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\$15,000 "Use it!" Lemelson-MIT Student Prize Graduate Winner

AlterEgo, a non-invasive-peripheral-nerve computer interface and ISGEC (in-silico gene expression construction), a customizable gene expression measurement platform

The Challenge: Computers and artificial intelligence have always been considered external entities or external black box devices that compute and act on our behalf. The question is, could we invert this and couple humans and computers (artificial intelligence) as a single entity to augment human cognition and abilities, instead of relying on external interfaces that unplug us from our environment?

There are upwards of 7.5 million people in the United States alone who suffer from a speech disability after an illness or injury.¹ The most commonly used systems that allow these patients to better communicate, however, are limited in their utility. Symbol sets—sheets with printed letters, words or icons—and a process called steady state visually evoked potential (SSVEP), which applies characters on a monitor that users choose via eye movement, are both difficult to use and make for frustratingly slow communication, as users can typically only select one character at a time. As such, individuals who suffer with speech disabilities are often unable to share their ideas and thoughts in real-time.

The Solutions: Arnav's primary invention, AlterEgo, is a three-part sensory and auditory feedback system. The first part uses subtle neuromuscular signals from the internal speech system to extract speech. When we talk out-loud, our brains transmit electrical signals to more than a 100 muscles and to the vocal cords to produce speech. When we talk to ourselves internally, by very subtly engaging only our internal speech systems, neural signals are sent to these internal systems. From the surface of the skin, AlterEgo is able to detect these signals originating from deep inside the mouth and understand what a person intends to say. The second part of the system transmits the information gathered from the electrical signals and sends it to an artificial intelligence agent running on the device in the background. The AI agent makes sense of the data and prepares a response for the audio feedback system to project. The third part of the device is two-fold. The user can hear the computer's response through

¹ <https://www.nidcd.nih.gov/health/statistics/statistics-voice-speech-and-language>

vibrations transmitted through the skull and inner ear through a bone conduction audio module, which sits right behind the user's ear. The combination of these different components of the system create a subjective experience of a conversational interface that is internal to the user—a personal, conversational AI that one could converse with internally to access information and services. If the user wishes to speak with other people using AlterEgo, the AI agent can send the information to the computer, allowing real-time communication.

AlterEgo allows humans and machines to collaborate seamlessly and intrinsically – it enables AI to serve as a direct internal extension of human cognition accessed through one's internal speech, by running in the background. A person with speech difficulties can use AlterEgo to communicate in real-time, as long as they have the cognitive ability to internally engage their speech system. Also, unlike some other brain-and-peripheral-nerve computer interfaces, AlterEgo is non-invasive to the user and does not need to be implanted through surgery. It also has the highest reported information transfer rate among all brain-and-peripheral-nerve computer interfaces.²

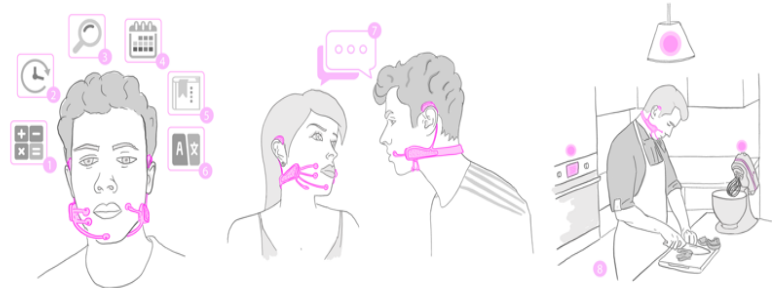


Figure 1: AlterEgo seeks to make computing a natural extension of the user. Photo Credit: Arnav Kapur, Neo Mohsenvand

For his secondary invention, to combat the issue of costly and lengthy tests that currently exist for gene expression measurement, Arnav created the in-silico gene expression construction (ISGEC) platform to construct gene expression measurements computationally. The process uses a selected portion of gene expression measurements, allowing for only selected genes to be isolated for analysis and the rest are constructed computationally using the system. The method uses biochemical markers for measurement, which can tell us more about how biomedical data is sourced and generated. ISGEC lends itself to far-reaching applications like differential gene analysis, class prediction, cancer investigation and non-invasive diagnosis. It is designed to drastically reduce the costs of gene expression measurement and make it more accessible.

Commercialization: AlterEgo is intended to be deployed at scale as a mobile system. Since the system enables computing as an extension and not a replacement of the human being, its applications are far-reaching beyond helping those with speech difficulties. For example, a patient with Alzheimer's disease could use AlterEgo as a memory aid by internally recording semantic information and accessing it at a later time. The system could also be used for real-time language translations.

² Kapur, Arnav. Human-machine cognitive coalescence through an internal duplex interface. Diss. Massachusetts Institute of Technology, 2018.

At present, large scale experiments are being conducted to collect data from participants across a broad range of demographics in order to make the platform more robust for different users. The testing is being done in collaboration with a number of homes and hospitals in the Boston area such as the Leonard Florence Center for Living, in hopes of being clinically deployed after being optimized for patients with amyotrophic lateral sclerosis (ALS), cerebral palsy, a history of strokes, or other conditions that affect speech.

There is already a patent in process for AlterEgo. The device is designed to have a high bandwidth for information transfer between the human user and the computer. The electronic architecture of the system has been custom designed and fabricated; it has an extensive number of commands and operates at a higher speed of interaction when compared to other systems.

The ISGEC has been extensively tested with genome-wide 119 gene expression experiments. The method democratizes gene profiling, much like how 3D printing seeks to democratize manufacturing. ISGEC is being further developed and tested on lab and human subjects in order to attain FDA approval for widespread use.