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The Brain As A Hackable Driver

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Abstract

Do our EEG, fMRI and other biometric data contain the essence of who we are and what we think? In the future could this data be used as an identifier for security and thought modification, as well as exploring virtual worlds? If our "brainotypes" or 'brain-finger prints' and concurrent cognitive processes are monitored, how do we prepare for this looming horizon? Though no one is entirely sure, these questions invite both scientific and metaphorical approaches to address these issues. This paper looks at past artistic investigations using the human brain. It then discusses the emergence of technologies, research, and methods on brain datatyping; privacy and its ethical implications; sending and receiving motor commands between two different brains; moving robotic prosthesis through thought; the formation of memory; manipulating memory via frequencies of light; and hacking brain computer interfaces (BCIs) to extract vital information.

Keeping these methods and techniques in mind, this paper then touches upon the author's nascent creation of a 'brain-opera' using both open source and proprietary BCIs. This research, in an early phase of development, will be developed throughout the coming year.

Keywords

surveillance, brain sensors, posthuman, memory, consciousness, brain opera, datatyping, BCI, EEG

Early Experiments

Artists have been working with brain sensors since the 1960s and 70s when modern composers and musicians Alvin Lucier, Richard Teitelbaum and David Rosenboom experimented with control sources of biofeedback and brainwaves producing a number of sonic events derived from brainwaves. Fellow faculty member at Brandeis University physicist Edmund Dewant who was researching alpha brainwaves for the U.S. Air Force approached Lucier and told him, "You should make a piece with brain waves". [1] Lucier discovered brain alpha waves produced sonic cycle sounds very low in tone. He utilized this knowledge to perform the first brainwave music composition using EEG electrodes and conductive paste, *Music for Solo Performer* at the Rose Art Museum. [2] Lucier sent his alpha waves through amplifiers, activating speakers triggering drums, trashcans, piano strings and cardboard boxes. These sounds affected the environment of the performance space, as well as the listeners and the performer. Any time one of these variables changed, it changed the entire event.

In 1967-1968 Teitelbaum used breath, EEG and heartbeats interfaced with a Moog Synthesizer inventing bizarre sonifications of human biofeedback systems as part of the "the American experimental tradition in which the 'idea' is expressed directly in its sonic manifestation. [3] Composer John Cage also embraced the American experimental tradition. He performed David Rosenboom's composition, *Brainwave Feedback* (Cage 1971), and again throughout the 1973 film *Homage to John Cage* by video artist Nam June Paik. [4] But it was Rosenboom who foresaw using the brain, as an instrument would lead to a "large-scale, musical theater or operatic works involving biotelemetric presentation by human and even non-human performers interacting with audiences, other performers, and environments. This could create a synergistic theater, linking participants in a large-scale organism, the ontology of which could provide a script of mythical proportions." [5] These initial experiments validated the brain as a device that could produce music and art, but the idea of the brain as a hackable driver still resided in the realm of science fiction.

Current Practices

In recent years numerous consumer grade BCI devices have inundated the market. The largest EEG driven neuro feedback ride in the world, "The Ascent" by Yehuda Duenyas used a consumer grade EEG reader to allow a participant to controls their own brain waves through focus and meditation. [6] Controlling their focus allowed them to also control the level of their levitation where they were strapped inside a mind-controlled harness that raised or lowered them depending on the level. If they could stay focused until the end of the levitation experience, a music and fireworks display was triggered.

Marina Abramovic's three-month performance at the Museum of Modern Art's *The Artist Is Present* where she sat across the table and gazed at the participants was the inspiration for her neuroscience experiment *The Magic of the Mutual Gaze*. [7] [8] It used an Emotiv wireless headset asking two people to gaze into one another's eyes as their brain activity was displayed real time on a screen behind them. When their brain activity was on the same wavelength, the images merged into one another. Lisa Park, a composer created *Euonia II* to use her emotions of anger, hate, desire, sadness and happiness coded into sound waves that produced vibrations in pools of water placed atop 48 speakers. [9]

These experiments and performances harness the specific mental states of focus and meditation. When more complex environments and sophisticated brain EEG readers are used, additional mental states are readily accessed, opening up new spheres of inquiry in the performance environment. The implications of these developments hold promise for rehabilitation, medical and gaming uses, and should be viewed with skepticism surrounding issues of brain surveillance, and the ability to manipulate and 'hack' the brain.

How Do I Know You?

Neuroscience researchers at the University of Pennsylvania suggest we are on the cusp of measuring psychological traits and personal information through functional neuroimaging. Instead of using the word 'geneotype' which references the Human Genome project, an international project that mapped all human genes, they refer to this newfound identifier as a 'brainotype.' When pressed to say how realistic this possibility is the researchers stated, "an explicit answer to this question is not available in the literature because published functional neuroimaging research has not been directed toward the measurement of normal psychological traits for the purpose of characterizing individuals." [10]

Suggesting this concern might be ahead of its time, they caution one should not dismiss the prospect of brainotyping outright. The study admits that "a modest degree of brainotyping capability already exists…(it) is not science fiction, but rather a realistic possibility, albeit limited in important ways." Farah raises the question if brain imaging could pose any real or future threat to brain privacy, given how simplistic current analyses of the brain are. She distinguishes between "behavioral privacy," which means one's words and actions, and "brain privacy," which are our inner mental and neural processes. She asks, "under what circumstances can brain privacy be breached? Will we eventually use brain-enabled devices to play in a virtual world? [11] [12]

In the future one could upload their brain data to the cloud in order to increase processing speed and facilitate multi-user access. Security and privacy from hackers and governmental intrusion and monitoring could be problematic using cloud services. What is the proper balance between the rights of the individual to brain privacy and the needs of society"? Farah concludes that current Institutional Review Board guidelines (IRB) are sufficient at this time for protecting the confidentiality of imaging data. [13]

Mind Melding Thoughts

Researchers at the University of Washington produced the first non-invasive human-to-brain interface by asking, "Can information that is available in the brain be transferred directly in the form of the neural code, bypassing language altogether"? [14] The researchers showed "that it is possible to use EEG to decode motor intentions from a ''sender'' brain, and TMS (Transcranial Magnetic Stimulation) to deliver an equivalent motor command to the motor cortex of a ''receiver'' brain, allowing the receiver to perform the hand movement that was initiated by the sender."

The first subject in the experiment wore an EEG cap. He imagined controlling a video game with his right hand. That brain signal was picked up by the EEG cap and sent over the Internet. The second subject had a TMS device placed on top of his head in the area of his left motor cortex, an area that controls the right side of the body. He received the Internet transmitted EEG impulse into his brain (non-invasively) through magnetic stimulation. Subject One in Lab One imagined moving his right hand. Subject Two in Lab Two received that impulse in his left-brain. His right hand involuntarily jerked when he received the impulse.

The experiment, the researchers suggest demonstrated that simple non-invasive technology already exists, and is developed enough to create rudimentary brain-to-brain information transmissions between subjects. They caution that a dialogue should now begin "between ethicists, neuroscientists, and regulatory agencies on the ethical, moral, and societal implications of BBIs (Brain to Brain Interfaces) whose future capabilities may go well beyond the rudimentary type of information transmission the researchers were able to develop." In the future will performers be able to transmit their intention to other performers through such devices? Though it seems unlikely at the present time, these types of experiments show we are on the cusp of such breakthroughs.

This notion is reinforced through the use of "Braingate." A quadriplegic used a Braingate device enabling her to control a robotic arm, grasp a cup, bring it to her lips and sip a drink through a straw. [15] [16] The device was powered solely by *her intention* to move her arm. [17] A tiny neural sensor, the size of a grain of rice had been implanted into her brain. It contained 100 electrodes that recorded activity in her motor cortex. These signals were decoded, and sent to the robotic arm that performed complex tasks when she imagined the movements of her non-functional limbs. As a quadriplegic her muscles could not move, but her neurons still fired at will.

Using EEG braincaps, thoughts and intentionality can now remotely power drones and planes. [18] [19] [20] These devices are being deployed for aerial surveillance and security ATLAS test drills, funded by the US military. [21] If these BCI devices can be hacked remotely then the brain does indeed become a hackable driver.

Memory Manipulated By Light: Optogenetics

What does memory look like as it forms on the spot? Can our memories be manipulated? Scientists at Albert Einstein College of Medicine at Yeshiva University in New York have filmed the molecular basis of memory using fluorescent-tagged neurons of mice. [22] Adina Buxbaum states that over 100 years ago scientists theorized memory had the potential to be stored by changing the shape and strength of synaptic connections between neurons. Up until the research team's experiment no one had been able to prove such changes.

Buxbaum tagged messenger RNA (mRNA) composed of beta-actin protein. mRNA's are a family of RNA, and copy DNA's genetic information translating it into proteins. The researchers stimulated neurons in a mouse's hippocampus in the area where memories develop. They watched fluorescent memory molecules develop deep inside neuron nuclei. From within the nuclei the mRNA molecules slid like a string of beads down dendrites, tree-like branch endings of neurons. Neurons meet at synaptic points that resemble fingers grasping one another. Beta-actin protein strengthens synaptic connections by altering the shape of the dendrite spines. Memories are created when lasting synaptic connections form between dendrites, which might explain the relationship between repetition and memory. Beta-actin, an active compound assembles and disassembles quickly, despite the fact that it assists in creating memory of events in real time. If memory is formed through the action of beta-actin protein, can that memory ultimately be manipulated? Could memory molecules be manipulated and hacked?

The answer to this question seems to be yes. MIT professors used optogenetics, stimulating individual brain cells with light. [23] "“Optogenetic” tools are genetically encoded molecules that, when targeted to specific neurons in the brain, enable their activity to be driven or silenced by light. [24] To test their findings, the scientists placed a special transgenic mouse in a box and shocked it. They used laser light to reach those select areas though optical fibers implanted via special cannulas to alter the genes of the mouse's brain cells in the region of the brain where the shock was administered.

The mouse was moved to a new location. It behaved normally. Researchers then shone a special blue light at the mouse. The blue light activated the genetically manipulated memory cells. The mouse's fear response returned even though there was no threat, and no shock. The mouse's response proved certain types of memory cells can be genetically manipulated, and activated according to specific types of light. The brain then becomes a hackable driver, with memory manipulated, in this case, by light.

Emotiv Cap to Future Spy Surveillance

The Emotiv Cap, a portable EEG device reads changes in electrical activity in the brain. [25] Those changes can be mapped to emotions, facial movements, eye, eyelid and eyebrow positions, smiles, laughter, clenched teeth, smirks, devices and even virtual avatars. It tracks six specific directions in a screen display; left, right, up, down, forward and ‘zoom’ or depth, as well as six rotations; counter clockwise, left and right, backward and forward, and one interesting one referred to as ‘disappear.” It takes about eight seconds using Emotiv's software to calibrate the specific contours and fold patterns of an individual's brain. It's a process so unique it is akin to a human fingerprint. Both conscious and non-conscious content has been mapped for accuracy into the software accounting for variations in the brain's multiple folding patterns. Billions of neurons constantly interact with one another emitting tiny electrical impulses. What scientists at Emotiv did was remap those signals back to their source in a specific area of the brain. The Emotiv reads and translates these electrical impulses with a latency of about 150 milliseconds.

The Emotiv could be used for focus group testing, directing a prosthetic, turning on a toaster, or creative arts practices. But there is a darker side. Ivan Martinovic at the University of Oxford notes that BCIs are growing in popularity in the gaming industry. [26] He states ”The security risks involved in using consumer-grade BCI devices and the impact of malicious software with access to the device is unexplored,” and concludes someone could conceivably use brain data to actually steal a bank PIN number.

His team examined the “P300″ brain “fingerprinting” signal, activated when an individual recognizes an image, sound, or even a smell. They had a 40-60 percent accuracy rate identifying details of where a subject banked, and what their PIN number was just by flashing subliminal photos of bank logos and various numbers while monitoring their subject's P300 responses. This experiment took place in a lab, but the implications for more sophisticated hacking are chilling. Could hackers break into big data banks of gamers playing in the cloud and harvest their thoughts? Could the brain as a game driver be hacked?

Artistic Interventions

All of these experiments point to a nascent potential to track, categorize, manipulate and surveil the human brain. As research on the brain continues throughout this decade and into the next, it raises a multitude of ethical, social, political, scientific, moral, and technical issues. These issues must be addressed by their various disciplines. However I believe it is Rosenboom's vision that is the most appropriate for my own practice when he indicated large scale theater or operas using biotelemetric means by human and non humans interacting with audiences, performers and the entire environment could create a mythical scale synergistic theater.

In order to realize that vision I am at the early stages of creating a "brain opera." Studying the recently developed open source brain computer interface, OpenBCI, has shaped my ideas. [27] Unlike previous BCIs that have proprietary SDKs (Software Development Kits), OpenBCI is open source. OpenBCI consists of an Arduino-based specially designed EEG capable shield that monitors between eight and sixteen different locations in the brain. The headset can be printed out using a Makerbot 3D portable printing device, and comes with special open-source monitoring software. Wet, or gel enabled contact points enhance the sensitivity of the connections.

Through studying the neuroscience necessary to create a BCI interface, it became apparent that current consumer level BCIs are a useful, if imperfect mechanism for harnessing human thought. [28] However, they do allow for more of an indicator of a range of mental states than previously existed on a consumer level. As of this writing I am in the testing phase of selecting the correct BCI device to use for my short form opera-in-progress titled "Noor," which translates as "light" in Arabic. The opera Noor poses a question, "is there a place in the human brain where surveillance can not go?" Through the use of an "actor" and audience interaction I hope to create a mode of inquiry that an audience can comprehend concerning this critical question.

I endeavor to create a performative work with one or more human actors enacting a multi-layered story inside an immersive, 360-degree, or other type of theater. Images, sounds and spoken words will be trigged by different areas of the subject's brain, derived from multiple databases of these mediums. They will be projected onto screens using the following brain states as drivers: *Relaxation, Engagement* (attention & concentration), either *Focus* (fixed attention on one task related to flow) or *Interest* - strong enjoyment/non enjoyment, and *Stress*. I intend to show live time brain processes of the performer on the screen as part of the event. This part of my research is currently under development while I investigate technologies, techniques, story, and coding options. This paper is a step in that process.

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