5 Neuroscience Experts Weigh in on Elon Musk's Mysterious "Neural Lace" Company

By Eliza Strickland (/author/strickland-eliza)
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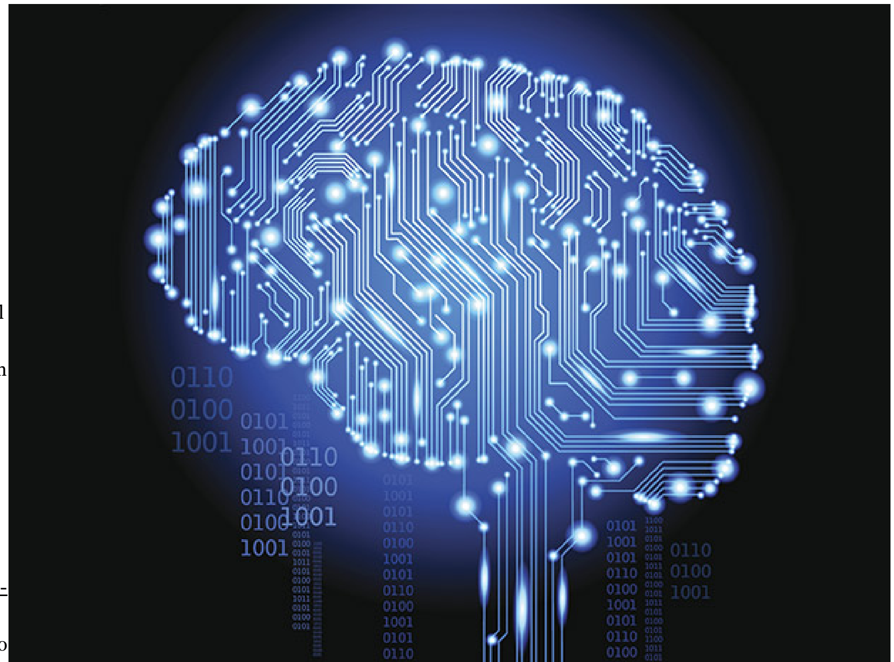


Image: iStockphoto

Elon Musk has a reputation as the world's greatest doer. He can propose crazy ambitious technological projects—like reusable rockets for Mars exploration and hyperloop tunnels for transcontinental rapid transit—and people just assume he'll pull it off.

So his latest venture, a new company called Neuralink that will reportedly build brain implants both for medical use and to give healthy people superpowers, has gotten the public excited about a coming era of consumer-friendly neurotech.

Even neuroscientists who work in the field, who know full well how difficult it is to build working brain gear that passes muster with medical regulators, feel a sense of potential. "Elon Musk is a person who's going to take risks and inject a lot of money, so it will be exciting to see what he gets up to," says Thomas Oxley, a neural engineer who has been developing a medical brain implant since 2010 (he hopes to start its first clinical trial in 2018).

Neuralink is still mysterious. An article in *The Wall Street Journal* (https://www.wsj.com/articles/elon-musk-launches-neuralink-to-connect-brains-with-computers-1490642652) announced the company's formation and first hires, while also spouting vague verbiage about "cranial computers" that would serve as "a layer of artificial intelligence inside the brain."

So *IEEE Spectrum* asked the experts about what's feasible in this field, and what Musk might be planning. First, though, a little background.

Musk did give a few seemingly concrete details at a conference last year (https://www.youtube.com/watch?list=PLKof9YSAshgyPqlK-UUYrHfIQaOzFPSL4&v=ZrGPuUQsDjo) (video excerpt below). His neural lace would serve as a "digital layer above the cortex," he said. Its components wouldn't necessarily require brain surgery for implantation; instead, the hardware could be injected into the jugular and travel to the brain through the bloodstream.

Neural implants are already a medical reality: Some 150,000 people with Parkinson's disease have had brain surgery to receive deep-brain stimulators, implants that send regular pulses of electricity through patches of brain tissue to control patients' tremors. Researchers are now experimenting with these pacemaker-like devices to treat depression and other neuropsychiatric diseases. Some epilepsy patients also have a new type of implant (http://spectrum.ieee.org/biomedical/bionics/life-as-a-bionic-woman) that monitors their brains for signs of impending seizures and sends out stimulating pulses to head them off.

Musk's neural lace would presumably be designed to treat some disease first; otherwise, it's hard to imagine the technology gaining regulatory approval. But his descriptions don't make it sound like existing brain stimulators, but rather like experimental brain-computer interfaces (BCI) that record brain signals and use the information to control external devices like computer cursors (http://spectrum.ieee.org/the-human-os/biomedical/bionics/new-record-for-typing-by-brain-paralyzed-man-uses-brain-implant-to-type-8-words-per-minute) and robotic arms (http://spectrum.ieee.org/biomedical/bionics/a-better-way-for-brains-to-control-robotic-arms). These BCI implants have shown great promise in giving more autonomy to people with paralysis, but none have yet been approved for clinical use.

Now, to the experts!

Mary Lou Jepsen is a Silicon Valley bigwig who recently founded the startup Openwater (http://www.opnwatr.io/) to develop a noninvasive BCI for imaging and telepathy (http://spectrum.ieee.org/the-human-os/biomedical/imaging/why-mary-lou-jepsen-left-facebook-to-transform-heath-care-and-invent-consumer-telepathy) (the latter could conceivably be done by reading out thought patterns in the brain). Like Musk, she's interested in both medical applications and augmenting people's natural abilities. But she says any invasive neural technology brings medical hurdles, even if it doesn't require splitting open patients' skulls.

"The approach as I understand it (not much is published) involves implanting silicon particles (so called "neural lace") into the bloodstream. One concern is that implanting anything in the body can cause unintended consequences," says Jepsen. "For example, even red blood cells can clog capillaries in the brain when the red blood cells are made more stiff by diseases like malaria. This clogging can reduce or even cut off the flow of oxygen to the parts of the brain. Indeed, clogging of cerebral capillaries has been shown to be a major cause of Alzheimer's progression. Back to neural lace: One concern I would have is whether the silicon particles could lead to any clogging."

Jepsen notes that the *Wall Street Journal* article (https://www.wsj.com/articles/elon-musk-launches-neuralink-to-connect-brains-with-computers-1490642652) lists a few neuroscientists who have reportedly been hired on for Neuralink, but says that's just the first step in a long process. "It's exciting, but embryonic," she says.

Thomas Oxley is a practicing neurologist (https://www.doximity.com/pub/thomas-oxley-md) and the inventor of the "stentrode," a neural probe that can be delivered to the brain through blood vessels (http://spectrum.ieee.org/tech-talk/biomedical/bionics/stent-electrode-reads-brain-signals-from-inside-a-vein)—so he has plenty of thoughts about the technology Musk might be developing. He's CEO of Synchron (http://www.synchronmed.com/#introducing), the company that's developing the technology and planning its first clinical trial for 2018 in Australia.

Oxley came up with his stentrode as an alternative to typical electrodes that are placed directly in the brain tissue. Those standard electrodes enable high-fidelity recording from individual neurons, but the stiff silicon and metal structures cause inflammation in the brain tissue, and scar tissue often forms around them over time. "The idea of moving up the blood vessel is that you avoid any direct penetration of the brain tissue," Oxley says, and thus avoid damaging it. In Oxley's system, a catheter is snaked up a vein to deliver the stentrode to one of the tiny blood vessels that nourishes the neurons. From there, they can't record neurons' activity directly, but Oxley says the "different type of signal" can be deciphered with the right kind of signal processing.

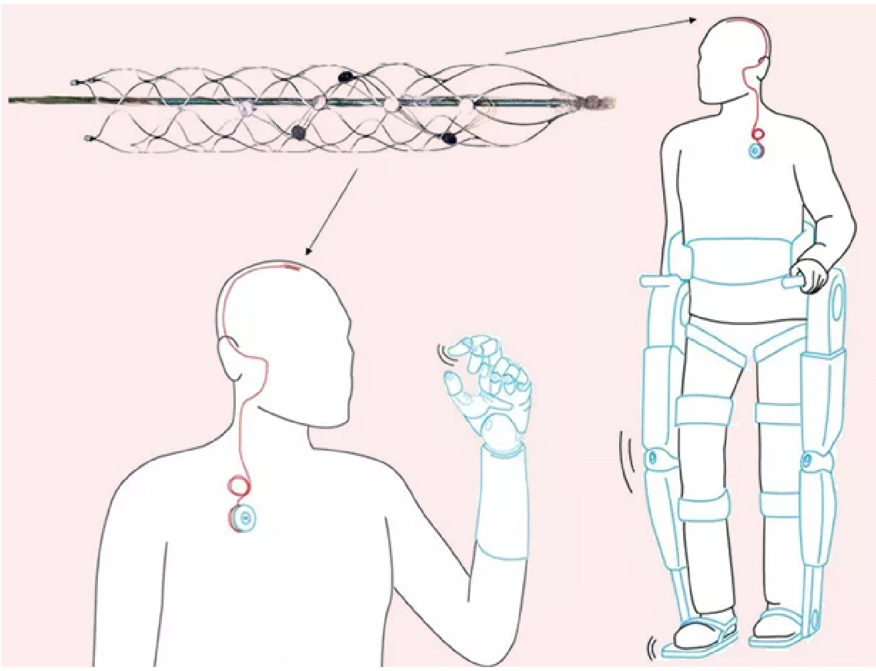


Illustration: University of Melbourne

If Musk is working on a similar delivery system for his neural lace, Oxley says, we shouldn't expect results anytime soon. "The medical device pathway takes a long time, and we had to conduct a lot of science to get to the point where we are now," he says. For the past two years, his research group has been working in sheep to develop a catheter delivery system that reliably positions an operational recording system in the motor cortex region of the brain.

Synchron's upcoming clinical trial (http://www.fiercebiotech.com/financials/synchron-bags-10m-series-a-for-brain-machine-interface-implant) will test the stentrode as a BCI for people with paralyzed or missing limbs, who will use the recorded neural signals to control exoskeletons and robotic prosthetics. Oxley says there's a big potential market for such devices, including people who have suffered strokes, spinal cord injuries, ALS, muscular dystrophy, and amputations. He notes that a McKinsey Global Institute report from 2013 (http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/disruptive-technologies) estimated that 50 million people in advanced economies could benefit from such "robotic human augmentation." So if Musk's Neuralink is following a similar technological path to Synchron, he'll be able to make a sound business case.

As for clotting concerns, Oxley says neurologists routinely use permanent stents in patient's brains to keep blood vessels open. They act like scaffolds that push against the walls of the blood vessel. "We understand how to manage patients with medication to ensure those stents don't close over," he says.

Charles Lieber and **Guosong Hong** offer another possibility for delicately inserting a BCI into the brain. Lieber, a Harvard professor of chemistry and engineering (https://cml.harvard.edu/people/charles-m-lieber), and Hong, one of his postdocs, are developing an "electronic mesh" that is injected by syringe into the brain tissue, where it unfurls to make contact with many neurons.

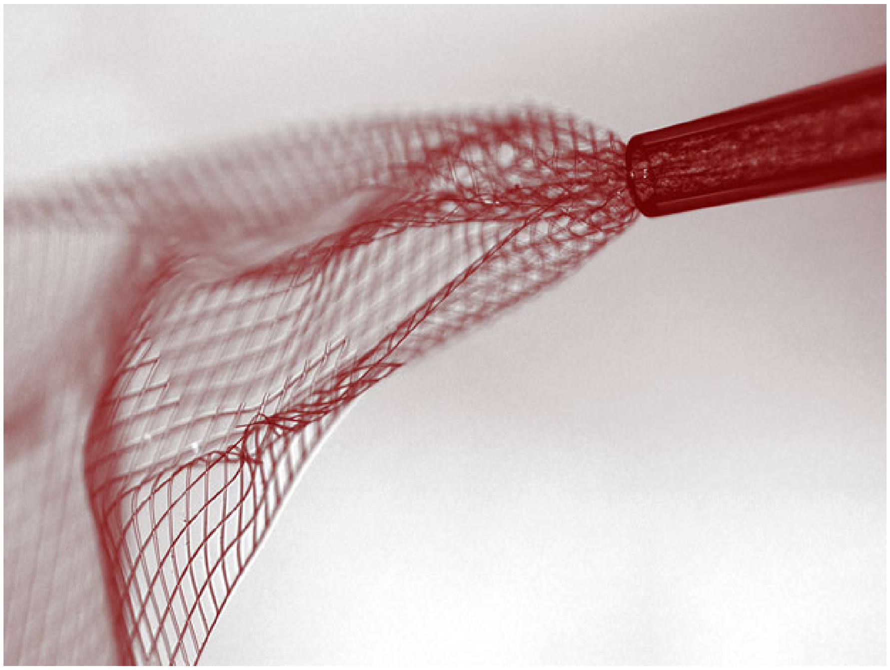
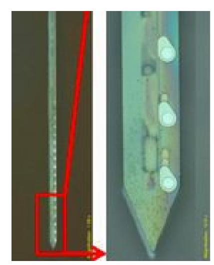


Image: Lieber Research Group

“The mesh electronics can be precisely targeted to any brain region by syringe injection and forms a seamless and stable interface with neural tissue—because it behaves very much like the brain tissue we seek to study,” Lieber says. “Mesh electronics cause negligible damage or chronic immune response.” His group has shown that the mesh is stable in the brain and can record from individual neurons over many months (http://spectrum.ieee.org/the-human-os/biomedical/devices/injectable-nanowires-monitor-mouse-brains-for-months).

Hong adds that the mesh electronics can both record from and stimulate neurons, opening up a variety of medical applications. “It will provide transformative capabilities for treatment of neurological and neurodegenerative diseases such as Parkinson’s and Alzheimer’s diseases via deep-brain stimulation,” he says, “as well as providing next-generation brain computer interfaces.”

Although Musk made reference to the neural lace acting as a “digital layer above the cortex,” these researchers don’t think it’s likely that Musk’s technology will resemble their unfurling electronic mesh. Hong notes that the three neuroscientists mentioned as Neuralink’s first hires work on very different kinds of brain implants.



(https://neurotech.l tolosa)

Image: Lawrence Livermore National Lab

Vanessa Tolosa (https://neurotech.llnl.gov/people/vanessa-tolosa) of Lawrence Livermore National Lab has been working on flexible polymer (http://ieeexplore.ieee.org/document/6945197/) probes (http://ieeexplore.ieee.org/document/6945197/) that look like little dipsticks; Philip Sabes (http://profiles.ucsf.edu/philip.sabes) of University of California, San Francisco has experimented with a “micro-ECoG” array (http://www.cell.com/neuron/abstract/S0896-6273(16)00014-3?_returnURL=http%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS0896627316000143%3Fshowall%3Dtrue) that drapes over the outer surface of the brain; and Timothy Gardner (https://www.bu.edu/biology/people/profiles/tim-gardner/) of Boston University works on carbon fiber electrodes (http://people.bu.edu/timothyg/resources/lab-publications/Guitchounts2013_JNE.pdf) that look like bundles of threads.

While Musk’s description of a neural lace “layer” makes Sabes’s superficial array sound like the winning contender, such a device couldn’t be injected through the jugular and travel through blood vessels to reach the upper surface of the brain. It’s possible that we shouldn’t take his works literally—Musk may have been speaking metaphorically about technology that would add a new layer of intelligence to the human brain.

Michel Maharbiz, an electrical engineering professor at UC Berkeley (https://www2.eecs.berkeley.edu/Faculty/Homepages/maharbiz.html), is working on tiny electrodes called “neural dust.” These sound like something that Musk would take an interest in; the idea is that tiny wireless electrodes could be scattered through the nervous system, acting together to record signals.

(http://ieeexplore.i

Image: UCSF

The team’s current version of this tech is a device that measures 2.4 cubic millimeters, and they’re working to scale it down much further—first to 1 mm^3, and eventually down to 50 cubic microns. Recently, Maharbiz and his colleagues demonstrated that their current mote of neural dust could record from a nerve (http://spectrum.ieee.org/biomedical/devices/4-steps-to-turn-neural-dust-into-a-medical-reality) while wirelessly receiving power and sending out data.

While Maharbiz couldn’t say whether neural lace and neural dust might have some similarities, he knows that scaling down his own tech to make it small enough to work in the brain is a big challenge. “The obstacles are a combination of circuit design, materials, communication schemes, and power,” he says, noting that his team’s work on miniaturization is “a difficult, multi-year endeavor which will happen in phases.”

To make a BCI work inside the brain's tiny blood vessels, Maharbiz says, it would have to either place electrodes measuring about 100 microns inside the vessels, or use long microwires that connect to a larger piece of electronics sited elsewhere in the vascular system.

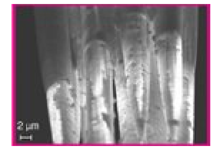


Image: Boston University

Musk's Neuralink team clearly has plenty of technical challenges ahead in miniaturizing a device, enabling its safe delivery and positioning in the brain, and figuring out how to use it to treat a serious medical disorder. Once Musk figures all that out—and he will, of course, because he's a doer—he can move on to neurotech for the general public. Then we can all get BCIs that channel our thoughts and commands directly to our smartphones and computers, increasing our efficiency and opening up brave new worlds.

Oxley, the stentrode inventor, doesn't expect to see miracles from the Neuralink team anytime soon. But he's excited anyway, saying that Musk's willingness to tackle the big technical challenges of neural engineering shows the maturity of the field. "It's a huge validating moment," he says. "The field of brain-computer interfaces is now taking center stage in Silicon Valley, and being recognized as one of the next great endeavors."

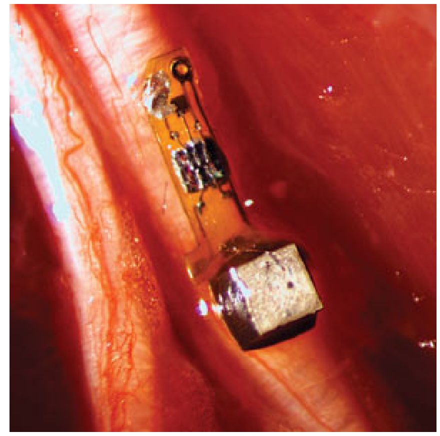


Photo: Ryan Neely