

Abstract for the general public

The goal of our 'Electrophysiological Discharges of Neuronal Assemblies' (electro DNA) project is to decipher the code of human memories on the level of electrical discharges of fast and slow brain wave activities. The fast brain waves called ripples can be recorded with special electrodes as bursts of neural networks on a micro-meter scale whereas the slow waves like the alpha or theta waves appear as bouts of synchronized firing in larger populations of neurons as our memories are first formed, then stored, and then finally recalled when we remember names or locations in our daily life experiences. Memory traces of each experience are preserved in the brain as so-called engrams of connected neurons and the discharges of brain waves are proposed to reflect when and where in the brain they are active.

To study these bursts and bouts of fast and slow brain waves we will employ recordings from epilepsy patients, who were implanted with special electrodes and state-of-the-art devices to treat their drug-resistant seizures. The electrical activity from inside their brain is continuously recorded as the patients perform computer-based tasks to remember words and locations either during their hospital stay or remotely from their homes thanks to the technological capabilities of the new implantable devices. In the final stage of the project, newly implanted patients in Poland and Czech Republic will perform the tasks with Augmented Reality goggles on a regular basis to track their performance and study the bursts and the bouts of brain waves during memory performance. This will be part of an established international collaboration between our teams of neuroscientists, engineers and clinicians.

During the three years of this project we will first focus analyzing unique datasets collected as part of our collaboration across the USA, Czech Republic and Poland. This includes several years of continuous brain wave recordings from five Mayo Clinic patients implanted with a special device system that enabled them to regularly perform memory tasks from their homes. As these large datasets are analyzed, we will apply for ethical approvals and recruit new epilepsy patients in Poland and Czech Republic to implant them with the latest version of the device to treat drug-resistant seizures as well as study and improve their remembering of words and object locations. This will be done using the goggle technology automatically during regular task performance.

We have shown that continuous deep brain stimulation with slow waves of electrical current delivered in a relay brain area called the thalamus can effectively restore memory performance in the five implanted Mayo Clinic patients. We do not know, however, what brain wave activities are underlying this positive effect of stimulation on memory. The results of our studies point to the bursts and the bouts of the fast and slow electrical discharges detected and stimulated as particular memories are encoded and recalled. We expect these discharges to reflect and explain the immediate and long-term therapeutic effects of the stimulation across weeks and months of regular task performance. We also expect that the discharges can be used to predict which words and locations will be remembered. By doing this we can show that particular discharges indeed are reflecting electrical activities of engrams and can be used to track and modulate specific memories.

Knowledge and technical 'know-how' from this study can potentially revolutionize the emerging neurotechnologies for fully implantable devices. Detecting and stimulating the basic electrical discharges underlying memory functions at the level of specific engrams has not been demonstrated in humans. The slow (theta) and the fast (ripple) discharges are ideal candidates for decoding and stimulating the engram activities. They can be easily detected, stored and analyzed to predict, control and improve the effects of new stimulation therapies in individual patients. Each detection takes little computation time and space thus the discharges can be directly applied for personalized treatments delivered online and at home with the latest implantable device technologies.