Excerpt from 'THE FUTURE OF THE MIND'

Houdini believed that telepathy was impossible. But science is proving Houdini wrong. Telepathy is now the subject of intense research at universities around the world, where scientists have already been able to use advanced sensors to read individual words, images, and thoughts in a person's brain. This could alter the way we communicate with stroke and accident victims who are "locked in" their bodies, unable to articulate their thoughts except through blinks. But that's just the start. Telepathy might also radically change the way we interact with computers and the outside world.

Indeed, in a recent "Next 5 in 5 Forecast," which predicts five revolutionary developments in the next five years, IBM scientists claimed that we will be able to mentally communicate with computers, perhaps replacing the mouse and voice commands. This means using the power of the mind to call people on the phone, pay credit card bills, drive cars, make appointments, create beautiful symphonies and works of art, etc. The possibilities are endless, and it seems that everyone— from computer giants, educators, video game companies, and music studios to the Pentagon— is converging on this technology.

True telepathy, found in science-fiction and fantasy novels, is not possible without outside assistance. As we know, the brain is electrical. In general, anytime an electron is accelerated, it gives off electromagnetic radiation. The same holds true for electrons oscillating inside the brain, which broadcasts radio waves. But these signals are too faint to be detected by others, and even if we could perceive these radio waves, it would be difficult to make sense of them. Evolution has not given us the ability to decipher this collection of random radio signals, but computers can. Scientists have been able to get crude approximations of a person's thoughts using EEG scans. Subjects would put on a helmet with EEG sensors and concentrate on certain pictures— say, the image of a car. The EEG signals were then recorded for each image and eventually a rudimentary dictionary of thought was created, with a one- to-one correspondence between a person's thoughts and the EEG image. Then, when a person was shown a picture of another car, the computer would recognize the EEG pattern as being from a car.

The advantage of EEG sensors is that they are noninvasive and quick. You simply put a helmet containing many electrodes onto the surface of the brain and the EEG can rapidly identify signals that change every millisecond. But the problem with EEG sensors, as we have seen, is that electromagnetic waves deteriorate as they pass through the skull, and it is difficult to locate their precise source. This method can tell if you are thinking of a car or a house, but it cannot re- create an image of the car.

That is where Dr. Jack Gallant's work comes in…

VIDEOS OF THE MIND

The epicenter for much of this research is the University of California at Berkeley, where I received my own Ph.D. in theoretical physics years ago. I had the pleasure of touring the laboratory of Dr. Gallant, whose group has accomplished a feat once considered to be impossible: videotaping people's thoughts. "This is a major leap forward reconstructing internal imagery. We are opening a window into the movies in our mind," says Gallant.

When I visited his laboratory, the first thing I noticed was the team of young, eager postdoctoral and graduate students huddled in front of their computer screens, looking intently at video images that were reconstructed from someone's brain scan. Talking to Gallant's team, you feel as though you are witnessing scientific history in the making.

Gallant explained to me that first the subject lies flat on a stretcher, which is slowly inserted headfirst into a huge, state- of- the- art MRI machine, costing upward of $3 million. The subject is then shown several movie clips (such as movie trailers readily available on YouTube). To accumulate enough data, the subject has to sit motionless for hours watching these clips, a truly arduous task. I asked one of the postdocs, Dr. Shinji Nishimoto, how they found volunteers who were willing to lie still for hours on end with only fragments of video footage to occupy the time. He said the people in the room, the grad students and postdocs, volunteered to be guinea pigs for their own research.

As the subject watches the movies, the MRI machine creates a 3-D image of the blood flow within the brain. The MRI image looks like a vast collection of thirty thousand dots, or voxels. Each voxel represents a pinpoint of neural energy, and the color of the dot corresponds to the intensity of the signal and blood flow. Red dots represent points of large neural activity, while blue dots represent points of less activity. (The final image looks very much like thousands of Christmas lights in the shape of the brain. Immediately you can see that the brain is concentrating most of its mental energy in the visual cortex, which is located at the back of the brain, while watching these videos.)

Gallant's MRI machine is so powerful it can identify two to three hundred distinct regions of the brain and, on average, can take snapshots that have one hundred dots per region of the brain. (One goal for future generations of MRI technology is to provide an even sharper resolution by increasing the number of dots per region of the brain.)

At first, this 3-D collection of colored dots looks like gibberish. But after years of research, Dr. Gallant and his colleagues have developed a mathematical formula that begins to find relationships between certain features of a picture (edges, textures, intensity, etc.) and the MRI voxels. For example, if you look at a boundary, you'll notice it's a region separating lighter and darker areas, and hence the edge generates a certain pattern of voxels. By having subject after subject view such a large library of movie clips, this mathematical formula is refined, allowing the computer to analyze how all sorts of images are converted into MRI voxels. Eventually the scientists were able to ascertain a direct correlation between certain MRI patterns of voxels and features within each picture.

At this point, the subject is then shown another movie trailer. The computer analyzes the voxels generated during this viewing and re- creates a rough approximation of the original image. (The computer selects images from one hundred movie clips that most closely resemble the one that the subject just saw and then merges images to create a close approximation.) In this way, the computer is able to create a fuzzy video of the visual imagery going through your mind. Dr. Gallant's mathematical formula is so versatile that it can take a collection of MRI voxels and convert it into a picture, or it can do the reverse, taking a picture and then converting it to MRI voxels.

I had a chance to view the video created by Dr. Gallant's group, and it was very impressive. Watching it was like viewing a movie with faces, animals, street scenes, and buildings through dark glasses. Although you could not see the details within each face or animal, you could clearly identify the kind of object you were seeing.

Not only can this program decode what you are looking at, it can also decode imaginary images circulating in your head. Let's say you are asked to think of the Mona Lisa. We know from MRI scans that even though you're not viewing the painting with your eyes, the visual cortex of your brain will light up. Dr. Gallant's program then scans your brain while you are thinking of the Mona Lisa and flips through its data files of pictures, trying to find the closest match. In one experiment I saw, the computer selected a picture of the actress Salma Hayek as the closest approximation to the Mona Lisa. Of course, the average person can easily recognize hundreds of faces, but the fact that the computer analyzed an image within a person's brain and then picked out this picture from millions of random pictures at its disposal is still impressive.

The goal of this whole process is to create an accurate dictionary that allows you to rapidly match an object in the real world with the MRI pattern in your brain. In general, a detailed match is very difficult and will take years, but some categories are actually easy to read just by flipping through some photographs. Dr. Stanislas Dehaene of the Collège de France in Paris was examining MRI scans of the parietal lobe, where numbers are recognized, when one of his postdocs casually mentioned that just by quickly scanning the MRI pattern, he could tell what number the subject was looking at. In fact, certain numbers created distinctive patterns on the MRI scan. He notes, “If you take 200 voxels in this area, and look at which of them are active and which are inactive, you can construct a machine-learning device that decodes which number is being held in memory.”

This leaves open the question of when we might be able to have picture quality videos of our thoughts. Unfortunately, information is lost when a person is visualizing an image. Brain scans corroborate this. When you compare the MRI scan of the brain as it is looking at a flower to an MRI scan as the brain is thinking about a flower, you immediately see that the second image has far fewer dots than the first.

So although this technology will vastly improve in the coming years, it will never be perfect. (I once read a short story in which a man meets a genie who offers to create anything that the person can imagine. The man immediately asks for a luxury car, a jet plane, and a million dollars. At first, the man is ecstatic. But when he looks at these items in detail, he sees that the car and the plane have no engines, and the image on the cash is all blurred. Everything is useless. This is because our memories are only approximations of the real thing.) But given the rapidity with which scientists are beginning to decode the MRI patterns in the brain, will we soon be able to actually read words and thoughts circulating in the mind?

READING THE MIND

In fact, in a building next to Gallant’s laboratory, Dr. Brian Pasley and his colleagues are literally reading thoughts— at least in principle. One of the postdocs there, Dr. Sara Szczepanski, explained to me how they are able to identify words inside the mind.

The scientists used what is called ECOG (electrocorticogram) technology, which is a vast improvement over the jumble of signals that EEG scans produce. ECOG scans are unprecedented in accuracy and resolution, since signals are directly recorded from the brain and do not pass through the skull. The flipside is that one has to remove a portion of the skull to place a mesh, containing sixty-four electrodes in an eight-by-eight grid, directly on top of the exposed brain.

Luckily they were able to get permission to conduct experiments with ECOG scans on epileptic patients, who were suffering from debilitating seizures. The ECOG mesh was placed on the patients’ brains while open- brain surgery was being performed by doctors at the nearby University of California at San Francisco.

As the patients hear various words, signals from their brains pass through the electrodes and are then recorded. Eventually a dictionary is formed, matching the word with the signals emanating from the electrodes in the brain. Later, when a word is uttered, one can see the same electrical pattern. This correspondence also means that if one is thinking of a certain word, the computer can pick up the characteristic signals and identify it. With this technology, it might be possible to have a conversation that takes place entirely telepathically. Also, stroke victims who are totally paralyzed may be able to "talk" through a voice synthesizer that recognizes the brain patterns of individual words.

Not surprisingly, BMI (brain-machine interface) has become a hot field, with groups around the country making significant breakthroughs. Similar results were obtained by scientists at the University of Utah in 2011. They placed grids, each containing sixteen electrodes, over the facial motor cortex (which controls movements of the mouth, lips, tongue, and face) and Wernicke's area, which processes information about language. The person was then asked to say ten common words, such as "yes" and "no," "hot" and "cold," "hungry" and "thirsty," "hello" and "good-bye," and "more" and "less." Using a computer to record the brain signals when these words were uttered, the scientists were able to create a rough one- to- one correspondence between spoken words and computer signals from the brain.

Later, when the patient voiced certain words, they were able to correctly identify each one with an accuracy ranging from 76 percent to 90 percent. The next step is to use grids with 121 electrodes to get better resolution. In the future, this procedure may prove useful for individuals suffering from strokes or paralyzing illnesses such as Lou Gehrig's disease, who would be able to speak using the brain-to-computer technique.

TYPING WITH THE MIND

At the Mayo Clinic in Minnesota, Dr. Jerry Shih has hooked up epileptic patients via ECOG sensors so they can learn how to type with the mind. The calibration of this device is simple. The patient is first shown a series of letters and is told to focus mentally on each symbol. A computer records the signals emanating from the brain as it scans each letter. As with the other experiments, once this one- to- one dictionary is created, it is then a simple matter for the person to merely think of the letter and for the letter to be typed on a screen, using only the power of the mind.

Dr. Shih, the leader of this project, says that the accuracy of his machine is nearly 100 percent. Dr. Shih believes that he can next create a machine to record images, not just words, that patients conceive in their minds. This could have applications for artists and architects, but the big drawback of ECOG technology, as we have mentioned, is that it requires opening up patients' brains.

Meanwhile, EEG typewriters, because they are noninvasive, are entering the marketplace. They are not as accurate or precise as ECOG typewriters, but they have the advantage that they can be sold over the counter. Guger Technologies, based in

Austria, recently demonstrated an EEG typewriter at a trade show. According to their officials, it takes only ten minutes or so for people to learn how to use this machine, and they can then type at the rate of five to ten words per minute.