non-deterministic, quantum-like fluctuation between two possibilities, concepts, or economic decisions (Fioretti et al., 2022). For example, two different images presented to the two eyes (Alais & Blake, 2004; Tong et al., 2006) or two different smells registered by the two nostrils (Zhou & Chen, 2009) do not form averages in perception but trigger a quantum-like fluctuation between the two possibilities.

Sensory activation evokes involuntary potentials and electric flows in primary sensory regions, forming spatiotemporal symmetry vis-à-vis the brain's resting modules (Bastos et al., 2015), which orients consciousness in time (Huang et al., 2020). Oscillations cross successive regulatory layers on their way to associative regions, but response restores the brain's resting state in a discrete energy processing. The gradually evolving resting equilibrium forms personal experiences, memories, and expectations of the moment.

The limited work produced by one cycle turns mental evolution into a stepwise process, giving rise to discrete understanding and beliefs, which supports self-consciousness' "quantized" character. For example, the evoked cycle discretizes the wave function, analogous to the particle's wave function in a "box."

$$E = \hbar\omega = \frac{\hbar^2 k^2}{2m} \qquad (1)$$

where k is the wavenumber and ω is the angular frequency, $\hbar$ is the reduced Planck constant, and m is the mass of the particle, which corresponds to rigidity. The total probability density of finding the meaning during the cycle somewhere between the subsequent resting states (B) is one. Therefore,

$$\int_0^B |\Psi\,(t)|^2 dx = 1 \qquad (2)$$

where Ψ is the wave function and is the mental location of a thought

The brain's identification with the body forms the basis of homeostatic self-regulation (Criscuolo et al., 2022; Guterstam, 2015). The sense of self, such as self-identification, self-location, and temporal continuity, feeds on exteroceptive and interoceptive bodily signals (Herzog et al., 2020; Park & Blanke, 2019). Continuous and bidirectional body–brain states with a hierarchical but flexible functional organization formulate a dynamic interactive system that includes perception and response (Criscuolo et al., 2022). The interference between bottom-up and top-down processes (Prentner, 2019) generates unified first-person perception (reviewed by Chen and Spence, 2017) even from diverse, confusing, or chaotic information. The decision turns all other options irrelevant, making unity a fundamental feature of consciousness and intellect (Bayne, 2009), satisfying the fermionic mind hypothesis (Deli, 2020a,b).

As bodily changes affect the brain and, inversely, emotions impact the body (Nashiro et al., 2022), a sense of brain-body unity or oneness emerges (Criscuolo et al., 2022). Because emotions are deeply enmeshed in the brain's energy regulation processes, they have immense potential to trigger behavioral, hormonal, and bodily changes to maintain the constancy of the resting state. Emotions ensure self-identification and the constancy of the self, signaling personal guidance. On the other hand, identification with our emotions can lead to adverse interpersonal outcomes (e.g., during anger or rage). Therefore, emotions serve as a master regulator, with the ability to adjust physiology and maintain optimal conditions.

Discussion

The thermodynamic foundation of emotion-temperature relation

The brain partakes in the energy/information cycle of the physical world via the sensory system. While exothermic processes dump entropy and energy into the environment, endothermic systems reduce entropy and require energy to operate. An intelligent process acquires information X= {x_1, x_2,..., x_m} and formulates decisions Y= {y_1, y_2, ..., y_q} via complex metabolic feedback networks, which produce endothermic regulation (Seebacher, 2020; Grigg et al., 2021).

Recent investigations have shown that stimulus and its response forms a closed and reversible thermodynamic cycle in discrete processing centering on the resting state (Deli and Kisvarday, 2020; Deli et al., 2021, 2022), operating between two information-density reservoirs (Fry, 2017; Deli et al., 2018). Therefore, thermodynamics, which can predict the behavior of systems with large numbers of particles in so many fields, might explain the emergence and nature of intellect. We will investigate how the thermodynamic cycle of perception, a classical system, can manifest a quantum process.

The midbrain's temperature regulation is a fundamental homeostatic process that keeps the core body temperature within a narrow range. Centralized primarily in the hypothalamus, it functions at the cellular, tissue, and, ultimately, organism level (Wang et al., 2016). Vasoconstriction, shivering, and non-shivering thermogenesis can elevate body temperature, whereas sweating and vasodilation prevent overheating (Madden & Morrison, 2019; Nowack et al., 2017). In addition, the autonomic nervous system, which encodes the perceived novelty and meaning of the stimulus, involuntarily regulates arousal, the "strength" or intensity of an emotional response (O'Neill & Schoth, 2022; Wang et al., 2018).

For example, sentiment contagion is a spontaneous spread of emotions among members of social groups (Goldenberg et al., 2017; Peters and Kashima, 2015). The phenomenon is analog to the temperature-dependent diffusion process in liquids. Therefore, a message or social media post's ability to motivate depends on the propagation probability or spontaneous transmission of kinetic or social energy via emotions and related behaviors (Zent and Zhu, 2019). Therefore, emotions, an integral part of the general neural architecture of the brain (Kao et al., 2015), share a control path with temperature (Escobar et al., 2021).

In addition, body temperature is often used as a proxy for emotional changes (e.g., Nummenmaa et al., 2014). For example, the word "hot" often associate with positively valenced and high-arousal emotions, while "cold" refers to negatively valenced and low-arousal emotions (Escobar et al., 2021). Accordingly, physiological changes can boost motivation (e.g., blushing when confused, shivering or sweating when stressed, or perspiring when afraid).

In the words of Conant and Ashby, "every good regulator of a system must be a model of that system" (1991). The ability to produce an intelligent (i.e., dynamic and responsive) response to a stimulus requires a model of that stimulus (Singer, 2021; Witkowski et al., 2022). Learning is a continuous improvement of the fit between incoming sensory signals and available mental models or predictions (Schoeller & Perlovsky, 2016) through a thermodynamic modification of the synaptic connections. For example, increased functional connectivity lowers the resting entropy in the parietal cingulate cortex and amygdala (Rowe and Fitness, 2018). Reduced Nucleus accumbens default mode network connectivity improves contentment (Shukuroglou et al., 2022), supporting the relationship between information erasure and resting synaptic flexibility.

The Thermodynamic Analysis of the Evoked Cycle

Computation theory shows that only two physical processes are possible—dissipative processes reconstruct the past, and intelligent ones control the future (Cox, 1979; Deli et al., 2021, 2022; Fry, 2017). The first ones are exothermic processes, which unpack and release accumulated energy and entropy, but endothermic cycles conserve entropy while requiring energy to operate. Therefore, exothermic cycles make endothermic possible. We will compare the entropy generation of the brain with physical systems while studying the evoked activations as exothermic and endothermic cycles.

A closed system exchanges only energy (as heat or work), not matter, with its surroundings. When the cycle repeats with constant parameters, such as entropy and temperature, it forms a Carnot engine. Likewise, the evoked activities operate between resting states with constant parameters; the brain's energetically expensive regulatory function ensures resting stability with constant parameters. Moreover, sensory processing is an energy-information exchange that turns the evoked cycle into a closed thermodynamic cycle (Northoff, 2018).

In information theory, Shannon entropy represents the amount of information needed to represent a random variable, roughly its surprise potential. Although Shannon entropy considers discrete random variables, and the brain's intelligent computation relies on continuous energy flow, brain entropy represents a discretization of a continuous time series. In the maximum entropy situation, the signal-to-energy ratio is very high (Zheng et al., 2022). For example, access to a significant number of neural states affords high degrees of freedom, fluid intelligence (Saxe et al., 2018; Yang et al., 2019), trust, and confidence (Ryan and Deci, 2017; Van Cappellen et al., 2018). Therefore, the brain's thermodynamic cycle is representative of the psychology of motivation.

Although the energy states of the brain operate behind conscious awareness to modulate what we see, hear and think, emotions' irresistible power over behavior gives rise to the belief in free will. Rewards require thalamic neurotensin production and release (Li et al., 2018a). The endothermic cycle requires attentional focus, responsibility, bravery, compassion, altruism, and love (Buckwalter, 2019; Schubert et al., 2019). However, the exothermic cycle does not require initial energy input; it comes for "free" of mental investment, which is the common notion of "free will." The above arguments can explain the compounded nature of attitude in long-term well-being (Chang et al., 2016; Moore & Depue, 2016; Pleeging et al., 2019).

Psychological Spin

The Stern–Gerlach experiment observes the deflection of a beam of silver atoms traveling in an inhomogeneous magnetic field. The spin-statistics theorem and the Pauli exclusion principle explain the experiment's results as the quantized angular momentum. Likewise, entanglement shares the same wave function in an interaction space with antagonistic positions. Antagonism is the source of a hierarchic social structure as well. Thus the evoked cycle is an abstract, multi-dimensional "spin space," which turns interaction into energy loss (exothermic cycle) or energy accumulation (endothermic cycle), see Figure 2.

In economics, a simple spin model can explain market frictions and herding behavior (Fotouhi & Rabbat, 2013; Kristoufek & Vosvrda, 2018; Krause & Bornholdt, 2013). Moreover, a modification of the above idea, the so-called Ising model, can account for decision-making in social and business situations (Sîrbu et al., 2017; León-Medina, 2019; Li & Dankowicz, 2018; Ishii & Kawahata, 2018; Zha et al., 2021; Vázquez et al., 2020; Salehi & Taghiyareh, 2019).

Emotions' varied personal histories, cultural, and brain activity profiles (Al-Qazzaz et al., 2019; Glomb et al., 2019; Khan et al., 2017; Lin et al., 2017; Suhaimi et al., 2020; Torres et al., 2020; Zhong et al., 2019) represent only positive or negative motivation (Hesp et al., 2021; Kao et al., 2015). Furthermore, emotions are the multi-dimensional representation of attitude, an instant feeling *for* or *against*, with a surprising analogy to spin (Surov, 2022). Therefore, like photons, emotions represent spin one condition.

Attitude or disposition represents the direction and magnitude of intention in an abstract vector space (Surov, 2022; Yih et al., 2018), uncovering *emotions as orientations in a Hilbert space*. Such context dependence in decision-making contributes to the reproducibility crisis in psychology and social sciences (Chang et al., 2019). Moreover, the evoked cycle's thermodynamics (Deli and Kisvarday, 2020; Deli et al., 2021, 2022; Chang et al., 2016; Pleeging et al., 2019) permit the spin's psychological interpretation as the cycle's direction.

The spin representation of information processing follows the Born rule (Born, 1926; Don et al., 2020). Let a be an observable vector with eigenvaluefor λ_i an eigenvector $\vec{e_i}$ from an orthonormal basis of eigenvectors$\{\vec{e_i}\}$ If a system such as a brain is in state ψ, then the probability $Pr(a = \lambda_i \mid \psi)$ that λ_i is observed for a equals $|\vec{e_i}, \psi|^2$ Furthermore, let $B \in 2^{H^4}$ i.e., is a collection of vectors that is a subset of a 4-dimensional Hilbert vector field (each vector in this Hilbert space has coordinates (x,y,z,t),t = instant in time. The Born rule for an observable is

$$\Pr(x \in B \mid \psi) = \int_B |\psi(x)|^2 dx \qquad (3)$$

which is the probability that the particle x is found in region B in brain state ψ

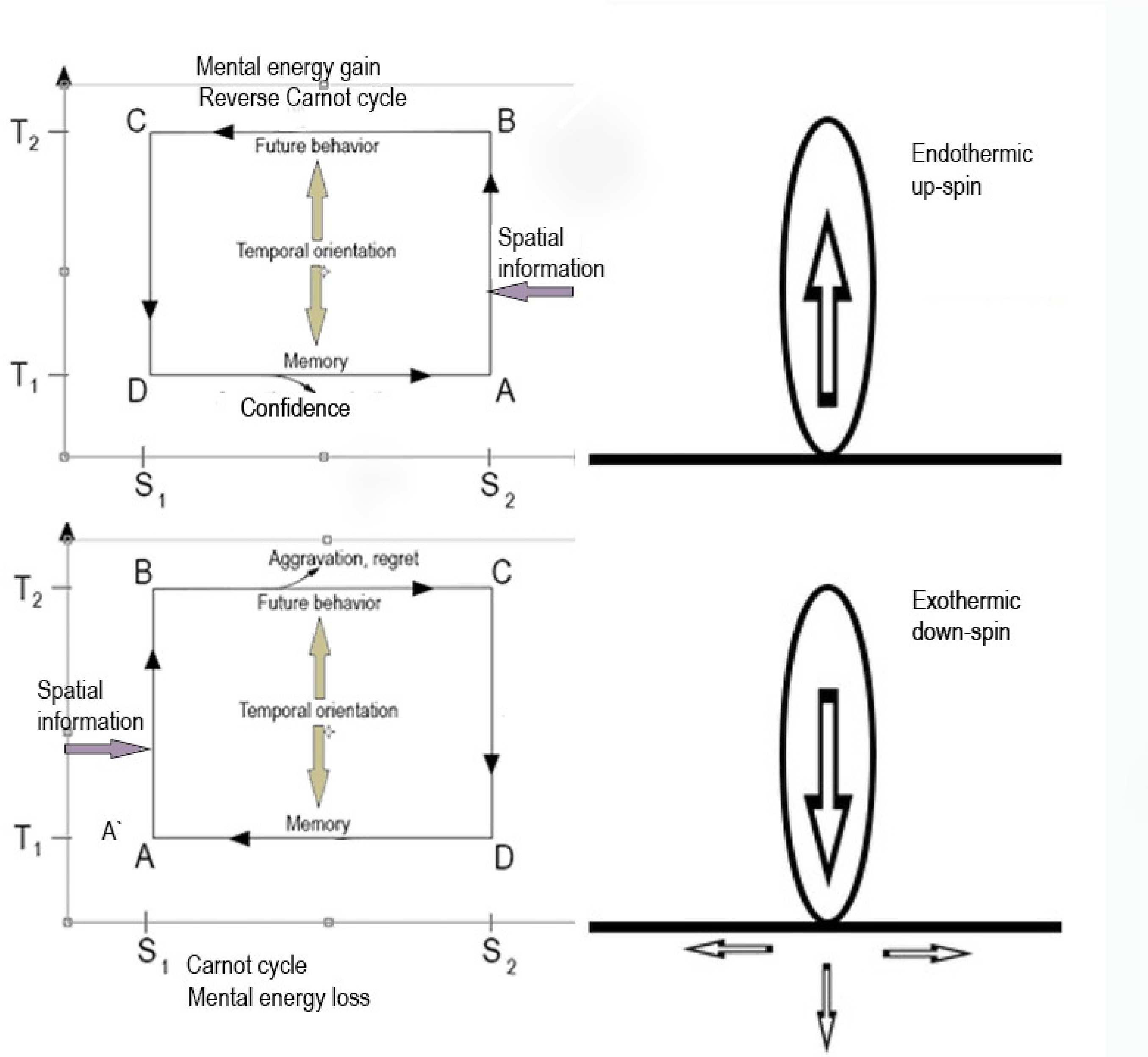

Figure 2. The thermodynamic origin of spin Sensory interaction with the environment triggers the evoked cycle. Its energy production represents spin (left). The endothermic reversed Carnot cycle absorbs energy from the environment to enhance mental energy. It forms up spin (top), whereas the exothermic (Carnot) cycle parallels down spin (bottom). Conversely, the Carnot cycle degrades mental energy by radiating heat toward the environment (drawn after Deli and Kisvarday, 2020).

The interpretation of spinor psychology

Spin is an intrinsic angular momentum that can change signs. So spin belongs to the particle states, but spinor properties emerge from connection with the field. For example, a spinor transforms to its negative when space is rotated through a complete 360° turn. Likewise, partiality (shown by prior stimulus and after-error negativity) inverts the thermodynamic cycle. The reversal overturns the stimulus's meaning, turning sincere words and loving caresses into cynicism and abuse (Jiang et al., 2019; Stavrova & Ehlebracht, 2019; Zhang et al., 2019) and tragedy into a farce.

A consequence of spinor is that only one electron can exist for each state in an atom, leading to the buildup of the periodic table of the elements. Psychological spinor may originate in the brainstem proximate and distal sensory projections (Festinger, 1954; Peng and Xie, 2016; Van Berkel et al., 2015; Wang et al., 2018). In this framework, social comparisons function as the "inner eye" for reflexive consciousness (Saaty and Vargas, 2017), with higher-power individuals perceiving a more pronounced social distance from others (Magee and Smith, 2013; Maglio et al., 2013). A hierarchic organization often infuses families, social relationships (Wato et al., 2020; van Berkel et al., 2015), career paths, and achievement (Du et al., 2019; Phan et al., 2019).

Therefore, emotions are central to behavior and self-determination (Fang et al., 2018). Even in the non-verbal language of the body, emotional valence and intensity communicate something essential about a person's credibility, popularity, and other qualities. Therefore, although emotions often remain hidden from conscious awareness, they underlie all cognitive processes and decision-making (Beall and Tracy, 2017). The involuntary nature and action-producing power of attitude are perhaps the best indications of the energy nature of emotions. Therefore, emotions represent the fundamental forces of motivation.

The Down Spin Psychology

A Carnot cycle acts as a heat engine. It performs work by transferring entropy from a hot to a cold reservoir during a complete thermodynamic cycle. Similarly, the thermodynamic cycle of perception operates between two information reservoirs. Because the information value of incoming stimulus depends on experience, education, and mood, the energetic needs of perception, which includes resting state recovery, changes constantly.

We speculate that the evolutionary purpose of the Carnot cycle has been mitigating mistakes in changing life conditions. Although it is difficult to distinguish particular emotions, the difference between happy and negative emotions (such as fear, sadness, anger, and disgust) is distinct (Esghaei et al., 2022). Furthermore, frequency-based binary emotion classification (positive and negative) can achieve 96.81% accuracy (Gao et al., 2022). Therefore, based on brain activation profiles, emotional valence is positive during lower frequencies and negative amid information-heavy higher frequencies (Gao et al., 2022; Hesp et al., 2021).

We have shown that punishment learning does not require energy investment (Li et al., 2018a). However, negative emotions' cumulative effects in the frontal lobe (Gao et al., 2022) lead to remorse, anxiety, guilt, rumination (Lugo et al., 2020), and mind-wandering (Beshai et al., 2018; Laws, 2019; Ruan et al., 2020; Sedighimornani, 2019). In addition, it takes persistent mental effort to alleviate the cognitive burden of the information-rich self-focus (Bechler et al., 2019; Stringer et al., 2019; Wang et al., 2021).

Likewise, unstable, high-frequency information processing causes erratic behavior, criticism, verbal attack, aggression, or physical violence (Lugo et al., 2020; Laws, 2019; Ruan et al., 2020; Vries, 2017). Negative facial expressions increase arousal via the hypothalamus (Dureux et al., 2022), narrow focus, and reduce the degrees of freedom (Apazoglou et al., 2019; Rowe and Fitness, 2018; Wang et al., 2019), which corrupts neutral and positive information processing (Flechsenhar et al., 2022). Increased functional connectivity lowers the resting entropy in the parietal cingulate cortex and amygdala (Rowe and Fitness, 2018).

As speeding reduces the engine's fuel economy, cognitive information accumulation overwhelms the neural system (Dureux et al., 2022; Gao et al., 2022). Higher frequencies and accompanying behaviors impose significant energy costs on the neural system (Kao et al., 2015; Saarimäki et al., 2017). For example, glutamate accumulation during long, demanding work corrupts decision control (Wiehler et al., 2022), causing deterministic, compromised post-error behavior (Nuno-Perez et al., 2021; Inzlicht et al., 2015). Energy loss turns the focus on the past (down spin). The long-term stress-inducing power and feeling of permanence of negative emotions were confirmed (Gao et al., 2022; Li et al., 2018b; Yang et al., 2018).

The exothermic low resting entropy cycle (Table II) can stabilize and increase stress sensitivity (Hollis et al., 2015; Picard & McEwen, 2018; Wiehler et al., 2022) through a Bayesian process. Therefore, mental diseases might have a thermodynamic origin.

Table II. The thermodynamic and psychological consequences of basic emotions.

The thermodynamic cycle of cognition	Reversed Carnot cycle – Endothermic conditions	Carnot cycle - Exothermic conditions
Entropy	High entropy resting-state	Low entropy resting-state
Mental state	Positive emotions, novelty	Negative emotions, repetitious thinking, aggravation, and violence
Temporal orientation	Future orientation	Past focus
Frequencies	Slow, information-poor oscillations	High, detail-oriented frequencies accumulate information
Future degrees of freedom	Expanding degrees of freedom	Loss of degrees of freedom
Thermodynamic consequences	An endothermic cycle absorbs energy and entropy from the environment.	An exothermic cycle dumps energy and entropy onto the environment.
Consequences for the organism	Mental energy accumulation (intellect)	Mental energy degradation → insecurity, mental and immune problems, depression

The Consequences of the Exothermic Cognition

Repeated stress exposure in rodents corrupts connectivity and reduces plasticity within the medial prefrontal cortex (PFC) to drive depressive behavior (Li et al., 2018b; Yang et al., 2018). Increased functional connectivity lowers the resting entropy in the parietal cingulate cortex and amygdala (Rowe and Fitness, 2018) in proportion to the severity of cognitive impairment (Wang, 2020). In addition, cognitive rigidity (putamen and cerebellum) (Hua et al., 2020) corrupts temporal coherence and self-identity (Sugimura et al., 2021).

The typical exothermic mental degradation follows a two-step process: criticism and physical violence, insecurity, and low self-esteem followed by hormonal disturbances, depression, or disease (Table II). Nevertheless, the trajectory of degradation can show significant individual differences. For example, mental energy loss in introverts might not produce any behavioral symptoms, nevertheless, they are vulnerable to developing depressive symptoms (De Fruyt et al., 2006; Jylha & Isometsa, 2006).

Anxiety (Stringer et al., 2019; Zanin et al., 2019) and rumination (Lugo et al., 2020) occupy significant attentional resources. Corrupted energy regulation is a precursor of pathologic brain conditions (Contreras et al., 2020; Greene et al., 2019; Rowe and Fitness, 2018), mental and other health problems (Kao et al., 2015; Picard et al., 2018; Trevisiol et al., 2017). For example, depression has excessive energy requirements (Kao et al., 2015; Saarimäki et al., 2016, 2017). Immune dysregulation triggers stress hormones (Alhussien & Dang, 2020; Kekic et al., 2020; Koomen et al., 2020).

The Up Spin Psychology

Mistakes represent a failure to move forward. Therefore, corrections, achievement, well-being, health behavior, risk behavior, and retirement planning (Kooij et al., 2018; Li et al., 2019) require future focus (Deli et al., 2018; Deli, 2020b; Fry, 2017; Cox, 1979). We have shown that the endothermic cycle requires thalamic neurotensin production and release (Li et al., 2018a). Just as a lower rpm engine can produce more significant outputs, intelligent computation or correcting mistakes requires a mental slowing down (Ryan and Deci, 2017). Slowing down can be an awe moment, but it often takes work, learning, or struggle. For example, acceptance removes the emotional weight of suffering by turning it into confidence and wisdom (Huang et al., 2020b; Jans-Beken et al., 2019; Ng et al., 2020).

The reversed Carnot cycle loops around a high entropy resting state (Gao et al., 2022), associated with intelligence (Keshmiri, 2020; Wang, 2021) and creativity (Shi et al., 2019). Slow frequencies can access broader cortical areas (microstates), supporting associative representations (Machado & Cantilino, 2016; Tozzi et al., 2017) and adaptive strategies (Brockman et al., 2017; Pavani et al., 2016). In line with the aforementioned slow oscillations, the resting-state temporal variability, i.e., high entropy, correlates with fluid intelligence (Yang et al., 2019), intellectual humility, and openness (Zmigrod et al., 2019).

Intelligent processing requires low social temperature (O'Neill and Schoth, 2022), allowing flexibility (Haimovitz et al., 2019) and optimism. In addition, goal-directed and purposeful action (Ryan and Deci, 2017; Van Cappellen et al., 2018) increase the degrees of freedom (Deli and Kisvarday, 2020; Deli et al., 2021, 2022; Wissner-Gross and Freer, 2013).

Positive psychology recognizes the role of a supportive environment or a positive mind in achievement (Buckwalter, 2019; Schubert et al., 2019). Optimism reinforces itself through a Bayesian process (Table II), predisposing the endothermic cycle (Schoeller & Perlovsky, 2016). For example, novelty (high surprise value) inflates reward expectations and dampens uncertainty (Cockburn et al., 2022), increasing confidence. Therefore, positive emotions have a pivotal role in meaning-making, social relationships (Du et al., 2019; Phan et al., 2019), self-reliance (Makarevskaya, 2018), and academic performance (Carmona-Halty et al., 2019).

Cognitive efficiency is the function of the brain network dynamics (Tomasi et al., 2017) and microscopic organization. Endothermic activity economizes cognitive resources (Poldrack, 2015; Velasco et al., 2019), allowing better fractal power (the power-law exponent) in diverse cortical areas, i.e., the ability to formulate a full range of emotions. For example, gamma oscillations in the somatomotor cortex during states of enhanced vigilance, alpha waves in posterior zones with eyes open, and others (Bongers et al., 2020; Manohar et al., 2018; Van Cappellen et al., 2018).

Mental energy permits wholesome emotional experiences (Deak et al., 2022), openness, and optimism. It gives the courage to take hold of opportunities and the capability to take advantage of them. Therefore, mental energy is the brain's structural quality (Dabaghian, 2019; Debatin, 2019; Dupree et al., 2019), ensuring the wisdom of the sage, the expertise of a doctor, a lawyer, or an expert. Thus, the thermodynamics of emotions can explain the compounded nature of attitude in long-term well-being (Chang et al., 2016; Pleeging et al., 2019). Therefore, mental progress and freedom of action might be fundamental psychological requirements for healthy mental function.

The Role of Time in Cognition

The way energy interacts with matter is the basis of the "arrow of time." Its thermodynamic interpretation connects time to entropy production (Gaspard, 2005; Andrieux et al., 2007; Lucia & Grisolia, 2020; Roldán and Parrondo, 2010) and the loss of work potential. However, the healthy brain's entropy production relies on irreversible resting activities (Zanin et al., 2019). Therefore, in contrast to the arrow of time, the brain's irreversible activations "reverse" time's arrow.

In physics, space and time are interconnected flexible fabrics that lead to time dilation via Lorentz's transformation. However, the spatiotemporal correlations of dynamic brain activities project space into a temporal manifold (Northoff et al., 2019; Tozzi et al., 2017): the temporal projection of a spatially sectioned environment (Tsao et al., 2018; Keppler, 2018). Thus, consciousness emerges from a topologically structured phenomenal space (Prentner 2019); non-linearly changing biological and psychological needs modulate motivation between urgency and relaxation (Fang et al. 2018), turning time perception into a relative experience.

The present moment is a flexible fabric that stretches or contracts depending on personal psychology (Gladhill et al., 2020). Adversity, such as seeing a negative face, increases time perception (Gladhill et al., 2020) through the stress response and allows for rapid and flexible action selection (Fadok et al., 2017). In contrast, positive states induce relaxation, wisdom, and generosity due to the wealth of time, whereas the stress of negative emotions leads to impatience and impulsivity. Both awe and mortal danger slow the inner clock (Tozzi et al., 2017) via a subjective, arousal-dependent dilation of the present moment (Lubashevsky, 2018; Tsao et al., 2018; Xu et al., 2018).

By carrying information about past experiences, visceral signals can provide rapid somatic feedback on the proper action selection process in a new situation, thereby acting as a secondary decision inducer (Nashiro et al., 2022). This kind of reinforcement exaggerates the original perception and leads to non-linear emotional regulation, which accelerates the decision process, particularly in stressful environmental conditions (fight, flight, freeze).

Arousal is not a state that can be permanently maintained. Despite a non-linear regulation, emotions oscillate around a neutral position (Northoff & Tumati, 2019), indicating the existence of an emotional set-point. Without the ability to look under the hood, emotions serve mental equilibrium by adjusting neural circuits, including serotonergic circuits, in controlling cognitive function and mood (Lowry et al., 2009), perception and response.

The immense power of emotions to influence physiology underlines the energy nature of emotional states (Ellard et al., 2017). In this view, blushing, psychogenic shivering, or even perspiration during stress are part of psychological homeostasis. These thermoregulatory pathways release emotional tension to maintain cognitive constancy based on cultural, learned, genetic, and subjective-personal characteristics (Kolvoort et al., 2020; Wolff et al., 2019). Emotions are the fundamental forces of motivation and the master regulators of personal cognitive comfort.

Discussion and Conclusions

Life's low entropy is maintained by homeostatic regulation occurring on many levels. In endotherms, cognitive self-regulation centered on the resting state sits at the top of this hierarchy, forming high entropy. Therefore, high entropy quantifies complexity, a fundamental property of conscious experience with emotions providing feedback on every aspect of bodily welfare and feedback to the brain's predictions (Peil, 2014). The emotional master regulation maintains a genetically, culturally, and personally determined cognitive comfort.

According to Conant and Ashby, "every good regulator of a system must be a model of that system" (1991). Therefore, intelligent (i.e., dynamic and responsive) feedback to a stimulus requires modeling the physical environment (Singer, 2021; Witkowski et al., 2022). Based on sensory input, the temporal brain internalizes the operating principles of the physical world into a fermionic organization (Deli, 2020a,b). Therefore, the brain's ability for superior response is the function of adopting the physical world's organizational principles.

Consciousness is the awareness of being separate from the environment, which defines a separate, inner mental cosmos. The orthogonal transformation of sensory information turns consciousness into a holographic organization. The first-person conscious experience (the inside, unique view of the individual), not available to anyone else, is the smallest unit of intellect. Therefore, the mind is both the observer and observee of the brain (Dennett, 2018). The fermionic mind hypothesis recognizes the temporal mind's separate, first-person view of the conscious experience (Deli, 2020a,b). This particle-like isolation might give rise to some of the most intractable aspects of consciousness.

The varied brain activity profiles and multi-dimensional representations of emotions represent only two energy directions (up and down) of psychological spin. The endothermic cycle parallels up spin, whereas the exothermic cycle corresponds to down spin with real, measurable, long-term consequences. Like the atomic structure, social hierarchy originates in entanglement and the spinor organization. Therefore, emotions represent the energy states of the brain with a constant presence in both conscious and unconscious mental states.

Energy input from a positive environment, learning, or acceptance, ensures an endothermic cycle, which fuels future orientation, motivating well-being, intellect, and creativity. The exothermic cycle disperses energy and entropy onto the environment through criticism, aggravation, or physical violence. Information accumulation lowers entropy and introduces reversible resting activations, which trigger repetitive thinking and remorse. Hormonal problems can cause psychological dysfunction and disease.

Cognitive perception, a closed, reversible, and probabilistic thermodynamic cycle, acts as a quantum system. Therefore, in contrast to quantum systems, which give rise to classical outcomes, the classical neural system produces quantum behavior. Nevertheless, the resting state's stability and evolution parallel classical features. This dichotomy may account for many puzzling features of the mind, such as unconscious, vs. conscious states, beliefs and uncertainty, context dependence, and cognitive constancy despite continuous mental evolution.

Future Perspectives

The fermionic mind hypothesis posits that the neural system's interaction with the physical environment perfected the understanding of the physical laws by projecting them into the mind. The orthogonal projection of the physical laws into a temporal system endowed the mind with a temporal organization based on memories, which helps to anticipate environmental changes. Therefore, the concepts, thoughts, and ideas have a probabilistic and fluid nature, but beliefs, knowledge, and convictions change discretely, showing long-term stability. This quantum and classical divide makes the abstract, nontangible mind so hard to conceptualize. Furthermore, the equivalence principle (the laws of physics are the same everywhere) applies to cognition.

Although the details of the hypothesis need to be worked out, the hypothesis has the potential to create a paradigm change in the understanding of consciousness. Computer simulations, such as the Blue Brain Project and psychological studies, can validate the hypothesis. For example, entanglement's contradictory tendency can be tested in psychology. Aggravation priming should result in adverse reactions to constructive ideas and suggestions (entanglement). Nevertheless, acceptance resolves contradictions, and contentment prevents them outright. A mathematical argument can work out the parallels of spinor operation between psychological phenomena and physics. Psychological studies can verify a possible analogy between time perception and Lorentz's transformation. Understanding emotions as the fundamental forces of motivation can aid education, psychiatry, and animal husbandry. The thermodynamic study of emotions will inspire better AI.

The universality of physical laws indicates the fundamental coherence of the natural world. The contrasting work production in material systems and the mind indicate their orthogonal relationship, which might provide a possible thermodynamic argument for intellect's evolutionary emergence. Living systems are highly efficient energy and entropy absorbers, an ability exponentially increasing during biological and technological evolution. Therefore, the second law of thermodynamics, which increases disorder in the physical world, facilitates complexity, intellect, and social advancement.

Data Availability

Data sharing does not apply to this article as no datasets were generated or analyzed during the current study.

The authors have no competing interests to declare.

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