What are some potential therapies that could be developed if we were fluent in the language of the brain?

What are potential applications of fully understanding how signal transmission works in our nervous system?

If we understand how to transmit specific messages to neurons by encoding them in action potentials, how could this be applied? What are electrophysiological experiments working toward and how can the knowledge gained from these experiments be used to minimize suffering?

Fluent in the language of the brain will enable us:
- To understand how the brain creates a representation of concept like smell, taste, hunger, touch, depression, sadness, anxiety from multisensory information.
- Answering these questions will put us on the path in understanding higher cognitive processes such as language, reasoning, learning, or memorization.

The list of potential therapies is infinite and the existing ones are already consequential and numerous. These are few examples on how progress in understanding brain communications have already delivered impressive results:
- Many patients after a stroke or affected by neurodegenerative diseases such ALS lose their ability to speak (like the famed late physicist Stephen Hawking). They can use brain-computer interfaces to convert their thoughts and control machines. Researchers are developing tools to decode speech-related brain activity and convert it into words spoken by a machine. In 2019 JHM and APL Johns Hopkins laboratories, created a BCI that allows a paralyzed patient to control his prosthetic limbs with his brain [1][2].
- A study showed that for people diagnosed with schizophrenia, the excitatory neurons had a diminished ability to stimulate one another: "Imagine you are trying to listen to someone speaking on the radio, but the signal is very weak; if you turn the volume up, the speech is louder–but so is all the static and background noise–and so you may mistake some of this noise for actual speech." With an understanding of the language of the neurons, we can imagine creating drugs to boost the weaker signal from these neurons [3].
- Memory loss: researchers found that they can improve episodic memory by simulating the left prefrontal cortex: applying slow repetitive transcranial magnetic stimulation (rTMS) led to reduce power of low-frequency (beta) waves in the parietal region of the brain, known to be involved in attention and perception. They also found that stimulation of the left dorsolateral prefrontal cortex with slow rTMS enhances verbal memory formation [4].
- Hearing aid: Columbia researchers have deciphered the brain's natural aptitude for detecting and amplifying any voice within a crowd and designed a brain-controlled hearing aid [5].

If we can draw a parallel between the point in time after which major breakthrough were made in signal processing theory after for example Shannon and Nyquist contributions and the applications which came out of them, which one could trace them back to the beginning of the entire numerical revolution, understanding neural communication will lead to that singularity point predicted by scientists like Kurzweil, in which "effective human intelligence will be multiplied by a billion fold". In the TEDx talk, Adam Cohen described that today to understand the brain is like listening to an opera with a straw. Using this analogy, if we are able to hear the full opera and tune to the other instruments, the instruments being other individual brains, we could imagine that improved and personalized therapies will be then possible.

Electrophysiological experiments could consist in:
- characterizing the neuronal signals using signal processing, and detection theory, or be classified and clustered using various machine learning algorithms
- how extracellular signals are translated into neurotransmitter/neuromodulator signals

- determining their connection to observations related to disease biomarkers, phenotypes or specific genes using methods from computational biology, statistical genetic, deep learning, representation learning, metric representations, causal inference and other scientific fields

There are already significant results which came out of the studies on action potentials, neural pathways, and transmission between neuron populations, here are some of fascinating ones:

- In mice, the nuclei of the ventral midline thalamus (vMT), the xiphoid nucleus (Xi) and nucleus reuniens (Re) are implicated in the network controlling behavioral responses to visual threats. Xi promotes saliency-reducing responses to threats (Xi → basolateral amygdala), whereas Re promotes saliency-enhancing (Re → mPFC). These findings may have implications for understanding phobias, post-traumatic stress and addictions. [6]
- The network approach applied to the brain, identifies differences between healthy and brains of patients with neuropsychiatric diseases or neurological disorders. Network neuroscience uses neurofeedback as a neuromodulation therapy. Using signals for EEG, fMRI or other imaging technologies, a patient may be taught to stimulate specific area or connection in their brain to bring back their brain network in line with how it is configured in healthy brains [7].
- Insights from human EEG implicate inter-regional theta (5-8 Hz) local filed potential LFP) synchrony is a key element in cognitive control which deficit is involved in almost every psychiatric illness. Deciphering how several prefrontal cortical regions are coordinated, could lead to fine-grained and precise cognitive control [8].
- Researchers in a genome-wide analysis of 1,331,010 individuals with insomnia, identified 202 loci implicating 956 genes involved in insomnia and investigated which brain regions, pathways, tissues and cells these genes frequently ate found. These new insights are significant as similar studies have found that the same genes are implicated in depression, anxiety, schizophrenia, coronary artery disease and type 2 diabetes. Understanding if there are different types of insomnia can lead to more targeted therapies including cognitive behavioral therapy which may be more effective than current drugs which have limited efficacity, can be additive and have side effects [9].

[1] Decoding Imagined Speech and Computer Control using brain waves https://arxiv.org/pdf/1911.04255.pdf

[2] Neuroprosthesis for Decoding Speech in a Paralyzed Person with Anarthria: https://www-nejm-org.proxy1.library.jhu.edu/doi/10.1056/NEJMoa2027540

[3] Computational Modeling of Electroencephalography and Functional Magnetic Resonance Imaging Paradigms Indicates a Consistent Loss of Pyramidal Cell Synaptic Gain in Schizophrenia: https://www-sciencedirect-com.proxy1.library.jhu.edu/science/article/pii/S0006322321014992?via%3Dihub

[4] https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.3001363

[5] https://zuckermaninstitute.columbia.edu/voice-crowd-experimental-brain-controlled-hearing-aid-automatically-decodes-identifies-who-you-want

[6] A midline thalamic circuit determines reactions to visual threat: https://pubmed.ncbi.nlm.nih.gov/29720647/

[7] A Network Neuroscience of Neurofeedback for Clinical Translation: https://pubmed.ncbi.nlm.nih.gov/29057385/

[8] Prefrontal cortex and cognitive control: new insights from human electrophysiology: DOI: 10.12688/f1000research.20044.1

[9] https://www-nature-com.proxy1.library.jhu.edu/articles/s41588-018-0333-3