Podcast Episode 15: Brain-computer (brain machine) interface – Part 1

As of 9.7.2021

Teaser

Hey everyone! Welcome to the new episode of the Life Extension Podcast – technology & magic, society & business. Brain-computer interfaces (or BCIs in short), more than any other technology presently under development, will change the life of the consumer in the future. In this first part you will hear what BCIs are and what they are used for. We'll look at involved technical processes and also dive into brain function and the underlying science.

This episode is the first part of an introduction into brain-computer-interfaces.

1. What is BCI

Brain-computer interfaces, or BCIs, connect the brain with external artificial devices. Neuroscience and medicine are building their assumptions on a reductionist model of the person: according to that model a person consists mainly of the brain, or more precisely of neuronal network action in the brain. The person acts in the world and communicates with the world through muscular function, while muscles are controlled by the brain through neural pathways. Both muscles and neural pathways are liable to disruption through accident or disease, resulting in malfunction or paralysis. In such cases BCIs are used as a medical solution to provide the brain with a new channel to communicate with and act in the external world. The idea is that the brain would accept artificial devises under its control as natural representation of its body. This is a very significant assumption, which is supported by human experience, such as when driving a car, or how we incorporate a smart phone into our daily routines. BCIs can be seen as artificial bridges between human thought, which is generated through neural network activities in the brain, and artificial devises, such as prosthesis, a wheelchair, a light switch at home, or a text generating computer.

2. Applications

The restoration of bodily function, cognitive, sensing, and communication abilities is perhaps the most obvious application of BCIs at the moment. That is because it solves an urgent problem involving strong human emotions, has an important market of disabled patients, and can benefit from immediately available funding through the public health care system. But providing an alternative communication and control channel for disabled people is not the only application at present. The military is investing in BCI technologies with the purpose to create new combat capabilities, e.g. soldiers using exoskeletons or independent robots, as well as to handle complex targeting and operational decision-making tasks within very short time spans.

The workplace environment promises to integrate BCIs in the future as well. Online monitoring of mental workload of pilots, air-traffic controllers, drivers (Babiloni 2016), or operators of critical industrial processes could reduce risks of major accidents. Companies could monitor attention levels and mental states of their employees, freakish as that may sound at the moment. Although still in an early stage, suppliers of such BCIs are already trying to sell products into the corporate market (Gonfalonieri 2020). Development of BCIs follows the money, same as other technologies.

Gaming and entertainment might become another industry where BCIs will be used widely in the future, not only in the form of the gamer navigating in virtual reality, but also through brain-to-brain communication between gamers.

BCIs mostly exist at an experimental level so far. However so many promising results have already been achieved, that commercially relevant products are only a few years away. BCIs have demonstrated the capability to write text, speak, control a cursor on a computer screen, navigate in virtual reality, control prostetic and robotic devises, and smart-home applications, and even to communicate between brains. As communication between brain and computer works both ways, brain states incl different types of emotions were already able to be interpreted correctly in a reliable way as well.

Applications of BCIs are basically limitless. Regarding bodily and cognitive abilities, focus will soon be extended from restoration to enhancement. Technologies called neurofeedback and biofeedback are under development, which train and enhance brain functions (Bitbrain 2020).

As a consumer, out of all the new technologies which will be integrated into our daily lives in the future, BCIs may be the most relevant. Anything we use the smart phone for today, could be done better through BCIs, and more. Whatever we imagine, could be done through BCIs. In modern societies this technology might one day determine and structure the entirety of human communication and action.

3. Technical processes

How is thought, including emotions, intent, and memories generated in the brain? This process remains poorly understood. Scientists are able to read electrical signals emanated during neuronal network activities as brain waves, which are associated with human thought. We should realize that thought is not associated with individual neurons, but always with assemblies of neurons and neuronal networks which are constantly oscillating. All this electrochemical activity forms a language, which scientist have hardly begun to understand. In comparison, learning a language from another human culture is way easier due to commonalities in grammar and concepts of meaning, as has been well described by the discipline of general linguistics. Human spoken and written languages consist of a linear flow of discreet phonetical and lexical elements, assembled by relatively simple grammatical rules, and which were culturally learned to be associated with human concepts of symbolic meaning. Compare this with the language of mass-distributed neurons, of which each brain has close to 100 billion with endless connections between them. This appears like trying to talk to a sea of water molecules, or to the universe. The challenge to artificial BCIs is not only to read these brain signals, but to interpret their meaning, and to translate them into human-level symbolic language of communication and command. This challenge at first sight appears almost impossible. Nevertheless, BCIs have been proven to work successfully when focusing on single, predefined tasks in controlled environments. Users can train to actively modulate brain activity, or we could say manipulate brain signals to generate specific commands to the external environment through a BCI. This really depends on training, and not all users succeed in this. A BCI does not understand the meaning of brain signals, but can sense signal changes, which were caused by the user in a deliberate way. Computer algorithms then interpret such signal changes as user intent. In a third step user intent is translated to actuate a device in the external environment. Therefore brain-computer interfaces do work for simple, predefined tasks. Furthermore, prosthetic or other robotic devices can be controlled in three-dimensional space by a user imagining their movement. This can be trained through repeatedly imagining a movement and obtaining feedback about the actual movement. At the moment a lot of hope is being laid in machine learning methods to decode and characterize task-related brain states based on physiological data. Task related signals need to be separated from other tasks, and from non-task related signals, incl noise from physiological processes like eye blinking. At an abstract level this could be interpreted as thought controlling machine, although still playing out at a very simple level of complexity. But BCIs are far away from actually understanding complex thought outside of predefined tasks performed in controlled environments.

Engineers are trying to overcome the limited understanding of complex brain processes by developing shared control systems, whereas intelligent artificial systems propose possible actions, and the human can perform simple control tasks of accepting or refusing such proposals.

BCIs work in active mode when operated by the user for control or communication. But they also work in passive mode, when the external computer is simply registering what's going on in the brain. BCIs can already distinguish between different brain states expressing emotions like happy, sad, and bored, or even register levels of awareness.

There exist various systems of BCIs: most-used are non-invasive electroencephalography devices (in short EEG), with the user wearing electrodes at scalp level. Other non-invasive technics involve large and expensive equipment like magnetic resonance imaging. Invasive systems involve inserting devices into the brain itself, a more risky procedure applied for deep brain stimulation in cases of debilitating diseases like Parkinson's or epilepsy. Last there are partially invasive devices which include chargeable neurochips with electrodes, the type of products Egon Musk's Neuralink is working on. They are placed under the skull but outside the brain.

All this is mind-boggling. Scientists are conducting experiments, and doctors are carrying out medical procedures and notice that all this works. Most is due to brain plasticity, the capability of neuronal pathways to reorganize through training or injury. There are even experiments with animal brain cells in a petri dish being trained by scientists to perform specific tasks (DeMarse 2004).

Brain cells seem to be self-organizing forming intelligent networks adapting to external stimulation. A brain is able to build representations of itself and extend such representations to a body, even including artificial devices. A brain can then imagine its body within a physical environment, whose reality is in no way absolute, but rather interpreted by the brain and shared between different brains through culture. Brains also develop intent and awareness, enabling them to communicate with and act in their environment as conscious subjects. Through intent brains can even change themselves. We can observe all this. But why it works remains a total mystery.

This is the end of the 1st part of a discussion about brain-computer-interfaces. The following episode includes the 2nd part.