Humans Computers And Everything in Between: Towards Synthetic Telepathy

by Linda Xu

When you imagine telepathy, your mind probably jumps immediately to science fiction: the Vulcans of Star Trek, Legilimency in Harry Potter, or the huge variety of superheroes and super-villains who possess powers of telekinesis or mind control. Twenty years ago, these concepts would have been mere fictional speculation, but today, in neuroscience labs around the world, new research is turning the startling possibility of brain-to-brain communication into reality.

Imagine this: a man wearing a strange polka-dot cap sits in front of a computer screen, watching an animated rocket fly from a pirate ship toward a city. In the game, the only defense against the rocket is a cannon, which can be fired by pressing a key on a keyboard in an adjacent room. As the man watches the rocket make its first flight from the ship, he thinks about moving his finger, without actually moving anything at all.

In the adjacent room, another capped man — his cap connected to the first man's through wires, a computer, and the internet — sits with his hand relaxed over the keyboard, unable to see the first man and oblivious to the impending doom of his animated city. Suddenly, his brain receives a jolt of electrical stimulation, and his finger involuntarily jerks down on the key, bringing down the rocket. Together, these two men have successfully saved the city, and more importantly, they have achieved the once unthinkable task of direct brain-to-brain communication (1).

If you haven't been keeping up with the current neuro-technology scene, the above scenario may sound like nothing more than a tale of scientific fancy. However, incredibly enough, this exact experiment was completed just a few months ago at the University of Washington and is only the latest in a long string of milestones toward "synthetic telepathy." In this article, we will touch upon each of these milestones, and most notably on the development of the brain computer interface, a key stepping stone in the path to the brain-to-brain interface. After a brief discussion of the research itself, we will then take a look at the ethics of the technology and what these advancements really mean for the rest of us.

From Synapses to Sensation

In order to fully appreciate brain interface technology, one must go back to the basics of neuroscience. The nervous system (consisting of the spinal cord and the brain) is made up of cells called neurons, which have the unique characteristic of being able to communicate with each other using electrical signals, through connections called neural synapses (2). Using this communication system, one neuron can send an electrical "message" to another neuron or even to an entire network of neurons, allowing for an immense number of possible firing patterns. This complexity is the primary reason why, to this day, the exact mechanisms by which neural firing patterns create phenomena like memory, consciousness, sensory experience, and motor action remain largely unknown.

Despite this obstacle, scientists have discovered ways to manipulate the brain without completely understanding the mechanisms behind its activity. Twentieth-century neurosurgeon Wilder Penfield was at the forefront of this advancement, earning the title as the "greatest living Canadian" for his famous neural stimulation experiments (3). During his surgeries, Penfield probed the brains of his numbed but conscious patients and observed what effect probing a certain area of the brain had on the patient. Remarkably, Penfield found that stimulation of specific areas of the brain correlated with very specific functions and areas of the body; for instance, probing the temporal lobes would cause the patient to undergo a vivid memory recall, while probing another area of the brain might cause the feeling of being rubbed on the stomach or pinched on the left foot (3).

This rudimentary "brain-poking" experiment was what eventually led scientists to the theory that thought and behavior could be predicted by measuring patterns of activity in the brain. In other words, Penfield's observations implied that someone could get an idea of what you were doing or thinking simply by taking relatively basic measurements of the changes in your brain activity. From this theory, the path was paved for the development of the first brain computer interface, a device that could connect a brain to a computer that would record and interpret its activity. Three basic steps would be required to achieve this landmark development: reliable detection of the electrical activity of the brain, accurate interpretation of the meaning of this activity, and prompt transformation of this interpreted activity into useful action.

The Dawn of the Brain Computer Interface

A solution to the first step in creating the first brain computer interface (reliable detection of the electrical activity of the brain) was already on its way by 1929, when German neurologist Hans Berger recorded the first human electroencephalogram (EEG) (4). By placing external electrodes on the scalp of a 17-year-old surgical patient, Berger was able to measure the electrical potential across the electrodes and thus detect the changing electrical activity of the neurons in the patient's brain. To this day, the EEG remains one of the most common methods of recording activity in the brain, favored over the MRI and PET scan for its cheap and relatively simple procedure. The next step, then, was to translate this recorded brain activity into meaningful information.

This step was taken in the 1970s by researchers at UCLA, funded by none other than the US Defense Advanced Research Projects Agency (DARPA), the leading national organization in military defense research. In a project rightfully named the Brain-Computer Interface project, researchers strove to develop the first interface between a brain and a computer that would not only detect brain activity but interpret it and use it for communicative or medical purposes (5). In a resulting publication from this project, researcher Jacques Vidal laid out the basics for BCI research, exploring the potential methods, limitations, and possibilities for the development of a EEG-based BCI, a device that he believed was still in the far future (5).

While laying the foundations for BCI research, Vidal could not have predicted the rapid string of breakthroughs that would follow in the next decades. Already by the late 1960s and 1970s, researchers like Eberhard Fetz were able to demonstrate that brain activity could actually be controlled to a significant extent, as demonstrated by the successful training of a monkey to deliberately increase the rate of its neural firing in specific neurons (6). In the 1980s, correlations between brain activity and motor response were specified in great detail, allowing scientists to pinpoint the exact neurons and firing patterns behind specific movements (7). In 1999, Miguel Nicolelis, who would go on to create the first animal brain-to-brain interface just fourteen years later, trained rats to control a robotic limb using only their brains (8).

By the 21st century, the media had caught up to the breakneck speed of BCI research, with the popularization of fMRI image reconstruction, touted by reporters to give scientists the ability to "pee[r] into another man's mind" (9). In these studies, subjects viewed specific images — anything from a simple black plus sign to a fully colored landscape — and their concomitant brain activity was recorded by an fMRI machine. Based solely on this recorded brain activity, scientists were able to use computer algorithms to "reconstruct" the image viewed by the subject with startling accuracy (10). Dubbed as "mind-reading" and as a possible avenue for an accurate lie detector, fMRI image reconstruction brought the incredible possibilities of BCI research into the public eye.

The Brain-to-Brain Interface: From Reading Minds to Controlling Minds

However, where things start to get truly exciting — and truly controversial — is not in brain-computer interface research, but in the pioneering field of brain-to-brain interface (BBI) research. While BCI connects a brain to a computer that then interprets brain activity, BBI connects a brain to another brain, which can then receive information from the first brain or even be induced to perform specific behaviors, as in the example of the telepathic cannon game. Arguably, BBI is not significantly different than BCI; a brain can simply be seen as a more sophisticated, organic computer, and the BBI as just the next logical extension of the BCI. Nevertheless, there is an undeniable sense of intrigue that comes with the idea of connecting living brains.

It is difficult to overstate the sheer magnitude of possibilities in this new field of research, but it is also important to not stray too far from the raw experimental findings. Research in this area began most notably in the aforementioned Nicolelis Lab at Duke University, in a study on rat brain-to-brain interface. In the 2013 study, "A Brain-to-Brain Interface for Real-Time Sharing of Sensorimotor Information," two rats were placed in separate cages and each given a choice of two levers — one that resulted in a reward of water and one that did not. A rat dubbed the "encoder" rat was shown a flash of light above the correct lever and was trained to learn this association. The "decoder" rat, on the other hand, was given no visual cues, but its brain received the stimulation from the cortical area of the "encoder" rat through the BBI. In a breakthrough finding, Nicolelis discovered that the "decoder" rat was able to make the correct choice of lever with over 70% accuracy, with no cues or information except for the learned knowledge "sent" by the neural activity of the "encoder" rat's brain (11).

Within the year, researchers at Harvard Medical School were able to connect a human brain and a rat brain through BBI and move a rat's tail with 94% accuracy, using only the deliberate neural activity of the human's brain (12). Four months later, the experiment described in the introduction was completed at the University of Washington, demonstrating the first successful use of a human brain-to-brain interface (1).

Hopes and considerations for the future

We are only in the infancy of BCI and BBI research, and as the technology continues to take leaps and bounds into the future, more and more areas of our lives will feel the impact of these advances. In particular, prosthetic limbs, prosthetic vision devices, prosthetic hearing devices, and communication devices for paralytics are all currently being implemented as prototypes, such as the robotic arm created at Brown University in 2012, which allowed a woman who had been paralyzed for nearly 15 years to use a robotic arm to drink a bottle of coffee (13). Outside of the medical field, research in military communication technology has continued to progress, as demonstrated in the research of Gerwin Schalk, who recently published a study on the successful identification of spoken and imagined words using EEG (14).

Although advances in games and entertainment may seem trivial compared to the more "practical" developments of medicine and technology, the impact of brain interface technology in everyday life is certainly worth pondering as well. Imagine, for instance, being able to play virtual video games in which you control your character simply by thinking an action or imagining a scenario. Companies like NeuroSky, Mindflex, and Necomimi are already putting out BCI products for the public, including a game that uses "brain force" to navigate a ball through a maze and a pair of costume cat ears that wiggle, perk up, or lay flat depending on your neural activity. As research continues, devices such as these are sure to be welcomed into the entertainment world and could even be used for educational or therapeutic purposes, for adults and children alike.

Undoubtedly, brain interface technology has both the power and the potential to do incredible good. With this in mind, it is crucial to also recognize the possibility for ethical wrongdoing. Concerns with privacy, autonomy, enhancement, and consequent aggravation of social stratification are only a handful of the ethical issues on the horizon, and these concerns are only intensified by the fear of media exaggeration and inaccuracy. Furthermore, philosophical questions of human existence will become increasingly important as research progresses. What does it mean for brains to be "connected?" What kind of information can be taken and shared between living brains? What distinguishes a human from a machine, and what — if anything — distinguishes a brain from a computer? These questions may have been impossible to answer in the past, but with the advancement of brain-to-brain interface technology, we may reach satisfying answers at last.

In the end, the future of a world with brain interface technology relies on the preparation and research done today. Consideration of the ethical issues to come, as well as thorough discussion of the boundaries that must be set, will help to ensure that ethical lines are not crossed in our enthusiasm to push the limits of technology. From medicine and military technology to games and recreation, brain interfacing truly has the potential to change the world. By maintaining a judicious balance between scientific progress and ethical caution, we can ensure that these changes are for the better.

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