Energy Modeling Human Brain Metabolism

_____, BSc.[1], T.J.P. Huggers, MSc.[2], and _____, PhD.[3]

[1] _____
[2] human intelligence institute
[3] _____

This hypothesis is a project proposal and a call for funding to model human brain metabolism through methods from the electrical engineering field. Inspired by the diabetes pathology and through an understanding of the brain-gut axis, an analogy for human brain metabolism is introduced. Through this analogy, a proposal is made for developing the introduced hypotheses in further (multidisciplinary) research.

Correspondence: ***tim.huggers@hiinstitute.org***

ENS enteric nervous system

CNS central nervous system

GABA γ-aminobutyric acid

CPU central processing unit

GPU graphics processing unit

Introduction

The key to understanding human intelligence is to first create a thorough understanding of human metabolism. This much under-studied subject has been getting more attention over the last five years, especially the gut-brain axis is starting to become a popular field of study, and with good reason. The deep brain area - and generally, the brain or central nervous system (CNS) itself - is an over-studied subject, and therefore this article will not cover it; instead it starts at the peripheral nervous system.

Physiology of the ENS and the Pancreas. Inspired by this MSc thesis [1]

The largest network of nerves in the periphery is dedicated to the enteric nervous system (ENS), spread along the gastrointestinal tract. Most of the function of the gastrointestinal tract is intrinsic, but for some circumstances, the CNS is connected through the autonomic nervous system to the ENS [2]. In case of temporary malfunction or shutdown of the CNS, the ENS ensures there is a sustained nutritional inflow into the bloodstream, which the CNS might need in order to recover [3]. The CNS needs a steady inflow of nutrition to function properly, this responsibility is mainly guaranteed by the ENS, where the pancreas, an organ connected to the ENS, bares the most. It aims to keep the nutritional content of the bloodstream within safe bounds for the delicate neuronal networks within the CNS. To this end, it injects hormones into the bloodstream that alter the concentration of specific nutritional molecules, controlled by a sophisticated adaptive and predictive control algorithm that we are yet to fully comprehend.

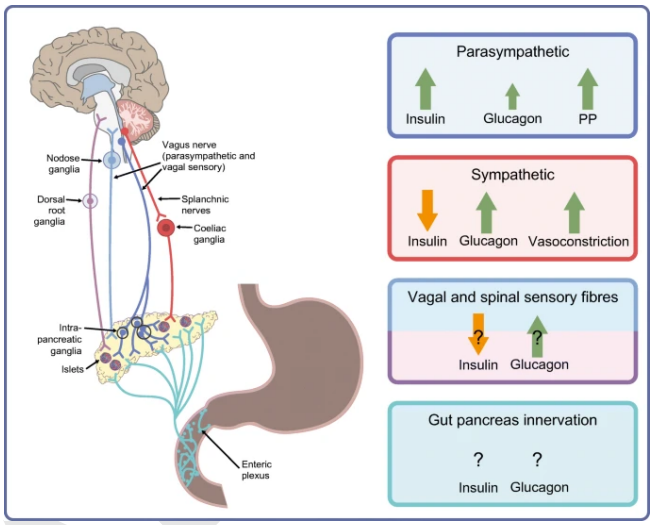

Fig. 1. Graphic summary of the pancreas as an important neural control node within the brain-gut axis. [4].

Diabetes Mellitus Pathology and Hyperglycemic episodes. Inspired by this BSc thesis [5]

Due to our increased intake of refined sugars over the past 100 years, injected into all possible foods and drinks because of their addictive influence on our dopaminergic circuits, it is becoming more and more difficult for the pancreas to keep glucose molecules in the bloodstream within safe limits by releasing the insulin hormone.
During these uncontrolled hyperglycemic episodes of toxic blood glucose concentration levels, possible complications include microvascular pathologies (retinopathy, nephropathy, neuropathy) and macrovascular pathologies (coronary artery disease, cerebrovascular disease, peripheral vascular disease) [6]. The question that lies at the origin of this article is: is it possible to enter a state of controlled hyperglycemia without risking the aforementioned pathologies?

The Analogy: CNS Glucose as CPU Voltage. Inspired by this blogpost [7]

The majority of the synapses in the CNS use γ-aminobutyric acid (GABA) as their inhibitory neurotransmitter. Glucose is the predominant precursor for GABA synthesis [8, p. 117]. In silicon (Si) semiconductors, an electron can jump into the conduction band of the Si molecule within a sufficiently

strong electrical field. The strength of the electric field in which the silicon molecules reside depends on the electric voltage to which it is applied [9, p. 56-57]. A popular practice in the online (gaming) community is to increase the voltage applied to the silicon semiconductors that make up their central processing unit (CPU)s and graphics processing unit (GPU)s in order to increase the frequency in which the semiconductors can change from insulating to conducting state, termed 'overclocking' [7]. This yields an increase in computational speed, at the cost of increased power consumption, increased CPU/GPU temperature and therefore decreased durability.

Hypothesis

Overclocking the human brain. Potentially, synapses (semiconductor transistors) within the CNS (CPU) can be overclocked by increasing the glucose supply (electric field voltage) in the blood stream that reaches the brain, entering a state of controlled hyperglycemia (overclock). This comes with the risk of experiencing uncontrolled hyperglycemic episodes and consequentially suffering the aforementioned pathologies.

Modeling CNS metabolism as CPU energy consumption. Taking the analogy further, the rate at which the human brain metabolizes glucose could be modeled in a similar method by which electrical engineers model energy consumption in semiconductor processing units [10]. By creating sufficiently complex mathematical models of human brain metabolism, it would be possible to finally understand the cause of metabolic and chronic psychological pathologies such as diabetes, obesity, depression, bipolar disorder and schizophrenia.

Academic potential

Opening up the black box of human (brain) metabolism (hitherto considered exclusively genetically determined), would give the medical science community the tools it needs to understand and treat the cause of psychological and metabolic pathologies.

Industrial potential

The trend of increasing mental disorders inhibits the productivity of the workforce [11]. In order to maintain a healthy and productive workforce, it is essential to find an effective and preventative treatment for mental illnesses. Potentially, the mean productivity of the current workforce could be improved through extensive understanding of human brain metabolism.

ACKNOWLEDGEMENTS
Without the initiation of the T1DM BSc assignment by P.H. Veltink I would have never come up with this hypothesis. Without T. Heida I could not have studied neuroscience as an electrical engineer. Without N. Rossetti and V. Mihajlović I would never had the confidence to publish this hypothesis without having a PhD degree. Without my family I would not have been raised a free thinker.

Bibliography

1. T.J.P. Huggers. Finite element method modeling of functionally selective peripheral nerve stimulation of an in silico myelinated nerve fiber model. https://essay.utwente.nl/104536/, 2024.
2. Mark A Fleming, 2nd, Lubaina Ehsan, Sean R Moore, and Daniel E Levin. The enteric nervous system and its emerging role as a therapeutic target. *Gastroenterol. Res. Pract.*, 2020:8024171, September 2020.
3. A Schmidt and G Thews. Autonomic nervous system. In W Janig, editor, *Human Physiology*, pages 333–370. Springer-Verlag, 1989.
4. Rollie F. Hampton, Maria Jimenez-Gonzalez, and Sarah A. Stanley. Unravelling innervation of pancreatic islets. *Diabetologia*, 65(7):1069–1084, Jul 2022. ISSN 1432-0428. doi: 10.1007/s00125-022-05691-9.
5. T.J.P. Huggers. Exploring the potential of reinforcement learning-based adaptive control to the artificial pancreas developed by inreda diabetics b.v. https://essay.utwente.nl/92285/, 2022.
6. Michelle Mouri & Madhu Badireddy. *Hyperglycemia*. StatPearls Publishing LLC., 2023.
7. Victoria Zhislina. Why has cpu frequency ceased to grow? https://web.archive.org/web/20170621074555/https://software.intel.com/en-us/blogs/2014/02/19/why-has-cpu-frequency-ceased-to-grow, 2014.
8. Purves. *Neuroscience 6th Edition*. Oxford University Press, Incorporated, 2017. ISBN 9781605356372.
9. Anne-Johan Annema. *Electronics*. IC-Design group, Electrical Engineering, University of Twente, 2019.
10. Zaid Al-Khatib and Samar Abdi. Operand-value-based modeling of dynamic energy consumption of soft processors in fpga. In Kentaro Sano, Dimitrios Soudris, Michael Hübner, and Pedro C. Diniz, editors, *Applied Reconfigurable Computing*, pages 65–76, Cham, 2015. Springer International Publishing. ISBN 978-3-319-16214-0.
11. World Health Organization. Mental disorders. https://www.who.int/news-room/fact-sheets/detail/mental-disorders, 2022.