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Review

Feeling the Heat: A Thermodynamic Perspective on Emotions, Motivation, and Time Perception

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Abstract: We are introducing a novel thermodynamic emotion model. In this model, emotions are regarded as deviations from equilibrium, akin to fluctuations in body temperature. This bipolar regulation maintains bodily and psychological homeostasis while spurring mental development. Emotional regulation typically occurs through expanding one's perception of time. Positive, low-information content emotions can reduce action drive, but stressful, information-rich conditions can heighten it. However, action accelerates time perception to facilitate fluid action performance, where a unique state of contentment and challenge represents flow. Therefore, time perception can control emotions' capacity to control motivation. By anchoring psychological processes to the principles of energy and entropy, our model offers a comprehensive bipolar foundation for understanding motivation and behavior. Beyond its theoretical implications, this model also lays the groundwork for addressing mental health conditions resulting from the dysregulation of emotions. It can inspire potential interventions to harness the mind-body connections elucidated in our thermodynamic perspective.

Keywords: emotions; motivation; time perception; thermodynamics; energy regulation; entropy; body temperature; binary regulation

Introduction

The unprecedented surge in stress disorders across the globe makes the understanding of the role of emotions in behavior an urgent problem (Nestler and Russo, 2024). Nevertheless, a comprehensive understanding of how emotions relate to subjective experiences (i.e., feelings), motivation, and disease progression has remained elusive. Traditional approaches have treated these processes as separate domains, failing to capture their intricate interdependencies. For example, cognitive theories have focused primarily on the mental processes underlying emotions (Barrett, 2017). At the same time, physiological research has investigated bodily responses like heart rate and facial expressions largely independently of motivational and subjective factors. This compartmentalized view has limited our ability to explain the complex relationships and paradoxes observed across these realms of human experience.

This article proposes a novel thermodynamic model integrating emotions, motivation, and associated physiological mechanisms under a unified framework. The brain keeps bodily and psychological equilibrium by intertwining every regulatory system with emotions. Nevertheless, the multifaceted nature of the relationship encourages further study. This work examines how emotions serve temperature regulation and psychological homeostasis. By conceptualizing the brain's

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functioning through thermodynamic principles of energy and entropy, we offer a cohesive perspective to resolve longstanding questions and paradoxes surrounding these interrelated processes.

Thermo-Emotional Covariations from a Thermodynamic Lens

Experimental research confirms the phylogenetically ancient relationship between emotions and temperature regulation across various species, including reptiles, foxes, pigs, rabbits, rats, mice, and humans (Cabanac, 1999; Moe and Bakken, 1997; Parrott et al., 1995; Frosini et al., 2000; Briese and Cabanac, 1991; Terlouw et al., 1996; Groenink et al., 1995; van der Heyden et al., 1997; Briese, 1995). Although thermoregulation exists to some degree in most animals, the endothermic phenotype—characteristic of humans and other mammals—depends on complex metabolic networks and multiple internal feedback loops (Seebacher, 2020; Grigg et al., 2021). For example, embryo incubation drives the evolution of endothermy (Farmer, 2020), which is phylogenetically predicated on thermoregulation (Clavijo-Baque et al., 2012). Endotherms maintain a stable core temperature with the help of crucial mechanisms such as vasoconstriction, shivering, and sweating (Madden & Morrison, 2019; Nowack et al., 2017). The brain's high energy use ensures optimal information processing while maintaining physical and psychological equilibrium (Dempsey et al., 2022; Huang, 2020). Thermal control is a vital component of an overarching regulatory system, exerting downstream effects on action motivation and behavioral adaptations (Kataoka et al., 2020; Inagaki et al., 2019; Nashiro et al., 2022).

Physical or mental instability prompts a wide range of protective mechanisms. Emotions are paramount in this regulatory hierarchy as they intertwine with other regulatory processes. Moreover, emotions' distinct physiological signatures represent specific energy configurations (Hesp et al., 2021; Kao et al., 2015; Sadowski et al., 2020), and like temperature, emotions oscillate around a neutral position, forming an emotional set-point (Northoff & Tumati, 2019). Contentment promotes rest and recovery (Brown and Thorsteinsson, 2020) by reducing metabolic rate and body temperature, which conserve energy via parasympathetic restorative processes (Seebacher, 2009). In contrast, stress is a highly demanding condition (Keller et al., 2019; Meeusen et al., 2020), where noradrenaline initiates the fight-or-flight response within seconds (O'Connor et al., 2021). Furthermore, stress' varied effects depend on personal, environmental, and other situational factors. However, its adverse health effects in anxiety, dissociation in trauma, or even depression (Mason et al., 2024; Comtesse et al., 2019) warrant a thermodynamic investigation.

Edit: Recent work suggests that emotion and temperature may be under thermodynamic control (as discussed in Deli and Kisvarday, 2021; Grigg et al., 2021; Seebacher, 2020). Lonely people's hunger for social "warmth," points to a direct, neurological emotion and temperature relationship (Bargh et al., 2012; Williams and Bargh, 2008). For example, substance abusers display fear-induced thermoregulation disturbances (Lowry et al., 2009; Raison et al., 2015). Similarly, median raphe stimulation degrades temperature regulation while producing depressive-like behavior (Fazekas et al., 2021). In contrast, while psychological stress is known to increase blood pressure, heart rate, and heart function, even during sleep (Hall et al., 2004), it also raises core temperature (PSRCT), the so-called psychogenic fever (Oka et al., 2001). PSRCT is a temporary elevation in the thermoregulatory set point, mediated by prostaglandin E2-dependent and prostaglandin E2-independent, 5-HT mechanisms (Morimoto et al., 1991; Fossat et al., 2015; Kluger et al., 1987; An and Kim, 2011). Inversely, heat stress speeds up the internal clock (van Maanen et al., 2019), precipitating impulsivity (Fredericks et al., 2018), drug-seeking behavior (Edwards et al., 2007), and crime (Corcoran et al., 2022). Therefore, the brain's heat and work transfer processes regulate emotional states and vice versa. To better understand the relationship, we will delve into thermodynamic regulation.

Edited: Recent work suggests that emotion and temperature may be under thermodynamic control (as discussed in Deli and Kisvarday, 2021; Grigg et al., 2021; Seebacher, 2020). This perspective posits that the brain's mechanisms for heat and work transfer play a crucial role in regulating emotional states, and conversely, that emotional states can influence thermoregulation. For instance, individuals experiencing loneliness often crave social "warmth," which suggests a neurological link

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between emotion and temperature (Bargh et al., 2012; Williams & Bargh, 2008). On the other hand, heat stress can lead to impulsivity (Fredericks et al., 2018), drug-seeking behavior (Edwards et al., 2007), and criminal activity (Corcoran et al., 2022). Similarly, fear triggers thermoregulation disturbances in substance abusers (Lowry et al., 2009; Raison et al., 2015) and median raphe stimulation, which affects temperature regulation, has also been shown to produce depressive-like behaviors (Fazekas et al., 2021).

Conversely, psychological stress, known to elevate blood pressure, heart rate, and heart function—even during sleep (Hall et al., 2004)—also leads to an increase in core temperature, a phenomenon referred to as psychogenic fever (Oka et al., 2001). This psychogenic fever results from a temporary elevation in the thermoregulatory set point, mediated by both prostaglandin E2-dependent and prostaglandin E2-independent, 5-HT mechanisms (Morimoto et al., 1991; Fossat et al., 2015; Kluger et al., 1987; An & Kim, 2011). To gain a deeper understanding of this relationship, it is essential to explore the mechanisms of thermodynamic regulation in more detail.

The Role of Entropy

Edit: Thermoregulation is crucial in efficient brain functioning. For example, rapid shifts from the brain's high-dimensional resting state to lower-dimensional evoked activities (Singer, 2021), facilitate optimal information transfer. However, the energy needs of neurons during intrinsic activities are orders of magnitude larger than the energy changes during stimulation and consistently so for all levels of cognition (de Lara, 2020; Raichle, 2010; Huang, 2019). Therefore, the brain's intrinsic activities dominate cognition, facilitating spontaneous resting state recovery. In this simplified view, sensory and motor processing represents a closed cognitive cycle, which generates intellect by exchanging energy and information with the external environment (Ahissar and Assa, 2016; Deli et al., 2017; Llinás and Paré, 1996; Northoff, 2018). Second, thermodynamic principles extend to organismic temperature regulation and information processing.

Edited Thermoregulation is crucial in efficient brain functioning. For example, rapid shifts from the brain's high-dimensional resting state to lower-dimensional evoked activities (Singer, 2021), facilitate optimal information transfer. Because the energy needs of neurons during intrinsic activities are orders of magnitude larger than during stimulation for all levels of cognition (de Lara, 2020; Raichle, 2010; Huang, 2019), the brain's intrinsic activities facilitate spontaneous resting state recovery. In this simplified view, thermodynamic principles can analyze intellect generation by energy and information exchange with the external environment (Ahissar and Assa, 2016; Deli et al., 2017; Llinás and Paré, 1996; Northoff, 2018). Therefore, sensory and motor processing represents a closed thermodynamic cycle.

Renyi's informational entropy, featuring a scalar exponent alpha (Jizba and Arimitsu, 2001), provides a valuable framework. Notably, there's a direct relationship between inverse temperature beta and Renyi's exponent alpha (Baez, 2011). Thus, inverse temperature beta (i.e., coldness) measures the correlation between information and emotion – usefully conceptualized as measuring the fluctuation of probabilities for different mental states. Intelligent information processing often involves a type of information erasure or compression. This process may induce a sense of "coldness" while increasing overall neural organization (see O'Neill and Schoth, 2022; Nave et al., 2014).

Renyi's informational entropy and Shannon's microscopic informational entropy closely relate to various psychological and cognitive states. Therefore, entropy fluctuations can predict task performance and mental well-being (Ince et al., 2017). For instance, higher variability at rest (i.e., high entropic states) correlates with fluid intelligence (Yang et al., 2019; Wang et al., 2018) and openness (Zmigrod et al., 2019), but decreases in brain entropy are seen in compromised states of consciousness (Varley et al., 2020). Thus, emotions are closely intertwined with the brain's energy and information processing. From a thermodynamic standpoint, stress is analogous to time pressure, the feeling of "lacking" time due to the brain's inability to cope with the pace or intensity of sensory influx (Deli et al., 2018, 2021, 2022). The following section will discuss the role of time perception in motivation.

The Thermodynamics of Time Perception

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Studies on behavioral activation systems have revealed overestimation bias scores for both positive (Lehockey et al., 2018; Simen and Matell, 2016; van Hedger et al., 2017) and stress-inducing situations (Wise et al., 2017; Remmers and Zander, 2018). For instance, novel stimuli or rewards dilate time perception through what is known as the 'oddball effect' (Failing & Theeuwes, 2016; Ma et al., 2024), with surprising or emotionally charged moments feeling as if "time froze." A similar sense of permanence occurs during stress (Hollis et al., 2015; Robbe, 2023). However, the two psychological experiences are polar opposites of each other. In a stressful context, the dilated time perception's sense of permanence is unbearable. The feeling of permanence during time pressure, which stress represents, evokes a desperate escape behavior through impatience and sympathetic arousal (Gladhill et al., 2022; Hosseini Houripasand et al., 2023), manifesting action motivation.

The dilation of time perception in both positive and negative states correlates with emotional intensity (Zanin et al., 2019; Déli and Kisvarday, 2020; Biderman et al., 2020), hinting at an underlying energy relationship (Toso et al., 2021). For example, the most pronounced alterations of time perception occur during emotional polarities of awe (Rudd et al., 2012) and depression (Stanghellini et al., 2016; Thönes and Oberfeld, 2015), where time seems to stand still (Figure 1). Emotions' connection to energy is also evidenced by the fact that the perception of time slows down more significantly during the transition to negative states than during the states themselves (Gable & Poole, 2012; Wang & Lapate, 2023). Likewise, the cognitive challenge of withdrawal (Gable et al., 2022; Bar-Haim et al., 2010; Di Lernia et al., 2018) and sleep deprivation (Şen et al., 2023) dilates time perception. Our argument defines time perception as an even function, representing a graph unchanged under reflection in the y-axis (Figure 1).

An intriguing question remains of why diverse experiences – from intense states of anxiety to the calmness inspired by awe or nature – dilate time perception (Bschor et al., 2004; Davydenko & Peetz, 2017; Failing & Theeuwes, 2016; Rudd et al., 2012; Bannister & Eerola, 2021; Mitchell et al., 2015). For example, information overload often defines stressful states, when excessive worry by anxious individuals leads to difficulty concentrating and inability to produce purposeful behavior (Nutt, 1999). Anxious people usually resort to impulsivity and meaningless, arbitrary actions until action motivation is halted in depression (Stanghellini et al., 2016), implying a proportional relationship between mental adversity and the perceived ability to change it. Therefore, chaotic thinking and behavior are associated with stress, which wastes time and energy.

In contrast, positive mental states' low action motivation indicates energy frugality, which might explain their connection to parasympathetic restorative processes in long-term psychological well-being (Table I). A muted action motivation in positive states indicates energy frugality or a minimum energy path. This minimum energy path might be analogous to the stationary-action principle in physics. At the curve's left minimum (Figure 1), awe slows or pauses the subjective time. Contentment is an uncluttered, information-scarce experience representing confidence in self-agency but lacking internal motivation.

Stress and contentment lie at opposite ends of an information-processing and action-motivation spectrum. It is a contradiction; those with the capacity to institute change (contentment) lack the desire, and those having the desire (stress) lack the agency. Gordon et al. (2023) confirmed that decision-making and planning intertwine with bodily functions and movement control, confirming our conclusion. Better body control (less stress) permits greater agency and vice versa.

Time perception regulation involves hormonal pathways, such as striatal dopamine. For instance, rats' dopamine release speeds up response (Simen and Matell, 2016). However, pharmacogenetic suppression of dopamine neurons decreased behavioral sensitivity to time (Soares et al., 2016). Elevated dopamine release, such as during reward processing or pleasant arousal, may result from amplified information processing (Behm and Carter, 2020). Therefore, time perception is integral to the brain's hormonal and energy regulation.

Physical movement across species and tasks hastens time perception, improving timing accuracy (Robbe, 2023). A particular case is the flow experience, formed by a unique point between motivational drive and confidence, fostering a spontaneous, coherent action flow (Failing & Theeuwes, 2016; Rutrecht et al., 2021). As physical time is relative to spatial motion, psychological

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time is also relative to imaginary motion (Spapé et al., 2021; Allingham et al., 2021). Imagining accelerating movement resulted in relative overestimation of time or time dilation while decelerating movement elicited relative underestimation or time compression (Hallez et al., 2023). In the following, we investigate motivation's regulatory framework in more detail.

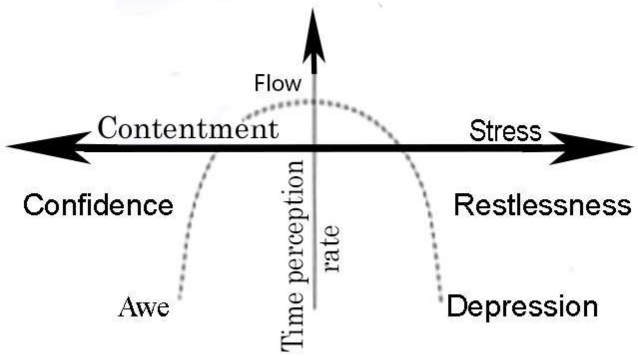

Figure 1. The Psychology of Contentment and Stress Movement speeds up time perception (vertical arrow). In positive experiences, time perception reduces action motivation, culminating in awe. The pain of stress motivates action but weakens self-confidence. Anxiety can progress to depression when action motivation halts. A unique point of action, motivation, and confidence is flow.

Table 1. Binary choices supporting bodily and psychological equilibrium .

	Experience	
Symptom	**Positive arousal**	**Stress**
Time perception increases (Dilation) Arousal	Parasympathetic	Action motivation
Time perception decreases (Compression) Action	Flow	Sympathetic
Physiological symptoms (shivering, sweating)	Accomplishment	Shame, fear

The Binary Regulation of Higher Cognitive Functions

The timing of a single spike in the giant fiber descending neuron determines whether a Drosophila evades a predator via a short or long takeoff (Ache et al., 2019). Similar bipolar spatial regulation persists in fish species (Sridhar et al., 2021), illustrating the role of the organism's internal spatial representation in decision-making. This framework shows that spontaneous and abrupt "critical" transitions, linked with specific geometrical relationships, shift from averaging vectorial information among options to abruptly excluding one among the remaining choices. The brain recurrently dissects multi-choice decisions into a sequence of binary decisions, which transform space and time. Binary choices also show up in temperature and emotion regulation in mammals (Hesp et al., 2021; Kao et al., 2015; Sadowski et al., 2020).

Likewise, in mammals, PAG stimulation can induce relaxation or escape behavior. Frontal PAG stimulation inspires a relaxed, immobile posture due to the sense of a wealth of time. However, lateral PAG stimulation also produces two typical behavioral responses. When there is enough time, increased blood pressure and enhanced pain sensitivity promote escape and defensive responses (Zelena et al., 2018). An immediate threat, when escape is no longer possible, mutes pain sensitivity and triggers immobile freezing behavior. In people, anxiety can induce aggravation or an emotional collapse into depression, where both time perception and action motivation appear to halt (Stanghellini et al., 2016), providing further support for our thermodynamic argument. Bifurcations

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from geometric principles can elucidate behavior and decision-making across various species and ecological scenarios (Sridhar et al., 2021).

The thermodynamic understanding of cognition also supports binary decision-making (Deli et al., 2017, 2022) because the reversible perception cycle forms a psychological spin based on attraction and aversion (Deli, 2023). These binary choices can generate multifaceted behavior regulation (summarized in Table I), such as (1) dilation of time perception to accelerate or mute motivation, (2) contraction of time perception to mediate action toward completion, (3) halting of action motivation or sudden cognitive changes. The brain's cognitive cycle, which automatically recovers psychological equilibrium, can evolve a new balance after every binary decision. Therefore, our model can explain regulatory complexity as infinitely increasing binary choices or effects built on each other. Dopaminergic mechanisms, which can magnify the motivational power of emotions through subjective time judgment, showcase the multifaceted nature of experiences influenced by internal and external factors.

Discussion and Future Directions

Decision-making from fruit flies to humans often boils down to binary choices based on geometric principles and critical transitions. The brain's cognitive cycle can maintain a bodily and psychological equilibrium through simple bifurcation stemming from geometric principles. This cognitive stability can form abstract decision-making, diverse emotional and motivational states, and complex behavior by utilizing binary choices. Binary options can refine cognitive and intellectual evolution through learning, beliefs, and individual capabilities ad infinitum. Moreover, emotion, temperature, and physiological symptom regulation recover and maintain constant resting entropy. Therefore, as the thermodynamic cycle stabilizes the psyche around a new equilibrium after every decision-making, it increases or decreases synaptic complexity, confidence, and mental health.

Time perception can lead to contrasting behavioral outcomes during stress (information overload) or contentment (information scarcity). Negative emotions inspire arbitrary and chaotic performance, corresponding to wasteful energy use, and might explain stress' adverse health effects. In positive conditions, frugal action motivation reflects a minimal energy path, analogous to the stationary action in physics. Moreover, faster time perception can manage ongoing action by inspiring cognitive coherence. A particular case is the flow experience, formed by a unique intersection of motivational challenge, confidence, and passion.

Significant situational changes, accomplishments, or adversity, such as fear or dread, trigger energy/information flows with physiological symptoms like shivering, chills, sweating, and changes in body temperature, which intertwine with emotions and other regulatory systems (Schoeller & Perlovsky, 2016). In this context, physiological symptoms can be both tools and consequences of the brain's energy regulation. By conceptualizing psychological processes through energy dynamics, we outlined how emotions can affect motivation through distorted time perception. Moreover, our thermodynamic model can explain how action motivation during stress can produce wasteful cognitive processes. The relationship between low entropy and compromised consciousness states (Varley et al., 2020) and depression (Wise et al., 2017) underlines the role of stress in mental problems.

Our model provides a framework for designing interventions and strategies that leverage the interconnections between emotions, motivation, and physiology. While our thermodynamic model focuses on the fundamental structural motivations underlying behavior, we acknowledge the importance of cultural norms, social expectations, and environmental factors in shaping emotional and motivational experiences. Integrating these contextual factors is crucial to understanding the complex interplay between emotions, motivation, physiology, and subjective experiences across diverse cultural and environmental settings.

Conclusion

The thermodynamic analysis of cognition points to the existence of binary regulation. First observed in fruit flies and fishes, this regulation can maintain bodily and psychological equilibrium and enable abstract decision-making by infinitely enhancing regulatory complexity details. A

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decision process based on geometric principles might be universal throughout biology and even physics, e.g., electromagnetism.

Our verifiable framework shows that identical dilation of time perception in arousing emotional states (such as anxiety and joy) and calming experiences (like awe and natural environments) can give rise to varied motivation and offer nuanced decision-making. Time perception, a function of information processing and entropic factors, potentiate emotions ability for motivation. The muting of action motivation in positive states represents energy frugality or a minimum energy path, analogous to the stationary-action principle in physics. In contrast, stress represents information overload and spurs chaotic decision-making and action-motivation, wasting effort and energy. Our model shows that emotions have a thermodynamic foundation, turning them into the forces of motivation.

The implications of our model extend beyond theoretical understanding, offering potential avenues for addressing mental health challenges and optimizing well-being through interventions that leverage the interconnections between emotions, motivation, and physiology. Our thermodynamic perspective originates emotions and their long-term mental consequences in the energy-information dynamics of the brain. It opens new avenues for interdisciplinary and innovative approaches to understanding and optimizing human functioning. Finally, it can inspire novel approaches in artificial intelligence research.

References

1. Ache, J.M., Polsky, J., Alghailani, S., Parekh, R., Breads, P., Peek, M.Y., Bock, D.D., Reyn, CR, & Card, G.M. (2019). Neural Basis for Looming Size and Velocity Encoding in the Drosophila Giant Fiber Escape Pathway. Current Biology, 29, 1073-1081.e4.
2. Ahissar E, Assa E. Perception as a closed-loop convergence process. Elife. 2016 May 9;5:e12830. doi: 10.7554/eLife.12830.
3. Allingham E, Hammerschmidt D, Wöllner C. Time perception in human movement: Effects of speed and agency on duration estimation. Q J Exp Psychol (Hove). 2021 Mar;74(3):559-572.
4. An, S. J. and Kim, D. (2011). Alterations in serotonin receptors and transporter immunoreactivities in the hippocampus in the rat unilateral hypoxic-induced epilepsy model. Cellular and Molecular Neurobiology, 31(8), 1245-1255. https://doi.org/10.1007/s10571-011-9726-x.
5. Baez JC (2011) Entropy and Free Energy. arXiv:1102.2098 [quant-ph]
6. Bannister, S., & Eerola, T. (2021). Vigilance and social chills with music: Evidence for two types of musical chills. Psychology of Aesthetics, Creativity, and the Arts.
7. Bargh JA, Shalev I. The substitutability of physical and social warmth in daily life. Emotion. 2012 Feb;12(1):154-62. doi: 10.1037/a0023527. Epub 2011 May 23. PMID: 21604871; PMCID: PMC3406601.
8. Bar-Haim, Y., Kerem, A., Lamy, D., and Zakay, D. (2010). When times slows down: the influence of threat on time perception in anxiety. Cognit. Emot. 24, 255–263.
9. Barker, G. R. I. et al. (2016) Separate elements of episodic memory subserved by distinct hippocampal–prefrontal connections. Nat. Neurosci. http://dx.doi.org/10.1038/nn.4472
10. Barrett, L. F. Social Cognitive and Affective Neuroscience, Volume 12, Issue 1, January 2017, Pages 1–23,
11. Behm, D. G., and Carter, T. B. (2020). Effect of exercise-related factors on the perception of time. Front. Physiol. 770. doi: 10.3389/fphys.2020.00770.
12. Biderman, N., Bakkour, A., & Shohamy, D. (2020). What Are Memories For? The Hippocampus Bridges Past Experience with Future Decisions. Trends in Cognitive Sciences, 24, 542-556.
13. Briese, E., 1995. Emotional hyperthermia and performance in humans. Physiology and Behavior 58, 615–618.
14. Briese, E., Cabanac, M., 1991. Stress hyperthermia: physiological arguments that it is a fever. Physlogical Behaviour 49, 1153–1157.
15. Brown, R., Thorsteinsson, E. (2020). Arousal States, Symptoms, Behaviour, Sleep and Body Temperature. In: Brown, R., Thorsteinsson, E. (eds) Comorbidity. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-32545-9_7
16. Bschor T, Ising M, Bauer M, et al. Time experience and time judgment in major depression, mania, and healthy subjects: a controlled study of 93 subjects. Acta Psychiatr Scand. 2004;109(3):222–229.
17. Cabanac, M. (1999). Emotion and phylogeny. Journal of Consciousness Studies, 6(6-7), 176–190.
18. Carmona-Halty, M., Salanova, M., Llorens, S., & Schaufeli, W. (2019). How Psychological Capital Mediates Between Study–Related Positive Emotions and Academic Performance. Journal of Happiness Studies, 20, 605-617.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 28 November 2024 doi:10.20944/preprints202411.2245.v1

19. Colombo, D., Pavani, J., Fernández-Álvarez, J., García-Palacios, A., & Botella, C. (2021). Savoring the present: The reciprocal influence between positive emotions and positive emotion regulation in everyday life. PLoS ONE, 16.
20. Composto, J., Leichman, E. S., Luedtke, K., & Mindell, J. A. (2021). Thermal comfort intervention for hot-flash related insomnia symptoms in perimenopausal and postmenopausal-aged women: an exploratory study. Behavioral Sleep Medicine, 19(1), 38-47.
21. Comtesse H., Powell S., Soldo A., Hagl M. and Rosner R. Long-term psychological distress of Bosnian War survivors: an 11-year follow-up of former displaced persons, returnees, and stayers. BMC Psychiatry. 2019; 19
22. Connelly BD, Bruger EL, McKinley PK, Waters CM. Resource abundance and the critical transition to cooperation. J Evol Biol. 2017;30: 750–761. Pmid:28036143.
23. Corcoran, J., Zahnow, R. (2022). Weather and crime: a systematic review of the empirical literature. Crime Sci 11, 16 https://doi.org/10.1186/s40163-022-00179-8
24. Craig A. D. (2009). Emotional moments across time: a possible neural basis for time perception in the anterior insula. Philosophical transactions of the Royal Society of London. Series B, Biological sciences, 364(1525), 1933–1942. https://doi.org/10.1098/rstb.2009.0008
25. Criscuolo, A., Schwartze, M., & Kotz, S.A. (2022). Cognition through the lens of a body–brain dynamic system. Trends in neurosciences.
26. D'Agostino O, Castellotti S, Del Viva MM. (2023) Time estimation during motor activity. Front Hum Neurosci. Apr 21;17:1134027.
27. Davydenko, M., & Peetz, J. (2017). Time grows on trees: The effect of nature settings on time perception. Journal of Environmental Psychology, 54, 20-26.
28. Day MV, and Bobocel DR The Weight of a Guilty Conscience: Subjective Body Weight as an Embodiment of Guilt. PLoS ONE, 2013, 8 (7): e69546.
29. de Lara, A.C. (2020). Interpreting the High Energy Consumption of the Brain at Rest. Proceedings. 46(1), 30; https://doi.org/10.3390/ecea-5-06694
30. Debatin, T. (2019). A Revised Mental Energy Hypothesis of the g Factor in Light of Recent Neuroscience. Review of General Psychology, 23, 201—210.
31. Deli, E. and Kisvarday, Z. (2020) The Thermodynamic Brain and the Evolution of Intellect: The Role of Mental Energy. Cognitive Neurodynamics, DOI: 10.1007/s11571-020-09637-y
32. Deli, E. K. (2023). "What Is Psychological Spin? A Thermodynamic Framework for Emotions and Social Behavior" Psych 5, no. 4: 1224-1240.
33. Deli, E., Peters, J. and Tozzi, A. (2017) "Relationships between short and fast brain timescales," Cognitive Neurodynamics, vol. 11, no. 539.
34. Deli, E., Peters, J., and Kisvarday, Z. (2021) The thermodynamics of cognition: A Mathematical Treatment, Computational and Structural Biotechnology Journal. (19) 784-793.
35. Deli, E., Peters, J., and Tozzi, A. (2018) The Thermodynamic Analysis of Neural Computation. J Neurosci Clin Res. 3:1.
36. Déli, É., Peters, J.F., & Kisvárday, Z.F. (2022). How the Brain Becomes the Mind: Can Thermodynamics Explain the Emergence and Nature of Emotions? Entropy, 24.
37. Dempsey, W. P. Du, Z., Nadtochiy, A. et al. (2022) Regional synapse gain and loss accompany memory formation in larval zebrafish. PNAS 119 (3) e2107661119.
38. Di Domenico, S. I., and Ryan, R. M. The emerging neuroscience of intrinsic motivation: a new frontier in self-determination research. Front. Hum. Neurosci. 2017, 11:145.16.
39. Di Lernia, D., Serino, S., Pezzulo, G., Pedroli, E., Cipresso, P., & Riva, G. (2018). Feel the Time. Time Perception as a Function of Interoceptive Processing. Frontiers in Human Neuroscience, 12.
40. Ellard, K.K., Barlow, D.H., Whitfield-Gabrieli, S.L., Gabrieli, J.D., & Deckersbach, T. (2017). Neural correlates of emotion acceptance vs worry or suppression in generalized anxiety disorder. Social Cognitive and Affective Neuroscience, 12, 1009 - 1021.
41. Failing, M., & Theeuwes, J. (2016). Reward alters the perception of time. Cognition, 148, 19–26.
42. Farmer, C.G. (2020). Parental Care, Destabilizing Selection, and the Evolution of Tetrapod Endothermy. Physiology, 35 3, 160-176.
43. Fazekas, C.L., Bellardie, M., Török, B. et al. (2021). Pharmacogenetic excitation of the median raphe region affects social and depressive-like behavior and core body temperature in male mice. *Life sciences*, 120037.
44. Fossat, P., Bacqué-Cazenave, J., Deurwaerdère, P. D., Cattaert, D., & Delbecque, J. (2015). Serotonin, but not dopamine, controls stress response and anxiety-like behavior in crayfish, procambarus clarkii.. Journal of Experimental Biology. https://doi.org/10.1242/jeb.120550
45. Frosini, M., Sesti, C., Palmi, M., Valoti, M., Fusi, F., Mantovani, P., Bianchi, L., Della, C.L., Sgaragli, G., 2000. The possible role of taurine and GABA as endogenous cryogens in the rabbit: changes in CSF levels in heat-stress. Advances in Experimental Medicine and Biology 483, 335–344.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 28 November 2024 doi:10.20944/preprints202411.2245.v1

46. Gable, P.A., & Poole, B.D. (2012). Perception Time Flies When You're Having Approach-Motivated Fun: Effects of Motivational Intensity on Time. 23(8) https://doi.org/10.1177/0956797611435817
47. Gable, P.A., Wilhelm, A.L., & Poole, B.D. (2022). How Does Emotion Influence Time Perception? A Review of Evidence Linking Emotional Motivation and Time Processing. Frontiers in Psychology, 13.
48. Gladhill, K.A., Mioni, G., & Wiener, M. (2022). Dissociable effects of emotional stimuli on electrophysiological indices of time and decision-making. PLOS ONE, 17.
49. Goffin, K., & Viera, G. (2023). Emotions in time: The temporal unity of emotion phenomenology. Mind & Language. Advance online publication. https://doi.org/10.1111/mila.12489
50. Gordon, E.M., Chauvin, R.J., Van, A.N. et al. A somato-cognitive action network alternates with effector regions in motor cortex. Nature 617, 351–359 (2023).
51. Grigg, G., Nowack, J., Bicudo, J., Bal, N.C., Woodward, H.N., & Seymour, R.S. (2021). Whole-body endothermy: ancient, homologous and widespread among the ancestors of mammals, birds and crocodylians. Biological Reviews, 97.
52. Groenink, L., Compaan, J., van der Gugten, J., Zethof, T., van der, H.J., Olivier, B., 1995. Stress-induced hyperthermia in mice Pharmacological and endocrinological aspects. Annals of the New York Academy of Sciences 771, 252–256.
53. Haar, A.J.H., Jain, A., Schoeller, F. et al. Augmenting aesthetic chills using a wearable prosthesis improves their downstream effects on reward and social cognition. Sci Rep 10, 21603 (2020).
54. Hall M, Vasko R, Buysse D, Ombao H, Chen Q et al. 2004. Acute stress affects heart rate variability during sleep. Psychosom. Med. 66:56–62.
55. Hallez, Q., Paucsik, M., Tachon, G., Shankland, R., Marteau-Chasserieau, F., & Plard, M. (2023). How physical activity and passion color the passage of time: A response with ultra-trail runners. Frontiers in Psychology, 13.
56. Herlambang, M. B., Cnossen, F., Taatgen, N. A. (2021) The effects of intrinsic motivation on mental fatigue. PLOS.
57. Hesp, C., Smith, R., Parr, T., Allen, M., Friston, K., & Ramstead, M.J. (2021). Deeply Felt Affect: The Emergence of Valence in Deep Active Inference. Neural Computation, 33, 1-49.
58. Hollis, F., van der Kooij, M.A., Zanoletti, O., Lozano, L., Cantó, C., & Sandi, C. (2015). Mitochondrial function in the brain links anxiety with social subordination. Proceedings of the National Academy of Sciences, 112, 15486 - 15491.
59. Hosseini Houripasand, M., Sabaghypour, S., Farkhondeh Tale Navi, F., & Nazari, M.A. (2023). Time distortions induced by high-arousing emotional compared to low-arousing neutral faces: an event-related potential study. Psychological Research, 1-12.
60. Huang, J. Greater brain activity during the resting state and the control of activation during the performance of tasks. Sci Rep 9, 5027 (2019). https://doi.org/10.1038/s41598-019-41606-2
61. Huang, Z., Zhang, J., Wu, J., Mashour, G. A., and Hudetz, A. G. (2020). Temporal circuit of macroscale dynamic brain activity supports human consciousness. Sci. Adv. 6, eaaz0087.
62. Inagaki, T.K., Hazlett, L.I., & Andreescu, C. (2019). Naltrexone alters responses to social and physical warmth: implications for social bonding. Social Cognitive and Affective Neuroscience, 14, 471 - 479.
63. Jizba P, Arimitsu T. 2001. The world according to Renyi: thermodynamics of fractal systems. AIP Conference Proceedings, 597, 341-348.
64. Kao, F-C., Wang, SR. and Chang, Yj.(2015) Brainwaves Analysis of Positive and Negative Emotions. ISAA, (12): 1263–1266.
65. Kataoka, N., Shima, Y., Nakajima, K., and Nakamura, K. (2020). A central master driver of psychosocial stress responses in the rat. Science 367, 1105–1112.
66. Keller, A.S., Leikauf, J.E., Holt-Gosselin, B., Staveland, B.R., & Williams, L. (2019). Paying attention to attention in depression. Translational Psychiatry, 9.
67. Kluger, M. J., O'Reilly, B. J., Shope, T. R., & Vander, A. J. (1987). Further evidence that stress hyperthermia is a fever. Physiology &Amp; Behavior, 39(6), 763-766. https://doi.org/10.1016/0031-9384(87)90263-0
68. Lehockey, K.A., Winters, A.R., Nicoletta, A.J. et al. The effects of emotional states and traits on time perception. Brain Inf. 5, 9 (2018).
69. Llinás, R. Paré, D. and M. (Ed.), "The brain as a closed system modulated by the senses.," in The churchlands and their critics, Cambridge, Mass., Blackwell Publishers, 1996.
70. Lowry, C. A., Lightman, S. L., and Nutt, D. J. (2009). That warm fuzzy feeling: brain serotonergic neurons and the regulation of emotion. J. Psychopharmacol. 23, 392–400.
71. Ma, A.C., Cameron, A.D. & Wiener, M. Memorability shapes perceived time (and vice versa). Nat Hum Behav (2024). https://doi.org/10.1038/s41562-024-01863-2
72. Madden, C. J., & Morrison, S. F. (2019). Central nervous system circuits that control body temperature. Neuroscience letters, 696, 225–232.
73. Mason, A.E., Kasl, P., Soltani, S. et al. Elevated body temperature is associated with depressive symptoms: results from the TemPredict Study. Sci Rep 14, 1884 (2024). https://doi.org/10.1038/s41598-024-51567-w

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 28 November 2024 doi:10.20944/preprints202411.2245.v1

74. Meeusen, R., Van Cutsem, J., Roelands, B. (2020) Endurance exercise-induced and mental fatigue and the brain, Experimental Psychology.
75. Mitchell, J.M., Weinstein, D., Vega, T.A., & Kayser, A.S. (2015). Dopamine, time perception, and future time perspective. Psychopharmacology, 235, 2783 - 2793.
76. Moe, R.O., Bakken, M., 1997. Effects of handling and physical restraint on rectal temperature, cortisol, glucose and leucocyte counts in the silver fox (Vulpes vulpes). Acta Veterinaria Scandinavica 38, 29–39.
77. Morimoto, A., Watanabe, T., Morimoto, K., Nakamori, T., & Murakami, N. (1991). Possible involvement of prostaglandins in psychological stress-induced responses in rats.. The Journal of Physiology, 443(1), 421-429. https://doi.org/10.1113/jphysiol.1991.sp018841.
78. Nashiro, K., Min, J., Yoo, H.J., et al. (2022). Increasing coordination and responsivity of emotion-related brain regions with a heart rate variability biofeedback randomized trial. Cognitive, affective & behavioral neuroscience.
79. Nestler, E.J., & Russo, S.J. (2024). Neurobiological basis of stress resilience. Neuron, 112, 1911-1929.
80. Northoff, G. "Is Our Brain an Open or Closed System? Prediction Model of Brain and World–Brain Relation," in The Spontaneous Brain, MIT press, 2018.
81. Northoff, G., & Tumati, S. (2019). "Average is good, extremes are bad" – Non-linear inverted U-shaped relationship between neural mechanisms and functionality of mental features. Neuroscience & Biobehavioral Reviews, 104, 11-25.
82. Nowack, J., Giroud, S., Arnold, W., & Ruf, T. (2017). Muscle Non-shivering Thermogenesis and Its Role in the Evolution of Endothermy. Frontiers in Physiology, 8.
83. Nutt, D.J. (1999). Care of depressed patients with anxiety symptoms. The Journal of clinical psychiatry, 60 Suppl 17, 23-7; discussion 46-8.
84. Oka T, Oka K, Hori T. Mechanisms and mediators of psychological stress-induced rise in core temperature. Psychosom Med. 2001 May-Jun;63(3):476-86. https://doi.org/10.1097/00006842-200105000-00018
85. O'Neill, J., & Schoth, A. (2022). The Mental Maxwell Relations: A Thermodynamic Allegory for Higher Brain Functions. Frontiers in Neuroscience.
86. Park, J., & Hadi, R. (2020). Shivering for Status: When Cold Temperatures Increase Product Evaluation. Journal of Consumer Psychology.
87. Parrott, R.F., Vellucci, S.V., Forsling, M.L., Goode, J.A., 1995. Hyperthermic and endocrine effects of intravenous prostaglandin administration in the pig. Domestic Animal Endocrinology 12, 197–205.
88. Raichle ME. Two views of brain function. Trends Cogn Sci. 2010 Apr;14(4):180-90. doi: 10.1016/j.tics.2010.01.008. Epub 2010 Mar 4. PMID: 20206576.
89. Raison, C. L., Hale, M. W., Williams, L. E., Wager, T. D., and Lowry, C. A. (2015). Somatic influences on subjective well-being and affective disorders: the convergence of thermosensory and central serotonergic systems. Front. Psychol. 5:1589.
90. Remmers, C. & Zander, T. Why you don't see the forest for the trees when you are anxious: Anxiety impairs intuitive decision making. Clin Psychol Sci, 2018, 6, 48–62.
91. Robbe, D. (2023). Lost in time: Relocating the perception of duration outside the brain. Neuroscience & Biobehavioral Reviews, 153: 105312.
92. Rudd, M., Vohs, K.D., & Aaker, J.L. (2012). Awe Expands People's Perception of Time, Alters Decision Making, and Enhances Well-being. Psychological Science, 23, 1130 - 1136.
93. Rutrecht, H.M., Wittmann, M., Khoshnoud, S., & Igarzábal, F.A. (2021). Time Speeds Up During Flow States: A Study in Virtual Reality with the Video Game Thumper. Timing & Time Perception.
94. Thönes, S. Oberfeld, D. Time perception in depression: A meta-analysis, Journal of Affective Disorders 175, 359-372, 12 January 2015.
95. Sadowski, S., Fennis, B.M., & van Ittersum, K. (2020). Losses tune differently than gains: how gains and losses shape attentional scope and influence goal pursuit. Cognition and Emotion, 34, 1439 - 1456.
96. Safron A. The Radically Embodied Conscious Cybernetic Bayesian Brain: From Free Energy to Free Will and Back Again. Entropy. 2021; 23(6):783.
97. Schoeller, F., & Perlovsky, L.I. (2016). Aesthetic Chills: Knowledge-Acquisition, Meaning-Making, and Aesthetic Emotions. Frontiers in Psychology, 7.
98. Seebacher, F. (2020). Is Endothermy an Evolutionary By-Product? Trends in ecology & evolution, 35 6, 503-511.
99. Seebacher, F. (2009). Responses to temperature variation: integration of thermoregulation and metabolism in vertebrates. *Journal of Experimental Biology*, *212*, 2885 - 2891.
100. Şen B, Kurtaran NE, Öztürk L. The effect of 24-hour sleep deprivation on subjective time perception. Int J Psychophysiol. 2023 Oct;192:91-97. doi: 10.1016/j.ijpsycho.2023.08.011.
101. Shannon, C.E. Source Coding with a Fidelity Criterion. Proc. IRE 1959.
102. Simen P, Matell M. Why does time seem to fly when we're having fun? Science. 2016 Dec 9;354(6317):1231-1232.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 28 November 2024 doi:10.20944/preprints202411.2245.v1

103. Singer, W. (2021). Recurrent dynamics in the cerebral cortex: Integration of sensory evidence with stored knowledge. PNAS, 118.
104. Soares, S., Atallah, B.V., & Paton, J.J. (2016). Midbrain dopamine neurons control judgment of time. Science, 354, 1273 - 1277.
105. Spapé, M.M., Harjunen, V.J., & Ravaja, N. (2021). Time to imagine moving: Simulated motor activity affects time perception. Psychonomic Bulletin & Review, 29, 819 - 827.
106. Sridhar, V.H., Li, L., Gorbonos, D., Nagy, M., Schell, B.R., Sorochkin, T., Gov, N.S., & Couzin, I.D. (2021). The geometry of decision-making in individuals and collectives. Proceedings of the National Academy of Sciences of the United States of America, 118.
107. Stanghellini G, Ballerini M, Presenza S, Mancini M, Northoff G, Cutting J, (2016) Abnormal time experiences in major depression. An empirical qualitative study. Psychopathology, DOI:10.1159/000452892.
108. Suhaimi, NS, Mountstephens, J., Teo, J. (2020). "EEG-Based Emotion Recognition: A State-of-the-Art Review of Current Trends and Opportunities," Computational Intelligence and Neuroscience, vol. Article ID 8875426, p19, 2020.
109. Tan, C.L., & Knight, Z.A. (2018). Regulation of Body Temperature by the Nervous System. Neuron, 98, 31-48.
110. Terlouw, E.M., Kent, S., Cremona, S., Dantzer, R., 1996. Effect of intracerebroventricular administration of vasopressin on stress-induced hyperthermia in rats. Physiology and Behavior 60, 417–424.
111. Toren, I., Aberg, K.C., & Paz, R. (2020). Prediction errors bidirectionally bias time perception. Nature Neuroscience, 1-5.
112. Torres P, E. P., Torres, E. A., Hernández-Álvarez, M., & Yoo, S. G. (2020). EEG-Based BCI Emotion Recognition: A Survey. Sensors (Basel, Switzerland), 20(18), 5083.
113. Toso, A., Fassihi, A., Paz, L., Pulecchi, F., & Diamond, M.E. (2020). A sensory integration account for time perception. PLoS Computational Biology, 17.
114. Tsao, A., Sugar, J., Lu, L., Wang, C., Knierim, J. J., Moser, M-B., & Moser, E. I. (2018). Integrating time from experience in the lateral entorhinal cortex. Nature, 561(7721), 57–62.
115. van der Heyden, J.A., Zethof, T.J., Olivier, B., 1997. Stress-induced hyperthermia in singly housed mice. Physiology and Behavior 62, 463–470.
116. van Hedger K, Necka EA, Barakzai AK, Norman GJ. The influence of social stress on time perception and psychophysiological reactivity. Psychophysiology. 2017 May;54(5):706-712. doi: 10.1111/psyp.12836.
117. van Maanen, L., van der Mijn, R., van Beurden, M.H.P.H. et al. Core body temperature speeds up temporal processing and choice behavior under deadlines. Sci Rep 9, 10053 (2019).
118. Varley, Thomas F., Robin Carhart-Harris, Leor Roseman, David K. Menon, and Emmanuel A. Stamatakis. 2020. "Serotonergic Psychedelics LSD & Psilocybin Increase the Fractal Dimension of Cortical Brain Activity in Spatial and Temporal Domains." NeuroImage 220 (October): 117049.
119. Wainio-Theberge, S., & Armony, J.L. (2023). Antisocial and impulsive personality traits are linked to individual differences in somatosensory maps of emotion. Scientific Reports, 13.
120. Wang D. J., Jann K., Fan C., et al., (2018) Neurophysiological basis of multiscale entropy of brain complexity and its relationship with functional connectivity. Front. Neurosci. 12:352.
121. Wang, J., & Lapate, R.C. (2023). Emotional state dynamics impacts temporal memory. bioRxiv.
122. WILLIAMS, L. E. and Bargh, J. A. (2008) Experiencing Physical Warmth Promotes Interpersonal Warmth. Science, 322(5901):606.
123. Wise, T., Marwood, L., Perkins, A. M. et al. (2017) nstability of default mode network connectivity in major depression: a two-sample confirmation study. Transl. Psychiatry 25;7(4) :e1105.
124. Yang, S., Zhao, Z., Cui, H. (2019). Temporal Variability of Cortical Gyral-Sulcal Resting State Functional Activity Correlates With Fluid Intelligence. Frontiers in neural circuits, 13, 36.
125. Zanin, M., Güntekin, B., Aktürk, T., Hanoğlu, L., & Papo, D. (2019). Time Irreversibility of Resting-State Activity in the Healthy Brain and Pathology. Frontiers in Physiology, 10.
126. Zelena, D., Menant, O., Andersson, F., & Chaillou, E. (2018). Periaqueductal gray and emotions: the complexity of the problem and the light at the end of the tunnel, the magnetic resonance imaging. Endocrine Regulations, 52, 222 - 238.
127. Zmigrod, L., Zmigrod, S., Rentfrow, P.J., & Robbins, T. (2019). The psychological roots of intellectual humility: The role of intelligence and cognitive flexibility. Personality and Individual Differences, 141, 200-208.

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