Original Paper

2026/6/24

The Syntelic Ape Hypothesis: The Emergence Mechanism of Consciousness through Constitutive Reactivity of VPA (Varicose Projection Astrocytes) and Supercompensation during REM Sleep (Working Hypothesis)

Reiji Kikuchi

mk9tmk9tmk9t@yahoo.co.jp

Keywords: VPA (Varicose Projection Astrocytes), Constitutive Reactivity / Exaptation, Physiological Warburg Effect, REM Sleep (Microdomain Local Wiring), Default Mode Network (DMN)

Summary

Human higher cognitive functions are thought to arise from the integration of brain-wide networks, typified by the Default Mode Network (DMN), but the physical basis of this integration remains elusive. This paper, the "Syntelic Ape Hypothesis," proposes a new working hypothesis that the uniquely human giant Varicose Projection Astrocytes (VPA) are responsible for this integration. This hypothesis argues that the massive expansion of VPA was driven by a cycle of "Constitutive Reactivity" (evolutionary exaptation of reactive phenotypes) and biomass accumulation through aerobic glycolysis (physiological Warburg effect) due to daytime social stress, followed by "supercompensation" (rewiring) through local calcium dynamics during nighttime Rapid Eye Movement (REM) sleep. This paper presents a theoretical framework connecting evolutionary theory, cellular metabolism, and sleep science, and proposes specific experimental verification protocols using the next-generation image analysis algorithm AQuA (Astrocyte Quantitative Analysis).

1. Introduction: Human Brain Specificity and the Discovery of VPA

Recently, VPA, a human-specific glial cell that extends long processes from the deep layers of the cerebral cortex to the white matter, has garnered attention as a physical basis for the highly advanced self-awareness of modern humans. While it has been confirmed that VPA possess long interlaminar processes, this paper goes further to hypothesize that VPA are the integrating entities that physically envelop synaptic clusters in distant brain regions (such as the DMN) to perform information binding (distant integration). We discuss the evolutionary and metabolic mechanisms behind why only human astrocytes evolved into this unique VPA morphology.

2. Evolutionary Background: The Acquisition of Fire and "Challenging Cooperation"

The reason astrocytes did not expand in other mammals to the extent they did in humans can be attributed to the ecological risks associated with "repair through sleep" (REM sleep).

Ecological risks of REM sleep and the acquisition of fire: Because REM sleep induces strong muscle atonia (complete paralysis), prolonged REM sleep in the wild carries a fatal predation risk (Everson et al., 1989). By routinely using fire and establishing ground camps, early humans reduced this predation risk (Wrangham, 2009; Samson & Nunn, 2015), acquiring the environmental foundation to secure prolonged REM sleep.

Speculation on Sapiens-specific environmental pressures: Homo sapiens routinely experienced the specific psychological and social stress of "challenging cooperation" (Syntelic behavior)—sharing goals and overcoming difficulties with others in fluid societies of hundreds of individuals. This paper proposes that this intense social overload acted as the evolutionary environmental pressure that triggered the expansion of brain networks.

3. Mechanisms during Wakefulness: Exaptation of Reactivity and Biomass Accumulation

In conventional medicine, brain inflammation (astrocyte reactivity) caused by social stress is considered a pathology that leads to "network atrophy" (Slavich & Irwin, 2014;

Setiawan et al., 2015). However, this hypothesis proposes that this phenomenon played the exact opposite role in human evolution.

3.1 Exaptation from Pathology to Function and Constitutive Reactivity

When faced with social stress, norepinephrine (NE) is released from the locus coeruleus, triggering widespread calcium waves in astrocytes and modulating the brain state (Paukert et al., 2014; Monai et al., 2016). Recent studies suggest that the astrocyte "reactive phenotype," which appears only under specific stress in other species, is associated with the VPA-like morphology in humans (Falcone et al., 2025; Kondev et al., 2026). This paper hypothesizes that during evolution, humans avoided this pathological reaction and instead exapted it into a "Constitutive Reactivity," physiologically normalizing only its high metabolism and functionality.

3.2 Significance of the Physiological Warburg Effect (Inference)

Cells in inflammatory or reactive states are known to shift their metabolism to aerobic glycolysis (Warburg effect) (Pellerin & Magistretti, 1994). This paper presents the bold inference that this metabolic shift occurs constitutively in VPA, and its primary purpose is not energy (ATP) production, but rather the explosive daytime accumulation of "biomass" (such as lipids and proteins) required for nighttime process elongation.

4. Mechanisms of REM Sleep: VPA "Supercompensation"

The core of this paper lies in linking daytime activity and nighttime sleep as a cycle of "VPA consumption (reaction) and supercompensation."

Global silence and the initiation of local wiring: Upon entering REM sleep, NE secretion in the brain decreases or ceases, and the massive calcium waves of wakefulness disappear (Bojarskaite et al., 2020). This paper predicts that behind this global silence, highly localized calcium waves occur at the distal ends of VPA processes (microdomains).

Proposal of the supercompensation model: We propose a model in which, under the silence where wakeful noise has subsided, VPA structurally hypertrophies and optimizes—similar to muscle supercompensation—by using the biomass accumulated during the day to prune unnecessary synapses (Bellesi et al., 2017) and integrate new ones.

5. Applied Interpretation to Psychopathology in Modern Society

Using this hypothetical framework, we can construct an explanatory model for the impact of modern digital society on the brain. The loss of unpredictable, real-world face-to-face interactions (challenging cooperation) leads to a "Use it or lose it" reduction in VPA usage. When combined with REM sleep repair dysfunction caused by hyperarousal (NE leakage) from constant notifications and blue light, it is suggested that VPA fails to enter a proper supercompensation mode, potentially triggering network self-destruction (psychopathologies such as depression).

6. Proposed Experimental Verification Models

While the "Syntelic Ape Hypothesis" presented in this paper is a working hypothesis containing theoretical inferences, its core components can be immediately verified using modern in vivo imaging technologies.

Phase 1: Quantification of REM Sleep-Specific Microdomain Calcium Dynamics

Previous studies have reported a decrease in macroscopic calcium signals centered on the soma during sleep (Bojarskaite et al., 2020). However, by combining cutting-edge in vivo imaging techniques with membrane-targeted calcium sensors (Lck-GCaMP) and applying the next-generation image analysis algorithm "AQuA" (Wang et al., 2019), it is possible to quantitatively prove (or disprove) the presence of "localized calcium events in microdomains (signs of supercompensation)" specifically during REM sleep, when the global network is silent. This verification will be the first step in elucidating the metabolic and integration basis of the prior state setting connecting VPA and challenging cooperation.

Phase 2: Observation of VPA Dynamics Using Humanized Chimeric Mice

Building upon the verification foundation of Phase 1, humanized chimeric mice will be generated by engrafting human astrocyte progenitor cells into wild-type mouse brains (Han et al., 2013). By using AQuA to quantify that human VPA-like cells—which hypertrophy according to their genetic program even within the mouse brain environment—perform overwhelmingly more extensive and complex microdomain wiring activities (supercompensation) during REM sleep than wild-type mouse astrocytes, we will demonstrate the human-specific evolutionary basis of this hypothesis.

7. Conclusion

This paper presented the "Syntelic Ape Hypothesis," which posits that the physical basis of human consciousness lies in the "structural hypertrophy of VPA," driven by a cycle of evolutionary exaptation of reactivity (Constitutive Reactivity) and supercompensation during REM sleep. Although this hypothesis currently includes multiple theoretical inferences, it can serve as a grand working hypothesis integrating evolutionary theory, cellular metabolism, and sleep science. We are convinced that elucidating "astrocyte local calcium dynamics during REM sleep"—the first step of this theory—is one of the most compelling challenges to be tested in next-generation glial research.

◇ References ◇

Bellesi, M., de Vivo, L., Chini, M., Gilli, F., Tononi, G., & Cirelli, C. (2017). Sleep loss promotes astrocytic phagocytosis and microglial activation in mouse cerebral cortex. Journal of Neuroscience, 37(21), 5263-5273.

Bojarskaite, L., Bjørnstad, D. M., Pettersen, S. R., et al. (2020). Astrocytic calcium signaling is reduced during sleep and is involved in the regulation of slow wave sleep. Nature Communications, 11, 3240.

Everson, C. A., Bergmann, B. M., & Rechtschaffen, A. (1989). Sleep deprivation in the rat: III. Total sleep deprivation. Sleep, 12(1), 13-21.

Falcone, C., et al. (2025). Cortical interlaminar astrocytes are hominid-specific and functionally distinct. bioRxiv.

Han, X., Chen, M., Wang, F., et al. (2013). Forebrain engraftment by human glial progenitor cells enhances synaptic plasticity and learning in adult mice. Cell Stem Cell, 12(3), 342-353.

Kondev, V., et al. (2026). Cortical astrocytes control stress resilience. bioRxiv.

Monai, H., Ohkura, M., Nakai, J., Washington, P. M., Borgens, R. B., Murphy, T. H., & Hirase, H. (2016). Calcium imaging reveals glial involvement in transcranial direct current stimulation-induced plasticity in mouse brain. Nature Communications, 7, 11100.

Paukert, M., Agarwal, A., Weingart, J., et al. (2014). Norepinephrine controls astroglial responsiveness to local circuit activity. Neuron, 82(6), 1263-1270.

Pellerin, L., & Magistretti, P. J. (1994). Glutamate uptake into astrocytes stimulates aerobic glycolysis: a mechanism coupling neuronal activity to glucose utilization. Proceedings of the National Academy of Sciences, 91(22), 10625-10629.

Samson, D. R., & Nunn, C. L. (2015). Sleep intensity and the evolution of human cognition. Evolutionary Anthropology, 24(6), 225-237.

Setiawan, E., Wilson, A. A., Mizrahi, R., et al. (2015). Role of translocator protein density, a marker of neuroinflammation, in the brain during major depressive episodes. JAMA Psychiatry, 72(3), 268-275.

Slavich, G. M., & Irwin, M. R. (2014). From stress to inflammation and major depressive disorder: a social signal transduction theory of depression. Psychological Bulletin, 140(3), 774-815.

Wang, Y., Del Rosario, M., Volkow, N. D., & Khakh, B. S. (2019). Accurate quantification of astrocyte and intracellular calcium dynamics. Nature Neuroscience, 22(8), 1346-1355.

Wrangham, R. (2009). Catching Fire: How Cooking Made Us Human. Basic Books.