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The VPA Loop Hypothesis: A Unified Model of Human Consciousness and Psychopathology via Varicose-Projection Astrocytes

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Summary

This paper proposes the "VPA Loop Hypothesis," positing that human-specific higher-order consciousness (qualia, imagination, self-consciousness, and free will) emerges from a four-stage closed loop of "Varicose-Projection Astrocytes (VPA)" that physically integrates the brain's three major networks (Salience Network: SN, Default Mode Network: DMN, Central Executive Network: CEN).

We modeled these conscious processes as interactions between physical connectivity and major neurotransmitters (dopamine, serotonin, noradrenaline, oxytocin, etc.). Furthermore, we discuss the possibility that "Evolutionary Mismatch" in modern society causes physical dysfunction in VPAs within this loop, thereby increasing the pathological risks associated with mental illnesses and developmental disorders.

1. Introduction: The "Physical Bridge" Unique to Humans

While the theories of Crick & Koch [Crick 90] and Tononi [Tononi 04] have contributed to the quantitative aspects of consciousness, the mechanism generating subjective feelings remains unexplained. Pereira Jr. and colleagues proposed the astrocentric hypothesis, suggesting that astrocytic calcium waves are responsible for the "emotional coloring" of consciousness [Pereira 10].

While animals possess primitive consciousness, humans possess a qualitatively different, higher form of consciousness. Oberheim et al. discovered that layer 5/6 of the human cerebral cortex contains massive, long-projection astrocytes (Varicose-Projection Astrocytes: VPA) that exist only in humans and great apes among primates [Oberheim 09].

In this paper, we define these "human-specific VPAs" as the hardware that physically bridges remote brain networks (SN, DMN, CEN) and creates the human form of consciousness comprising "qualia, imagination, self-consciousness, and free will."

2. Theoretical Framework: The "4 VPA Loops" Generating Consciousness

We hypothesize that human-specific conscious experience is established through the circulation of the following four stages, involving both physical (VPA) and chemical (neurotransmitter) processes.

2.1 Phase 1: Affective Simulation

① Insula (SN): Generation of Qualia (Affect)

The VPAs in the insula, the hub of the Salience Network (SN), are thought to convert bodily inputs into "raw qualia" and ignite the system [Craig 09]. Human-specific Von Economo Neurons (VEN) are also involved here, suggesting coordination with VPAs [Seeley 07]. Input stimuli trigger dopamine (craving), providing the energy to drive the subsequent simulation.

② Precuneus (DMN): Deployment of Imagination (Simulation)

The VPAs in the precuneus, the posterior hub of the Default Mode Network (DMN), are inferred to simulate memory traces as "visuospatial images" [Cavanna 06]. It is considered that VPAs appropriately absorb and inhibit excessive excitation (glutamate), thereby maintaining vivid images that are not hallucinations.

2.2 Phase 2: Contextual Integration & Execution

③ Posterior Cingulate Cortex (PCC / DMN): Contextualization of Self-Consciousness

The VPAs in the Posterior Cingulate Cortex (PCC), the core of the DMN, may endow images with the narrative context of "Self" [Raichle 01]. Information is integrated in this region, which has the highest metabolism [Leech 14]. Here, serotonin and oxytocin are thought to act to quell information runaway and form harmony with others and society (Context).

④ Anterior Cingulate Cortex (ACC / SN) & Execution System (CEN): Free Will and Execution

At the final point of the loop, the "Will" of the Anterior Cingulate Cortex (ACC) is positioned to top-down activate the Central Executive Network (CEN) [Sridharan 08]. The ignition from ACC to CEN is inferred to be a process involving the release of dopamine (motivation) and noradrenaline (arousal), converting thought into action.

3. Modern Society's "6 Deficiencies" and Pathological Models

Environmental factors in modern society cause physical dysfunction in the VPA loop, which can serve as factors increasing the following pathological risks when interacting with genetic predispositions.

3.1 Lack of Exercise → Insula Runaway [Addiction Risk]

It is thought that the interruption of lactate supply from muscles and somatic sensory input causes the VPAs in the insula to starve for "living qualia" [Pellerin 94]. As a result, there is a possibility of falling into an addiction-like state where "craving" for artificial strong stimuli (drugs, smartphones) runs out of control [Naqvi 07].

3.2 Lack of Focus → Precuneus Malfunction [Schizophrenia-like Symptoms]

It has been reported that smartphone notifications and their "mere presence" permanently drain brain cognitive resources (Brain Drain) [Ward 17]. This state of hyper-vigilance can serve as a factor hindering inhibitory control over the DMN, increasing the risk that VPAs in the precuneus will mix internal noise with external input and erroneously deploy them as "hallucinations of reality" [Garrity 07]. This raises concerns about the potential for cognitive dysfunction similar to schizophrenia [Palaniyappan 12].

3.3 Lack of Interaction → PCC Disconnection [ASD-like Symptoms]

It has been shown that "Neural Synchrony," unique to face-to-face interaction, does not occur in digital communication [Hirsch 17]. The lack of synchronous stimuli may reduce oxytocin secretion and physically inhibit long-range connectivity (context formation) by VPAs in the PCC [Lee 13]. Consequently, it is inferred that contexts with others are not shared, making circuit disconnection (Underconnectivity) characteristic of Autism Spectrum Disorder (ASD) more likely to occur [Just 04].

3.4 Phase 4 Faults (Execution System)

① Lack of Challenge → ACC/dlPFC Underdevelopment [Depression/Apathy]

Safe environments lacking prediction error pose a risk of disuse atrophy in the VPAs of the ACC [Diamond 64] [Rajkowska 99]. Furthermore, parental over-interference is thought to deprive the ACC of opportunities for "decision making" and the Dorsolateral Prefrontal Cortex (dlPFC) of "self-regulation" [Perry 18]. These are inferred to be background factors for the reduced motivation seen in Major Depressive Disorder.

② Lack of Rhythm → CEN Fuel Depletion [ADHD-like Symptoms]

Sedentary environments may inhibit physical pumping (lactate supply) to VPAs caused by fidgeting, etc. [Sarver 15]. Additionally, blue light at night is thought to stop the glymphatic system during sleep, hindering brain clearance [Xie 13]. This causes astrocytic dysfunction in the dlPFC (GABA metabolism abnormalities, etc.) [Boddum 16], fearing a decline in inhibitory function similar to Attention-Deficit/Hyperactivity Disorder (ADHD).

③ Lack of Exploration → CEN Wiring Error [LD-like Symptoms]

A lack of three-dimensional exploration in early childhood can be a factor resulting in insufficient VPA wiring formation in the Posterior Parietal Cortex (PPC) [Siok 08]. Dependence on GPS and surveillance is suggested to deprive opportunities for "deviation into the unknown" and "spatial reasoning," physically halting activity in the PPC and hippocampus [Javadi 17] [Maguire 00]. Furthermore, it has been reported that coerced action reduces the brain's processing of Sense of Agency [Caspar 16], potentially inducing a state similar to Learning Disabilities (LD) where motivation (ACC) exists but manipulation (PPC) is impossible.

4. Discussion: Evolutionary Mismatch and Therapeutic Strategies

4.1 Evolutionary Shift: "Poison" into "Medicine"

Why do only humans carry such a massive VPA loop and the risk of psychopathology simultaneously?

Traditionally, astrocytic "reactivity (activation)" has been viewed negatively as neuroinflammation. However, the latest research from 2025-2026 offers a new perspective. Falcone et al. suggested the possibility that VPAs are a "reactive phenotype" appearing only under specific stress environments [Falcone 25], and Kondev et al. showed that elevated calcium activity in prefrontal astrocytes under stress contributes to the acquisition of resilience [Kondev 26]. Gao et al. also reported that the ability of astrocytes to change morphology in response to stress could be key to preventing depression [Gao 25].

These findings support the "Evolutionary Shift" in this hypothesis. That is, it is inferred that human ancestors converted the state of astrocytic activation, originally "inflammation (stress response)," into a system supplying dopamine (motivation) and lactate (activity energy) necessary for higher brain functions by daring to normalize it [Zhou 24]. Modern society's "Evolutionary Mismatch" may be eliminating the physical load that triggers this activation, driving the brain not toward "challenge (activation)" but toward "atrophy."

4.2 Therapeutic Strategies: 6 Prescriptions

Based on this hypothesis, the essence of treatment is thought to lie in the "rehabilitation" of astrocytes that have undergone physical degeneration (hypertrophy or atrophy) [Torres-Platas 11]. We propose the following six elements as essential for reintroduction into the living environment:

1. Exercise: Normalization of insular qualia through lactate supply.

2. Focus: Protection of the DMN through control of digital noise (notifications off, airplane mode, etc.).

3. Interaction: Recovery of neural synchrony and oxytocin secretion through physical face-to-face interaction.

4. Challenge: Reactivation of the ACC through tasks involving failure and prediction error.

5. Rhythm: Normalization of glymphatic function through morning walks and blocking blue light at night (wearing 99% cut glasses, etc.).

6. Exploration: Strengthening of PPC wiring through spatial trial and error without GPS or surveillance.

4.3 Limitations and Simplification

The "VPA Loop Model" and the "6 Pathological Responses" presented in this paper are theoretical simplifications used to explain the diversity of complex brain functions and psychopathology. Actual neural activity is highly parallel, and a single network failure does not necessarily correspond to a single disease. However, we believe this structural simplification offers a useful perspective as a "heuristic compass" for unraveling the causal relationships between modern environmental factors and psychopathology.

5. Conclusion

We hypothesized that human-specific consciousness is the massive loop structure of VPAs existing within the brain itself.

It is impossible to turn back modern society, which pursues convenience, nor is it necessary. What is important is to use AI and technology to redesign the "inconvenience, discomfort, and uncertainty—stress necessary for survival" that has been eliminated in the name of convenience into "appropriate loads (play and challenge)" and to construct a social system where these can be enjoyed.

That may serve as an important key to a futuristic and constructive solution for maintaining the health of "qualia, imagination, self-consciousness, and free will" unique to humans.

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