BY DAVID KING

NEUROTECHNOLOGY IS READY FOR ITS CLOSE-UP (almost)

Let's go back, for a moment, to 2014. If you happened to be one of the millions of viewers who tuned in that year to the World Cup, then you might remember this unusual sight: Juliano Pinto, a paraplegic man only 29 years old, making the symbolic first kick of the competition, despite having complete paralysis in the lower half of his body. He accomplished this, for those of you who missed the game, with the use of a highly advanced robotic exoskeleton. The kick itself was gentle and his movements were slow, but what makes the technology so advanced was how he controlled it—with his mind. The exoskeleton was capable of reading the impulses in his mind, and interpreting the commands within them. This may seem like science fiction, but the technology, in a rudimentary form, has become fairly common in certain circles.

So called "Neurotechnology," and its area of study, "Neuroscience," have become a hot topic in tech circles recently. Thanks to Silicon Valley bigwigs like Elon Musk and Mark Zuckerberg expressing interest, but it's still relatively unknown among most Americans. These brain-computer interfaces, (BCIs) as the technology is known, are more common than you think. Last year, another paraplegic man, Rodrigo Hübner Mendes, became the first person to drive a race car solely with his mind. Even more noteworthy about the stunt, the device he employed to control the race car—a portable and wireless wearable headset monitoring brainwaves. This is available online for roughly the same cost as an X-box, according to representatives for its manufacturer, Emotiv, a San Francisco based company. Although most commonly associated with efforts to improve the mobility and independence of those suffering from mental-health disorders, such as dementia and Alzheimer's disease, or physical disabilities like Pinto's, the technology has already found many other applications.

The headset Mendes used, for example, has become popular with gamers who use it to move their avatars in virtual worlds

with their mind, freeing their hands to shoot monsters or whatever else their game requires. Others use the headset to monitor their sleep or to meditate. The automobile industry is using it to monitor the level of attention of drivers and have cars stop automatically or sound an alarm when the drivers start falling asleep. That function has been adapted to other workplaces where attention to information is a life-and-death matter, everything from airline traffic controllers to nuclear plant operators. In 2014, President Obama only half-jokingly announced that the U.S. government was building Iron Man, in the form of a "smart armor" known as TALOS. Soldiers of the very near future will be equipped with brain-computer interfaces allowing them to simultaneously control armor-like exoskeletons and rely on powerful databases, enabling them to be stronger, faster, and more resistant while making optimal decisions.

Needless to say, with all this investment and innovation going on, the money has started to roll in. For devices alone, Neurotech Report projected a $7.6 billion market in 2016, and that could reach $12 billion by 2020. And, the hardware market is just the tip of the iceberg, as illustrated by an analysis of more than 10,000 IP filings worldwide by market research firm SharpBrains. The overall financial impact of such neurotechnologies is tremendous. Optimistic projections suggest that, if you include the medical uses of neurotech, other devices, and all the businesses that can benefit from brain-related technologies, this is a field that's generating well over $150 billion in revenues annually. But, for all the progress and hype, the looming question remains of where, exactly, the sector goes from here.

For techies and investors attention obviously turns to the bigwigs. Zuckerberg said in 2015 that he believes one-day people will share "full sensory and emotional experiences" online the way they now share photos, but Facebook has been cagey about its

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neuroscience plans, with some sources suggesting a much more modest goal of thought-to-text typing. Musk, the CEO of Tesla, announced a new company to handle his neuroscience goals. Neuralink will be dedicated to developing even more powerful brain-machine interfaces. This new breed of neurotechnology will allow the merging of the human brain with the power of machines empowering humans to keep up with artificial intelligence, by increasing their information processing and creativity. They have a way to go before meeting that ambitious goal.

This leads into one of the main problems facing the neurotech field, despite all the progress and investment in recent years the field remains fundamentally cutoff from the masses, most of its technology is still bulky, expensive, and unusable for the general public. The Emotiv headset is a step in the right direction, but the most ambitious neurotech still requires implants that can interact directly with neurons. And, existing devices have lots of drawbacks. They involve wires that pass through the skull; they provoke immune responses; they communicate with only a few hundred of the 85bn neurons in the human brain. Furthermore, the brain itself is still a foreign country. Scientists have little specifics about how it works, especially when it comes to complex functions like memory formation. Research is more advanced in animals, but experiments on humans are hard to come by.

All of which comes down to the single biggest obstacle the industry has to overcome, old-fashioned commercialization. It takes time, money and expertise to get medical devices approved, but beyond that consumer applications will only take off if they perform a function people find useful enough to justify the lifestyle adjustments. And, more so than any other field, neurotech would require a lot of adjustments. Assuming that scientists manage to develop wireless implants that still leaves the issue of the surgery required to imbed them. Assuming a cheap and efficient solution to that is found that still leaves the most pressing question—how many people would actually want a computer chip implanted in their skull? The safety issues concerning possible hackers, not to mention a sense of being plugged into the Matrix, would be more than enough to scare away scores of potential customers. And, on top of that there is the privacy issue, what happens to the refuge of the inner voice? Inequality is another issue, access to superhuman cognitive abilities would almost certainly be so expensive as to be beyond the means of all except those on the high rungs of the income ladder. The result would be a self-perpetuating elite wielding superior strength and intellect, powered by their neurotech implants—the arguments that justified Social Darwinism a century ago suddenly made real.

Fortunately, there is still plenty of time to find answers to those problems. Right now the neuroscience boom is at an unusual stage, it has no shortage of pie in the sky ideas, everything from devices to aid in hearing high frequencies to telepathic communication, and produced important technological developments. Yet it remains in its own bubble, still waiting for the invention that will be accessible enough to capture the public's imagination. With the amount of interest it has managed to attract recently though, it is safe to say that won't be a problem for long. Ready or not, a neuroscience revolution is just around the corner.