The application of nanorobots to cure and prevent brain disorders

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***Abstract*—Currently there are limited options to cure and prevent brain disorders. They also focus more on suppressing symptoms than to effectively heal the conditions behind them. Nanorobots in the human brain might enable huge possibilities for disease prevention and studying the human brain.**

Keywords—robots, brain, neural nanorobots, brain/cloud interface, neurodegenerative diseases

I. Introduction

Follow your heart

but take your brain with you.

~ Alfred Adler

Robots are a promising opportunity to expand knowledge about the human brain for individuals as well as for the whole brain research. A concept called "Human Brain/Cloud Interface" aims to connect neural nanorobots to an artificial intelligence on the internet. This student paper intends to outline the present application of robots in neuroscience and depict a possible direction in which the field could develop.

II. State of the Art

A. Current state of robots in the brain

1) Robotics in neurosurgery: Robotic systems in neurosurgery can be classified in three different categories. [1]

a) Telesurgical robots can mimic the movement of a surgeon's hand. The information is transferred by telecommunication and carried out by a master controller. This allows the surgen to be at a different hospital than the patient, reducing travel costs and travel-related health risks. The technique also mimimizes the risk of infection for patients and surgeons by viruses like Sars-CoV-2. There are however limitations like latency, collaboration problems between the many involved medical centers and legal issues.[2]

b) Shared-Control devices do not carry out the procedures themselves. They just help the surgeon to do the operation, compensating tremor and muscle fatique while also allowing the surgeon to operate with as much freedom as without robots. This enables both entities to bring what they can do best. [3]

c) Supervisory-controlled robots assist surgeons to carry out precise tasks. The procedure is executed independently by the robot. This takes a lot of planning and programming for each patient which makes it very expensive. It also does not make surgeons redundant as they are still needed for planning the procedure and overseeing the operation. [1]

2) Other ways to measure the brain [7]

a) Single-Cell Recording: Single-Cell Recording is a technique used in research to observe changes in voltage or current in a neuron.

b) MEA: Multi-electrode arrays consist of a grid of many closely spaced electrodes. Electrically active cells, such as neurons, are activated via the electrodes. When neurons trigger action potentials, the electrodes measure voltages in the time interval of microseconds. When the neurons attach and network with each other, the spread and synchronization of neural activity can be detected via the cell network.

c) Functional magnetic resonance imaging, or fMRI: This technique measures the relative oxygen content in the blood. This allows conclusions to be drawn about the activity patterns of neurons.

d) Electroencephalography, or EEG: EEG records the brain's activity via electrodes placed on the scalp of the subject.

e) Electrocorticography: This technique is similar to EEG but the electrodes are placed under the scalp of the subject. Because of that it is just done when a surgery is already necessary.

B. Common brain conditions and their current treatment options [9]

1) Brain injuries: [6]

a) Seizures: After a traumatic brain injury people can develop seizures. It may occur in the early stage. Post-traumatic epilepsy is characterized by recurrent seizures.

b) Hydrocephalus: Some people who have suffered traumatic brain injuries may develop increased swelling and pressure in their brains due to the accumulation of cerebrospinal fluid.

c) Infections: A skull fracture or a penetrating wound can tear the layers of protective tissues that surround the brain, allowing bacteria to enter and cause infection.

d) Blood vessel damage: Several blood vessels in the brain can be damaged, which could lead to strokes, blood clots, any much more.

e) Headaches: Frequent headaches are common after a traumatic brain injury.

f) Vertigo: A traumatic brain injury often leaves victims experiencing vertigo, a condition characterized by dizziness.

2) Brain tumors: [5]

a) Gliomas: These tumours begin in the brain or spinal.

b) Meningioma: These tumours grow in the membranes that surround your brain or spinal cord.

c) Acoustic neuromas: These tumors grow on the nerves that control balance and hearing.

d) Pituitary adenomas: These tumors grow in the pituitary gland at the base of the brain.

e) Medulloblastomas: These tumors grow in the lower back part of the brain.

3) Neurodegenerative diseases: Neurodegenerative diseases such as Alzheimer's disease, Parkinson's disease or Huntington's disease cause neurodegeneration in nerve cells in the brain or peripheral nervous system. Currently there are no known cures. Available treatments may relieve some of the associated symptoms but cannot slow down or reverse the nerve damage. The risk of developing a neurodegenerative disease is linked to genes and environmental factors. Main research challenges are identifying what influences the occurrence of such diseases and finding ways to minimize them. [8][10]

III. Concept

A promising strategy to monitor the human brain is through a system of nanorobots in connection with the internet proposed by scientist Robert A. Freitas Jr named "Human Brain/Cloud Interface". So-called "neural nanorobotics" in the brain are anticipated to detect and decode brain waves and send the data to an artificial neocortex on the internet made by artificial intelligence. This should enable early diagnosis and eventually cures for the ~400 conditions that affect the human brain. The Brain/Cloud Interface might also allow access to external knowledge improving education and intelligence. [11][12][17]

A. How are the robots going into the brain

As the robots are going to be nano-sized a surgical procedure to put the neural nanorobots in the brain is not necessary as it is possible to inject the robots into the skin. Then they will travel through the blood stream and cross the blood brain barrier. The blood brain barrier separates the blood in the brain from the rest of the system. This allows the brain tissue to be protected against neurotoxins and pathogens to avoid infections. At the same time the blood brain barrier enables vital nutrients to reach the brain and helps to maintain constant levels of hormones, nutrients, and water in the brain. By crossing that barrier, the neural nanorobots have accessed the brain and must now find their position. [11][12][13]

B. Where will the robots be located?

It is planned to locate the neural nanorobots in the brain area neocortex. It is the youngest part of the brain and is divided in the frontal-, temporal-, parietal- and occipital lobe. The neocortex is involved in higher-order brain function such as the neuronal computations of attention, thought, perception and episodic memory. [16]

Neurons receive signals via branches called dendrites and send out signals with a branch called axon. One neuron can have up to thousand dendrites but only one axon. The cell body is named soma and contributes to receiving signals. The contact between one neurons dendrite and another neurons axon is called synapse. There information is passed on. A human brain has eighty-six billion neurons each having seven thousand synaptic connections to other neurons on average. The human brain does not only consist of neurons but also glia cells. They outnumber neurons by a ratio of 10:1 and help to keep them in place, isolate them from one another, supply them with nutrients and water, destroy pathogens and remove dead neurons.[14][15]

Each of the three neural nanorobot types has a different purpose and therefore a different location. Synaptobots will position themselves very close to synapses and detect changes in the processed action potentials. Endoneurobots are anticipated to interface with neurons directly and will therefore auto position themselves at the axon initial segments of neurons. Gliabots will position themselves on glial cells.

C. Communication

First the data measured by the Synaptobots needs to be transferred to the local Endoneurobots and Gliabots. For communication between the robots and the outside world a high-speed nanofiber-optic network is needed.[12]

D. Energy supply

In order that we can use nanorobots in the medical area they need to be powered by an external power supply, an internal power supply or by an internal generator. Therefore, scientist research an extremely small energy harvester that can supply electrical power to the nanoscale devices. These extremely small power plants are called nanogenerators. To power nanodevices it is tried to convert mechanical energy like body movement, vibration energy like acoustic and ultrasonic waves and hydraulic energy like the flow of blood into electric energy to. Options include electricity generation due to heat differences in the body and using the piezoelectric effect, too. These nano-systems operate on an extremely low power level at the range of nanowatts to microwatts. [4]

IV. Implementation

There is no implementation of the Human Brain/Cloud Interface or neural nanorobots yet. It is within the realm of possibility to solve the problems in the next twenty to thirty years to enable a Human Brain/Cloud Interface. Next, the advantages as well as the difficulties of the theoretical concept are presented. [17][12]

A. Problems [17][12]

1) Biocompatibility: A problem that still needs to be solved is to avoid a defence reactions of the body. To be used safe and effectively neural nanorobots must not induce injury or inflammation to brain tissue like tearing cells apart or activating glia cells. The material used for the robots must be soft and flexible while also being strong enough to potentially transmit data. Also the surface must be smooth to reduce inflammation passively.

2) Autonomy: Another challenge to face is creating robots that can travel autonomously or semi-autonomously to their specific location in the body. Their nanoscopic dimension makes it hard to navigate as for them even a small distance is huge and full of obstacles.

3) Data Transfer: For interfacing with external computers a sufficient and robust information transfer bandwidth is needed which will be the ultimate bottleneck between the cloud and the human brain.

B. *Possibilities [17][12]*

1) Diagnosis: Early, accurate diagnosis of conditions affecting the human brain to ensure the best available treatment options by knowing of all specific conditions affecting the patient.

2) Comprehension: Collection of immense amounts of data of healthy as well as diseased brains to find out about possibilities to cure and prevent neurodegenetaive diseases and getting a thorough understanding of the human brain in general.

3) Cognitive Enhancement: Nanorobots in the brain could purposely stimulate specific areas of the brain to enhance certain cognitive abilities like memory or problem-solving. If the robots were connected to an artificial intelligence in the internet the access to information would be endless.

V. Conclusion

Neural nanorobots might be able to send real time data about the current brain state from a human brain to a computer, named the Brain/Cloud Interface. This could help monitoring brain diseases and find ways to cure and prevent them from occurring, enhance human cognitive abilities and get a more thorough understanding of the human brain. There are still problems to be solved which may take twenty to thirty years, the effects however could be life changing and worth the effort.

References

[1] Robotics in neurosurgery. Website. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5956573/ Access on 30.03.

[2] Telesurgery and Robotics: An Improved and Efficient Era. Website. Available at: https://www.cureus.com/articles/54068-telesurgery-and-robotics-an-improved-and-efficient-era Access on: 30.03.2022

[3] Robotic surgery. Website. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3941295/ Access on: 30.03.2022

[4] How Self-Powered Nanotech Machines Work. Website. Available at: https://www.scientificamerican.com/article/how-self-powered-nanotech-works/ Access on: 30.03.2022

[5] Brain tumor. Website. Available at: https://www.mayoclinic.org/diseases-conditions/traumatic-brain-injury/symptoms-causes/syc-20378557 Access on: 30.03.2022

[6] Traumatic brain injury. Website. Available at: https://qbi.uq.edu.au/brain/brain-functions/how-measure-brain-activity-people# Access on: 30.03.2022

[7] How to measure brain activity in people. Website. Available at: https://qbi.uq.edu.au/brain/brain-functions/how-measure-brain-activity-people# Access on: 30.03.2022

[8] Neurodegenerative disease. Website. , Available at: https://en.wikipedia.org/wiki/Neurodegenerative_disease , Access at: 28.03.2022

[9] Brain Disorders. Website Available at: https://www.healthline.com/health/brain-disorders#types Access on: 28.03.2022

[10] Neurodegenerative Diseases. Website. Available at: https://www.niehs.nih.gov/research/supported/health/neurodegenerative/index.cfm Access on 28.03.2022

[11] Brain to cloud interface: A new perspective for human enhancement, Website. Available at: https://www.brainlatam.com/blog/brain-to-cloud-interface-a-new-perspective-for-human-enhancement-843 Access on: 01.04.2022

[12] Are Nanobots the Future of Neurotech? Website. Available at: https://medium.com/predict/are-nanobots-the-future-of-neurotech-223d0fc21e92 Access on: 01.04.2022

[13] Role of the Blood-Brain Barrier in Central Nervous System Insulin Resistance. Website . Available at: https://www.frontiersin.org/articles/10.3389/fnins.2019.00521/full Access on: 01.04.2022

[14] Neuron. Website. Available at: https://en.wikipedia.org/wiki/Neuron Access on: 01.04.2022

[15] Glia. Website. Available at: https://en.wikipedia.org/wiki/Glia Access on: 01.04.2022

[16] Neocortex. Website. Available at: https://www.kenhub.com/de/library/anatomie/neokortex-isokortex Access on: 01.04.2022

[17] Human Brain/Cloud Interface Website. https://www.frontiersin.org/articles/10.3389/fnins.2019.00112/full Access on: 01.04.2022