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The Autotelic Ape: Acquisition of "Challenge Propensity" through Mutation of Varicose Projection Astrocytes, and the Emergence of Self-Consciousness and Free Will

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Summary

This paper argues that the fundamental trait distinguishing the human lineage from the genus Pan is not a specific adaptation, but an antecedent psychological "Challenge Propensity." While dominant theories such as Tomasello's "Shared Intentionality" and Wrangham's "Cooking Hypothesis" explain the definitive "results" of human evolution, we propose that "Challenge" is the fundamental "driver."

We argue that the physical basis of this human-specific "Challenge Propensity" lies in the mutational enlargement and functional expansion of "Varicose Projection Astrocytes (VPA)," a type of glial cell, during the course of evolution. With their unique complex morphology, VPAs function as "sensors" that macroscopically integrate neuronal activity and the body's energy state, thereby forming the physical basis of "self-consciousness." At the same time, by functioning as "controllers" that modulate neuronal circuits top-down based on integrated information, they facilitated the emergence of "free will."

This paper presents a new theoretical framework positing that energy management and information integration by VPAs enabled high-cost "challenge" behaviors transcending short-term survival instincts, evolving humans into autotelic beings.

1. Introduction

What makes humans human? To answer this question, conventional evolutionary anthropology has focused on cognitive abilities and behavioral patterns unique to humans. For example, Tomasello argued that "shared intentionality," which enables the formation of joint intentions with others ("we"), generated cumulative culture and complex cooperation [Tomasello 14]. Wrangham asserted that the technological innovation of "cooking" provided the energy basis supporting a massive brain and brought about social tolerance [Wrangham 09].

These theories are powerful but explain adaptations (results) after the emergence of the genus Homo, and are insufficient to explain the "driver" of the divergence prior to that. This paper proposes a psychological and behavioral "Challenge Propensity" as a more fundamental driver preceding these adaptations. This hypothesis is based on the possibility that Sahelanthropus tchadensis, about 7 million years ago, was already "experimenting (challenging)" with difficult bipedalism before being "forced" by the environment [Brunet 02].

However, why were humans alone able to select "challenges" involving high energy costs and risks of failure? Conventional neuron-centric neuroscience has struggled to provide a sufficient answer to this question. The purpose of this paper is (1) to redefine human essence as "Challenge Propensity," and (2) based on recent research findings on glial cells in neuroscience, particularly the discovery of human-specific "Varicose Projection Astrocytes (VPA)," to present the "VPA Hypothesis" positing that the mutation of these cells is the physical basis of "challenge" as well as "self-consciousness and free will."

2. Related Work and the Positioning of this Paper: "Challenge" as Human Essence

This paper's "Challenge Propensity" hypothesis attempts to reconstruct existing evolutionary theories from physical changes at the cellular level of the brain.

2.1 "Challenge" as Autotelic (Csikszentmihalyi)

If "challenge" were merely a "means" for survival, it should cease once the environment stabilizes. However, humans spontaneously continue "challenges" unrelated to survival (art, science, etc.). This reason can be explained by Mihaly Csikszentmihalyi's "Flow" theory [Csikszentmihalyi 90]. In the

process of evolution, individuals who felt pleasure in "challenging itself" were selected, and "Challenge Propensity" evolved into an intrinsic motivation that became "Autotelic" (rewarding in itself).

2.2 Limits of Neuron-Centrism

Conventional neuroscience has regarded the network of neurons emitting electrical signals as the entirety of intelligence. However, the basic structure of neurons does not differ significantly between humans and chimpanzees, and pointing out the limitations in explaining the integration of human-specific long-term and abstract "will" or "consciousness" solely by the function of single neurons.

2.3 Human-Specific Astrocytes (Oberheim)

In 2009, Oberheim et al. discovered that astrocytes present in the human cerebral cortex are physically huge and have extremely long and complex processes compared to mice and other primates. In particular, the type called "Varicose Projection Astrocyte (VPA)" exists only in humans and some higher primates [Oberheim 09]. These cells have the ability to simultaneously monitor and control tens of thousands of synaptic connections, which is considered key to the dramatic improvement of human cognitive functions.

3. VPA Hypothesis: Physical Basis of Challenge, Self-Consciousness, and Free Will

This paper proposes the following VPA hypothesis regarding the emergence mechanism of human "Challenge Propensity" and mental functions.

3.1 Mutation of VPA as Physical Basis

The enlargement and complexity of astrocytes (emergence of VPA) that occurred during evolution brought about a revolution in information processing within the brain. In "humanized mouse" experiments by Han et al., mice transplanted with human astrocyte progenitor cells showed significant improvement in synaptic plasticity and learning/memory abilities [Han 13]. This proves that even if neurons remain unchanged, simply humanizing the OS (astrocytes) dramatically improves learning efficiency for unknown tasks, that is, the "ability to challenge."

3.2 Emergence of "Self-Consciousness" as Sensor Function

VPAs monitor extensive neuronal activity (fragments of thought and perception) via countless processes while simultaneously directly sensing the body's energy state from blood vessel walls [Attwell 10].

In the VPA hypothesis, we consider that these heterogeneous pieces of information are aggregated into a single integrated physicochemical state, such as changes in calcium ion concentration inside astrocytes. This function of "maintaining the 'now' state of the entire brain as a single integrated physical state while preserving diversity" is the physical basis of "information integration" proposed by Tononi in Integrated Information Theory (IIT) as a condition for consciousness, and can be interpreted as the entity of "Self-Consciousness" [Tononi 04].

3.3 Action of "Free Will" as Controller Function

Furthermore, based on integrated information, VPAs release chemical substances such as ATP and glutamate to actively modulate the excitability of specific neuronal circuits. While neuronal electrical signals occur on a millisecond scale, astrocyte activity takes place on a much slower time scale of seconds to tens of seconds.

Recent studies have shown that this slow dynamics of astrocytes governs the switching of brain-wide states (cortical states) [Poskanzer 16]. We consider the process of "slow top-down circuit selection based on integrated internal state (self-consciousness)" to be the biological entity of "Free Will." The readiness potential observed in Libet's experiments [Libet 83] is also likely capturing the process of chemical "decision making" by VPAs preceding neuronal firing.

4. Discussion

The VPA hypothesis presented in this paper explains the difference between humans and chimpanzees not merely as a quantitative increase in neurons but as a qualitative transformation of the brain's control system (glial cells).

Because of the advanced energy management and information integration functions provided by VPAs, humans became able to simultaneously process conflicting emotions of "fear (amygdala)" and "curiosity (frontal lobe)" and select "challenges" prioritizing future possibilities over immediate gains. As this "Challenge Propensity" became established at the behavioral level, a unique social strategy called "Challenging Cooperation" emerged, and cognitive abilities such as shared intentionality likely evolved to adapt to it.

5. Conclusion

This paper argued the hypothesis that "Challenge Propensity," the fundamental driver distinguishing the human lineage, originates from the mutation and functional expansion of Varicose Projection Astrocytes.

We humans are autotelic apes who, more than just a collection of computing devices called neurons, possess a consciousness of "I" through a massive integrator called VPA and acquired "Free Will" to step into the unknown beyond instinctual reactions. Understanding this intracerebral system

will be the most critical key to unlocking the essence of humanity.

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