'Super-vision' contact lenses let wearers see in the dark — even with their eyes closed

published May 22, 2025

Researchers have developed new contact lenses that enable vision in the near-infrared range, and they could restore color perception to people with color blindness.

A study participant places one of the night vision lenses in their eye. (Image credit: Yuqian Ma, Yunuo Chen, Hang Zhao)

Scientists have created night-vision contact lenses that they claim can grant people "super-vision."

The lenses — which use nanoparticles to absorb low-frequency light before emitting it in the visible spectrum — enable wearers to see infrared wavelengths that are otherwise invisible to the human eye.

And unlike traditional night-vision goggles, these lenses don't require a power source. The researchers described the new lenses May 22 in the journal Cell Press.

"Our research opens up the potential for non-invasive wearable devices to give people super-vision," senior author Tian Xue, a neuroscientist at the University of Science and Technology of China, said in a statement. "There are many potential applications right away for this material. For example, flickering infrared light could be used to transmit information in security, rescue, encryption or anti-counterfeiting settings."
First used in night combat during World War II, traditional night-vision goggles use an electronic image-intensifier tube to turn visible light or near-infrared photons into electrons. These electrons are then channeled onto a luminescent screen, causing it to glow green.

But these goggles typically need an energy source, which makes them bulky. Infrared goggles are also unable to precisely distinguish light across the infrared range, especially those at longer wavelengths.

To create the new lenses, the scientists embedded nanoparticles inside flexible, nontoxic polymers typically used in soft contact lenses. The nanoparticles — which consist of sodium gadolinium fluoride embedded with luminescent ytterbium, erbium and gold — absorb near-infrared photons in the 800- to 1,600-nanometer wavelength range before emitting them as visible light, wavelengths from around 380 to 750 nanometers

The researchers first tested their new lenses in mice. Mice sporting the new lenses favored dark boxes over those illuminated by infrared light, while those without the lenses showed no preference. (Mice are crepuscular animals that usually stick to dark environments to evade predators.) Additionally, the pupils of lens-wearing mice constricted in the presence of infrared light sources, with brain scans showing that their visual processing centers were firing.

Next, the team tried the lenses in humans. The people could perceive flickering infrared light and pick up on its direction. This infrared vision was enhanced when the participants closed their eyes, the researchers said.

"It's totally clear cut: without the contact lenses, the subject cannot see anything, but when they put them on, they can clearly see the flickering of the infrared light," Xue said. "We also found that when the subject closes their eyes, they're even better able to receive this flickering information, because near-infrared light penetrates the eyelid more effectively than visible light, so there is less interference from visible light."

The scientists replaced the nanoparticles embedded in the lenses with modified versions that mapped specific parts of the near-infrared spectrum to blue, green and red. The researchers suggested that this tweak could be used to aid people with color blindness.

"By converting red visible light into something like green visible light, this technology could make the invisible visible for color blind people," Xue said.

Despite these promising advances, more work is needed before the lenses see the light of day. Currently, they only pick up light projected from LED sources, which are incredibly bright, so the scientists will need to boost the lenses' sensitivity to pick up light of lower intensities.

The lenses' proximity to the retinas also may prevent them from detecting finer details, so the researchers have developed a wearable glass system for viewing objects at higher resolutions.

New cells discovered in eye could help restore vision, scientists say

published March 27, 2025

A new study suggests that never-seen-before stem cells in the human retina can restore vision in mice with a common eye disorder. But more work is needed to translate the treatment to people.

The findings of a new study may provide hope for patients with common eye diseases. (Image credit: abbestock via Getty Images)

Scientists have identified never-before-seen cells in the human eye that could potentially help reverse vision loss caused by common diseases, such as macular degeneration.
The researchers discovered the cells in the retina, a light-sensitive structure at the back of the eye that is vital for vision. The cells were found in donated samples of fetal tissue.

The scientists also identified the same cells in lab-grown models of the human retina — and when they tried transplanting those models into mice with a common eye disorder, it restored the rodents' vision.

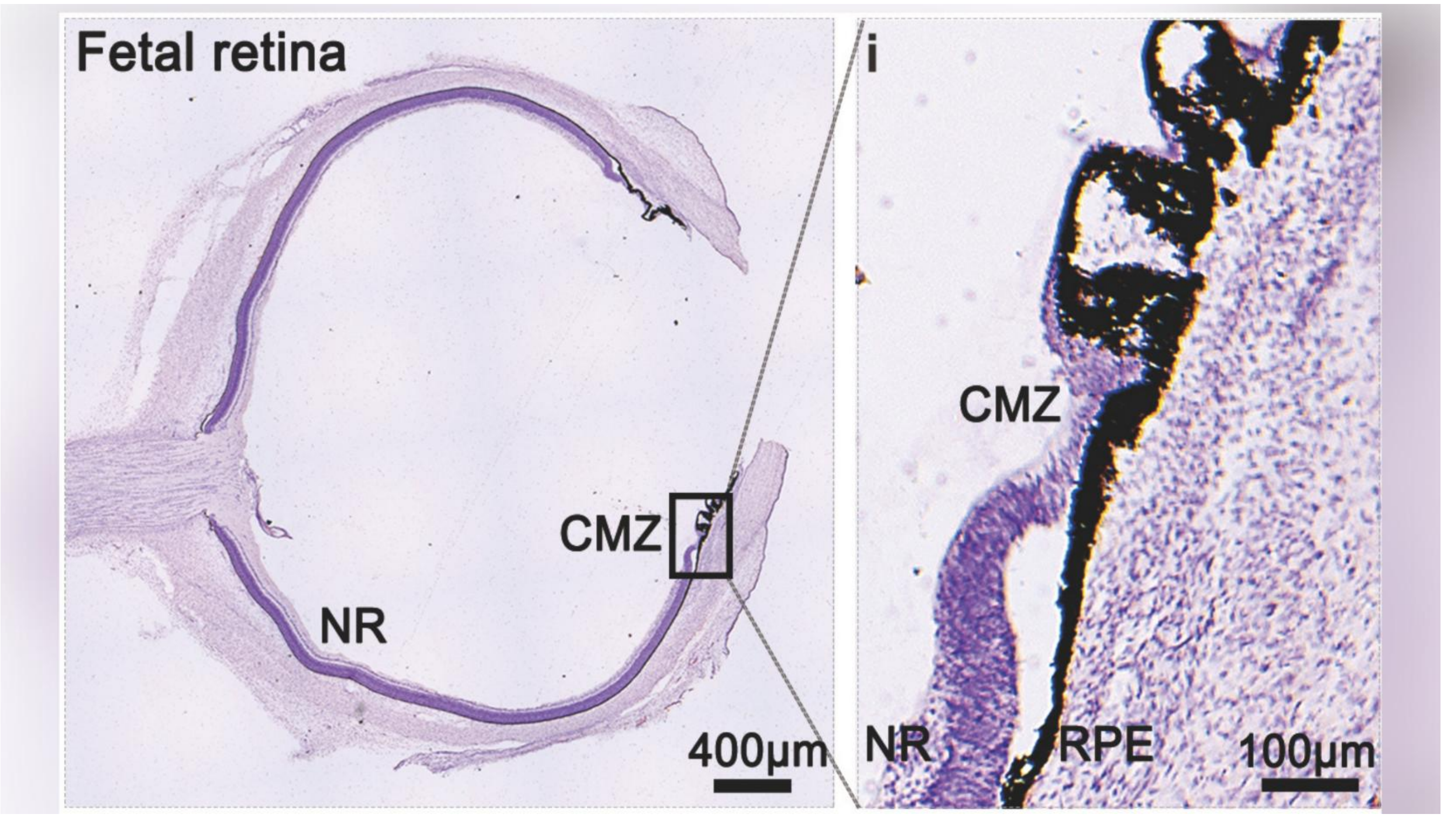
"This research not only deepens our understanding of retinal biology but also holds immense potential for advancing therapeutic interventions in RD [retinal degeneration] diseases," the researchers wrote in a paper describing the findings, which was published March 26 in the journal Science Translational Medicine.

The retina detects light and converts it into signals that the brain can then interpret to determine what we're seeing. Deterioration of the retina is a leading cause of blindness worldwide. It can be triggered by many things, including aging, diabetes and physical injury, and the degeneration can lead to common eye diseases, such as macular degeneration and retinitis pigmentosa.

Current treatments for these conditions focus mainly on reducing the rate at which retinal cells deteriorate, and protecting those that are still healthy. However, there are currently no effective therapies that promote repair of the retina, which would effectively reverse the deterioration.

A potential solution is to replace deteriorated cells with stem cells — cells that can mature to become any type of cell in the body under the right conditions. Yet, until now, scientists haven't found suitable stem cells in the human retina to achieve this, the authors of the new study wrote.

In the new research, the team analyzed the activity of cells in the fetal retinal samples in the lab. The scientists discovered two types of retinal stem cells with promising regenerative properties: human neural retinal stem-like cells (hNRSCs) and retinal pigment epithelium (RPE) stem-like cells.



This image shows retinal stem cells in dyed tissue from human fetuses. (Image credit: Jianzhong Su, State Key Laboratory of Eye Health, Eye Hospital, Wenzhou Medical University)

The researchers found that both types of cells, which were located in the outer edge of the retina, could clone themselves. However, only hNRSCs could turn into other types of retinal cells under the right conditions.

In a separate experiment, the researchers grew miniature replicas of the human retina in petri dishes. These 3D tissue models, known as organoids, better mimic the unique complexities of human organs than traditional animal models do.

An analysis of the cells within these organoids revealed that they contained hNRSCs similar to those found in the fetal tissue samples. The team also identified specific molecular chains of events that turned the stem cells into other retinal cells and regulated the repair process.

When transplanted into the retina of mice with a disease similar to retinitis pigmentosa, the stem cells from the organoids turned into the retinal cells needed to detect and process light signals. These new retinal cells ultimately improved the vision of the mice, compared with rodents that didn't receive any transplanted cells. This effect was seen for the duration of the experiment, up to 24 weeks.

Taken together, these early findings suggest that hNRSCs could be used to develop new treatments for retinal eye disorders in humans. But more research will be needed to confirm the potential of these cells for restoring the vision of human beings.

'Night vision lenses' could give you power to see in the dark using simple eyeglasses

published June 28, 2024

Super-slim night-vision tech could be within reach thanks to a new material breakthrough that can capture infrared and visible light at the same time.

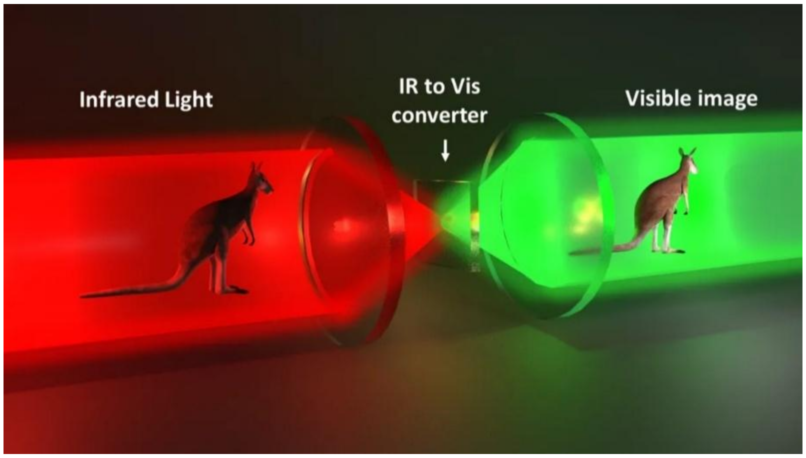

This breakthrough has opened the path to smaller, slimmer and more efficient night-vision systems for a variety of applications including the advent of night-vision filters that could be worn over eyeglasses to help people see at night. (Image credit: Pixsooz via Getty Images)

One day we could have everyday eyewear with night vision, thanks to an ultra-thin material that can capture infrared and visible light at the same time.

In a new study published May 23 in Advanced Materials, researchers in Australia have found that by using "metasurface-based up-conversion technology", you can create a night vision effect without the need for bulky light-processing and cryogenic cooling components.

"These results promise significant opportunities for the surveillance, autonomous navigation, and biological imaging industries, amongst others," chief investigator Dragomir Neshev from the Australian Research Council's Centre of Excellence for Transformative Meta-Optical Systems (TMOS) said in a statement. "Decreasing the size, weight and power requirements of night vision technology is an example of how meta-optics, and the work TMOS is doing, is crucial to Industry 4.0 and the future extreme miniaturisation of technology."

Traditional night-vision goggles work by visible light or infrared photons passing through a lens into an electronic image-intensifier tube consisting of a photocathode and a microchannel plate. The photocathode turns the photons into electrons, and these electrons then hit the microchannel plate, which has millions of holes that amplify their number. The electrons then interact with a phosphor-coated screen and exhibit a green glow, illuminating the scene that the wearer is viewing.



As the infrared photons only pass through a single resonant metasurface and are then mixed with a pump beam — a source of light used to amplify energy levels — night vision can be provided without the need to convert photons to electrons. (Image credit: Laura Valencia Molina, Australian National University)

The researchers explained that this current setup poses challenges due to its large size for a head-mounted device, thermal noise and the inability to augment infrared and visible imaging.

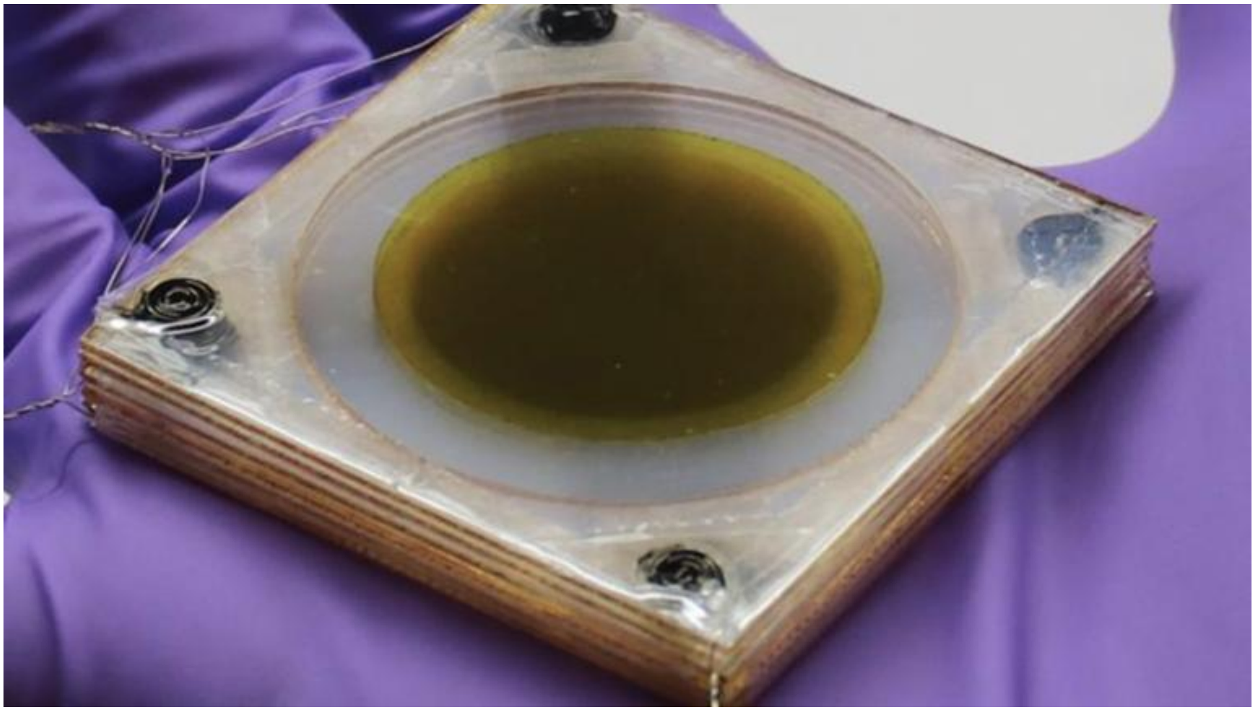
However, by using an "ultra-compact, high-quality-factor lithium niobate resonant metasurface" — a very thin photonic device that can modulate the behavior of electromagnetic waves — the researchers boosted the energy of the infrared photons, increasing their frequency so as to bring their wavelengths within the visual spectrum.

Let there be visible light

As the infrared photons only pass through a single resonant metasurface and are then mixed with a pump beam — a source of light used to amplify energy levels — night vision can be provided without the need to convert photons to electrons. This then bypasses the need for multiple heavy optical and cooling components to reduce thermal noise; the up-conversion from IR to visible light via the metasurface takes place at room temperature. Furthermore, this up-conversion can capture both visible and nonvisible light in one image, which standard night-vision systems cannot as they must display images from each spectrum side-by-side. This leads to non-identical images. As such, the researchers found their approach offers direct imaging and edge detection via infrared simultaneously in a single view, enhancing the overall quality of a night-vision image.

This breakthrough has opened the path to smaller, slimmer and more efficient night-vision systems for a variety of applications, the scientists said. We could even see the advent of night-vision glasses or filters that could be worn over eyeglasses to help people see at night. Uses could range from helping keep track of a dog during an evening walk to making driving at night safer.

Cooling pump made of thin films drops temperatures by 16 degrees, can transform wearables



Cooling pump made of thin films drops temperatures by 16 degrees, can transform wearables

A new cooling innovation developed by scientists pumps away heat continuously using layers of flexing thin films. The design is based on the electrocaloric effect, in which an electric field causes a temporary change in a material's temperature, according to researchers.

Developed by UCLA materials scientists, the prototype could lower ambient temperatures of its immediate surroundings by 16 degrees Fahrenheit continuously and up to 25 degrees at the source of the heat after about 30 seconds during lab experiments.

Qibing Pei, a professor of materials science and engineering at the UCLA Samueli School of Engineering, stated that their long-term goal is to develop this technology for wearable cooling accessories that are comfortable, affordable, reliable and energy-efficient — especially for people who work in very hot environments over long hours.

Material is composed of a circular stack of six thin polymer films

"As average temperatures continue to rise with climate change, coping with heat is becoming a critical health issue. We need a variety of solutions to the problem and this could be the basis for one," added Pei.

Scientists revealed that the experimental material is composed of a circular stack of six thin polymer films, just under an inch in diameter and one-quarter of an inch thick for the entire stack. Each layer is coated with carbon nanotubes on both sides. The resulting material is ferroelectric, which means it changes shape when an electric field is applied.

When the device's electric field is switched on, the stacked layers compress against each other in pairs. When the electricity switches off, the stacked pairs come apart to then press against the other neighboring layers. As this alternating process repeats itself, the self-regenerative, accordion-like cascading action continually pumps heat away, layer by layer, according to a press release.

Polymer films use a circuit to shuttle charges

Hanxiang Wu, one of the study's co-lead authors and a postdoctoral scholar working in Pei's lab, stated that the polymer films use a circuit to shuttle charges between pairs of stacked layers, which makes the flexible cooling device more efficient than air conditioners.

Scientists maintained that traditional cooling technology relies on air conditioning and refrigeration, which require vapor compression that not only consumes a great deal of energy but also uses carbon dioxide as a coolant. The new device is a simpler design that does not require greenhouse-gas-generating coolants or liquids. It operates solely with electricity, which can be sustainable when generated through renewable energy sources such as solar panels, as per the release.

Wenzhong Yan, a postdoctoral scholar in mechanical engineering, stated that this cooling device integrates advanced materials with an elegant mechanical architecture to deliver energy-efficient cooling by embedding functionality directly into its structure, reducing complexity, energy use and computational demands.

Pei highlighted that electrocaloric cooling would be most-ideal for next-generation wearables that can keep us cool under strenuous conditions. “It could also be used to cool electronics with flexible components,” said Pei.

How can the brain continue to learn without overloading our memory?

Article author: Cédric DEPOND

Source: Science

A recent study from Cornell University reveals that sleep not only consolidates memory but also resets neurons, allowing the brain to keep learning without depleting its resources. This discovery could have major implications for treating neurological disorders such as Alzheimer's disease or post-traumatic stress disorder.

When a person learns or experiences new things, neurons in the hippocampus, a key brain region for memory, become active. During sleep, these neurons replay the activity patterns observed during the day, a process essential for memory consolidation, with memories then stored in the cortex. However, scientists have questioned how the brain can continue acquiring new information throughout life without exhausting its neurons.

The study, published in *Science*, shows that at certain moments during deep sleep, specific regions of the hippocampus "shut down," allowing neurons to reset. Azahara Oliva, assistant professor of neurobiology and lead author of the study, explains: "This mechanism might allow the brain to reuse the same neurons for new learning the next day."

The hippocampus is divided into three main regions: CA1, CA2, and CA3. The CA1 and CA3 regions, well-studied, are involved in encoding time-and-space-related memories. In contrast, the function of CA2 was less understood until now. This research demonstrated that CA2 is essential in causing the silencing of other hippocampal regions, thus facilitating memory "reset" during sleep.

Researchers implanted electrodes in the hippocampus of mice to record neural activity during learning and sleep. They observed that neurons in the CA1 and CA3 regions replay neural patterns developed during the day before being silenced by the influence of CA2. This suggests the brain has parallel circuits regulated by two types of neurons: pyramidal neurons, crucial for learning, and interneurons, which ensure memory resetting.

This discovery is pivotal in understanding why sleep is essential in all animals: it not only serves to consolidate memories but also to reset the brain for continued functionality during waking hours. Researchers hope this knowledge can be used to enhance memory and treat related disorders, like Alzheimer's, or to erase traumatic memories.

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Fascinating Facts About the Human Brain

Prepare to be amazed as we delve into the extraordinary world of the human brain! This incredible organ not only orchestrates our thoughts, emotions, and behaviors but also holds secrets that are as fascinating as they are vital to understanding ourselves. From its astonishing capacity to generate electricity to its ability to adapt and heal, join us as we explore some of the most interesting and surprising facts about the human brain that will surely captivate your curiosity.

The Brain's Water Content

The human brain is approximately 75% water. This high water content is crucial as it helps maintain chemical processes, delivers nutrients to brain cells, and removes waste. Dehydration, even in small amounts, can affect cognitive function and the ability to think clearly.

Neuron Count

There are roughly 86 billion neurons in the human brain. Each neuron is capable of forming thousands of connections with other neurons, leading to an almost infinite number of potential neural pathways. This vast network is what allows for the complexity of human thought, memory, and emotion.

Electrical Power

The brain operates on the same amount of power as a 10-watt light bulb, even when you’re sleeping. The electrical activity generated by the brain is enough to power a small light bulb, highlighting the organâs efficiency and energy management.

Blood Vessels Length

If stretched out, the blood vessels in the brain would be about 100,000 miles long. This extensive network ensures that brain cells receive a constant supply of oxygen and nutrients essential for optimal function.

New Neurons

The adult human brain can grow new neurons, a process known as neurogenesis. Primarily occurring in the hippocampus, this phenomenon is vital for learning and memory. It challenges the old belief that adults cannot grow new brain cells.

Brain Weight

The average adult human brain weighs about 3 pounds, which is about 2% of total body weight. Despite its weight, it uses about 20% of the body’s energy and oxygen intake, emphasizing its importance and metabolic demand.

Processing Power

The human brain can process images the eye sees for as little as 13 milliseconds much faster than a blink, which takes about 100 to 400 milliseconds. This rapid processing ability is critical for quick reactions and seamless visual understanding.

Language and the Brain

The brain’s left hemisphere is predominantly responsible for language abilities in right-handed individuals. This lateralization shows how certain high-level functions are compartmentalized within the brain.

Synapses

For each neuron, there can be between 1,000 to 10,000 synapses, amounting to over 100 trillion in total. This immense network of connections is what allows for complex thought, learning, and the formation of memories.

Speed of Information

Information in the brain travels at different speeds but can be as fast as 270 miles per hour. This fast processing speed enables quick reflex responses and seamless coordination of physical actions.

Oxygen Usage

The brain consumes about 20% of the oxygen we breathe in. Its high oxygen use reflects its intense metabolic activity, required for maintaining normal cognitive and neurological functions.

The Visual Brain

Around 30% of the brainâ□□s cortex is devoted to visual processing, more than any other sense. This extensive area highlights the importance of vision in human evolution and function.

Memory Capacity

The storage capacity of the human brain is considered to rival about 2.5 petabytes of binary data, which is equivalent to about three million hours of TV shows. This vast capacity allows humans to store a tremendous amount of information over a lifetime.

Protective Blood-Brain Barrier

The brain is protected by a selective barrier called the blood-brain barrier, which prevents most substances in the blood from entering the brain. This feature is essential for protecting the brain from pathogens and toxins.

The Brain’s Clock

The suprachiasmatic nucleus in the brain acts as the master clock, coordinating all the biological clocks in a human body, regulating circadian rhythms, and ensuring timely hormone release for sleep and other body functions.

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Brain Growth

The human brain continues to grow until about the age of 25. This extended period of development is crucial for the maturation of advanced cognitive functions and emotional regulation.

Neural Plasticity

The brain has the remarkable ability to reorganize itself by forming new neural connections throughout life. This plasticity allows for learning new skills, adapting to new environments, and recovering from injuries.

Gamma Waves

The brain can produce gamma waves, which have a frequency of about 25 to 100 Hz and are associated with higher mental activity, including perception, problem-solving, and consciousness.

The three-pound human brain is one of the most intricate organs, surpassing the most advanced supercomputer. It controls everything you do, from reading this sentence to dreaming up wild inventions. Despite being a small organ, the brain is packed with complexities scientists are still trying to understand.

Stores Massive Data

Our brains can reserve 2.5 petabytes of data, equivalent to roughly 3 million hours of TV shows. This immense capacity allows us to retain a lifetime of memories and experiences. Thanks to the intricate 100 trillion neural networks, we quickly and accurately remember information.

Consumes 20% of Total Body Energy

Are you aware that your brain uses about 20% of your body's energy despite accounting for only about 2% of your body weight? The high energy demand is necessary to support continuous electrical activity, which coordinates every thought, movement, and sensation.

A Fast Information Processor

Neurons in the brain can transmit information at high speeds of up to 268 miles per hour. The brain's rapid transmission facilitates quick reflexes, instant decision-making, and seamless body movement coordination.

A Lifetime Learning Machine

Human brains have the superpower to change and adapt throughout life. Neuroplasticity allows the brain to rearrange itself by creating fresh neural links whenever you learn or experience new things. A new lesson means a new connection.

Naps Fire Up Its Creative Potential

During naptime, the brain sometimes generates vivid, often surreal experiences that can inspire creativity and problem-solving. Nier Bohr, the physicist behind the atom's structure, credited this revelation with a dream. Scholars, linguists, and artists — across disciplines — report similar breakthroughs.

Powerful Emotional Processor

You're mistaken if you think your heart determines your emotions because that's the brain's job! The limbic system within the brain processes emotions using the amygdala, hippocampus, and hypothalamus to regulate all your emotional responses, including sexual stimulation, memory, and motivation.

It Has Two Areas Focused on Fluency

Our speech capability to understand and communicate is also part of the brain's functioning. The Wernicke's area controls word comprehension, and the Broca's area, working with the motor cortex, helps with speech production.

Directly Links to Your Gut

Have you ever felt happy or motivated after consuming certain foods? Coffee, chocolate, or berries? Well, that is because of the gut-brain axis. Specific foods interact with some neurotransmitters to influence mood, digestion, and overall well-being. The gut's network of neurons influences these changes.

Acts as a Memory Converter

The hippocampus, a small structure within the brain, forms and stores memories. After a while, the hippocampus converts short-term memories into long-term ones, helping the limbic system learn and recall better. Your brain makes remembering grade 2 math a piece of cake.

Powers Consciousness

Scholars — scientists, philosophers, and researchers — term consciousness as a state of awareness. When conscious, you can make decisions and solve problems faster because the brain's flexible response mechanism takes in information and reacts accordingly.

It Needs Sleep to Heal

As you sleep, your brain also takes a break and starts healing. It clears out toxins, consolidates memories, and supports learning and cognitive performance. This nightly restoration is crucial for maintaining mental health and overall well-being. Just make sure you sleep for 7-9 hours!

Stress Stresses the Brain

Chronic stress shrinks the hippocampus, affecting memory and learning. Stress also aggravates inflammation, spreading the damage to your heart. You can protect your brain from its demise by having a routine, getting enough sleep, exercising, and eating right.

Each Brain Hemisphere Has Specialized Jobs

The brain has two hemispheres: the left hemisphere handles all the logical reasoning and language tasks, and the right, creativity, non-verbal memory, and spatial awareness. The right side also controls muscles on the left side of your body and vice versa.

The Brain Dances to Music

When listening to your favorite jam, certain brain sections light up, evoking emotion, memory, and motor control. This incredible response shows how deeply music is wired into our neural circuitry. Music can also create new neural connections, keeping our brains healthy and young.

It Stores Scented Memories

Ever found a familiar scent instantly transporting you to a specific moment? That is because the brain stores all the memories and emotions associated with smells. The olfactory bulb links to the hippocampus and amygdala, making scents powerful triggers for emotional memories.

How the Brain Maps Out Space

By YASEMIN SAPLAKOGLU

When most of us walk into a grocery store, we can find our way around what is, in fact, a fairly complex maze. We navigate the aisles swiftly, swerving a cart around other shoppers, tight corners and piles of fruit. We can collect many items, check out and proceed to the exit without much thought.

We can do this because humans have an intrinsic navigation system that helps us move around without bumping into things, remember places we've been before, and locate ourselves and others in space. Only in the last few decades have scientists started to understand how this brain GPS works, propelled by two fundamental findings about the cells that store these maps.

The first came in the 1970s, when John O'Keefe, a neuroscientist at University College London, was recording the brain activity of rats freely moving about in a space. He observed that different subsets of neurons in the hippocampus, the part of the brain central to learning and memory, fired in response to the rats' specific locations. For example, if the rats were in the northeastern part of their space, one subset would fire; another subset was active when the rats were in the southwestern part. He concluded that the mammalian brain uses these so-called place cells to create a spatial map.

Then, in the early 2000s, May-Britt Moser and Edvard Moser, a then-married couple working together at the Norwegian University of Science and Technology, discovered "grid cells" in the entorhinal cortex, a region right next to the hippocampus. These cells form an internal positioning system. Grid cells don't fire for one specific location, but rather encode a coordinate system represented as a hexagonal grid in the brain. If an animal navigates to one of the six vertices of its coded hexagon, that grid cell will fire.

Taken together, place cells and grid cells explain how the mammalian brain creates a map of the world. In 2014, O'Keefe and the Mosers jointly won a Nobel Prize for their discoveries.

Of course, our internal navigation system isn't limited to grid and place cells. And new studies are finding that the same cells involved in mapping out space might also map out other kinds of information, such as time, abstract concepts and memories.

What's New and Noteworthy

When we navigate physical worlds, we're often navigating social ones, too. In a room there might be fixed objects, such as furniture, and ever-shifting social objects, as people walk in and out. By studying social fruit bats, Michael Yartsev, who studies the neural basis of behavior, and his team at the University of California, Berkeley found that place cells encode for both social and physical environments. The cells reacted not only to a bat's location, but also to the locations of other bats nearby, as *Quanta* reported in 2023. The cells also seemed to carry information about individual identities: The neurons fired differently if a bat flew near a friend than they did for an acquaintance.

As studies uncover more roles for place and grid cells, some scientists are pondering whether the brain maps other knowledge the way it does space. For instance, cells might structure conceptual spaces like physical ones, according to research *Quanta* covered in 2019. In the study, participants watched on a screen as a bird silhouette was stretched and compressed. As the participants navigated this "bird space," their cells fired in a hexagonal grid pattern just as if they were navigating a physical space. The findings suggested that the brain might represent many kinds of information in grids.

A few years ago, researchers discovered a limitation of these studies. Grid cells have usually been studied and mapped in two dimensions, as rodents scurry around a flat area. However, work *Quanta* reported in 2021 shows that the brain encodes 2D space differently than 3D space. The hexagonal pattern that grid cells typically form in 2D disappears in 3D, a pair of studies showed. In three dimensions, grid cell activity becomes disorderly and complicated — a structural breakdown that suggests that grid cells may play a wider role in processes such as memory that aren't strictly spatial.

“The brain has so many surprises for us,” Ila Fiete, a computational neurobiologist at the Massachusetts Institute of Technology, told *Quanta*. “Here’s this system that you kind of understand, and it’s orderly — and the brain just throws a curveball.”

Meta has launched the world's 'most advanced' glasses. Will they replace smartphones?

Humans are increasingly engaging with wearable technology as it becomes more adaptable and interactive. One of the most intimate ways gaining acceptance is through augmented reality (AR) glasses.

Last week, Meta debuted a prototype of the most recent version of their AR glasses—Orion. They look like reading glasses and use holographic projection to allow users to see graphics projected through transparent lenses into their field of view.

Meta chief Mark Zuckerberg called Orion "the most advanced glasses the world has ever seen." He said they offer a "glimpse of the future" in which smart glasses will replace smartphones as the main mode of communication.

But is this true or just corporate hype? And will AR glasses actually benefit us in new ways?

Old technology, made new

The technology used to develop Orion glasses is not new.

In the 1960s, computer scientist Ivan Sutherland introduced the first augmented reality head-mounted display. Two decades later, Canadian engineer and inventor Stephen Mann developed the first glasses-like prototype.

Throughout the 1990s, researchers and technology companies developed the capability of this technology through head-worn displays and wearable computing devices. Like many technological developments, these were often initially focused on military and industry applications.

In 2013, after smartphone technology emerged, Google entered the AR glasses market. But consumers were disinterested, citing concerns about privacy, high cost, limited functionality and a lack of a clear purpose.

This did not discourage other companies—such as Microsoft, Apple and Meta—from developing similar technologies.

Looking inside

Meta cites a range of reasons for why Orion are the world's most advanced glasses, such as their miniaturized technology with large fields of view and holographic displays. It said these displays provide: "compelling AR experiences, creating new human-computer interaction paradigms [...] one of the most difficult challenges our industry has ever faced."

Orion also has an inbuilt smart assistant (Meta AI) to help with tasks through voice commands, eye and hand tracking, and a wristband for swiping, clicking and scrolling.

With these features, it is not difficult to agree that AR glasses are becoming more user-friendly for mass consumption. But gaining widespread consumer acceptance will be challenging.

A set of challenges

Meta will have to address four types of challenges:

1. ease of wearing, using and integrating AR glasses with other glasses
2. physiological aspects such as the heat the glasses generate, comfort and potential vertigo
3. operational factors such as battery life, data security and display quality
4. psychological factors such as social acceptance, trust in privacy and accessibility.

These factors are not unlike what we saw in the 2000s when smartphones gained acceptance. Just like then, there are early adopters who will see more benefits than risks in adopting AR glasses, creating a niche market that will gradually expand.

Similar to what Apple did with the iPhone, Meta will have to build a digital platform and ecosystem around Orion.

This will allow for broader applications in education (for example, virtual classrooms), remote work and enhanced collaboration tools. Already, Orion's holographic display allows users to overlay digital content and the real world, and because it is hands-free, communication will be more natural.

Creative destruction

Smart glasses are already being used in many industrial settings, such as logistics and health care. Meta plans to launch Orion for the general public in 2027.

By that time, AI will have likely advanced to the point where virtual assistants will be able to see what we see and the physical, virtual and artificial will co-exist. At this point, it is easy to see that the need for bulky smartphones may diminish and that through creative destruction, one industry may replace another.

This is supported by research indicating the virtual and augmented reality headset industry will be worth US$370 billion by 2034.

The remaining question is whether this will actually benefit us.

There is already much debate about the effect of smartphone technology on productivity and well-being. Some argue that it has benefited us, mainly through increased connectivity, access to information, and productivity applications.

But others say it has just created more work, distractions and mental fatigue.

If Meta has its way, AR glasses will solve this by enhancing productivity. Consulting firm Deloitte agrees, saying the technology will provide hands-free access to data, faster communication and collaboration through data-sharing.

It also claims smart glasses will reduce human errors, enable data visualization, and monitor the wearer's health and well-being. This will ensure a quality experience, social acceptance, and seamless integration with physical processes.

But whether or not that all comes true will depend on how well companies such as Meta address the many challenges associated with AR glasses.

Neuroscience Says Your Brain Craves 'New' For the Dopamine Rush, but Research Shows You Can Replace That Sensation Much More Productively

New products and ideas can be attractive because they're exciting to discover. But they can also make it less likely you'll achieve your actual goal.

A friend hates keeping his books. (He hates filing corporate taxes even more, but that's another story.) Over the past three years, he's adopted and abandoned five different small-business accounting packages--not because the software didn't work, but because he kept finding newer, shinier, more robust tools that he felt sure would solve all his problems.

Except they didn't. Accounting is still accounting, and he's still him. But that's also because he--and we--are made that way.

A study published in *Neuron* found that dopaminergic novelty processing (a fancy way of saying your brain lights up when you encounter something new) makes a new product or service--or new diet, new workout plan, new longevity enhancement breakthrough, etc.-- hard to resist.

As a corollary, the more complicated something sounds--like a comprehensive, multi-step morning routine--the more likely we are to believe it will work, even though science shows simple is always better.

Add it all up, and we're built to shrug off the commonplace. Same stuff, different day might work, but it's also neurologically boring. Our hippocampi love the dopamine rush that comes from finding a new approach.

They especially love the dopamine rush that comes from finding a new, and extreme, approach--even though the more extreme and complicated the approach, the less likely you'll embrace it over the long term.

My friend cares about cash flow, but running discounted cash flow models? Not so much. He cares about profitability, but he has no interest in reviewing sensitivity models, much less in creating them. He's successful because he's the king of sales, cash flow, and profitability -- not esoteric (to him) financial reports.

In short, he doesn't need "new," even though his hippocampus tells him he does. He needs simple, reliable, and easy-to-use.

And so do you. New can be better, but new without purpose is not. Productive people don't just know what to do--they know *why*. They have long-term goals. They have short-term goals that support their long-term goals. In short, they have purpose--and that purpose informs everything they do.

That's why productive people appear so dedicated, organized, and consistently on-task. They're not slaves to a routine, nor are they slaves to the occasional dopamine rush that comes from considering something new.

They're just driven to reach their goals, and quick to eliminate roadblocks and put aside distractions that stand in their way.

If you're an entrepreneur, your goal is to build a successful business. Your system--and your tools--are your processes for sales, marketing, fulfillment, operations, etc. Already have something that works? Great. Embrace it. Enhance it. Optimize it.

And seek your dopamine rushes elsewhere. In simple terms, dopamine is a reward your brain releases when you've achieved--or are close to achieving--a goal, helping you feel more motivated and satisfied.

A Harvard nutritionist and a neuroscientist agree this is the No. 1 food for a healthy brain© Provided by CNBC

What you eat can, and does, impact the function of your brain, including your ability to ward off Alzheimer's disease and there are certain foods — like sunflower seeds and whole grains — that provide greater benefits.

There is one food in particular that Dr. Uma Naidoo, a Harvard nutritionist, and Lisa Genova, a Harvard-trained neuroscientist, say is the key to a healthy brain: Green leafy vegetables.

DON'T MISS: ***5 doctors and nutritionists share the foods they eat every day for brain health, longevity and overall wellness***

The No. 1 food for a healthy brain: Green leafy vegetables

Across the board, experts agree that eating leafy greens is essential for overall health, especially for your brain.

Some of the green leafy vegetables that you can add to your meals are:

- Kale
- Spinach
- Lettuces
- Cabbage
- Swiss chard
- Bok choy
- Mustard greens

3 reasons experts say a diet rich in leafy greens is good for your brain

1. They're rich in B vitamins

Often, conditions like depression and dementia are associated with a vitamin B deficiency, according to a study from the Wayne State University School of Medicine.

Green leafy vegetables are a wonderful source of vitamin B9, Naidoo told CNBC Make It in 2022. The vitamin, also known as folate, is "a key vitamin for supporting brain and neurological health, optimal neurotransmitter function, and balanced psychological health," she added.

Leafy greens are the first type of food that Naidoo suggests for her patients who are looking to boost their mood.

2. They're high in brain-boosting nutrients

Green leafy vegetables are also full of what Genova calls "brain-boosting nutrients" including folate, lutein and beta-carotene.

Lutein has been linked to an improvement in brain function and brain structure for older adults. And a systematic review found that taking beta-carotene supplements can boost "verbal and cognitive memory."

3. They're full of fiber

Increasing intake of dietary fiber was associated with a lower chance of developing depression, a study published in "Complementary Therapies in Medicine" in 2021 found.

Naidoo prefers to recommend getting more fiber through your diet, specifically plant-based foods. And leafy greens just so happen to be fiber-dense.

FEBRUARY 20, 2025

Eating walnuts for breakfast may boost your brain function

by University of Reading

Eating walnuts for breakfast could improve brain function throughout the day for young adults, a new study has shown.

Researchers at the University of Reading found that eating 50 g of walnuts (a generous handful) mixed into muesli and yogurt led to faster reaction times throughout the day and better memory performance later in the day when compared to eating an equivalent calorie-matched breakfast without nuts.

The research, published this month in *Food & Function*, involved 32 healthy young adults aged 18–30 who consumed both a walnut-rich breakfast and a matched breakfast on separate occasions. Participants completed various cognitive tests while their brain activity was monitored in the six hours after eating each breakfast.

Professor Claire Williams, who led the research from the University of Reading, said, "This study helps strengthen the case for walnuts as brain food. A handful of walnuts with breakfast could give young adults a mental edge when they need to perform at the top of their game. It's particularly exciting that such a simple dietary addition could make a measurable difference to cognitive performance."

More work to be done

The findings build on previous research showing the cognitive impacts of regular nut consumption, including walnuts. This is the first study to examine the immediate effects of walnuts on brain function in young adults throughout a single day.

Brain activity recordings revealed changes in neural activity that suggest walnuts may help the brain work more efficiently during challenging mental tasks, while blood samples revealed positive changes in glucose and fatty acid levels—both factors that could influence brain function.

The researchers suggest that walnuts' mix of nutrients—including omega-3 alpha linolenic fatty acids, protein, and plant compounds called polyphenols—may enhance cognitive performance. However, they note that more research is needed to fully understand how walnuts produce these beneficial effects on the brain.

More information: L. Bell et al, The impact of a walnut-rich breakfast on cognitive performance and brain activity throughout the day in healthy young adults: a crossover intervention trial, *Food & Function* (2025). DOI: 10.1039/D4FO04832F
Journal information: Food & Function
Provided by University of Reading

The Hunt For The Laws Of Physics Behind Memory And Thought

One of the curious features of the laws of physics is that many of them seem to be the result of the bulk behavior of many much smaller components. The atoms and molecules in a gas, for example, move at a huge range of velocities. When constrained in a container, these particles continually strike the surface creating a force.

But it is not necessary to know the velocities of all the particles to determine this force. Instead, their influence averages out into a predictable and measurable bulk property called pressure.

This and other bulk properties like temperature, density and elasticity, are hugely useful because of the laws of physics that govern them. Over one hundred years ago, physicists like Willard Gibbs and others determined the mathematical character of these laws and the statistical shorthand that physicists and engineers now use routinely in everything from laboratory experiments to large scale industrial processes.

The success of so-called statistical physics raises the possibility that other systems that consist of enormous numbers of similar entities might also have their own "laws of physics". In particular, physicists have long hoped that the bulk properties of neurons might be amenable to this kind of approach.

Neural Physics

The behavior of single neurons is well understood. But put them together into networks and much more significant behaviors emerge, such as sensory perception, memories and thought. The hope is that a statistical or mathematical approach to these systems could reveal the laws of neural physics that describe the bulk behavior of nervous systems and brains.

"It is an old dream of the physics community to provide a statistical mechanics description for these and other emergent phenomena of life," say Leenoy Meshulam at the University of Washington and William Bialek at Princeton University, who have reviewed progress in this area.

"These aspirations appear in a new light because of developments in our ability to measure the electrical activity of the brain, sampling thousands of individual neurons simultaneously over hours or days."

The nature of these laws is, of course, fundamentally different to the nature of conventional statistical physics. At the heart of the difference is that neurons link together to form complex networks in which the behavior of one neuron can be closely correlated with the behavior of its neighbors.

It is relatively straightforward to formulate a set of equations that capture this behavior. But it quickly becomes apparent that these equations cannot be easily solved in anything other than trivial circumstances.

Instead, physicists must consider the correlations between all possible pairs of neurons and then use experimental evidence to constrain what correlations are possible.

The problem, of course, is that the number of pairs increases exponentially with the number of neurons. That raises the question of how much more data must be gathered to constrain the model as the number of neurons increases.

One standard system in which this has been well measured is the retina. This consists of a network of light sensitive neurons in which activity between neighbors is known to be corelated. So if one neuron is activated there is a strong possibility that its neighbor will be too. (This is the reason for the gently evolving, coral-like patterns in vision that people sometimes notice when they first wake up.)

Experiments in this area began by monitoring the behavior of a handful of neurons, then a few dozen, a few hundred and now approach thousands (but not millions). It turns out that the data helps constrain the model to the point where they give remarkably accurate predictions of neural behavior when asked, for example, to predict how many neurons are active out of any given set of them.

That suggests the system of equations accurately captures the behavior of retinal networks. In other words, "the models really are the solutions to the mathematical problem that we set out to solve," say Meshulam and Bialek.

Of course, the retina is a highly specialized part of the nervous system so an important question is whether similar techniques can generalize to the higher cognitive tasks that take place in other parts of the brain.

Emergent Behavior

One challenge here is that networks can demonstrate emergent behavior. This is not the result of random correlations or even weak correlations. Instead, the correlations can be remarkably strong and can spread through a network like an avalanche.

Networks that demonstrate this property are said to be in a state of criticality and are connected in a special way that allows this behavior. This criticality turns out to be common in nature and suggests networks can tune themselves in a special way to achieve it.

"Self-organized criticality" has been widely studied in the last two decades and there has been some success in describing it mathematically. But exactly how this self-tuning works is the focus of much ongoing research.

Just how powerful these approaches will become is not yet clear. Meshulam and Bialek take heart from the observation that some natural behaviors are amenable to the kind of analysis that physicists are good at. "All the birds in a flock agreeing to fly in the same direction is like the alignment of spins in a magnet," they say.

The fact that this is merely a metaphor concerns them - metaphors can help understanding but the real behavior of these system is often much more complex and subtle.

But there are reasons to think that mathematical models can go further. "The explosion of data on networks of real neurons offers the opportunity to move beyond metaphor," they say, adding that the data from millions of neurons should soon help to inform this debate.

"Our experimentalist friends will continue to move the frontier, combining tools from physics and biology to make more and more of the brain accessible in this way," conclude Meshulam and Bialek. "The outlook for theory is bright."

Ref: Statistical mechanics for networks of real neurons : arxiv.org/abs/2409.00412

You might already know about the benefits of specific nutrients — like vitamin A in carrots for eye health or calcium in dairy products for strong bones — but nutrients that support brain health often receive less attention. Yet the brain is vital for everything from memory and mood to managing stress, so it’s essential to keep it well-nourished.

Here are the best foods to support your brain and the nutrients that make them so beneficial — with the bonus that they can also help with weight loss.

1. Fatty Fish

Salmon, herring, whitefish, and anchovies top the Cleveland Clinic's list of brain-boosting fatty fish, packed with omega-3s like DHA and EPA. Maggie Moon, a Los Angeles–based registered dietitian and author of *The MIND Diet: 2nd Edition*, shares that these omega-3s protect the brain from inflammation linked to cognitive decline, Alzheimer's disease, and depression.

Research shows that omega-3 fatty acids may improve learning, memory, and cognitive well-being by enhancing blood flow in the brain. "This translates into how well the brain thinks, learns, and remembers," says Moon. DHA also benefits mental health from early childhood into adulthood, according to research.

"Seafood is an excellent lean protein choice for people who want to make the most of their calories while losing weight, including salmon and tuna, two of the most accessible fatty fish popular in the U.S.," says Moon. The American Heart Association recommends eating fish twice a week, and the Dietary Guidelines for Americans from the U.S. Department of Agriculture (USDA) advise at least 8 ounces of seafood per week based on a 2,000-calorie diet. But for those just getting started, Moon suggests eating fatty fish once a week, and building from there.

2. Dark Chocolate

If you're a chocolate lover, you may be happy to know that dark chocolate has brain-boosting benefits. Research shows dark chocolate is rich in flavonoids, a type of antioxidant that may positively impact cognitive performance. Another study suggests dark chocolate may reduce both mental and physical fatigue, which can enhance overall vitality, allow for better executive function, improve memory, and increase gray matter volume in the brain.

Moon says if you're looking for the highest flavonoid content from a cacao bean, taking a cocoa flavonol supplement or eating cacao nibs, which have no sugar, are best. "Otherwise, the best thing to do is seek out the highest percentage of dark chocolate your palate enjoys," says Moon. She says dark chocolate is commonly available at 60 to 85 percent cocoa, and the higher the percentage, the more beneficial bioactives it contains. Moon notes that higher cocoa levels also generally mean less added sugar and saturated fat, which can be helpful for weight loss, though it will taste more bitter.

3. Seeds

Certain seeds, like flaxseeds and chia seeds, are packed with omega-3 fatty acids in the form of alpha-linolenic acid (ALA). The National Institutes of Health says the body can't make this fatty acid on its own, so you must get ALA from your diet.

Bryan Quoc Le, PhD, food scientist and author of *150 Food Science Questions Answered: Cook Smarter, Cook Better*, from Puyallup, Washington, says "during the early development of the brain, ALA serves as an important structural component for brain tissue." Research confirms that eating chia seeds may support healthy brain development. This is also seen with flaxseeds; research credits them with helping to protect the brain from diseases, ease depression, and reduce stress-related damage. Dr. Le adds that ALA, found in seeds, may even boost a protein called BDNF, which research indicates can aid learning and memory.

Chia seeds and flaxseeds both contribute greatly to a high-fiber diet — which research ties to weight loss by way of improved metabolism, lowered hunger hormones, and increased satiety. Chia seeds offer 5 grams (g) of dietary fiber per tablespoon, per the USDA, while flaxseeds add 2 g of dietary fiber per tablespoon, according to the USDA.

Work seeds into your weight-loss meal prep with tasty overnight chia pudding and almond butter flaxseed granola bars.

4. Blueberries

Blueberries are packed with anthocyanins, which Le says protect brain cells and give the fruit its blue color. According to Le, the brain's high energy use can create harmful byproducts, but the antioxidants in blueberries help neutralize them to keep the brain healthy. Research supports this and further explains that anthocyanins may help prevent or treat brain disorders like Alzheimer's and Parkinson's diseases.

Other research shows that eating more blueberries (or anthocyanins) helps reduce the risk of cardiovascular disease, type 2 diabetes, and death, as well as promotes a healthy weight and mind. "Blueberries have a very low glycemic index, low sugar, and high fiber," says Le, who recommends eating them freely — like in smoothies, whole-grain muffins, or high-protein pancakes.

5. Leafy Greens

"I always recommend eating more leafy green vegetables for brain health," says Moon. The MIND diet, known for its brain-boosting benefits, includes a specific recommendation to eat leafy greens at least six times a week. Research shows that following this diet can reduce the risk of Alzheimer's disease by up to 53 percent and keep the brain about 7.5 years younger.

Moon cited a study showing that older adults who regularly ate leafy greens, especially those from the cabbage family like bok choy, had cognitive abilities equivalent to being 11 years younger compared to those who rarely ate them.

"We always have a big box of prewashed salad greens in our refrigerator, which makes it easy to add a big handful of greens to meals, snacks, and smoothies throughout the day," says Moon. Plus, 3 ounces of arugula contain just 20 calories, according to the USDA, making it a great low-calorie option for weight loss, too.

The Wrap-Up

A varied diet plays a crucial role in brain health, with omega-3s and antioxidants being particularly vital. Fatty fish, dark chocolate, seeds, blueberries, and leafy greens deliver nutrients that drive brain development and function. Incorporating these foods into meals or snacks nourishes the body, fuels the brain, and aligns with weight loss goals.

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Brain-Computer Interfaces©Image Credit: Kohji Asakawa from Pixabay

These devices let brains talk directly to computers. They could help paralyzed people move again or let us control machines with our thoughts. Some companies are already testing early versions. By 2030, they might be helping people with disabilities and changing how we all use technology.

Ever wish you could memorize every detail? Colleague's outfit? Neighborhood cat's meows? Newsflash: It's a memory meltdown waiting to happen!

Your brain, like a digital detoxing device, declutters by forgetting. Not a weakness, but a well-being weapon! Dive into the surprising science of remembering... less.

As Dubai-based neuropsychiatrist Nadia Khan explains, “Forgetting actually helps us focus on what matters now. We don’t carried away with every detail from the past. And so, with a little help from forgetting, we can actually adjust to different situations with agility. You can also see it as prioritising tasks on your list; you deal with the relevant ones first,” she says.

Neurological housekeeping

Research indicates that, at least in some cases, forgetting is due to “altered memory access” rather than memory loss. Image Credit: Shutterstock
As Khan explains, our brain is wired to optimise memory storage. It’s not intended to carry every detail. This complex, dynamic process of forgetting actually allows us to rid ourselves of outdated information. It makes room for learning and experiences. This kind of neurological housekeeping enhances our ability to process the present better. “As a result, we make healthier decisions that actually benefit our well-being,” she says.

Needless to say, forgetting usually comes at the cost of information, but research indicates that, at least in some cases, forgetting is due to “altered memory access” rather than memory loss.

So, how does this work? Well, it comes down to the neurons. The international journal, Nature Reviews Neuroscience, explained the complicated neuron activity that goes on, during the process of forgetting and recalling. In the study, the researchers examined the unique ensemble of neurons called “engram cells”. When we recall a memory, these cells fire collectively, and our memory surges. However, what happens when we forget?

As the researchers explain, forgetting doesn’t necessarily mean that the memory is gone. Instead, it proposes that these engram cells become inaccessible. However, this “inaccessibility”, is actually an active process.

It’s not a passive decay, as the researchers emphasise. In fact, our brain actively remodels the memory circuits, making specific engram cells harder to access based on the environmental factors. And so, in certain environments, it’s not completely essential to hold on to every detail. When we forget, we actually focus on what's important.

The research highlights that while natural forgetting is generally a necessary process, it could potentially be reversed in certain situations. However, in the case of severe diseases like Alzheimer's, the natural mechanisms are 'hijacked', leading to excessive forgetting and memory loss. These new findings could open up avenues for research into how to restore healthy forgetting processes and treat memory loss in diseases like Alzheimer's.

Forgetting: An active part of learning

In order to update your memory, your brain does a little clever forgetting. It provides more clarity to decision-making. Image Credit: Shutterstock
Forgetting could just be an ally in learning and mastery, if done right.

According to the 2023 study published in the US-based scientific journal Cell Reports titled Adaptive expression of engrams by retroactive interference, researchers studied how forgetting things is actually an active part of learning and memory maintenance. In fact, it is actually an active process that involves neural plasticity. This helps in modulating the functionality of specific memories.

In simpler words, in order to update your memory, your brain does a little clever forgetting. It provides more clarity to decision-making.

Forgetting is an important part of the learning process, says Dubai-based neuropsychiatrist, Anne Thomas. It helps the brain to sort, separate crucial information from all the details. In this day and age of excessive information overload, this particular filtering process is essential, says Khan. In order to retrieve information that is relevant and appropriate, we forget the unwanted and irrelevant information.

How to revive dormant memories

These forgotten memories still exist; they haven't been wiped out, as the Cell Reports study explains. They just become dormant. As Thomas explains with an example: For instance, you can't remember someone's name. Yet, when they re-introduce themselves, you realise that you knew it all along.

Your brain is playing a clever trick, there. "These forgotten memories aren't actually gone," explains Thomas, elaborating on the process of 'recognition' and 'recall'. So, when you see a familiar face, you recognise the familiarity, even if you're not able to recall the name. It's kind of like your brain getting a hint. You just take time to recall the name.

And so, in order to "revive" dormant memories, you need to review what you had previously learned, explains Thomas. For example, if you studied the previous night, and slept on time, the next morning, do a quick review of what you read. According to a 2016 study, titled Relearn Faster and Retain Longer published in US-based Academic journal Psychological Science, people who studied before bed, slept, and then later did review the next morning not only spent less time studying, they also increased their long-term retention memory by 50 percent. "A good rest does help your brain in filing away what you learned, and it also makes the information easier to access," explains Khan.

The brain needs to keep learning and adapting, she says. Learning and forgetting is a deeply inter-linked process. If you learn something, you need to keep reviewing it, to keep it in your memory. You need to keep revisiting it as well, so that the process of retrieval becomes easier.

This also helps you strengthen important memories through reviewing and tests, you make the important ones far more accessible, adds Khan. "Your brain needs to keep forging connections and building new pathways. 'Forgetting' old connections forces your brain to create new ones, keeping it flexible and adaptable," she says.

- The two Harvard students who put facial recognition AI in Meta's Ray-Ban glasses have big ideas.
- The duo, AnhPhu Nguyen and Caine Ardayfio, are known for their innovative tech projects.

- They plan to apply AI advancements to construction, enhancing robotics with reasoning.

Two Harvard students spooked the world with their demonstration of facial recognition using Meta Ray-Bans. Now, the duo says they have big ideas for AI in the construction industry.

and Anthropic's Claude over the past year have allowed more rapid innovations "in a way that you haven't been able to before," Ardifiyo said.
For example, if an autonomous construction robot trying to dig a hole was blocked by a person standing in the way, it would previously have needed an engineer to hardcode every one of its movements to avoid the person, Ardifiyo said.

But a construction robot with LLM reasoning can say to itself, "I'm going to wait for this person for a couple seconds until they move, and then if they don't, then I'll do this, and you can have a very strong likelihood that whatever it does is pretty reasonable," Adifiyo said.

"That's actually, like, very incredible, and a capability that has only existed in the past six months, essentially," he added.

Privacy concerns have been raised after two Harvard students just demoed a proof-of-concept system called I-XRAY which uses smart glasses to access personal information about others.

The system combines the use of the glasses along with custom software to ID strangers and retrieve personal data about them. The system has been coined 'I-XRAY.'

The students, AnhPhu Nguyen and Caine Ardayfio, took to the social media platform X to share their experiment writing: "Are we ready for a world where our data is exposed at a glance?"

They tested I-XRAY on Harvard's campus and correctly identified random people, before taking it to the subway to test on non-students.

Five technologies have been used and integrated to make the system function. To use it, people simply put the glasses on, then as you walk by people the glasses will detect when somebody's face is in the frame.

synergy between LLMs and reverse face search allows for fully automatic and comprehensive data extraction that was previously not possible with traditional methods alone.
"From the LLM extracted name, a FastPeopleSearch lookup can identify the person's home address, phone number, and their relatives.

The two creators of the system say the tool "quickly highlighted significant privacy concerns."

In a document where they give people the know-how to remove their information from online sources, they write that the purpose of building the system isn't for misuse and will not be released.

"Our goal is to demonstrate the current capabilities of smart glasses, face search engines, LLMs, and public databases, raising awareness that extracting someone's home address and other personal details from just their face on the street is possible today."

While the duo won't be publicly releasing I-XRAY, the demo alone does expose the concerns for privacy and surveillance in the new AI age.

Meta’s glasses include a privacy light, but it’s not always easily visible.© Photo by Amelia Holowaty Krales / The Verge

Two Harvard students have created an eerie demo of how smart glasses can use facial recognition tech to instantly dox people's identities, phone numbers, and addresses. The most unsettling part is the demo uses current, widely available technology like the Ray-Ban Meta smart glasses and public databases.

Facial recognition tech has been frighteningly accurate for a while now, and I-XRAY is largely just chaining together a bunch of existing technologies. It relies in part on PimEyes, which *The New York Times* described in 2022 as an "alarmingly accurate" face search engine that "anyone can use." Concerns around this tech have been heightened since it came out that Clearview AI was using facial recognition to help law enforcement. What's new about Nguyen and Ardayfio's demo is how the tech is being paired with a consumer gadget that is discreet and easy to access.

"The purpose of building this tool is not for misuse, and we are not releasing it," Nguyen and Ardafiyo write in a document explaining the project. Instead, the students say their goal is to raise awareness that all this isn't some dystopian future — it's all possible now with existing technology. In particular, they point out that I-XRAY is unique because large language models (LLMs) enable it to work automatically, drawing relationships between names and photos from vast data sources.

As you can see from this photo, the privacy light can be very hard to see in outdoor lighting. Even at night.© Photo by Amelia Holowaty Krales / The Verge

Privacy has always been a major concern with smart glasses. Google Glass originally failed due in part to public backlash at being recorded without consent in public spaces. However, it's also true that in the decade since, people have become more accustomed to being filmed due to the rise of smartphones, vloggers, and TikTok. What's unsettling about modern smart glasses, however, is that they don't stand out quite as much as Google Glass did.

Meta Connect 2024 recap: Mark Zuckerberg reveals Orion smart glasses, new AI features, transparent Ray-Bans, and an affordable Quest 3S©Getty/picture alliance

- Mark Zuckerberg kicked off the Meta Connect 2024 developer conference on Wednesday with a keynote.
- The big news was his demo of Meta's first "true AR" prototype glasses, "Orion," which are still a work in progress.
- He also revealed new Meta AI features, limited-edition Ray-Ban smart glasses, and a $299 Quest 3S.

Mark Zuckerberg knocked it out of the park during Meta's big day.

The Meta CEO looked calm, cool, and collected as he took the stage on Wednesday to announce a slew of new AI and hardware products — including a teaser of the company's long-awaited fully holographic glasses, Orion.

The Orion glasses were the news of the day, and in a surprising turn for AR glasses, they looked ... pretty slick!

The smart glasses integrate visuals into the lenses, making them the company's first "true AR" glasses. They still have a ways to go until they truly blend in like Meta's Ray-Ban smart glasses, but they were notably sleeker than the rival Snap Spectacles that Snap CEO Evan Spiegel showed off last week.

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Scroll on to get the full recap of Zuckerberg's Meta Connect keynote.

Phones drool, glasses rule. That's the mantra Meta is banking on customers adopting. It starts with updates to the company's smart Ray-Ban glasses, but those may be just a stepping stone to a future with holographic augmented-reality glasses, where people can have more lifelike video calls, watch TV, or read text messages, all while still seeing the world around them.

In a July earnings call, Zuckerberg said the second generation of glasses "continue to be a bigger hit sooner than we expected — thanks in part to AI." People were buying the glasses quicker than the company could make them, he said. The market-intelligence firm International Data Corporation says some 700,000 pairs have been shipped since last October. Meta's Ray-Bans have a camera and speaker and are packed with AI. Updates give the wearer real-time translation if someone is speaking with them in Spanish, English, French, or Italian, and they also have features for everyday use, like remembering where you parked your car or helping you create an outfit from the clothes in your closet or make a smoothie with the fruits in front of you.

Earning a modicum of cool in what's been panned as perhaps the dorkiest market in tech is a big leap.

They're far from being widely adopted, but Meta hopes this will be the next frontier. Glasses are "a very natural computing platform," Zuckerberg said. The Ray-Bans also have the benefit of being "just good-looking glasses," he told the crowd during Meta's Connect 2024 event, and he said "people want to have something on their face that they're proud of and that looks good."

not expected to sell more than 500,000 devices this year (in comparison, some 500,000 iPhones are sold globally every *day*). Its $3,500 price point is certainly a deterrent to widespread adoption, but so is the feasibility; they're clunky, there are too few programs made for them, and they're stuck among a niche user.

VR headsets are "not going to be mass market, ever, in this current form," says George Jijiashvili, the senior principal analyst of games at the research firm Omdia. But if Meta's can make AI work in a way that combines video capture, sound, and location context together, the glasses could be a game changer. "If they manage to create an AI solution that actually works very well, then having glasses in that situation makes a lot of sense. You can see the road to mass adoption more clearly with glasses than with VR headsets."

That's what Zuckerberg hopes, too. Even though the Orion glasses won't be sold anytime soon, if ever (Zuckerberg acknowledged they have to become more stylish and affordable), he's trying to drum up excitement, and, as my colleague Peter Kafka noted, convince the world that he can build the future of computing. "These glasses exist. They are awesome," Zuckerberg said. "They are a glimpse of a future that I think is going to be pretty exciting." So far, it's been hard to convince the average person they need a computer strapped to their face. But a fancy version of the same specs worn by Bob Dylan, Lady Gaga, and countless other celebrities who arguably bring more cool cache than a founder wearing an oversize T-shirt emblazoned with "Either Zuck or nothing" in Latin at a product launch may be the way to start.

Smart glasses, an arguably niche but rapidly advancing category of wearable devices that allows users to interact with digital content while keeping their eyes on the real world, will largely replace smartphones as the world's primary computing platform by the end of the decade, according to the latest word from Mark Zuckerberg, co-founder, chairman, and CEO of Meta. Zuckerberg, who is partially known for having dropped out of Harvard after creating a successful platform called Facebook, shared the prediction last week following the introduction of Orion, Meta's first true augmented reality glasses. A look at Orion, including Zuckerberg's thoughts, can be found below.

What I think is going to happen with glasses is that we're going to get to this point, probably sometime in the 2030s, where you have your phone with you, but it's *going to stay in your pocket more, because you're going to be doing more and more things on your glasses than maybe today you'd do on your phone. The glasses will be your main computing platform, and that will be kind of your default, go-to thing.*

It's official; we're living in a dystopian nightmare, only without any of the cool clothes or neon-covered megacities. As first reported by 404 Media, two Harvard students recently proved that it was possible to knock together some software that can turn a pair of Ray-Ban Meta smart glasses into a face recognition doxxing tool.

PimEyes offers a fairly simple opt-out process which involves uploading a photo of yourself . PimEyes will then remove any photos that are a match in its database. The original images will still exist on whichever websites they were scraped from, but anyone making a search for your face using PimEyes will no longer find any matching results.

1. Visit the PimEyes website.
2. At the top of the screen, select **Opt-out**.
3. Click **Upload photo**.
4. You should choose high-quality photos that are full-face, well-lit, and with nothing covering your face or eyes.
5. For the best results, upload multiple photos that give different angles of your face.
6. Agree to the terms and confirm that you are over 18, then click **Next**.
7. Upload a scan or photograph of a government issued ID. You should blur or cover any personal information such as your name, address, and any other personal information. Make sure that the photograph and expiry date of the ID remains uncovered.

8. Once you have uploaded your ID, enter an email address. This will only be used to send you confirmation that your images have been removed. You can use an email alias for safety if you wish.
9. Once your application has been processed, you should receive an email confirming that your images have been removed from the PimEyes database.

How to remove your photos from FaceCheck

Images are removed immediately but can take five days to be permanently deleted

Instructions to remove photos from FaceCheck website

FaceCheck / Pocket-linet
FaceCheck is another website that offers the ability to search based on an image of a face. Searching for a face will bring up results from other websites that include images of the same face. The results are ranked using a color coding system, with dark orange results being certain matches, yellow being confident matches, green being uncertain matches, and gray being weak matches.

Apple has been stuck in an innovation rut for the past few years. Aside from the Vision Pro headset — which expectedly didn't gain a mass reception — the company hasn't made any notable hardware strides apart from its bread-and-butter mobility and computing portfolio. That could change in the next few years.

For Apple, the inspiration would come from its pricey headset."The plan is to bring the Vision Pro's ability to understand its surroundings to more products," adds the report. But it's going to be a long wait until we see Apple's take on the smart glass category.

The XR wearables industry is at somewhat of a pivotal point. On one hand, we have products like the Meta Quest 3s headset that are bringing premium features like color passthrough to a price point that is nearly one-tenth of what Apple commands for the Vision Pro.

Digital Trends© Provided by Digital Trends

Then we have players like Xreal, Rokid, and RayNeo trying to make smart glasses that don't look like nerdy gizmos. Yet, at the same time, we have giants like Microsoft shutting the doors on ambitious XR products like the HoloLens despite being at the forefront of the AI race.

Meta Ray-Ban glasses can collect data from other people.© meta.com, Meta

Ray-Ban Meta glasses may look like a simple accessory, but their features can be surprising. Two students from Harvard University conducted an experiment that demonstrated how quickly and easily personal

By integrating facial recognition systems, public databases, and artificial intelligence, a glasses user could gather detailed information about people captured by the camera. As the experiment indicates, **Ray-Ban glasses** could become dangerous for obtaining personal data, such as names, addresses, phone numbers, and even insurance policies.

Meta's Orion Glasses: The Future of Augmented Reality Unveiled

It’s mea culpa time as the Macalope is here again to talk about Meta, AR glasses, and the icky mess that is humanity. First off, here’s to today’s college kids! When the Macalope was in college he… well, let’s just say mistakes were made. He was decidedly not doing experiments to point out the flaws in modern technology.

And now? We cheer for these new devices. Last week the Macalope wrote about Meta’s Orion prototype, taking a look at the variety of opinions about the device. And even he neglected to bring up the privacy issue, focusing instead on the aesthetics. Yes, Meta’s Orion pass better for regular glasses than the Vision Pro. Meta’s Ray Bans pass even easier for regular glasses.

Is that something we *want*, though? It’s all well and good if they’re being used for harmless entertainment, walking directions or idly looking up what “brat” is supposed to mean, anyway. But that’s not all they’re going to be used for.

Remember how Facebook got started.

It all began in 2003, when Facebook founder and CEO Mark Zuckerberg created an online programme called “Facemash,” which allowed users to objectify fellow students by comparing photos of their faces and selecting who they deemed as “hotter.”

Who knew that rewarding someone for making something gross by turning them into a billionaire would be a mistake?

Immediate, in-the-wild privacy violation is simply the next logical step. Social media companies do not care about your privacy except for the way it tastes as it slides past their tongues. So sweet.

Meta Connect 2024 recap: Mark Zuckerberg reveals Orion smart glasses, new AI features, transparent Ray-Bans, and an affordable Quest 3S©Getty/picture alliance

- Mark Zuckerberg kicked off the Meta Connect 2024 developer conference on Wednesday with a keynote.
- The big news was his demo of Meta's first "true AR" prototype glasses, "Orion," which are still a work in progress.
- He also revealed new Meta AI features, limited-edition Ray-Ban smart glasses, and a $299 Quest 3S.

Mark Zuckerberg knocked it out of the park during Meta's big day.

The Meta CEO looked calm, cool, and collected as he took the stage on Wednesday to announce a slew of new AI and hardware products — including a teaser of the company's long-awaited fully holographic glasses, Orion.

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The smart glasses integrate visuals into the lenses, making them the company's first "true AR" glasses. They still have a ways to go until they truly blend in like Meta's Ray-Ban smart glasses, but they were notably sleeker than the rival Snap Spectacles that Snap CEO Evan Spiegel showed off last week.

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- Meta's Reality Labs is exploring all kinds of wearable AI tech, CTO Andrew Bosworth says.

- Its projects include camera earbuds and mixed-reality goggles.
- Reality Labs, known for VR and AR, has also faced budget cuts and layoffs.

The rapid advancement of wearable technology is making it easier to accessorize with incorporate AI.

But the cuts haven't stopped Reality Labs from dabbling in new ideas. Behind the scenes, Reality Labs has many projects, from camera earbuds to mixed reality goggles. "If there's a concept that you could imagine, we either have had or do have somebody building a thing around it," Bosworth told Command Line.

Reality Labs uses a step-by-step process to develop products from concept to release, Bosworth said. It begins with a pre-discovery team that prototypes new ideas, which are then reviewed to select a few for further exploration. After prototyping, successful concepts enter the company's product road map, and about half of those make it through final testing to be released to the public.

The camera earbuds are in an early stage of development, while a pair of "steampunk" mixed reality goggles have advanced to the product release process, Command Line reported.

"We definitely don't want to be outflanked by someone who came up with some clever, integrated wearable that we hadn't thought about," Bosworth said.

Meta did not immediately respond to a request for comment from Business Insider.

- Meta Ray-Ban smart glasses make it easier to document things that happen in your life.
- A new project by two students called I-XRAY showcases what can be done with custom software and a pair of Meta Ray-Bans.
- The app allows almost instant recognition of subjects, with data that includes names, addresses, phone numbers, and more.

Meta makes one of the best smart glasses you'll find on the market, with the Ray-Ban collaboration sitting at the very top of our "best of" list. Of course, this is still a very niche product, which means, you're probably not going to see many of these out in the wild, despite the latest version of these glasses being available for close to a year now. Again, these glasses aren't for everyone, but if you're someone that likes to take photos and videos, and wants to capture the world in a different way, then the Meta Ray-Ban smart glasses are going to be worth trying out.

Ray-Ban Meta Black close-up with charging case in the background© Provided by Android Police

Related

Ray-Ban Meta smart glasses review: Built for social creators

Ray-Ban style meets Meta smarts to create a pair of almost perfect POV glasses for social creators

Now, with the introduction of these types of devices, there will always be privacy concerns. Especially now, with the implementation of AI in lots of modern products, which has led to companies to be very cautious about how their products are portrayed and how each device collects data that's captured. Meta even has a dedicated privacy page that goes through the ins and outs of its Ray-Bans in order to try and better educate its users. Of course, a brand can only control so much, which is why there will always be outlying examples of tech that can be used in ways not originally intended.

This isn't the future, this is our new reality

This is where a project called I-XRAY by two Harvard students comes into play, with AnhPhu Nguyen and Caine Ardayfio giving us real world examples of how the Meta Ray-Bans can be used when some clever tweaks are applied (via The Verge). In a post on X by Nguyen, we can see the work in action, showcasing how a string of available services and a custom application that can process it all, can really make an episode of Black Mirror come to life.

So let me paint a word picture for you (it is my job, after all). I've got two big things to save up for — my wedding and my home. It was all going so well until Meta Connect 2024, when the Zuck came up on stage and showed off the new transparent Ray-Ban Meta smart glasses.

The moment I saw them, I knew it was inevitable. Even if it meant I had to live off instant noodles for the next month, these are *extremely* my vibe. And now that I have one of the 7,500 pairs that Meta sold of this limited edition, zero regrets are felt. These see-through specs are easily the best-looking gadget I've seen in a long time.

Ray-Ban Meta smart glasses (with transition lenses): $379 @ Best Buy These smart glasses far exceed their 12MP camera capture abilities. Meta AI features give them all the smarts to answer any questions about the world around you (thanks to multimodal AI). And all of this is underpinned by a stellar-looking set of specs that feel great to wear all-day round.View Deal

Nothing at all...nothing at all...

((Image credit: Future))

Stupid sexy glasses! There is absolutely nothing new about them — no improvement to the Bluetooth and wi-fi connectivity, no Meta AI for me in the U.K. (unless you use one of the best VPNs to trick them), and no updates to the camera or battery life.

All Meta has done in its love-in with Ray-Ban is house all of the components in a completely transparent frame. And that's all these two needed to do, as it tickles every single of my nerdy itches at once to make this oh-so-divine on my face.

And the most recent additions are set to make these smarter than ever — an updated prompting system with the multimodal AI that understands more natural questions leads the charge. Instead of having to say "hey Meta, look and…" followed by your question, you can word it a lot more naturally.

But everything else coming too makes these a must-buy, from the ability to remember the location of items on request, reading QR codes and calling numbers it sees. Special shout-out to live translation, which is going to be *huge* for a traveler like me.

Outlook

((Image credit: Future))

So while this limited edition is sold out now, I'd still highly recommend you pick up a pair with transition lenses. The capabilities extend super far beyond just being a pair of camera glasses — thanks to all of its AI smarts.

Yes, I may be looking at my bank account and diet of baked beans and feeling a little poor right now, but damn do these look like something special.


Apple smart glasses tipped to launch in 2027 to fight Meta with Visual Intelligence© Martin Hajek/iDropnews)

Following up on a report from February this year, Bloomberg's Mark Gurman is doubling down on claims that Apple is developing new wearable products, suggesting that it could bring smart glasses and AirPods with cameras to market as early as 2027, as discussed in his latest Power On newsletter.

And while it's hard to say how AirPods with cameras could benefit the average user, Gurman has previously stated that the rumored product "would give consumers many of the benefits of smart glasses without needing lenses and frames."

Of course, if Gurman's report is to be believed, we're a few years out from seeing these products go on sale, we may have to settle for the Apple Intelligence features which are expected to arrive with iOS 18.2 in December.

In the meantime, you can access similar features such as the ability to take photos, record video stories, and access an AI voice assistant via the Ray-Ban Meta smart glasses.

Revolutionizing Neuroprosthetics Through AI-Driven Brain-Computer Interfaces: New Frontiers Unlocked by Dr. Pulicharla

he integration of Artificial Intelligence (AI) with neuroprosthetics is opening new horizons in the world of Brain-Computer Interfaces (BCIs). This innovative approach is transforming the way we understand human cognition and interaction with external devices, especially for individuals with neurological conditions. Dr. Mohan Raja Pulicharla's recent research, *"**AI-powered Neuroprosthetics for Brain-Computer Interfaces (BCIs)**,"* delves deep into this cutting-edge technology, exploring its potential and future implications.

What Are Brain-Computer Interfaces (BCIs)?

BCIs are systems that allow direct communication between the brain and external devices, enabling individuals to control machines or computers using their thoughts. Historically, BCIs have been an experimental technology used primarily in research settings. However, the advent of AI has propelled their development, allowing for more precise, adaptable, and efficient systems.

Applications and Future Impact

Dr. Pulicharla's study outlines several promising applications of AI-powered BCIs, particularly in medical settings. For instance, individuals with spinal cord injuries or neurodegenerative diseases can regain motor function through the use of neuroprosthetics controlled by BCIs. AI-powered systems can also assist stroke survivors in recovering speech or motor abilities by bypassing damaged neural pathways and directly connecting the brain to assistive devices.

Beyond medical applications, this technology has the potential to revolutionize various industries. Imagine hands-free control of machinery, computers, or even vehicles, driven purely by thought. AI-powered BCIs could also serve as communication tools for individuals with severe disabilities, offering them a newfound sense of independence and control over their environment.

The Future of Human-Machine Integration

As highlighted in Dr. Pulicharla's research, the fusion of AI with BCIs and neuroprosthetics is still in its early stages, but the trajectory of this technology is clear. The enhanced capabilities provided by AI will allow BCIs to evolve from experimental setups to widely available tools with broad applications. The continuous development of AI algorithms, coupled with advancements in neuroprosthetic devices, will drive the next wave of innovation in human-machine integration.

In the coming years, we can expect AI-powered BCIs to become more intuitive, efficient, and accessible, with far-reaching impacts on healthcare, rehabilitation, and everyday life. Dr. Pulicharla's research marks an important step in this journey, paving the way for future breakthroughs in this rapidly evolving field.

For a deeper dive into this pioneering work, read the full article here: AI-powered Neuroprosthetics for Brain-Computer Interfaces (BCIs).

Human study provides evidence that theta phase precession supports memory formation and retrieval

Past neuroscience research has pinpointed many of the neural processes through which the human brain forms, stores and retrieves important information, such as domain-specific knowledge and memories. One dimension of human memory is the ability to link various aspects of experience to specific life events.
Past studies have suggested that this memory-related process is supported by phase precession, which is a shift in the timing at which specific neurons are fired. Up until now, however, this hypothesis had not been confirmed experimentally.

Researchers at the University of California, Davis, Harvard Medical School, Toronto Western Hospital and Cedars-Sinai Medical Center recently carried out a study aimed at probing the relationship between phase precession and memory.

Their findings, published in *Nature Human Behaviour*, suggest that theta phase precession, the shift in the time at which specific neurons fire relative to the theta rhythm in brains, contributes to memory formation and retrieval.

"Our study was inspired by previous work showing that the relative timing of spikes with respect to population activity in the form of field potentials dynamically changes as animals navigate through an environment," Jie Zheng, first author of the paper, told Medical Xpress.

"Extending this idea to human memory, the primary objective here was to test the functional role of such dynamic spike timing signals during episodic memory formation and retrieval of complex event sequences in a natural and non-spatial task."

Zheng and her colleagues recruited 22 study participants and recorded single-neuron activity and local field potentials in their medial temporal lobe as they encoded and retrieved memories from movie clips. The team embedded the movie clips with event boundaries (i.e., contextual shifts), as this allowed them to mimic the process through which humans form memories in their everyday lives.

The researchers subsequently asked participants to recall events they observed in the movie clips and the order in which they occurred. They then analyzed the single-neuron activity they recorded as the participants were both viewing the movie clips and recalling the memory of the watched clips.

"The study was conducted in patients with pharmacologically resistant epilepsy where we could concurrently record the activity of individual neurons as well as population field potential signals," said Zheng. "We observed that the precise time at which neurons fired was related to the ongoing theta rhythms inside brains and that this relative timing evolved dynamically (called phase precession)."

The experiments carried out by Zheng and her colleagues yielded very interesting results. The team observed dynamic phase precession in the brains of participants throughout the experiment, with specific neurons shifting the timing with which they fired at different stages of the experimental task.

"We found strong theta phase precession at event boundaries when participants watched the clips and also when the participants answered memory questions," said Zheng. "The strength of theta phase precession was also predictive of participants' memory accuracy, especially for their order memory."

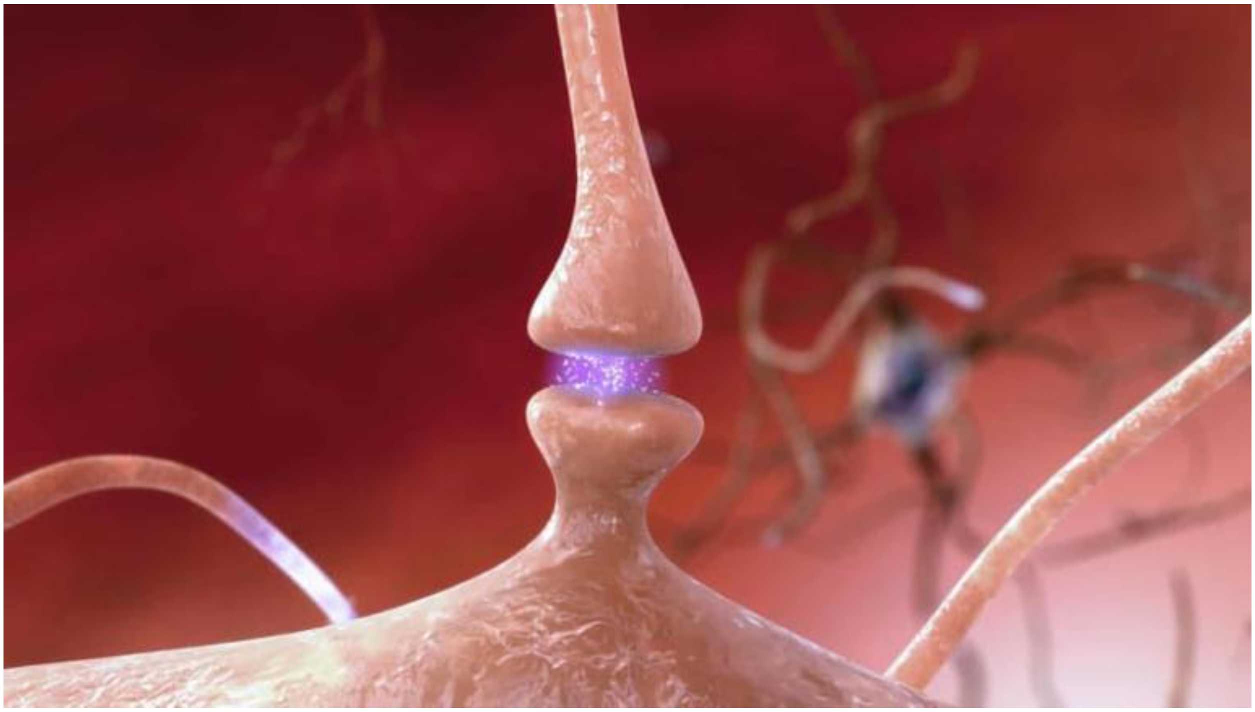
Overall, the findings of this recent study confirm the role of theta phase procession in the formation and retrieval of episodic memories. In the future, they could pave the way for further studies exploring the link between phase precession and specific memory processes.

"We would like to investigate the mechanisms underlying memory formation and retrieval of dynamic experiences with different sensory inputs (e.g., both visual and auditory), how the order of events is encoded, and how theta phase precession supports these consolidation and retrieval processes," added Zheng.

More information: Jie Zheng et al, Theta phase precession supports memory formation and retrieval of naturalistic experience in humans, *Nature Human Behaviour* (2024). DOI: 10.1038/s41562-024-01983-9

Science and Technology

Human brain can store 10 times more information than previously thought



Our memories and thoughts stem from complex patterns of electrical and chemical activity in the brain. Central to this activity are synapses, the junctions where branches of neurons connect, similar to electrical wires. Here, an axon from one neuron links to a dendrite of another. At these synapses, neurotransmitters carry signals across the gap, instructing the receiving neuron to pass on an electrical signal to others. Remarkably, each neuron can form thousands of these connections.

Similar to computers, we measure the brain's memory storage in "bits," and the number of bits it can hold rests on the number and strength of its synapses. It's worth noting that brains are analog — just so you don't get the wrong idea. Brains process everything in parallel, in continuous time rather than in discrete intervals, so the "bit" (the smallest unit of digital data) in this case is not a perfect analogy for how information is stored in a biological system. Nevertheless, it serves the purpose of estimating information processing.

Previously, it was believed that synapses came in very limited sizes and strengths. However, recent research suggests otherwise. The human brain's capacity to store information is almost ten times greater than previously estimated, according to a new study.

New Insights into Synaptic Strength and Memory Storage

A team of researchers from the University of California, San Diego and the Salk Institute developed a highly precise method to assess the strength of synapses in the brain of a rat. These synapses, where brain cells communicate and store information, play a critical role in learning and memory. By understanding how synapses strengthen and weaken, the scientists precisely quantified the information storage capacity of these connections.

In the human brain, over 100 trillion synapses exist between neurons. These synapses facilitate information transfer across the brain by launching chemical messengers. As we learn, specific synapses strengthen, enabling us to retain new information. This process is known as synaptic plasticity, is essential for memory formation and cognitive function.

When neurons talk, they do so at different volumes — some neurons whisper to each other while others shout. The 'volume' setting of the synapse, or the synaptic strength, is not static, but rather can change in both the short term and long term. Synaptic plasticity refers to these changes in synaptic strength.

However, aging and neurological diseases like Alzheimer's can weaken synapses, reducing our cognitive ability. This is why studies like these are important — they can help scientists unlock new therapies that may stave off or even cure neurodegenerative diseases that currently plague millions of patients across the world. However, measuring the strength of synapses has traditionally been challenging.

The team analyzed pairs of synapses from a rat hippocampus, a brain region vital for learning and memory. The new study's method leverages information theory, which allows scientists to quantify how much information synapses can store and transmit. What this means is that a framework typically reserved for computers was applied to the brain in order to estimate the number of bits that synapses can hold. They found that these pairs of synapses responded to the same type and amount of brain signals, performing synaptic strength adjustment.

Current and Future Potential

Ultimately, this analysis indicated that hippocampal synapses could store between 4.1 and 4.6 bits of information. Scientists thought each synapse could hold one bit. Overall, this means the human brain could store ten times more information than previously thought, or at least a petabyte — that's as much as 500 billion DVDs or all the movies ever made in high-definition.

While the study focuses on a small part of the rat brain, future research could explore how information storage capacity varies across different brain areas and species. This method could also compare healthy and diseased brain states, offering insights into conditions that affect cognitive functions.

In 2016, the Salk researchers reached the same conclusions. The new findings serve to confirm this initial assessment. Back then, the researchers also made another important revelation: there are at least 26 size categories of synapses, rather than just a few.

These findings also provide insight into the brain's remarkable efficiency. Despite its complexity, the waking adult brain uses only about 20 watts of continuous power, comparable to a very dim light bulb. These discoveries could inspire computer scientists to design highly precise yet energy-efficient computers. These innovations could particularly benefit "deep learning" and artificial neural networks, enhancing their capabilities in areas like speech recognition, object identification, and language translation.

The findings appeared in the journal *Neural Computation*.

Ultra-thin wonder material absorbs 99% electromagnetic waves with ease

Scientists have developed a new material: an ultra-thin film that can absorb over 99% of electromagnetic waves.

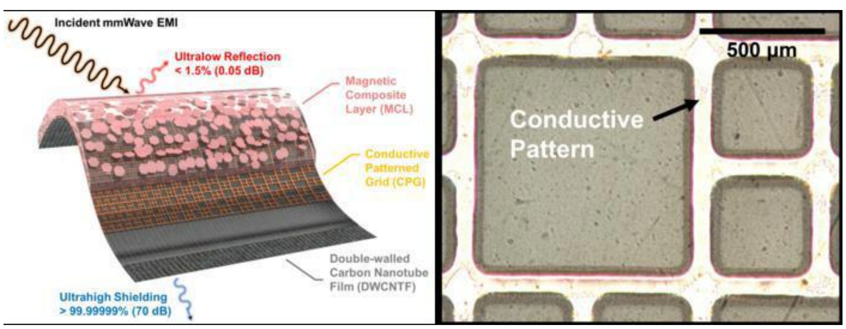
The Korea Institute of Materials Science (KIMS) states it to be the "world's first ultra-thin film composite material capable of absorbing over 99% of electromagnetic waves."

This material is less than half a millimeter thick, but it can effectively shield against a wide range of frequencies, including those used by 5G, 6G, Wi-Fi, and autonomous vehicle radar.

Unlike traditional shielding materials that reflect electromagnetic waves, this new material absorbs them, minimizing interference and improving the performance of electronic devices.

"As the applications of 5G/6G communications continue to expand, the importance of electromagnetic wave absorption and shielding materials is growing," said Byeongjin Park, senior researcher of KIMS, who led the development.

Park added: "This material has the potential to significantly improve the reliability of wireless communication devices such as smartphones and autonomous vehicle radars."



A conceptual diagram of the electromagnetic wave absorption and shielding material developed by the research team, along with the designed conductive pattern. Korea Institute of Materials Science (KIMS)

Need for new material

Electronic devices can emit waves that mess with other nearby devices, resulting in performance degradation.

These invisible waves can lead to glitches, signal loss, and even safety hazards.

Electromagnetic shielding materials are employed to mitigate this interference. These materials hold the potential to absorb the waves, which is said to be more effective than just reflecting them.

Conventional shielding materials primarily reflect electromagnetic waves, absorbing only a small fraction of 10%. Additionally, materials with higher absorption rates are often limited to a single frequency band.

To fix these problems, the team made a new material that can absorb waves from many different frequencies at the same time.

99% absorption

The material is super thin, bendy, and tough. It can bend without breaking, making it great for rollable phones and wearable tech.

“The team synthesized a magnetic material by altering the crystal structure of ferrite, enabling it to selectively absorb desired frequencies,” the press release noted.

They then combined this material with a thin polymer film and added conductive patterns to control wave propagation.

Finally, a carbon nanotube film was added to further improve the material’s shielding properties.

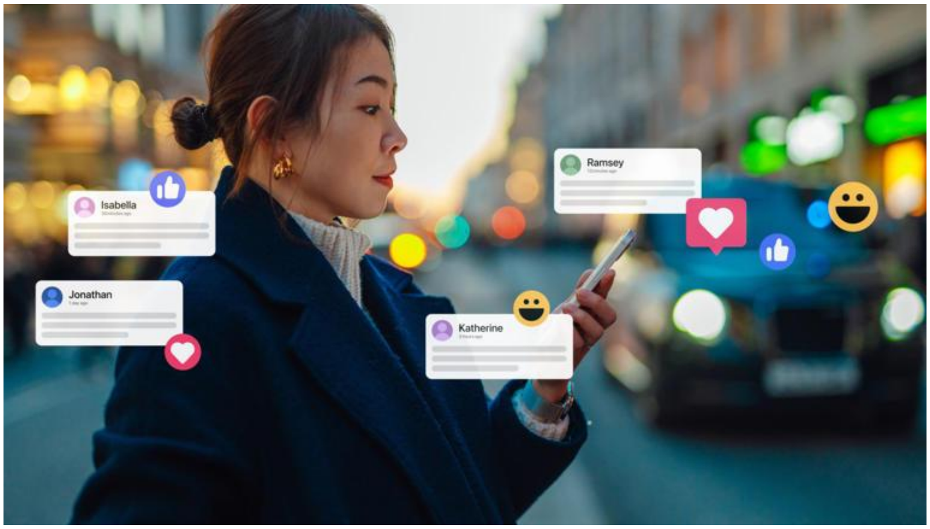
“This electromagnetic wave absorption and shielding material is less than 0.5mm thick and is distinguished by its low reflectance of less than 1% and high absorbance of over 99% across three different frequency bands,” the press release added.

The research was supported by KIMS and the National Research Council of Science & Technology. The team has secured patents domestically and internationally and has licensed the technology to several companies for use in real-world applications, including communication devices and automobiles.

The findings were published in the journal *Advanced Functional Materials*.

The revolution of millimeter-wave (mmWave) technologies is prompting a need for absorption-dominant EMI shielding materials. While conventional shielding materials struggle in the mmWave spectrum due to their reflective nature, this study introduces a novel EMI shielding film with ultralow reflection (<0.05 dB or 1.5%), ultrahigh absorption (>70 dB or 98.5%), and superior shielding (>70 dB or 99.99999%) across triple mmWave frequency bands with a thickness of 400 μm. By integrating a magnetic composite layer (MCL), a conductive patterned grid (CPG), and a double-walled carbon nanotube film (DWCNTF), specific resonant frequencies of electromagnetic waves are transmitted into the film with minimized reflection, and trapped and dissipated between the CPG and the DWCNTF. The design factors for resonant frequencies, such as the CPG geometry and the MCL refractive index, are systematically investigated based on electromagnetic wave propagation theories. This innovative approach presents a promising solution for effective mmWave EMI shielding materials, with implications for mobile communication, radar systems, and wireless gigabit communication.

understand written sentences in the 'blink of an eye,' study reveals



Human brains can discern the basic structures of written language from a single glance — enabling us to quickly consume the torrent of information fed to us by smartphones, a new study finds.

By measuring the brain activity of 36 volunteers, scientists found that people can detect basic sentence structures in as little as 125 milliseconds, or about the speed of a blink of an eye.

This means that people can process words as quickly as we comprehend visual scenes, a skill that enables us to continually observe and navigate the world around us. The new finding, published Wednesday (Oct. 23) in the journal Science Advances, could help reveal key clues about how our brains encode language, the researchers said.

Studying how the brain processes written messages enables scientists to understand more about the properties of language — particularly those properties that are not linked to speech, Liina Pylkkanen, a professor of linguistics and psychology at New York University, told Live Science.

Studying the neurobiology of language is often made difficult by the mouth, in that it "forces us to turn the language into a sequence" of brain activity in order to speak words aloud, Pylkkänen said. This restricts our understanding of language's properties to those demanded by the word-by-word serialization needed for speech.

To sidestep this issue, the researchers used a non-invasive technique called magnetoencephalography, which uses magnetic fields to track electrical activity in the brain. While being scanned, volunteers were presented with a three-word sentence structure that flashed onto a screen for 300 ms, followed by a second set of words that was either left the same or altered by one word. The participants' task was to assess whether the second sentence was the same as the first or had been changed.

The scans revealed that the brain's left temporal cortex — part of the organ's outermost layer that's key for understanding language — showed higher activity for three-word sentences than unstructured lists of words, and this activity showed up in just 125 ms.

Participants performed their best when the sentences contained a subject, verb and object, with the fastest brain activity being seen for phrases such as "nurses clean wounds," compared to noun lists like "hearts lungs livers."

This rapid detection was also seen for sentences that contained agreement errors, in which the verb doesn't match the pluralization of the subject — for example, "nurses cleans wounds." The brain also quickly detected implausible sentences, such as "wounds clean nurses." The researchers said this suggests that our brains aren't just detecting the presence of the words but are applying our previous knowledge of the world to better parse what the sentences mean right away.

"So just like your own car is quickly identifiable in a parking lot, certain language structures are quickly identifiable and can then give rise to a rapid effect of syntax in the brain," Pylkkänen said. "It's interesting since the [sentence] structural knowledge is abstract, but somehow you're still able to grasp it from the stimulus."

The researchers plan to follow up on their findings by further studying the types of sentence structures that the brain can detect quickly, and by looking into whether these align with the types of sentences people first learn as children. They also plan to study whether other visual stimuli, such as images, are processed using any of the same mechanisms we use to understand text.

Your native language may shape the wiring of your brain

The connections between different regions of the brain responsible for language processing depend on which language you grew up with.

A person's native language may shape how their brain builds connections between different hubs of information processing, a new brain scan study reveals.

The observed differences in these language network structures were related to linguistic characteristics in the native languages of the study participants: German and Arabic.

"So the difference we find there shouldn't be due to different ethnic background but really because of the language we [they] speak," Alfred Anwander, a researcher at the Max Planck Institute for Human Cognitive and Brain Sciences in Germany who led the study, told Live Science. The research was published online in February in the journal NeuroImage.
Although the language network grows to be one of the strongest networks in the brain, the connections at birth are weak. As we learn to speak, links strengthen between the various brain regions that are responsible for different types of language processing, such as recognizing words from sounds and interpreting the meaning of sentences, Anwander explained.

Different languages may tax some types of language processing more than others. The researchers wanted to see how these differences affect the formation of connections in the brain.

Previous studies had highlighted regions of the brain that activate during language processing. These are primarily situated in the left hemisphere, although both sides of the brain are invoked in auditory processing, and the region that assesses stress and intonation in the pronunciation of words lives in the right hemisphere.

Discussing the paper at a seminar, Patrick Friedrich, a researcher at the Institute for Neuroscience and Medicine at Forschungszentrum Jülich in Germany who was not involved in the study, noted that the brain's language network is understood to be "more or less universal among participants of different native languages." Yet, scientists have observed differences in how the brain processes second languages.

"I thought this study was really interesting because it shows for the first time a structural difference depending on the native experience," rather than languages learned later, Friedrich said.

The study included 94 participants. Half spoke only German, and the other half spoke only Arabic, having recently settled in Germany. Although they spoke different languages and grew up in different cultures, the participants were closely matched in terms of other factors that can influence brain wiring, such as age and education level.

Brain scans were obtained using "diffusion MRI," which tracks the directional mobility of water molecules to identify structures such as axons, which the water can move along easily.

The scans revealed that the native German speakers showed increased connectivity in the regions of the left hemisphere involved in language processing, compared with the Arabic speakers. Anwander noted that German is considered syntactically complicated, meaning the sense of a sentence is gleaned less from the word order and more from the grammatical forms of the words. Thus, words that depend on each other for their meaning may be at opposite ends of a sentence. Syntactic processing regions are mostly in frontal parts of the left hemisphere, so the higher connectivity within the left hemisphere makes sense, he said.
In contrast, Anwander described Arabic as semantically complex — while the sentence word order remains more fixed, the words' meanings can be more taxing to decode. The researchers observed increased connectivity between the left and right hemispheres for Arabic speakers that reflected this.

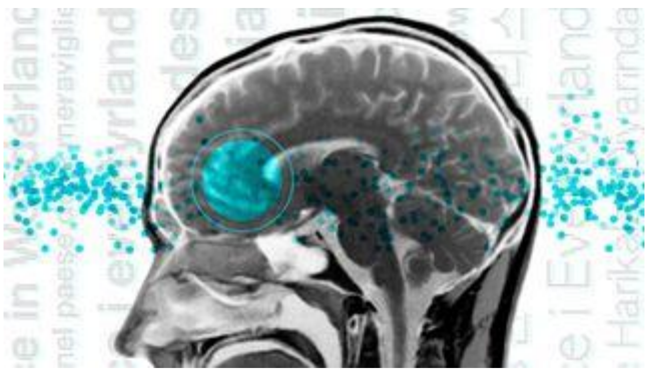
It's possible that the language network shaped by a person's first language might influence other nonlinguistic cognitive abilities, Anwander said. For example, a German speaker's memory might be influenced by their having to hear whole sentences before parsing their meaning.

David Green, an emeritus professor of psychology at University College London, described the work as "technically accomplished" but voiced reservations. Beyond the linguistic features of a language, cultural features of conversation, such as how people use gestures, may also shape brain networks, he told Live Science in an email.
The study also didn't cover all the brain regions involved in language processing, nor did it include measures of brain activity that could be compared across

individuals. "We do need to grasp the variety of ways in which the brain may solve a given task and the nature of that variety across individuals," he said.

Nonetheless, Anwander sees potential for this line of research, and wonders whether it might be possible to predict the native language of an individual from a brain scan. He and his colleagues would like to extend the study to more languages, to find out.

'Universal language network' identified in the brain



The brain's language processing network is mostly located in the left hemisphere. (Image credit: Christine Daniloff, MIT; iStock image)

Japanese, Italian, Ukrainian, Swahili, Tagalog and dozens of other spoken languages cause the same "universal language network" to light up in the brains of native speakers. This hub of language processing has been studied extensively in English speakers, but now neuroscientists have confirmed that the exact same network is activated in speakers of 45 different languages representing 12 distinct language families.

"This study is very foundational, extending some findings from English to a broad range of languages," senior author Evelina Fedorenko, an associate professor of neuroscience at MIT and a member of MIT's McGovern Institute for Brain Research, said in a statement.
"The hope is that now that we see that the basic properties seem to be general across languages, we can ask about potential differences between languages and language families in how they are implemented in the brain, and we can study phenomena that don't really exist in English," Fedorenko said. For example, speakers of "tonal" languages, such as Mandarin, convey different

word meanings through shifts in their tone, or pitch; English isn't a tonal language, so it might be processed slightly differently in the brain.
The study, published Monday (July 18) in the journal Nature Neuroscience, included two native speakers of each language, who underwent brain scans as they performed various cognitive tasks. Specifically, the team scanned the participants' brains using a technique called functional magnetic resonance imaging (fMRI), which tracks the flow of oxygenated blood through the brain. Active brain cells require more energy and oxygen, so fMRI provides an indirect measure of brain cell activity.

During the fMRI scans, the participants listened to passages from Lewis Carroll's "Alice's Adventures in Wonderland" (better known as "Alice in Wonderland") read in their native languages. In theory, all of the listeners should use the same language network to process stories read in their native tongues, the researchers hypothesized.

The participants also listened to several recordings that, theoretically, wouldn't activate this language network. For example, they listened to recordings in which the native speaker's words were distorted beyond recognition and to passages read by a speaker of an unfamiliar language. In addition to completing these language-related tests, the participants were asked to do math problems and perform memory tasks; like the incoherent recordings, neither the math nor the memory tests should activate the language network, the team theorized.

"Language areas [of the brain] are selective," first author Saima Malik-Moraleda, a doctoral student in the Speech and Hearing Bioscience and Technology program at Harvard University, said in the statement. "They shouldn't be responding during other tasks, such as a spatial working memory task, and that was what we found across the speakers of 45 languages that we tested."

In native English speakers, the brain areas that activate during language processing appear mostly in the left hemisphere of the brain, primarily in the frontal lobe, located behind the forehead, and in the temporal lobe, located behind the ear. By constructing "maps" of brain activity from all their subjects, the researchers revealed that these same brain areas activated regardless of the language being heard.

The team did observe slight differences in brain activity among the individual speakers of different languages. However, the same, small degree of variation has also been seen among native English speakers.

These results aren't necessarily surprising, but they lay a critical foundation for future studies, the team wrote in their report. "Although we expected this to be the case, this demonstration is an essential foundation for future systematic, in-depth and finer-grained cross-linguistic comparisons," they wrote.

Originally published on Live Science.

'Secret code' behind key type of memory revealed in new brain scans

The "secret code" the brain uses to create a key type of memory has finally been cracked.

This type of memory, called working memory, is what allows people to temporarily hold on to and manipulate information for short periods of time. You use working memory, for example, when you look up a phone number and then briefly remember the sequence of digits in order to dial, or when you ask a friend for directions to a restaurant and then keep track of the turns as you drive there.

The new work represents a "fundamental step forward" in the study of working memory, Derek Nee, an assistant professor of psychology and neuroscience at Florida State University, told Live Science in an email.

A critical process

For decades, scientists have wondered how and where the brain encodes transient memories.
One theory suggests that working memory relies on special "storehouses" in the brain, separate from where the brain handles incoming sensory information from the eyes or nose, for instance, or where long-term memories — like memories of who you attended

prom with, or foundational knowledge you learned in school — are stored, said Nee, who was not involved in the new study.
Another, opposing theory suggests that "there are no such special storehouses," Nee told Live Science. In this alternate theory, working memory is essentially an emergent phenomenon — one that shows up "when sensory and motor representations are kept around as we link the past to the future," Nee said. According to this theory, the same brain cells light up when you first read through a phone number as do when you run through that number again and again in working memory.

The new study, published April 7 in the journal Neuron, challenges both of these theories. Rather than reflecting what happens during perception or relying on special memory storehouses, working memory seems to operate one step up from sensory information gathering; it extracts only the most relevant sensory information from the environment and then sums up that information in a relatively simple code.
"There have been clues for decades that what we store in [working memory] might be different from what we perceive," study senior author Clayton Curtis, a professor of psychology and neural science at New York University (NYU), told Live Science in an email.

To solve the mysteries of working memory, Curtis and co-author Yuna Kwak, a doctoral student at NYU, used a brain scanning technique called functional magnetic resonance imaging (fMRI), which measures changes in blood flow to different parts of the brain. Active brain cells require more energy and oxygen, so fMRI provides an indirect measure of brain cell activity.

The team used this technique to scan the brains of nine volunteers while they performed a task that engaged their working memory; the two study authors also completed the task and contributed brain scans to the study.

In one of the trials, the participants viewed a circle composed of gratings, or slashes, on a screen for roughly four seconds; the graphic then disappeared, and 12 seconds later, the participants were asked to recall the angle of the slashes. In other trials, the participants viewed a cloud of moving dots that all shifted in the same direction, and they were asked to recall the exact angle of the dot cloud's motion.

"We predicted that participants would recode the complex stimulus" — the angled grating or moving dots — "into something more simple and relevant to the task at hand," Curtis told Live Science. Participants were only asked to pay attention to the orientation of the slashes or angle of the dot cloud's motion, so the researchers theorized that their brain activity would reflect only those specific attributes of the graphics.

And when the team analyzed the brain scan data, that's just what they found.

The researchers used computer modeling to visualize the complex brain activity, creating a kind of topographical map representing peaks and valleys of activity in different groups of brain cells. Brain cells that process visual data have a specific "receptive field," meaning they activate in response to stimuli that appear in a particular zone of a person's visual field. The team took these receptive fields into account in their models, which helped them understand how the participants' brain activity related to what they'd observed on-screen during the memory task.

This analysis revealed that, instead of encoding all of the fine details of each graphic, the brain stored only the relevant information needed for the task at hand. When viewed on the topographical maps, the brain activity used to encode this information looked like a simple, straight line. The angle of the line would match the orientation of the gratings or the angle of the dot cloud's motion, depending on which graphic the participants had been shown.

These line-like brain activity patterns appeared in the visual cortex, where the brain receives and processes visual information, and the parietal cortex, a key region for memory processing and storage.

What's crucial isn't that the brain settled on using lines to represent the images. "It is the fact that the representation has been abstracted from gratings [or] motion to something different," Nee said.

One limitation of the study is that the team used very simplistic graphics, which don't necessarily reflect the visual complexity of the real world, Nee noted. This limitation extends to many studies of working memory, and Nee said he uses similar simple graphics in his own research.

"The field will need to move towards richer stimuli that better match our natural visual experiences to bring us from the laboratory to practical utility," he said. But with that in mind, the new study still "provides a novel insight into what it means to hold something online in mind for the future," he said.

Working memory essentially acts as a bridge between perception (when we read a phone number) and action (when we dial that number). "This study, in identifying a representational format that resembles neither what was perceived nor what will be done but can be clearly read out from visual signals, offers an unprecedented look into this mysterious intermediate zone between perception and action," Nee said.

Originally published on Live Science.

Unique Brain Signal Just Discovered. And It Might Make Us 'Human'

A new study suggests that human neurons may have more computing power than once thought.

Cells nestled in the outermost layers of the human brain generate a special kind of electrical signal that might grant them an extra boost of computing power, new research suggests. What's more, this signal may be unique to humans — and may explain our unique intelligence, according to the study authors.

Brain cells, or neurons, link up through long, branching wires and shuttle messages along these cables to communicate with each other. Each neuron has both an outgoing wire, called an axon, and a wire that receives incoming messages, known as a dendrite. The dendrite passes on information to the rest of the neuron through bursts of electrical activity. Depending on how the brain is wired up, each dendrite may receive hundreds of thousands of signals from other neurons along its length. While scientists believe these electrical spikes help wire the brain and may underlie abilities like learning and memory, the exact role of dendrites in human cognition remains a mystery.
Now, researchers have uncovered a new flavor of electrical spike in human dendrites — one they think might allow the cells to perform computations once thought too complex for a single neuron to tackle on its own. The study, published Jan. 3 in the journal Science, notes that the newfound electrical property has never been observed in any animal tissue other than human, raising the question of whether the signal uniquely contributes to human intelligence, or to that of primates, our evolutionary cousins.

A strange signal

Up until now, most dendrite studies have been carried out in rodent tissue, which shares basic properties with human brain cells, said study co-author Matthew Larkum, a professor in the department of biology at Humboldt University in Berlin. However, human neurons measure about twice as long as those found in a mouse, he said.

"That means the electrical signals have to travel twice as far," Larkum told Live Science. "If there was no change in the electrical properties [between rodents and people], then that would mean that, in the

humans, the same synaptic inputs would be quite a bit less powerful." In other words, electrical spikes received by a dendrite would weaken significantly by the time they reached the cell body of the neuron.
So Larkum and his colleagues set out to uncover the electrical properties of human neurons to see how these longer dendrites actually manage to send signals effectively.

This was no easy task.

First, the researchers had to get their hands on human brain tissue samples, a notoriously scarce resource. The team ended up using neurons that had been sliced from the brains of epilepsy and tumor patients as part of their medical treatment. The team focused on neurons resected from the cerebral cortex, the wrinkled exterior of the brain that contains several distinct layers. In humans, these layers hold dense networks of dendrites and grow to be extremely thick, an attribute that may be "fundamental to what makes us human," according to a statement from Science.
"You get the tissue very infrequently, so you've just got to work with what's in front of you," Larkum said. And you have to work fast, he added. Outside the human body, the oxygen-starved brain cells only remain viable for about two days. To take full advantage of this limited time window, Larkum and his team would gather measurements from a given sample for as long as they could, sometimes working for 24 hours straight.

During these experimental marathons, the team chopped brain tissue into slices and poked holes in the dendrites contained within. By sticking thin glass pipettes through these holes, the researchers could inject ions, or charged particles, into the dendrites and observe how they changed in electrical activity. As expected, the stimulated dendrites generated spikes of electrical activity, but these signals looked very different from any seen before.

Each spike ignited for only a brief period of time — about a millisecond. In rodent tissue, this type of supershort spike occurs when a flood of sodium enters a dendrite, triggered by a particular accumulation of electrical activity. Calcium can also trigger spikes in rodent dendrites, but these signals tend to last 50 to 100 times longer than sodium spikes, Larkum said. What the team saw in human tissue, though, seemed to be a strange hybrid of the two.

"Although it looked like a sodium event, it was actually a calcium event," Larkum said. The team members tested what would happen if they prevented sodium from entering their sample dendrites and found that the spikes continued to fire unabated. What's more, the supershort spikes fired in rapid succession, one right after the other. But when the researchers blocked calcium from entering the neurons, the spikes stopped short. The scientists concluded that they had stumbled upon a brand-new class of spike, one similar in duration to sodium but controlled by calcium.

"These [spikes] look different than whatever we have known so far from other mammals," said Mayank Mehta, a professor in the departments of neurology, neurobiology physics and astronomy at the University of California, Los Angeles, who was not involved in the study. The big question is, how do these spikes relate to actual brain function, he said.

Computational powerhouses

Larkum and his colleagues couldn't test how their sliced-up samples might behave in an intact human brain, so they engineered a computer model based on their results. In the brain, dendrites receive signals along their length from nearby neurons that can either push them to generate a spike or prevent them from doing so. Similarly, the team designed digital dendrites that can be stimulated or inhibited from thousands of different points along their lengths. Historically, studies suggest that dendrites tally up these opposing signals over time and fire a spike when the number of excitatory signals outnumbers the inhibitory ones.

But the digital dendrites didn't behave this way at all.

"When we looked closely, we could see that there was this strange phenomenon," Larkum said. The more excitatory signals a dendrite received, the less likely it was to generate a spike. Instead, each region in a given dendrite seemed "tuned" to respond to a specific level of stimulation — no more, no less.

But what does this mean in terms of actual brain function? It means that dendrites may be processing information at each and every point along their lengths, working as a unified network to decide which information to send along, which to discard and which to handle alone, Larkum said.

"It doesn't look that the cell is just adding things up — it's also throwing things away," Mehta told Live Science. (In this case, the "throw away" signals would be excitatory signals that are not properly tuned to the dendritic region's "sweet spot.") This computational superpower could enable dendrites to take on functions once thought to be the work of whole neural networks; for instance, Mehta theorizes that individual dendrites could even encode memories.
Once, neuroscientists thought that whole networks of neurons worked together to perform these complex calculations and decided how to respond as a group. Now, it seems like an individual dendrite does this exact type of calculation all on its own.

It may be that only the human brain possesses this impressive computational power, but Larkum said that it's too early to say for sure. He and his colleagues want to search for this mysterious calcium spike in rodents, in case it has been overlooked in past research. He also hopes to collaborate on similar studies in primates to see if the electrical properties of human dendrites are similar to those of our evolutionary relatives.

It is very unlikely that these spikes make humans special or more intelligent than other mammals, Mehta said. It may be that the newfound electrical property is unique to L2/3 neurons in the human cerebral cortex, as the rodent brain also produces specific spikes in particular regions of the brain, he added.

In past research, Mehta found that rodent dendrites also generate a wide variety of spikes whose exact function remains unknown. What's interesting is that only a fraction of these spikes actually trigger a reaction in the cell body they plug into, he said. In rodent neurons, roughly 90 percent of dendritic spikes don't prompt electrical signals from the cell body, suggesting that dendrites in both rodents and humans may be processing information independently, in ways we don't yet understand.
Much of our understanding of learning and memory stems from research on electrical activity generated in the neuron cell body and its output cable, the axon. But these findings suggest that "it may be that the majority of spikes in the brain may be taking place in the dendrites," Mehta said. "Those spikes could change the rules of learning.

We finally know why the brain uses so much energy

Your brain may be leaking ... energy, according to a new study that may explain why your noggin consumes 20% of the energy needed to keep your body running.

The study researchers found that tiny sacs called vesicles that hold messages being transmitted between brain cells may be constantly oozing energy, and that leakage is likely a trade-off for the brain being ready to fire at all times, according to a new study published Dec. 3 in the journal Science Advances.

"The brain is considered a very expensive organ to run," said senior author Timothy Ryan, a professor of biochemistry at Weill Cornell Medicine in New York City.
Scientists previously assumed this energy suck had to do with the fact that the brain is electrically active, which means that brain cells, or neurons, are constantly firing electrical signals to communicate, a process that burns large amounts of an energy molecule known as adenosine 5'-triphosphate (ATP).

But over the past couple of decades, clinical studies showed that the brains of people who were in a vegetative state or coma, meaning very minimal electrical brain activity, still consumed massive amounts of energy, Ryan told Live Science. So neuroscientists were faced with a conundrum: If electrical activity isn't using up all the energy in the brain, what is?

Leaky vesicles

In recent years, Ryan and his team have been researching junctions in the brain called synapses, where neurons meet and communicate by launching tiny vesicles packed with chemical messengers called neurotransmitters.

They previously showed that active synapses use up a lot of energy. But in a new study, in which they inactivated rat neuron synapses in lab dishes with a toxin and then measured ATP levels inside the synapses, the team realized that synapses consumed a lot of energy even when neurons weren't firing.

To figure out why, they knocked out various pumps on the surfaces of the tiny vesicles that move neurotransmitters and other molecules in and out, and so deprived synapses of fuel. They imaged the synapses using a fluorescent microscope and figured out how much ATP the synapse had burned. They found that a "proton pump" was responsible for about 44% of all the energy used in the resting synapse. When they dug further, the researchers discovered that the proton pump had to keep working, and burning ATP, because the vesicles were always "leaking" protons.

Inactive synapses prepare to launch these vesicles at a moment's notice by pre-packing them with neurotransmitters.

They do that with the help of another pump that sits on the surfaces of the vesicles. This type of pump, called transporter proteins, change shape to carry neurotransmitters inside and in exchange, they grab a proton from inside the vesicle, change shape again and spit the proton out of the vesicle. For this process to work, the vesicles must have a higher concentration of protons inside than in its surroundings.
But the researchers found that even after the vesicles were full of neurotransmitters, the transporter proteins continued to change shape. Even though they weren't carrying neurotransmitters into the vesicles, they continued to spit protons out, requiring the proton pump to keep working to refill the vesicle's reservoir of protons.

"So we discovered what is sort of an inefficiency in it," Ryan said. The leakage is small, but if you add up trillions of leakages together, that "ends up being quite a large expense even without any electrical activity."

The studies were conducted using rat neurons in the lab, but "the machinery involved is incredibly well conserved" between rats and humans, so the findings would very likely hold true for human brains as well, Ryan said.

It's not clear why our brains evolved to have this leakage, but the easy shape change is likely a trade-off for vesicles to quickly be able to pack neurotransmitters, he said.

Just imagine how quickly you can accelerate if you had a car idling at all times at a high rev rate, but how much fuel you'd waste, he added. "Maybe the price of keeping synapses at the ready was what seems to be an inefficient use of energy."

Ryan and his team hope that the findings may help not only in the fundamental understanding of the human brain, but also clinically. For example, the discovery could lead to a better understanding and treatment of certain diseases, such as Parkinson's, in which the brain may not have enough fuel to make ATP.
In that case, "you're talking about a car idling [and] you cut the gas line," Ryan said. You're "really going to have a problem."

Originally published on Live Science.

Things You Didn't Know About the Brain

Throughout history, the human brain has been remarkably good at dismissing itself. Everyone from ancient Egyptians to Aristotle has downplayed the role of the mysterious stuff between our ears. Famed anatomist Galen gave the brain credit as commander of movement and speech, but even he brushed aside the white and gray matter, figuring the fluid-filled ventricles inside the brain did most of the work.

Human brains are big...

The average adult brain weighs just under 3 pounds (between 1.3 and 1.4 kilograms). Some neurosurgeons describe the texture of a living brain as that of toothpaste, but according to neurosurgeon Katrina Firlik, a better analogy can be found in the local health-food store.
"[The brain] doesn't spread like toothpaste. It doesn't adhere to your fingers the way toothpaste does," Firlik writes in her memoir, "Another Day in the Frontal Lobe: A Brain Surgeon Exposes Life on the Inside" (Random House, 2006). "Tofu — the soft variety, if you know tofu — may be a more accurate comparison."

If you aren't charmed by that description, consider this: About 80 percent of the contents of your cranium is brain, while equal amounts of blood and cerebrospinal fluid, the clear liquid that buffers neural tissue, make up the rest. If you were to blend up all of that brain, blood and fluid, it would come to about 1.7 liters, or not quite enough to fill a 2-liter soda bottle.

...But they're getting smaller

Don't get too cocky about your soda-bottle-sized brain. Humans 5,000 years ago had brains that were even larger.

"We do know from archaeological data that pretty much everywhere we can measure — Europe, China, South Africa, Australia — that brains have shrunk about 9 cubic inches (150 cubic centimeters), from an average of about 82 in^3 (1,350 cm^3). That's roughly 10 percent," University of Wisconsin at Madison paleoanthropologist John Hawks told LiveScience in 2009.

Researchers don't know why brains might be shrinking, but some theorize that they're evolving to be more efficient. Others think our skulls are getting smaller because our diets include more easily chewable foods and so large, strong jaws are no longer required.

Whatever the reason, brain size doesn't directly correlate with intellect, so there's no evidence that ancient man was brainier than humans of today.

Our brains burn through energy

The modern brain is an energy hog. The organ accounts for about 2 percent of body weight, but it uses about 20 percent of the oxygen in our blood and 25 percent of the glucose (sugars) circulating in our bloodstream, according to the American College of Neuropsychopharmacology.

These energy requirements have spurred a debate among anthropologists about what fueled the evolution of big brains in the first place. Many researchers credit meat, citing evidence of hunting in our early ancestors. But meat would have been an unreliable food source, say other scientists. A 2007 study published in the Proceedings of the National Academy of Science found that modern-day chimps know how to dig for calorie-rich tubers on the savanna. Perhaps our ancestors did the same, boosting their brainpower with veggies.

As for what motivated the brain to balloon in size, there are three major hypotheses: climate change, the demands of ecology, and social competition.

Synapses

For each neuron, there can be between 1,000 to 10,000 synapses, amounting to over 100 trillion in total. This immense network of connections is what allows for complex thought, learning, and the formation of memories.

Speed of Information

Information in the brain travels at different speeds but can be as fast as 270 miles per hour. This fast processing speed enables quick reflex responses and seamless coordination of physical actions.

Oxygen Usage

The brain consumes about 20% of the oxygen we breathe in. Its high oxygen use reflects its intense metabolic activity, required for maintaining normal cognitive and neurological functions.

The Visual Brain

Around 30% of the brain's cortex is devoted to visual processing, more than any other sense. This extensive area highlights the importance of vision in human evolution and function.

Memory Capacity

The storage capacity of the human brain is considered to rival about 2.5 petabytes of binary data, which is equivalent to about three million hours of TV shows. This vast capacity allows humans to store a tremendous amount of information over a lifetime.

Wrinkles make us smart

What's the secret to our species' smarts? The answer may be wrinkles. The surface of the human brain is convoluted by deep fissures, smaller grooves called sulci, and ridges called gyri. This surface is called the cerebral cortex and is home to about 100 billion neurons, or nerve cells.

The folded, meandering surface allows the brain to pack in more surface area — and thus, more processing power — into the limited confines of the skull. Our primate relatives show varying degrees of convolution in their brains, as do other intelligent creatures like elephants. In fact, research done by Emory University neuroscientist Lori Marino has found that dolphins have even more pronounced brain wrinkles than humans.

Most of our brain cells aren't neurons

The old saw that we use just 10 percent of our brainpower isn't true, but we now know that neurons make up just 10 percent of our brain cells.

The other 90 percent, which account for about half the brain's weight, are called glia, which means "glue" in Greek. Neuroscientists used to think glia were simply the sticky stuff that holds neurons together. But recent research has shown glia to be much more. A 2005 paper in the journal Current Opinions in Neurobiology laid out the roles of these unsung cells, which range from mopping up excess neurotransmitters to providing immune protection to actually promoting and modulating synapse growth and function. (Synapses are the connections between neurons.) It turns out the silent majority isn't so silent after all.

The brain is an exclusive club

Like bouncers at a night club, an assembly of cells in the brain's blood system, called the blood-brain barrier, lets only a few molecules into the nervous system's inner sanctum – the brain. The capillaries that feed the brain are lined with tightly bound cells, which keep out large molecules. Special proteins in the barrier transport necessary nutrients and substances into the brain. Only an elite few make it through.

The blood-brain barrier protects the brain, but it can also keep out lifesaving medications. Physicians trying to treat brain tumors can use drugs to open the junctions between cells, but that leaves the brain temporarily vulnerable to infection. One new way to sneak meds past the barrier might be nanotechnology. A 2009 study published in the journal Cancer Research showed that specially-engineered nanoparticles can cross the barrier and attach to tumor tissue. In the future, combining nanoparticles with chemotherapy drugs could be one way to target tumors.

The brain starts as a tube

The foundation for the brain is set early. Three weeks after conception, a sheet of embryonic cells called the neural plate folds and fuses into the neural tube. This tissue will become the central nervous system.

The neural tube grows and differentiates throughout the first trimester. (When cells differentiate they specialize into various tissues needed to create body parts.) It isn't until the second trimester that glia and neurons begin to form. The brain doesn't wrinkle up until even later. At 24 weeks, magnetic resonance imaging shows just a few nascent grooves in the otherwise smooth surface of the fetal brain, according to a 2000 study in the journal Radiology. As the third trimester begins in week 26, the grooves deepen and the brain begins to look more like that of a newborn.

Teen brains aren't fully formed

Parents of stubborn teenagers rejoice, or at least relax: That adolescent attitude stems, in part, from the vagaries of brain development.
The gray matter of the brain peaks just before puberty and is pruned back down throughout adolescence, with some of the most dramatic

development happening in the frontal lobes, the seat of judgment and decision-making.

A 2005 study published in the journal Child Development found that the parts of the brain responsible for multitasking don't fully mature until we're 16 or 17 years old. And research presented at the BA Festival of Science in 2006 revealed that teens also have a neural excuse for self-centeredness. When considering an action that would affect others, teens were less likely than adults to use the medial prefrontal cortex, an area associated with empathy and guilt. Teens learn empathy by practicing socializing, the researchers said. So much for grounding them until they're 20.

Brains never stop changing

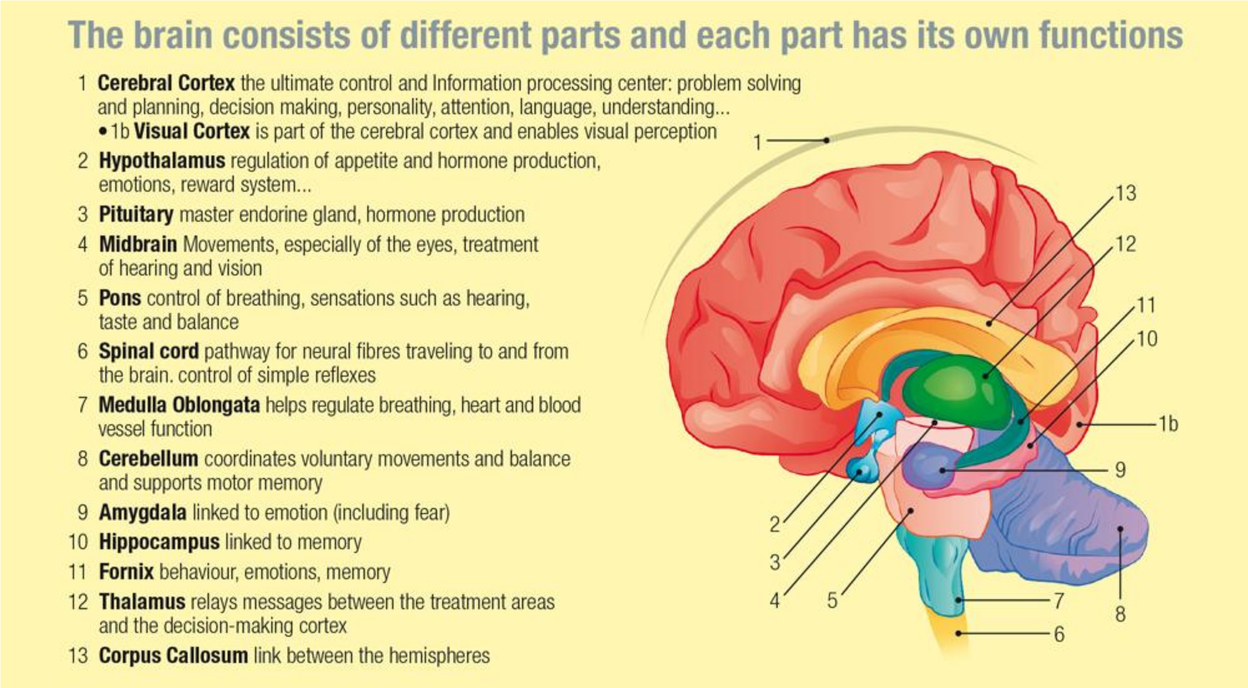
Scientific wisdom once held that once you hit adulthood, your brain lost all ability to form new neural connections. This ability, called plasticity, was thought to be confined to infancy and childhood.

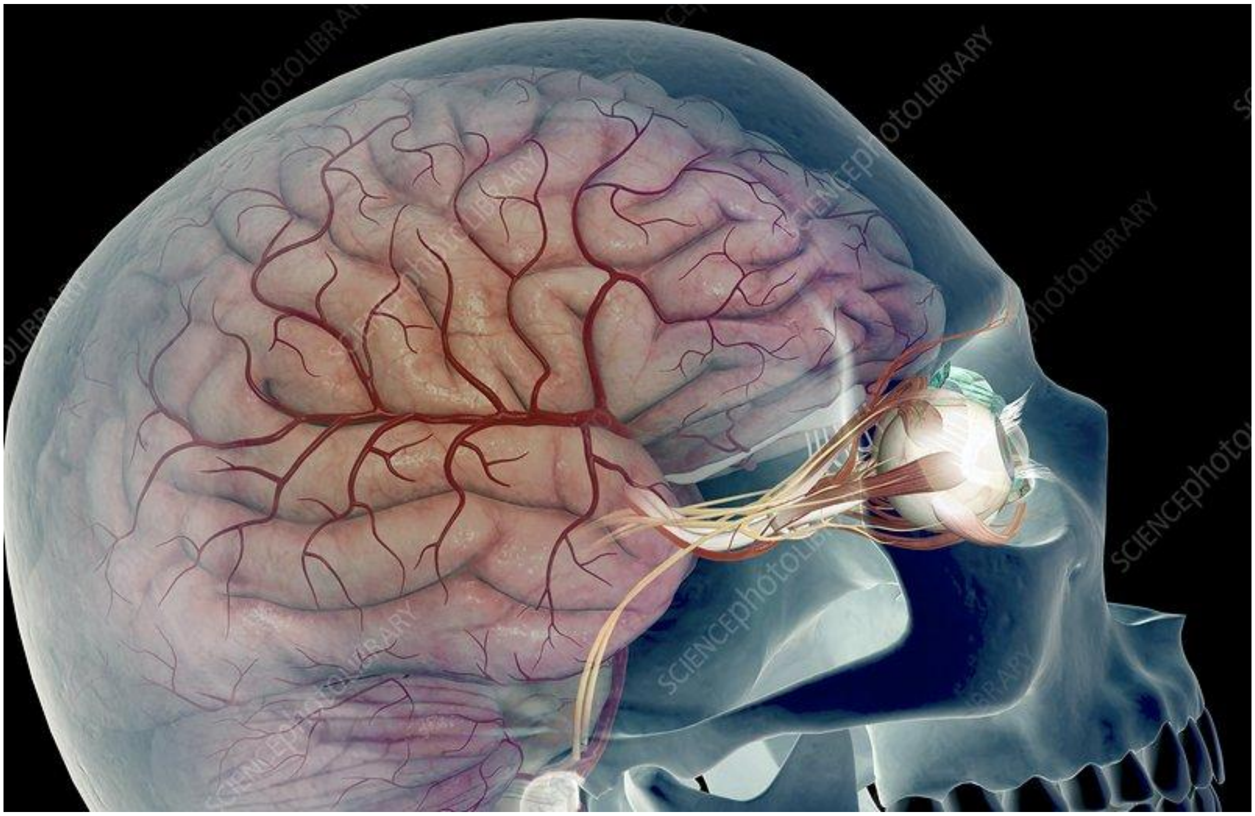
Wrong. A 2007 study on a stroke patient found that her brain had adapted to the damage to nerves carrying visual information by pulling similar information from other nerves. This followed several studies showing that adult mice could form new neurons. Later studies found more evidence of human neurons making new connections into adulthood; meanwhile, research on meditation showed that intense mental training can change both the structure and function of the brain.

Women aren't from Venus after all

Popular culture tells us that women and men's brains are just different. It's true that male and female hormones affect brain development differently, and imaging studies have found brain differences in the ways women and men feel pain, make social decisions and cope with stress. The extent to which these differences are genetic versus shaped by experience — the old nature-versus-nurture debate — is unknown.

But for the most part, male and female brains (and brainpower) are similar. A 2005 American Psychologist analysis of research on gender differences found that in 78 percent of gender differences reported in other studies, the effect of gender on the behavior was in the small or close-to-zero range. And recent studies have debunked myths about the genders' divergent abilities. A study published in the January 2010 Psychological Bulletin looked at almost half a million boys and girls from 69 countries and found no overall gap in math ability. Focusing on our differences may make for catchy book titles, but in neuroscience, nothing is ever that simple.





BOE Technology Group Co., Ltd is a leading company in the global semiconductor display industry and have a strong focus on innovative display solutions.

BOE Flexible AMOLED Display

Flexible display refers to the display technology designed for ultra-thin, ultra-light, and flexible products on the base of a flexible substrate.

mobile phone can be worn on the wrist, tablet computer can be folded into a small pocket, and TV can also be rolled up like a scroll.

Active matrix organic light-emitting diode (AMOLED) is an organic light-emitting display device mainly consisting of a substrate, a TFT-driven array and OLED light-emitting device (metal cathode + organic light-emitting layer + anode). It is an ultra-thin device with fast response time, wide view angle, and high contrast， which is suitable for flexible display technology. AMOLED, with polymer plastic or metal foil as its flexible substrate material, has a strong anti-bending capability and can realize dynamic bending display or even folding display. It has broad application prospects in smart phones, wearable devices, and automotive devices. Through persistent technical innovation, BOE has made great breakthroughs in several key technologies such as flexible AMOLED display. BOE has now successfully developed foldable display, wrist display, flexible display with double fixed edges and other flexible AMOLED products, presenting unlimited potential of the innovation of smart display devices.

As China’s first enterprise mastering flexible display technology, BOE has been actively building flexible AMOLED production lines in many regions, which will further enhance the global competitive power of China's display industry.

BOE Life Data Detection Technology

Life data detection is a technology that obtains the physiological information of human body by utilizing a special acquisition method, and evaluates the health conditions via data processing and analysis, which is mainly used for the detection of electrophysiological indexes (e.g. ECG, EEG, EMG, etc.), biochemical indexes (e.g. blood oxygen, blood glucose, etc.), image indexes (e.g. CT, PET, etc.), and other physiological indexes (e.g. body temperature, blood pressure, etc.), so as to comprehensively evaluate the health conditions of the user and provide a reliable basis for disease diagnosis and chronic disease management.

However, limited by the sensor technology and computing power of chips, the existing life data detection devices cannot completely satisfy users' demand for sport
health and chronic disease management due to such shortages as poor wearing ability of electrophysiological index detectors, impossibility of non-invasive detection of biochemical index detectors, and impossibility of continuous detection of physiological index detectors. Considering this, it is a major trend to transform life detection technologies from small to wearable, from invasive to non-invasive, and from random to continuous.

BOE integrates its years of experience in the four core technologies of display, sensor, AI, and big data with the medical and life science for cross-border innovation.
In the field of non-invasive vital sign detection device, BOE has launched MTX (noninvasive multi-parameter detector), with which, the patients can accurately measure and record 14 important physiological indexes such as blood pressure, oxyhemoglobin saturation, and hemoglobin within 1 minute by wearing MTX on the finger without blood sampling, so as to evaluate the user's health conditions based on the measurement results. In the field of continuous detection of life data, BOE has independently developed an undisturbed blood pressure measuring technology that is completely different from the traditional method of blood pressure measurement. It deduces the blood pressure by computing the transmission time with pulse signal and ECG signal without a cuff and air pump, and achieves wearable and continuous blood pressure monitoring.

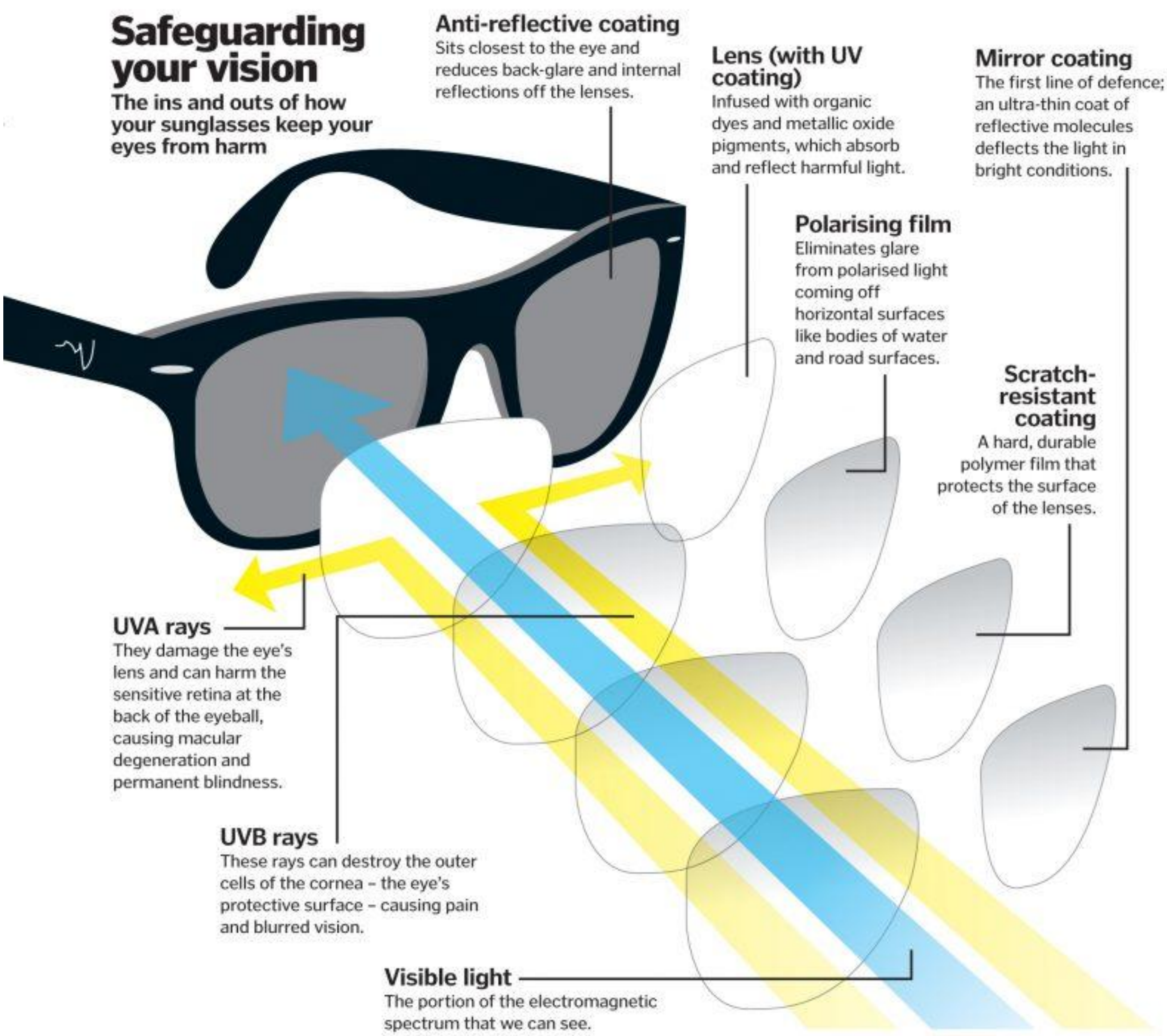
In the future, the company will continue to forge ahead in the field of life data detection, launch more high-end products and services, and make more contributions to the healthcare of human beings.

BOE ADSDS Ultra Hard Screen Technology

In the last century relatives and friends used to sit in front of a black-and-white TV to watch a program chosen from a very limited number of channels, which is now still
a nice and unforgettable memory about sharing. In BOE, we seek to bring this happiness to a higher level. As one of the world' s leading Ultra Hard screen technologies, the unique ADSDS (Advanced Super Dimension Switch) technology owned by BOE provides higher transmittance, brightness, and contrast ratio, as well as a visual angle of about 180° to present a vivid image effect. Meanwhile, the ADSDS panel is featured by low power consumption and environmental friendliness, and can be used as the screen of smart phones, tablet PCs, laptops, displays, and TVs.

As for the traditional TN/VA display mode, the liquid crystal molecules are vertically arranged, with a relatively narrow visual angle. When an external force is exerted on the screen, the liquid crystal molecular structure will obviously sink in a herringbone pattern, and the recovery is slow, a phenomenon called VA. There will be an evident "water ripple" when it is touched, which may affect the user' s experience. ADSDS technology is a general name for core technologies invented by BOE independently, which is represented by the wide-view-angle technology. In the ADSDS mode, the liquid crystal molecules are arranged horizontally, with a much wider visual angle. When an external force is exerted on screen, the liquid crystal molecular structure only sinks slightly, but the overall molecular structure remains horizontal, without producing any water ripple. In addition, BOE' s ADSDS technology effectively solves the problem of low light transmittance, and achieves high light transmittance with a wide visual angle.

Currently, a series of high-end display technologies developed by BOE based on the ADSDS Technology Platform have been successively applied to the whole series of TV products from HD to 8K UHD, and from 32inch to 110inch, and have contributed a lot to the perfect integration of high definition and low power consumption, bridging China's gap in large-sized high-end TFT-LCD display products and improving the competiveness of China's display industry in the field of high-end displays worldwide.



What Are Augmented Reality (AR) Contact Lenses?

AR contact lenses are smart contact lenses embedded with microelectronics that overlay digital information onto a user's real-world view.

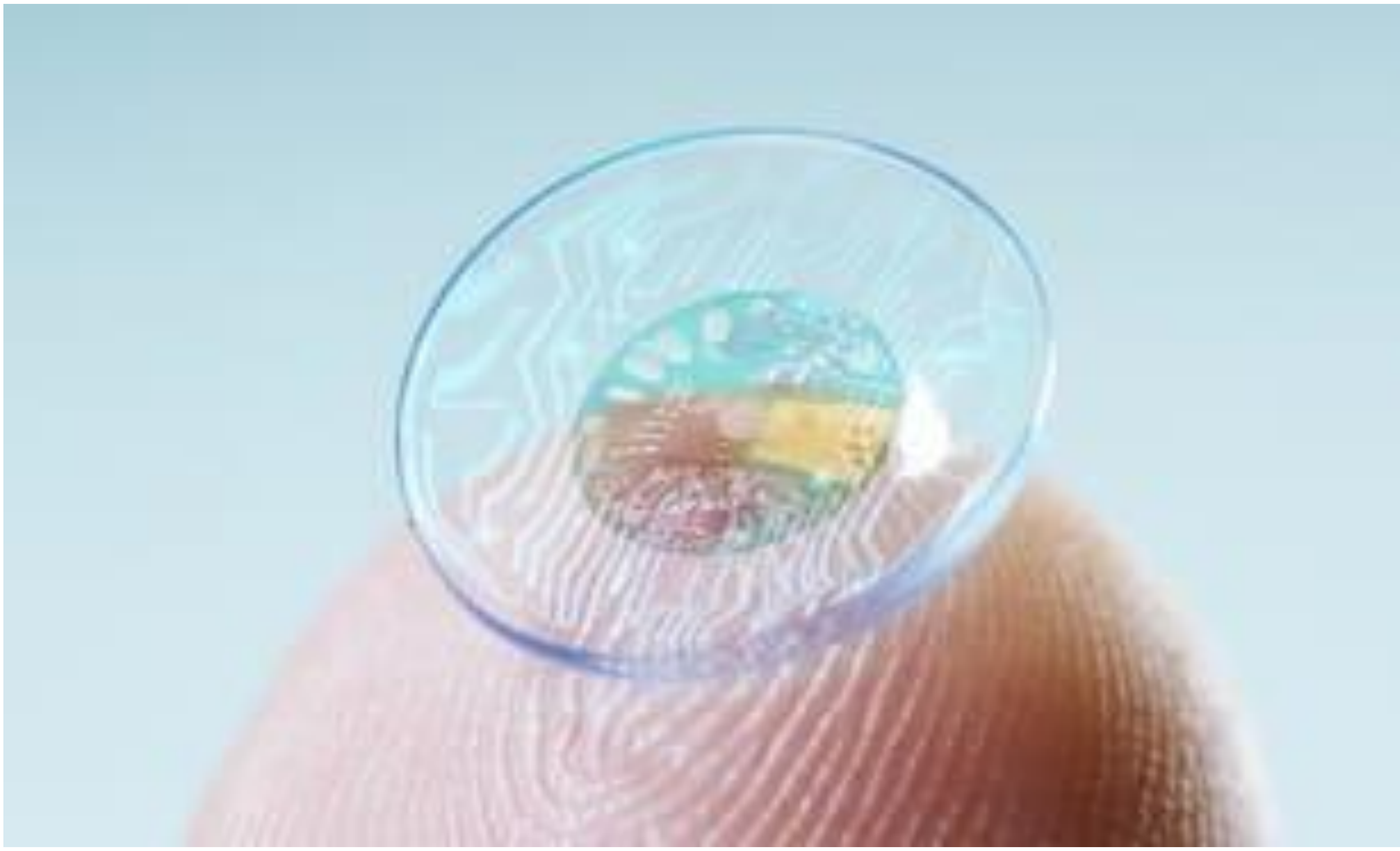


Image: Shutterstock

Does looking through a screen, rather than at one, still count as screen time?

AR contact lenses promise the immersiveness of augmented reality without having to wear a bulky headset or use your smartphone. These thin, curved lenses display digital information on top of your real-world view — and they're placed directly on the surface of your eye.

What Are Augmented Reality (AR) Contact Lenses?

Augmented reality contact lenses are wearable devices that overlay digital information onto a user's real-world view while applied directly to the eye. Like regular contact lenses, they're made out of hydrogels or silicone, but embedded with flexible microbatteries, tiny LED displays, microprocessors, sensors and wireless communication components.

Offering hands-free access to digital content in real-time, the idea is to project images, data or interactive elements directly onto a user's natural line of vision without obstructing it or disrupting social interaction. A user can control its interface with the flick of an eye or holding a prolonged glance thanks to built in eye-tracking technology.

Unlike bulky headsets and glasses that may have awkward and limited angles, smart contact lenses would provide a highly discreet and seamless AR experience with a natural field of view, including peripheral vision. Without the barriers posed by traditional AR devices, this innovation could revolutionize how users interact with digital information, impacting daily activities such as navigation and gaming while transforming workflows across a wide array of sectors, from medical and education to industrial and professional sports.

Do Augmented Reality Contact Lenses Exist?

Technically, yes. Prototypes of AR contact lenses exist, but none of them have made it out of the research lab.

The first prototype was developed by California-based startup Mojo Vision, which debuted the Mojo Lens in 2020. The project broke ground on smart lens technology, including preclinical testing and a live on-eye demonstration in 2022, but was indefinitely canceled the following year due to "significant challenges in raising capital."

Other AR contact lens and smart lens projects have emerged in its wake, many of which are geared toward medical applications. And while each new prototype brings AR contact lenses closer to consumer availability, reaching the mass market will require developers to successfully miniaturize electronics with sufficient battery life and display quality, in addition to undergoing rigorous clinical trials for regulatory clearance that ensures the product is biocompatible and ready for everyday use.

Examples of AR Contact Lenses

As augmented reality and virtual reality software, headsets and smart glasses establish a $40 billion market, stakeholders are eager to take part in the expanding space. So far, tech giants Sony, Google and Samsung have all filed for smart contact lens patents. But it's deep-tech startups that are leading the charge in AR-enabled and smart contact lens innovation. Consider the following projects that are establishing a proof of concept.

Mojo Vision's Mojo Lens

Mojo Vision's smart contacts, the Mojo Lens, was the first AR contact lens prototype. Now defunct, the device featured a 14,000 pixel-per-inch MicroLED display, eye-tracking and computer-vision image sensors and a micro-battery system. Measuring less than 0.5 millimeters in diameter, the smart contacts also included built-in, wireless radio communication antenna and a data-sorting ARM processor worn in a companion neck band device.

Innovega's eMacula system combines smart contact lenses with spectacles. | Video: eMacula

Innovega's eMacula System

Innovega is a smart AR/VR eyewear company developing a dual system that pairs disposable, daily smart contact lenses with high-tech glasses for those with moderate to severe visual impairments. In tandem, the "lens within a lens" picks up the images and media from the sunglasses display and projects them directly onto the eye, allowing a user to simultaneously view digital content transposed over the natural world. Innovega has filed over 80 patents, and is entering Phase III FDA clinical trials for its eMacula smart eyewear system.

InWith Corporation has made the first electronic soft contact lens capable of accessing AR. | Video: CNET

InWith Corporation's Soft Smart Lenses

InWith Corporation has the first claim to creating AR-enabled contact lenses of the soft variety. These lenses feature electronic circuits built directly into the hydrogel that are designed to work with a smartphone. The idea is that anything you can access on your smartphone would be cast directly into a user's line of vision, whether it be augmented or virtual reality. For those with a prescription to enhance sight, this feature would also be able to "tune" a user's vision for a sharper image.

XPANCEO's Smart Contact Lens Series

Dubai-based deep-tech company XPANCEO has developed a series of AR smart contact lenses, showcasing five different prototypes for various use cases. One uses its on-eye display to adjust lighting, contrast and enhance color perception for colorblind users. Another comes with optical verification tools that allows users to tackle digital tasks, such as making payments, transferring funds and gaining access to restricted areas, with intuitive gaze commands. Other features include night vision and zoom capabilities as well as app control.

Watch as Blink Energy's CTO tests their smart lens-powering eyelid patch. | Video: Vadoo AI

Blink Energy's BlinkIT Patch

Blink Energy developed BlinkIT, a device-agnostic patch that sits on the user's eyelid and is designed to wirelessly power and connect AR contact lenses, smart lenses and other smart ocular devices, like eye implants. Although this technology is not an AR-enabled lens itself, it makes the list for addressing one of the major pain points companies and startups are facing in the space — providing sufficient battery life within such a small footprint. External accessories like BlinkIT that accompany a smart lens could be the quickest way to actualizing autonomous ocular devices.

Azalea Vision's ALMA lens controls light exposure for users with light sensitivities. | Video: Andres Vasquez Quintero

Azalea Vision's ALMA Lens

Healthtech startup Azalea Vision developed a smart contact lens that offers a non-surgical option for users suffering from keratoconus, corneal irregularities, presbyopia and light sensitivities. While it's not specifically geared toward AR use, this device contains a microchip, micro battery, configurable light filter and radio frequency antennae and contributes to advances in on-eye electronic wearables.

In partnership with Novartis, Google set out to develop a smart contact lens in 2014 that could measure a user's glucose levels through their tears. Using tiny sensors, the device wirelessly transmitted data to an external source via RFID as a prick-free way for people with diabetes to monitor their blood sugar levels, generating a reading once per second. But the project shutdown in 2018 due to technical hurdles.

Sensimed Triggerfish Contact Lens Sensor

Swiss-based company Sensimed have developed a silicone soft contact lens, the Sensimed Triggerfish, that's designed to provide 24-hour glaucoma monitoring. Although the device doesn't have anything to do with augmented reality, its embedded sensors can track fluctuations in a user's intraocular pressure throughout the day, which may indicate a patient's risk factor for the chronic eye disease. In 2016, it became the first smart contact lens to receive FDA approval.

Challenges Creating AR Contact Lenses

As an emerging technology, AR contact lenses face a number of setbacks.

Working on the Nanoscale

Embedding electronics into a contact lens requires working on an extremely small scale with ultra-miniaturized components. This means that researchers have to figure out a way to embed tiny, wireless sensors and microbatteries into a thin, flexible material without interfering with the user's line of vision or blinking. Some aspects of creating a functioning AR contact lens rely on the entire nanotechnology field to advance and innovations that have yet to be discovered.

Biocompatibility

Any material used in an AR contact lens must be safe for prolonged exposure to the sensitive tissues of the eye. This means rethinking the typical build of electronic components. For example, making microLED displays and sensors without toxic metals and chemicals, batteries without lithium and processors without flame retardants. Figuring out a way to power these devices without overheating, losing connectivity, disturbing the eye's natural moisture and pH levels, triggering an allergic reaction or imposing on the user's line of sight prove to be significant challenges when working within the limited space of a contact lens.

Regulatory Approval

AR contact lenses are considered to be a medical device through the eyes of the FDA. Gaining regulatory clearance requires a product to pass a thorough, multi-step process — including preclinical research, animal testing and three clinical trial phases — that takes several years to complete, as its strict guidelines are designed to protect potential users. While no AR contact lenses have made it through the clinical trial stage, smart contact lenses with embedded electronics *have* achieved regulatory clearances: In 2016, Sensimed's Triggerfish device became the first smart contact lens to receive FDA approval.

Marketability

AR contacts have an obvious appeal to those who are visually impaired and other specified medical use cases, for sports enhancement, entertainment and technical training across sectors; however, a major disadvantage smart contact lenses have in comparison to AR glasses and headsets is that users may not actually be comfortable applying an electronically enhanced lens directly onto their eye. As beneficial as a smart contact lens may be for warehouse employees taking inventory or in-field construction workers, for example, it's unlikely that a company would be able to require its employees to wear AR contact lenses — limiting their viability to a certain degree.

Ethical Dilemmas

AR contact lenses pose several ethical dilemmas related to privacy, consent and information overload. If these devices are built with eye tracking technology, that means data is being collected in an extremely intimate way based on a user's behaviors as they glance around. This information could be used by companies to build a profile in order to generate targeted advertisements based on a user's interests and habits from information that wasn't necessarily gathered in a consensual way. Plus, there's something inherently dystopian about projecting ads directly onto a user's cornea. The advent of AR smart contact lenses also raises concerns about the device being used as a covert surveillance tool — of both the user and those in their line of sight — as well as a hazardous distraction, negatively impacting a person's ability to engage with the real world.

Contact lenses bring 3D holograms to life for augmented reality

A better way to fabricate metasurfaces allows scientists to create contact lenses capable of projecting 3D holographic images.

Scientists have developed contact lenses that project 3D holograms using specialized nanostructures embedded on them, known as metasurfaces. Metamaterials, in general, are engineered materials with properties not found in nature. A metasurface, as the name suggests, is a type of metamaterial simply applied to a surface. These structures are often smaller than the wavelengths of light, enabling them to manipulate electromagnetic waves, such as light and sound, in a unique way.

“[Metasurfaces] manipulate light […] with high precision,” explained the *Advanced Science* study’s author, Junsuk Rho at the Pohang University of Science and Technology in South Korea.

Why metasurfaces?

Metasurfaces have been useful in areas like biomedicine, speech recognition, and energy harvesting, but integrating them into contact lenses for virtual and augmented reality remains difficult. However, the potential they hold to surpass current technologies in significant ways makes them compelling.

“These augmented reality contact lenses [would] offer several significant advantages over existing technologies,” Rho explained. “Usually, there are gratings, prisms, or mirrors for delivering a virtual image from a display source located near the temple to the retina. At the same time, the light of the real-scene must be free from unwanted diffraction effects. Due to the complexity of these design requirements, the optical system is bulky.

“Because the lenses are worn directly on the eye, they preserve the natural field of view, providing an unparalleled level of immersion without the limitations imposed by external devices, like headsets or glasses.”

Outside of entertainment and gaming, there are boundless applications, from environmental monitoring, identity recognition, diagnosis, and real-time navigation, providing directions and contextual information directly in the user’s field of view.

“In settings, such as healthcare, the lenses could assist medical professionals by overlaying vital information during procedures,” Rho said. “Additionally, the lenses could serve personal health monitoring purposes, displaying real-time biometric data.”

But before any of this can come to fruition, barriers inherent in metasurface production need to be overcome. “First, ensuring the biocompatibility of the materials is critical, as contact lenses interact directly with the eye,” said Rho. “Traditional nanostructure transfer methods [for their production] often do not account for long-term biocompatibility, raising concerns about safety during extended wear.

“Second, maintaining structural stability is difficult due to the flexible and moist nature of contact lenses, which can lead to deformation or damage of the nanostructures. And finally, achieving precise pattern transfer on a flexible substrate like a contact lens is technically challenging.”

Producing metasurfaces for contacts

These hurdles only motivated Rho who has been working in this area since 2008. “I saw a news story about an ‘invisibility cloak’ being realized using metamaterials," he said. From there, his research has expanded to include reality displays.

He and his team were motivated to overcome challenges around embedding metamaterials into contacts by developing a new production method. Their approach relies on hyaluronic acid, a naturally occurring molecule found throughout the body, particularly in the eyes, joints, and skin.

"We use it as a soft mold that allows for the gentle transfer of complex nanostructures onto the lens surface without compromising the structural integrity of the metasurface," explained Rho. "It plays a crucial role in both the biocompatibility and functionality of the contact lenses."

Metasurfaces are usually created using advanced fabrication techniques like photolithography or electron beam exposure. These methods involve coating a surface with a light-sensitive material, exposing it to light or electrons through a mask, and developing the pattern.

After this, additional desired materials, like semiconductors for electronics, are deposited onto the patterned substrate and etched away to form the final nanostructures that are small enough to alter or shape electromagnetic radiation. Once the metasurface is complete, it is transferred from the temporary substrate to the final material, such as a contact lens.

In the current study, the team's fabrication process involved depositing gold onto a flexible, rubber-like material called polyurethane acrylate, which acts as the first mold for the fabricated surface. This 3D-patterned gold layer is then transferred from this initial mold to a second, hydrated hyaluronic acid film –for its final transfer onto the contact lens — that is then protected with a silicon capping layer.

"The SiO_2 capping layer, situated between the contact lens material and the gold patterns, prevents direct contact with the eye, thereby minimizing any potential risk of adverse effects," wrote the team in their paper.

The silicon layer also acts as a waveguide that directs electromagnetic waves from one point to another, not only enhancing the lens' stability, but overall performance.

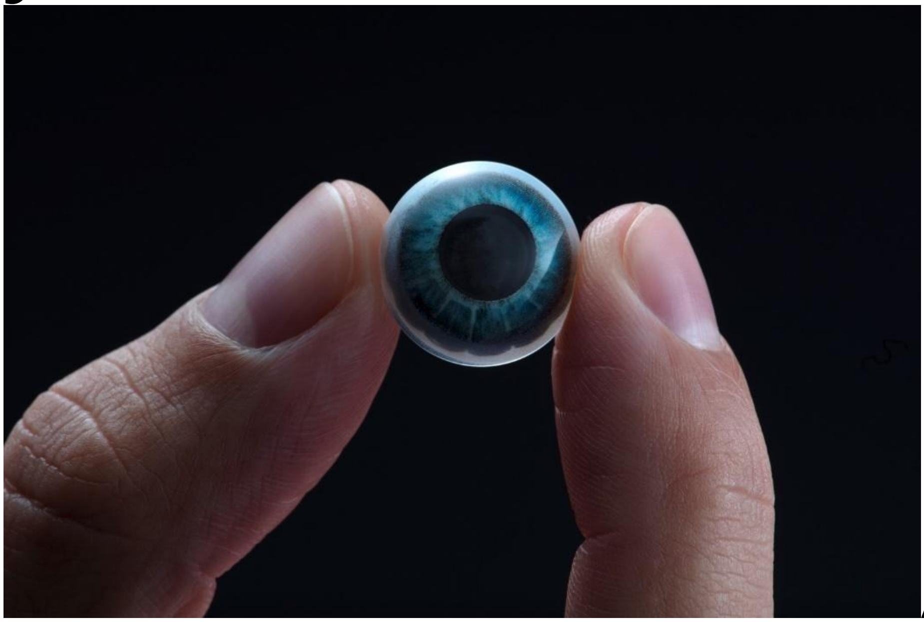
Static holograms are just the beginning…

Now comes the fun part: creating holograms using the metasurfaces embedded in the new lenses. When light hits the metasurface — this could be from a controlled light source from a wearable device or perhaps even sunlight — each tiny, carefully crafted component changes the light's intensity, angle, and direction to create the holographic image that you can see, explained Rho.

In this iteration of the technology, the images are static, but the team has plans to further develop this. Dynamic holographic videos could one day be generated by

embedding a metasurface designed to function as a diffuser, and light source such as micro-LED into the contact lens, Rho said.
Before any of this, safety needs to be thoroughly assessed and the technology developed further. “Next steps include extensive live testing to assess the long-term safety and performance of the lenses in real-world conditions,” said Rho. “Additionally, we plan to refine the manufacturing process to ensure scalability and cost-effectiveness for commercial production,” he continued. |Regulatory approvals will also be a critical step, as we will need to demonstrate compliance with safety standards for medical devices.”
Reference: Jun-Ho Jeong, Inkyu Park, Junsuk Rho, et al.,Metasurface-Embedded Contact Lenses for Holographic Light Projection, Advanced Science (2024). DOI: 10.1002/advs.202407045

The Future of Vision: Augmented reality contact lenses will make you bionic


Augmented reality contact lenses have been “around the corner” for years. They’re finally set to arrive. Mojo Vision

Tech for Change

This story is part of Tech for Change: an ongoing series in which we shine a spotlight on positive uses of technology, and showcase how they're helping to make the world a better place.

Today (-ish): Long a dream, smart contacts are here, Tomorrow: Is infrared vision in your future?

Technology is reshaping every aspect of our lives. Once a week in The Future of series, we examine innovations in important fields, from farming to transportation, and what they will mean in the years and decades to come.

A decade ago, Google's ambitions seemed unchecked: The company would design self-piloting cars through Waymo, sponsor moonbases, and even conquer death. One of the company's plans: Smart contact lenses to measure the glucose level of your tears — and perhaps help reduce the damage caused by diabetes. "It's still early days for this technology, but we've completed multiple clinical research studies, which are helping to refine our prototype," wrote Google's Brian Otis and Babak Parviz back in 2014.

Seven years later, the company's ego remains just as inflated, but Verily's smart contact lenses are nowhere to be seen; the side project of Google parent Alphabet was officially abandoned in 2018. Yet smart lenses are finally becoming a reality, thanks to the efforts of countless scientists and engineers. And the future of this intriguing technology is nothing like what you might expect.

- FDA approves augmented reality surgery tool that gives surgeons 'X-ray vision'

Today (-ish): Long a dream, smart contacts are here

There have been many efforts to advance contact lenses, of course. Acuvue sells Oasys with Transitions lenses that automatically darken in sunlight, like tiny sunglasses for your pupils, and researchers have been working for years on smart lenses that zoom on demand, measure chemical levels in your body, and administer drugs (notably antihistamines). But smart ones? They've never really made it to market.

InWith Corp. is about to change that. At CES 2021, the company unveiled a method to place augmented vision display chips into the soft hydrogel contact lenses that millions of people wear daily. Smart contact lenses! In early 2020, the company announced a partnership with Bausch + Lomb, showing flexible electronic circuitry embedded directly into lenses. No, you can't buy 'em yet. But they're clearly almost here — and not just from InWith.

"It's closer than you'd think, but it's not tomorrow," Steve Sinclair, senior vice president of product at Mojo Vision, told me. Mojo's the big competitor to InWith, and has been secretly engineering lenses embedded with an enormous array of proprietary technology, including a nearly invisible Micro LED display under half a millimeter in size (think a grain of sand), tiny inertial sensors such as accelerometers and gyroscopes, a super-efficient image sensor to gauge the world around you, adorably tiny batteries, and more.

PreviousNext
Mojo Vision's contact lenses promise to enhance our vision. Image used with permission by copyright holder
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Mojo Vision's contact lenses promise to enhance our vision. Image used with permission by copyright holder

Like InWith's lenses, Mojo's are "just around the corner," Sinclair told me. About a dozen people in his company have worn the latest prototypes, and a new model this summer promises even more advancements. What can you do with them? Augmented reality applications probably leap to your mind, at least they do for me: Direction overlays that guide you through unfamiliar city streets, information about the people and buildings you pass by, and so on. But the power of a display in your eye is nothing like what you might expect. Sinclair offers different use cases, things that give you your mojo back (hence the name of the company): The text of a big speech, notes for a presentation, a checklist for a major repair project, and so on.

One area that will be important is performance athletics: Today's runners have a world of metrics on their wrists, but who wants to navigate a menu while sprinting at top speed? Imagine the power of biometric data directly in your field of view.

And as for AR? Eh, we'll get there.

Meanwhile, smart lenses hold huge immediate promise for people with low vision — glaucoma, macular degeneration, and so on. Mojo's chips will be able to take in the scene before a person and in real time add edges to buildings, boost the contrast around signs and people, and help those with dim vision navigate the world around them. This could be a game changer — but it's just the beginning.

Tomorrow: Is infrared vision in your future?

Vision is a complex dance between your hardware (meaning your retina, lens, the tiny rods and cones tucked away in there, and so on) and your brain, which interprets the electrical impulses sent from your eyes and translates them into images. Your brain accommodates for flaws in your hardware, to some extent. In the future, it may not have to.

Smart lenses could some day correct for an imperfect lens, or even replace it entirely, fixing those electrical impulses before your brain receives them for interpretation. Smart lenses could also interject different data before your lenses, giving you super-binocular vision, or infrared vision. Heck, researchers have already scienced up supermice with infrared vision. Why not you? The potential powers you could receive with a fresh pair of contacts is limitless, once the tech is perfected.

"We're just on the very precipice of figuring out what some of those things are," Sinclair told me. "The sky's the limit on what we can do with the information and the platform we've built."

"It's like talking to Siri 15.0."

Peer further down the road, into the post-smartphone era, and lenses like this could replace our very eyes. Futurist Gary Bengier, a former Silicon Valley technologist, writer, and philosopher, envisions a world 140 years from now, where displays aren't just worn in contact lenses but are actually part of you, thanks to a chip inserted behind your ear and connected to a corneal implant. In his new book *Unfettered Journey*, he describes how artificial intelligence and mind-machine interfaces combine with retinal implants to essentially build Wikipedia directly into your body:

"He picked out the distinctive towers of an occasional fusion plant. Joe hadn't taken a long flight since grad school. The scene below him awakened his scientific curiosity. He let the keyword search fill his head, opening the NEST corneal connection, and images and words filled the viewer occupying the corner of his eye."

Wild stuff, right?

"You basically use this to connect to the cloud, the net, whatever. It's like talking to Siri 15.0," Bengier told me recently. In the not-too-distant future, he believes, smarter artificial intelligence will combine with data about where you are and sensors that pick up on your every whim. You'll be able to simply think about pizza and you'll see a little map on your cornea showing where you can buy one.

Now *that's* a vision for vision.

Huge milestone as human subject wears augmented reality contact lens for first time

For the very first time, an AR contact lens was worn on the eye of a human subject. And it has about 30 times the pixel density of an iPhone.

KEY TAKEAWAYS

- For the very first time, an augmented reality (AR) contact lens was worn on the eye of a human subject.
- AR contact lenses pose wildly difficult engineering challenges, the biggest of which is finding a way to provide these tiny devices with power. A company called Mojo Vision has done that.
- One day, we will look back at the years when people walked down the street, necks bent, staring down at little screens in their hands as an absurdly primitive way to interact with information.

Three decades ago, the first group of human subjects interacted with a mixed reality of real and virtual objects. They did this by climbing into a large upper-body exoskeleton, pressing their face to a vision system hanging from the ceiling, and manually performing tasks that required them to engage both physical and simulated objects. They were testing a prototype augmented reality system at Air Force Research Laboratory (AFRL) known as the Virtual Fixtures platform. The hardware filled half a room and cost nearly $1M, but it worked — showing for the first time that AR could boost human performance in real-world tasks.

Last week, an important new milestone was achieved in the field of AR, and it highlights how far the technology has come over the last 30 years: the first authentic test of an augmented reality contact lens. It was conducted in a research lab at Mojo Vision in Saratoga, California. No, it wasn't a crude bench test of oversized hardware with wires dangling. This was a genuine test of an AR contact lens worn directly on the eye of a human subject for the very first time.

A wildly difficult engineering challenge

As someone who has been involved in AR from the early days, I need to highlight the importance of this new milestone. Building a wearable augmented reality contact lens is a wildly difficult engineering challenge. When I say this, people usually ask about the display technology. Sure, the ability to put a high resolution display on a tiny transparent lens is difficult, but it's not the most challenging piece of the puzzle. The harder issue is that this tiny lens, which needs to sit comfortably on the human eye, has to communicate wirelessly with external devices and be fully powered without a physical tether of any kind. That is a daunting task, and yet it is what Mojo Vision achieved in their latest demonstration.

We will look back at the years when people walked down the street, necks bent, staring down at little screens in their hands as an absurdly primitive way to interact with information.

Louis Rosenberg

According to Mojo Vision, the prototype lens includes medical grade micro-batteries. It's unclear what the battery life is for the current prototype, but according to the company, their product goal is power management that enables all-day wear.

Of course, their display technology is impressive too. According to the company, the Mojo Lens has a 14,000 pixel-per-inch MicroLED display with a pixel pitch (the distance between adjacent pixels) of 1.8 microns. For context, an iPhone 13 with a Super Retina XDR Display has 460 pixels per inch resolution. In other words, the Mojo Lens hardware has about 30 times the pixel density of a current iPhone. In addition, these lenses include an ARM processor with a 5GHz radio transmitter, along with an accelerometer, gyroscope, and magnetometer to track eye movements. And all of this sits directly on the human eye.

AR contact lenses are the future

Still, many years of development will be required to get from today's prototypes to mass market consumer products that bring immersive AR capabilities to people around the world. I predict that AR eyewear, first as glasses and then as contacts, will eventually replace the mobile phone as our primary interface with digital content. Further, I believe augmented reality will completely change our relationship with information, transforming digital content from discrete artifacts we selectively access into seamless features of our physical world.

A few years ago, I wrote a futurist piece entitled "Metaverse 2030" that portrays what life will be like when AR contacts become commonplace — a world where mainstream consumers get fitted for new contacts whenever they sign up for a mobile subscription. When that day comes, we will look back at the years when people walked down the street, necks bent, staring down at little screens in their hands as an absurdly primitive way to interact with information. Will this happen in the next decade? Only time will tell, but the achievement from Mojo Vision takes us a large step closer.

Apple is crashing the smart glasses party, but Meta's Orion will be a tough act to follow

Apple is crashing the smart glasses party, but Meta's Orion will be a tough act to follow© Apple

Apple's Vision Products Group, the brilliant minds behind the ultra-deluxe Vision Pro, are reportedly working on several new VR/AR/Mixed reality projects, including a part of smart glasses that may arrive by 2027.

Following this year's Meta Connect event, smart glasses are the talk of the town (in no small part thanks to Meta's Orion frames) and even VR and AR are receiving some notable attention in the build-up to tomorrow's Meta Quest 3S release.

To that end, it's no surprise that Apple would put pedal to metal on its own projects — especially as Meta's holographic smart glasses aren't expected to face a consumer release until we near the end of the decade.

From Vision Pro fumble, to ready to rumble

According to *Bloomberg*'s Mark Gurman, Apple likely has four major projects in the works within its Vision Products Group: a lower-end Vision Pro, a second-generation Vision Pro, camera-touting AirPods, and a pair of high-tech glasses to go up against the Ray-Ban Meta smart glasses.

Sidestepping Apple's new Vision Pro models — which are no doubt destined to fall into the same price-tag punji pit that both the original Vision Pro and Meta Quest Pro fell into — Apple's smart glasses may have the most potential to perform, especially against Meta's smart glasses lineup. Apple will be late to the party on this one, but that's not to say it won't turn heads when entering.

As long as it shows up before Meta CEO Mark Zuckerberg sweeps everyone away to the private Orion after-party, anyway.

Apple: Late to the race, but often in first place

Apple has a long-standing tradition of showing up late to the party yet being credited for its inception — a feat they've managed to repeat ever since the iPod hit store shelves in 2001.

At the time, CEO Steve Jobs claimed that the iPod was a "Quantum leap" for portable MP3 players. If you forgot about the Nomad Jukebox offering the same features with more storage and a lower price tag, anyway.

Still, fittingly, there's no room for the Nomad in the history books, leaving its existence but a roaming memory in the minds of bitter tech fans like myself.

Being first through the door matters little when you have an adoring fanbase like Apple's behind you just waiting for the opportunity to blindly sacrifice their paychecks in lock-step unison at the altar of "different thinking."

This is something Apple may be able to bank on when going toe-to-toe with Meta in the smart glasses realm, especially as the next few generations of smart glasses become more advanced and more expensive, and Apple's history of delivering deluxe falls in their favor.

Outlook

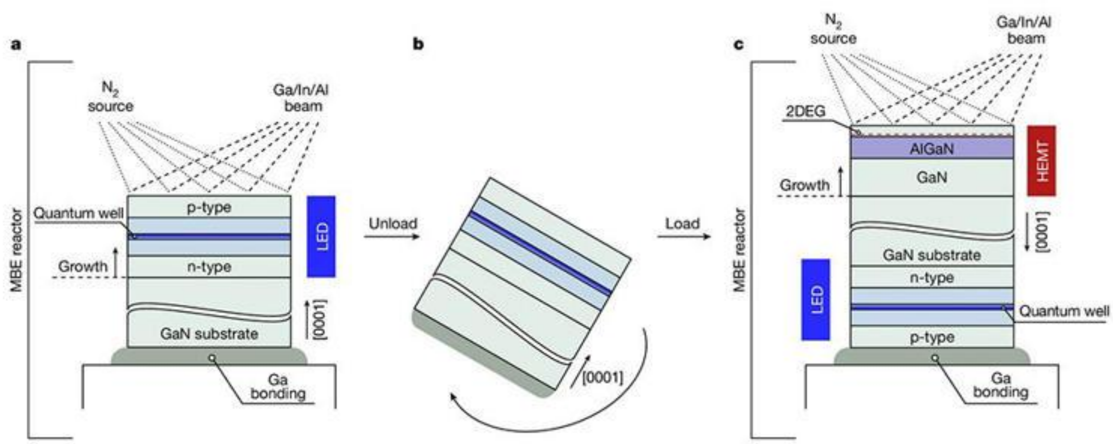
Reportedly targeting a 2027 release, Apple smart glasses still have plenty of time to brew. However, when they do arrive it's unlikely that these will be the glasses to tackle Meta's Orion holographic glasses. Industry insiders claim that Apple's response to those hyper-advanced frames is likely five years off at least, placing them in the same end-of-the-decade release window as Meta.

In the meantime, we expect to see Meta release its third-generation smart glasses next year, the first to feature a heads-up display for visual feedback. These glasses will likely be paired with the company's neural wristband for control, which may find itself repurposed as a smartwatch.

With that in mind, if Apple is seeking to compete with Meta's glasses directly, we'd assume that the company's frames will offer similar features.

We've already seen the Apple Watch make use of gestures like double tap, and the device could be tweaked to capture more gestures in later models to better pair with the visual element of future smart glasses while strengthening the walls of Apple's tightly-knit eco-system.

Only 'limited by your imagination': Gallium Nitride breakthrough could make LED displays more affordable and convert your smartphone screen into an antenna



Only 'limited by your imagination': Gallium Nitride breakthrough could make LED displays more affordable and convert your smartphone screen into an antenna© Nature

Researchers at Cornell University, in collaboration with the Polish Academy of Sciences, have made a major breakthrough in semiconductor technology by developing the first-ever dual-sided chip - referred to as a "dualtronic" chip - that integrates both photonic and electronic devices on a single Gallium Nitride (GaN) wafer.

This innovation could shrink device sizes, improve energy efficiency, and reduce manufacturing costs.

The GaN wafer's unique crystal structure is key to its dual functionality. Each side of the wafer has different properties, similar to how the poles of a magnet differ. The team utilized the metal-polar (Ga-polar) side to create light-emitting diodes (LEDs) and the nitrogen-polar (N-polar) side to construct high-electron mobility transistors (HEMTs). By doing so, they were able to achieve a configuration where the HEMT on one side powers the LED on the other - an accomplishment never before realized in any semiconductor material.

Limited only by the imagination

The research, led by Cornell professors Debdeep Jena and Huili Grace Xing, along with co-lead authors Len van Deurzen and Eungkyun Kim, has been published in the *Nature* journal.

"To our knowledge, nobody has made active devices on both sides, not even for silicon," noted co-lead author Len van Deurzen, emphasizing how this feat was possible only because of GaN's polarity-dependent properties. Traditional silicon wafers are cubic, making both sides nearly identical, which prevents such a design.

According to the researchers, this dualtronic approach could have immediate applications in making microLED displays more affordable and energy-efficient. By integrating photonic and electronic functions into a single chip, fewer components would be needed, leading to lower production costs and a smaller device footprint. This advancement could significantly impact display manufacturing, potentially making LED displays cheaper and more compact.

The technology's potential goes even further. With the ability to use the same wafer for different functions, dualtronics could enable smartphone screens to be repurposed as antennas, supporting wireless communications directly through the display. The polarization properties of GaN and the dualtronic chip's multifunctionality could transform not only displays but also radio frequency devices, lasers, and future 5G/6G technologies.

“A good analogy is the iPhone,” explained Debdeep Jena. “It is, of course, a phone, but it is so many other things. It’s a calculator, it’s a map, it lets you check the internet. So there’s a bit of a convergence aspect of it. I would say our first demonstration of ‘dualtronics’ in this paper is convergence of maybe two or three functionalities, but really it’s bigger than that.”

This breakthrough could reshape how semiconductor devices are designed and utilized. By eliminating the need for separate chips to handle different functions, dualtronics promises to optimize both performance and resource utilization across a variety of technologies. As the researchers point out, this development marks a significant step forward, and the potential applications are "limited only by the imagination."

Microsoft Co-Founder Bill Gates Says Everyone In Future Will Have A 'Utilitarian AI Agent' That Will Help You At Work

Microsoft co–founder Bill Gates has shared his insights on the future of workplace efficiency, emphasizing the transformative role of AI agents. In a conversation with Reid Hoffman and Aria Finger during Wednesday’s episode of “Possible” podcast, Gates highlighted that AI will drastically change task execution.

What Happened

Gates elaborated on AI’s potential to handle complex tasks, particularly in white-collar sectors, surpassing initial expectations. He noted the surprising sequence in which AI has affected job types, with the automation of white-collar tasks preceding that of blue-collar ones. Gates foresees AI robots performing tasks at construction sites and hotels within a decade.

Reflecting on his original vision of a PC on every desk, Gates predicted that AI would extend this concept. He envisions natural language becoming the primary programming language, enabling everyone to have a coding assistant. This shift will allow for more efficient data navigation and business operations without needing custom software.

New memory chip controlled by light and magnets could one day make AI computing less power-hungry

New memory chip controlled by light and magnets could one day make AI computing less power-hungry© Brian Long, UCSB

Researchers have developed a new type of memory cell that can both store information and do high-speed, high-efficiency calculations.

The memory cell enables users to run high-speed computations inside the memory array, researchers reported Oct. 23 in the journal Nature Photonics. The faster processing speeds and low energy consumption could help scale up data centers for artificial intelligence (AI) systems.

"There's a lot of power and a lot of energy being put into scaling up data centers or computing farms that have thousands of GPUs [graphics processing units] that are running simultaneously," study co-author Nathan Youngblood, an electrical and computer engineer at the University of Pittsburgh, told Live Science. "And the solution hasn't necessarily been to make things more efficient. It's just been to buy more and more GPUs and spend more and more power. So if optics can address some of the same problems and do it more efficiently and faster, that would hopefully result in reduced power consumption and higher throughput machine learning systems."

The new cell uses magnetic fields to direct an incoming light signal either clockwise or counterclockwise through a ring-shaped resonator, a component that intensifies light of certain wavelengths, and into one of two output ports. Depending on the intensity of light at each of the output ports, the memory cell can encode a number between zero and one, or between zero and minus one. Unlike traditional memory cells, which only encode values of zero or one in one bit of information, the new cell can encode several non-integer values, allowing it to store up to 3.5 bits per cell.

Those counterclockwise and clockwise light signals are akin to " two runners on a track that are running in opposite directions around the track, and the wind is always in the face of one and to the back of the other. One can go faster than the other," Youngblood said.. "You're comparing the speed at which those two runners are running around the track, and that allows you to basically code both positive and negative numbers."

The numbers that result from this race around the ring resonator could be used to either strengthen or weaken connections between nodes in artificial neural networks, which are machine learning algorithms that process data in ways similar to the human brain. That could help the neural network identify objects in an image, for example, Youngblood said.

Unlike traditional computers, which make calculations in a central processing unit then send results to memory, the new memory cells perform high-speed computations inside the memory array itself. In-memory computing is particularly useful for applications like artificial intelligence that need to process a lot of data very quickly, Youngblood said.

The researchers also demonstrated the endurance of the magneto-optic cells. They ran more than 2 billion write and erase cycles on the cells without observing any degradation in performance, which is a 1,000-fold improvement over past photonic memory technologies, the researchers wrote.Typical flash drives are limited to between 10,000 and 100,000 write and erase cycles, Youngblood said.

In the future, Youngblood and his colleagues hope to put multiple cells onto a computer chip and try more advanced computations.

Eventually, this technology could help mitigate the amount of power needed to run artificial intelligence systems, Youngblood said.

'A mobile phone as thin as a credit card': How massless batteries, similar to the human skeleton, could give rise to the world's strongest power cell and change the future of our society forever

R esearchers at Chalmers University of Technology in Sweden have made significant strides in developing a structural battery that could drastically reduce the weight and energy consumption of vehicles and electronic devices.

The structural battery, made from a carbon fiber composite, functions as both a power source and a load-bearing component, making it ideal for a range of purposes. "We have succeeded in creating a battery made of carbon fiber composite that is as stiff as aluminum and energy-dense enough to be used commercially. Just like a human skeleton, the battery has several functions at the same time," said Richa Chaudhary, lead author of a paper recently published in *Advanced Materials*.

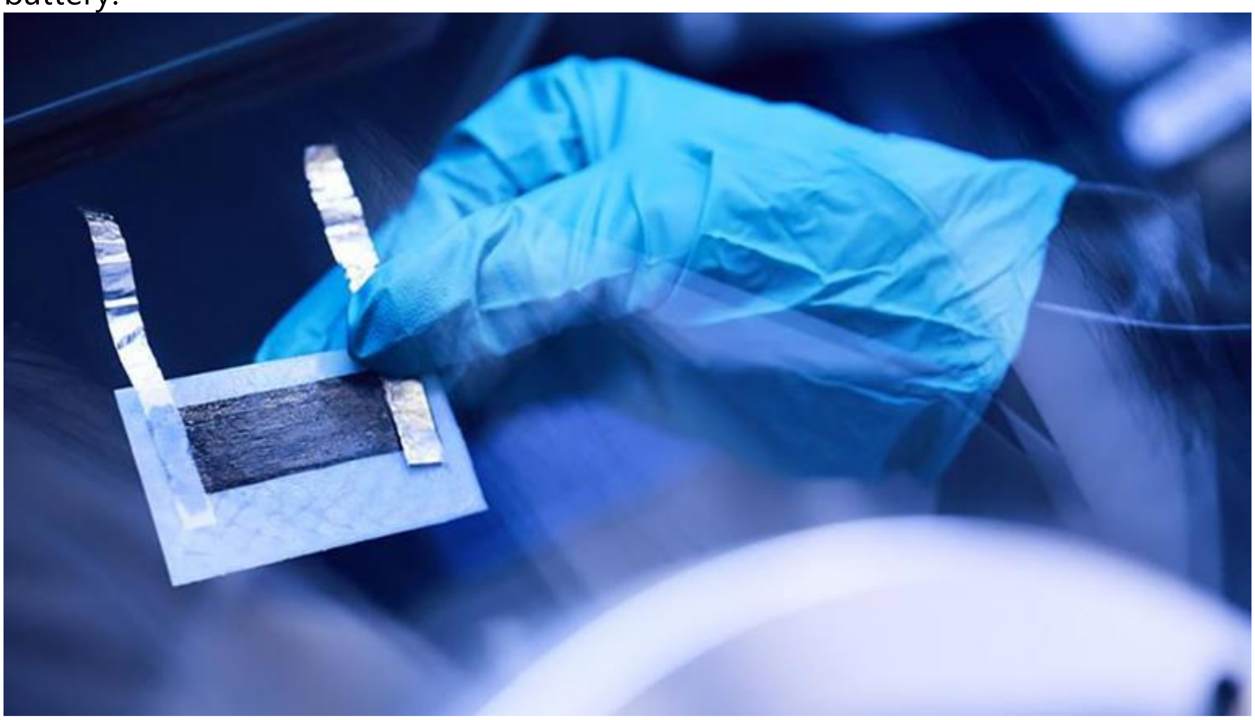
The battery offers an energy density of 30 watt-hours per kilogram (Wh/kg), which is lower than standard lithium-ion batteries but allows for a significant reduction in overall weight.

A huge boost for electric cars

Professor Leif Asp, who leads the research, explained that electric cars using this battery could see a huge boost in driving range. "Investing in light and energy-efficient vehicles is a matter of course if we are to economize on energy and think about future generations," said Asp. "We have made calculations on electric cars that show they could drive for up to 70 percent longer than today if they had competitive structural batteries."

The structural battery also has improved stiffness, now reaching 70 gigapascals (GPa), allowing it to carry loads as effectively as aluminum while being much lighter. Asp stated, "In terms of multifunctional properties, the new battery is twice as good as its predecessor – and actually the best ever made in the world."

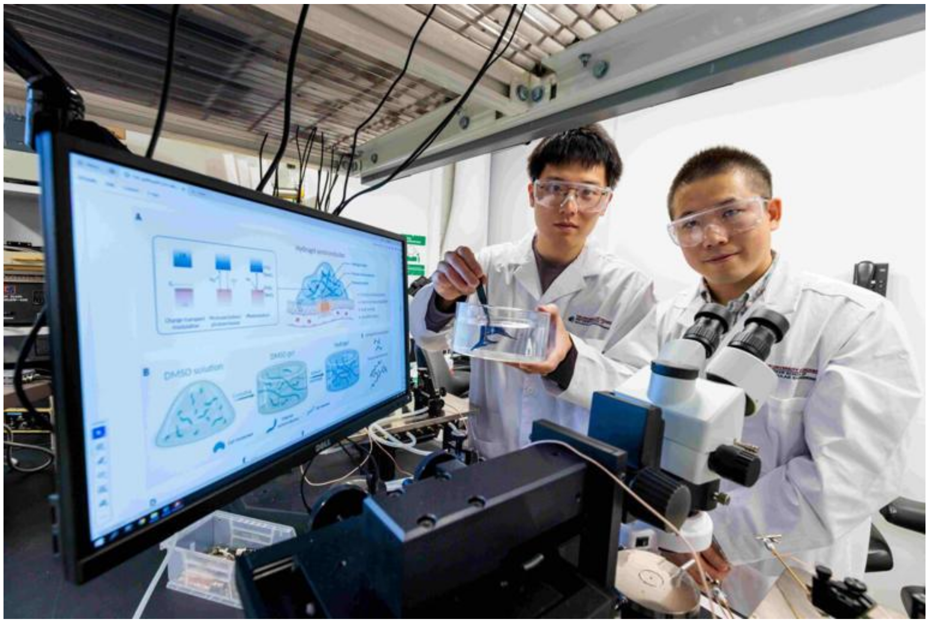
Although the technology is still under development, Sinonus AB, a spin-off from Chalmers Ventures, is working to bring this innovation to the market. Asp envisions that lightweight laptops, mobile phones, and electric vehicle components will be among the first products to benefit from the structural battery.



New hydrogel semiconductor could lead to better tissue-interfaced bioelectronics

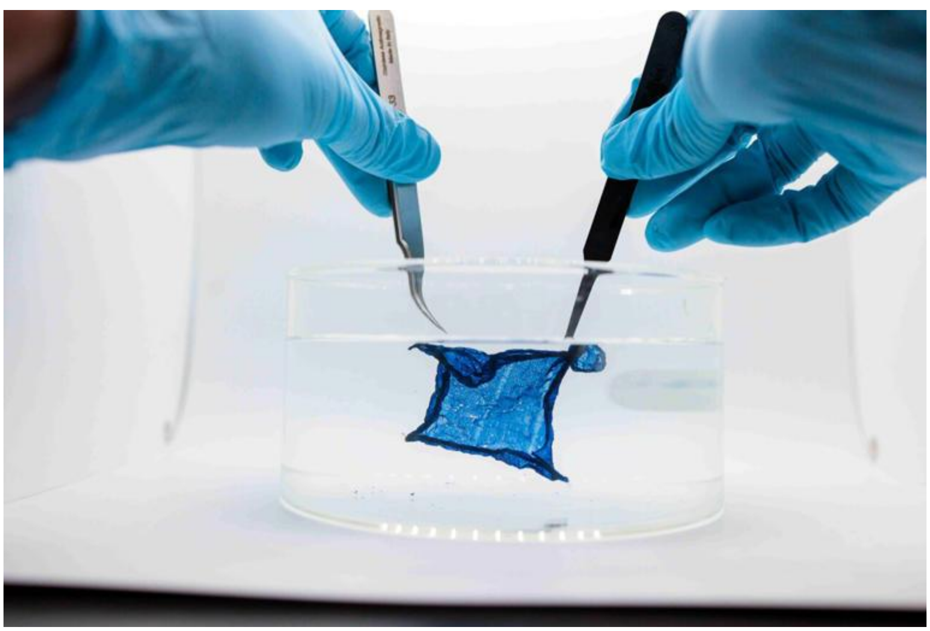
Researchers in the lab of UChicago Pritzker School of Molecular Engineering Asst. Prof. Sihong Wang have developed a hydrogel that retains the semiconductive ability needed to transmit information between living tissue and machine, which can be used both in implantable medical devices and non-surgical applications. Credit: UChicago Pritzker School of Molecular Engineering / John Zich

The ideal material for interfacing electronics with living tissue is soft, stretchable, and just as water-loving as the tissue itself—in short, a hydrogel. Semiconductors, the key materials for bioelectronics such as pacemakers, biosensors, and drug delivery devices, on the other hand, are rigid, brittle, and water-hating, impossible to dissolve in the way hydrogels have traditionally been built.



UChicago Pritzker School of Molecular Engineering Asst. Prof. Sihong Wang (right) and Ph.D. student Yahao Dai, first author of the new paper, with the newly developed hydrogel semiconductor. Credit: UChicago Pritzker School of Molecular Engineering / John Zich

A paper published today in *Science* from the UChicago Pritzker School of Molecular Engineering (PME) has solved this challenge that has long stymied researchers, reimagining the process of creating hydrogels to build a powerful semiconductor in hydrogel form. Led by Asst. Prof. Sihong Wang's research group, the result is a bluish gel that flutters like a sea jelly in water but retains the immense semiconductive ability needed to transmit information between living tissue and machine.



Researchers in the lab of UChicago Pritzker School of Molecular Engineering Asst. Prof. Sihong Wang have developed a hydrogel that retains the semiconductive ability needed to transmit information between living tissue and machine, which can be used both in implantable medical devices and non-surgical applications. Credit: UChicago Pritzker School of Molecular Engineering / John Zich

The material demonstrated tissue-level moduli as soft as 81 kPa, stretchability of 150% strain, and charge-carrier mobility up to 1.4 $cm^2 V^{-1} s^{-1}$. This means their material—both semiconductor and hydrogel at the same time—ticks all the boxes for an ideal bioelectronic interface.

"When making implantable bioelectronic devices, one challenge you must address is to make a device with tissue-like mechanical properties," said Yahao Dai, the first author of the new paper. "That way, when it gets directly interfaced with the tissue, they can deform together and also form a very intimate bio-interface."

Although the paper mainly focused on the challenges facing implanted medical devices such as biochemical sensors and pacemakers, Dai said the material also has many potential non-surgical applications, like better readings off the skin or improved care for wounds.

"It has very soft mechanical properties and a large degree of hydration similar to living tissue," said UChicago PME Asst. Prof. Sihong Wang. "Hydrogel is also very porous, so it allows the efficient diffusion transport of different kinds of nutrition and chemicals. All these traits combine to make hydrogel probably the most useful material for tissue engineering and drug delivery."

'Let's change our perspective'

The typical way of making a hydrogel is to take a material, dissolve it in water, and add the gelation chemicals to puff the new liquid into a gel form. Some materials simply dissolve in water, others require researchers to tinker and chemically modify the process, but the core mechanism is the same: No water, no hydrogel.

Semiconductors, however, don't normally dissolve in water. Rather than find new, time-consuming means of trying to force the process, the UChicago PME team re-examined the question.

"We started to think, 'Okay, let's change our perspective,' and we came up with a solvent exchange process," Dai said.

Instead of dissolving the semiconductors in water, they dissolved them in an organic solvent that is miscible with water. They then prepared a gel from the dissolved semiconductors and hydrogel precursors. Their gel initially was an organogel, not a hydrogel.

"To eventually turn it into a hydrogel, we then immersed the whole material system into the water to let the organic solvent dissolve out and let the water come in," Dai said.

An important benefit of such a solvent-exchange-based method is its broad applicability to different types of polymer semiconductors with different functions.

'One plus one is greater than two'

The hydrogel semiconductor, which the team has patented and is commercializing through UChicago's Polsky Center for Entrepreneurship and Innovation, is not merging a semiconductor with a hydrogel. It's one material that is both semiconductor and hydrogel at the same time.

"It's just one piece that has both semiconducting properties and hydrogel design, meaning that this whole piece is just like any other hydrogel," Wang said.

Unlike any other hydrogel, however, the new material actually improved biological functions in two areas, creating better results than either hydrogel or semiconductor could accomplish on their own.

First, having a very soft material bond directly with tissue reduces the immune responses and inflammation typically triggered when a medical device is implanted.

Second, because hydrogels are so porous, the new material enables elevated biosensing response and stronger photo-modulation effects. With biomolecules being able to diffuse into the film to have volumetric interactions, the interaction sites for biomarkers-under-detection are significantly increased, which gives rise to higher sensitivity. Besides sensing, the responses to light for therapeutic functions at tissue surfaces also get increased from the more efficient transport of redox-active species. This benefits functions such as light-operated pacemakers or wound dressing that can be more efficiently heated with a flick of light to help speed healing.

"It's a 'one plus one is greater than two' kind of combination," Wang joked.

More information: Yahao Dai et al, Ultrasoft hydrogel semiconductors with augmented biointeractive functions, *Science* (2024). DOI: 10.1126/science.adp9314. www.science.org/doi/10.1126/science.adp9314

Provided by University of Chicago

Virginia Tech's breakthrough in flexible electronics tech

Scientists from Virginia Tech have developed a method for manufacturing flexible electronics. This technology can significantly impact the development of soft robots, interesting gadgets, and wearable electronics.

Virginia Polytechnic Institute and State University researchers presented their findings in the journal "Nature Electronics." They introduced an innovative approach to creating flexible printed circuit boards. Their method allows for efficient current flow between system layers without drilling holes, which is crucial for the miniaturization and flexibility of future electronics. Although commercial applications are still far off, this marks a new direction in developing flexible electronics.
The new technique relies on using liquid metal microparticles to create a stair-like structure. This architecture forms small, conductive connections both within and between circuit layers. The process involves the targeted placement of liquid metal droplets in a photosensitive resin, which is then illuminated with UV rays. This method remains versatile and can be adapted to various materials.

Soft electronics

"This brings us closer to exciting possibilities like advanced soft robotics, wearable devices, and electronics that can stretch, bend, and twist while **maintaining high functionality**," says project leader Prof. Michael Bartlett.

The research team harnessed typically undesirable effects that appear when working with UV-cured materials, known as mask edge anomalies. They turned this problem into an advantage—the edges of UV-exposed areas cause the liquid metal droplets to settle and layer up in a stair-like pattern.

"By leveraging these otherwise unwanted edge effects, we can create soft, conductive vias that connect different circuit layers in a rapid and parallel fashion. We can do this all while maintaining flexibility and mechanical integrity of the soft device," explains the lead author of the publication, Dr. Dong Hae Ho.

Integrating connections both within and between layers enables the creation of soft, flexible circuits with a complex, multilayered architecture.

"This enables new forms of soft electronics, where multiple soft vias and interconnects are created in a parallel and spatially controlled manner. This is crucial for advancing the field," emphasizes Prof. Bartlett.

Flexible electronics may, for instance, offer a new approach to creating smartphones. Currently, manufacturers are focusing on foldable smartphones. In the future, they may consider using rollable screens. The first attempts have already been made with devices like the Motorola Rizr.

Korean breakthrough: Ultra-thin film absorbs 99% of EM waves

The material developed in Korea can absorb up to 99% of electromagnetic waves. A thin film with a thickness of just 0.02 inches is sufficient. Until now, screens have only absorbed about 10% of the radiation.


Base station (illustrative photo)

A research team from the Korea Institute of Materials Science (KIMS) has created an innovative material that, in the form of a thin film just 0.02 inches thick, absorbs up to 99% of electromagnetic waves. This solution can significantly help eliminate interference generated by such waves. The development represents a significant breakthrough compared to existing shielding materials, which have only allowed the absorption of about 10% of the radiation.

The new material can absorb electromagnetic waves over a wide range of frequencies, including those used in 5G, 6G technologies, and Wi-Fi networks. This feature is crucial in environments filled with sources of such waves. Proper shielding can eliminate interference, which can negatively affect the performance of nearby devices.

Absorption of electromagnetic waves

Traditional electromagnetic shielding materials often reflect over 90% of waves, meaning the actual absorption is minimal, around 10%. Additionally, materials with higher absorption typically only work in a narrow range of frequencies, limiting their versatility. According to reports, the invention by scientists at KIMS does not have these limitations. Its significant advantages include high effectiveness while maintaining minimal thickness and appropriate flexibility.

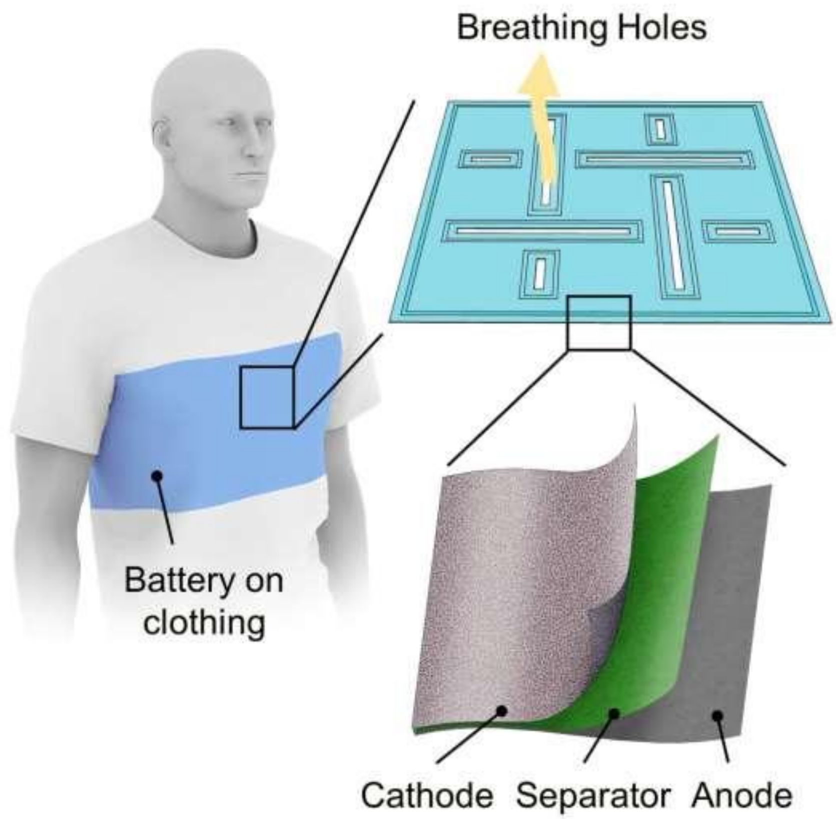
The process of creating the material involved modifying the crystal structure of ferrite, which was then combined with a thin polymer film. Special conductive patterns were applied to the backside, enabling the control of electromagnetic wave propagation. By

adjusting the shape of the conductive patterns, the reflection of electromagnetic waves at specific frequencies can be significantly reduced.
In addition, a thin film of carbon nanotubes was applied to the back of the material. These have a high shielding value, and this process is intended to further enhance the performance of the developed shielding material.
The material developed by the Korean researchers maintains its shape even after repeated bending and straightening. Scientists claim it can be bent thousands of times. For this reason, it is well-suited for applications in mobile devices, such as foldable smartphones or wearable devices.
"As 5G/6G communication applications expand, the importance of materials that absorb and shield electromagnetic waves grows. This material has great potential to improve the reliability of communication devices, such as smartphones and autonomous vehicle radars," said project leader Byeongjin Park.

JANUARY 28, 2025

Unique hole type and placement makes a wearable battery more bendable and breathable

by Bob Yirka , Tech Xplore



Graphical abstract. Credit: *Matter* (2025). DOI: 10.1016/j.matt.2025.101959

A team of engineers and materials scientists from the U.S. has found that holes of a certain size and shape placed in certain locations can turn a slightly flexible and stretchy battery pouch into one that can be stretched significantly or folded 180 degrees. In their paper published in *Matter*, the group describes how they came up with the design and explain how it makes a battery that is barely stretchy into one that can be folded.

Over the past couple of decades, as electronics have become smaller and more resilient, textile makers have been looking for ways to add them and their batteries to clothes. Advances in small devices and displays have led to the development of clothes that can display electronic messages or allow them to change colors and patterns; the tricky part has been in powering them. Some small devices that can be added to clothes consume so little energy that they can be powered by a wearer's movement. Unfortunately, most others still need a battery.

The difficulties of adding batteries to clothes include size, weight and stiffness. There have also been fears of batteries setting clothes on fire. In this new effort, the research team has developed a battery that is both bendable and has a built-in cooling mechanism to prevent overheating.

The battery made by the team is essentially the same as other battery pouches, except for one major difference—it has holes cut in it. Pouch batteries are typically just a little bit flexible. To make them more flexible, other researchers have tried cutting square or round holes in them in various places.

In this new effort, the researchers studied how putting holes in such a material increases stretchiness, and worked to find a design that would provide the most stretchiness without sacrificing battery capacity.

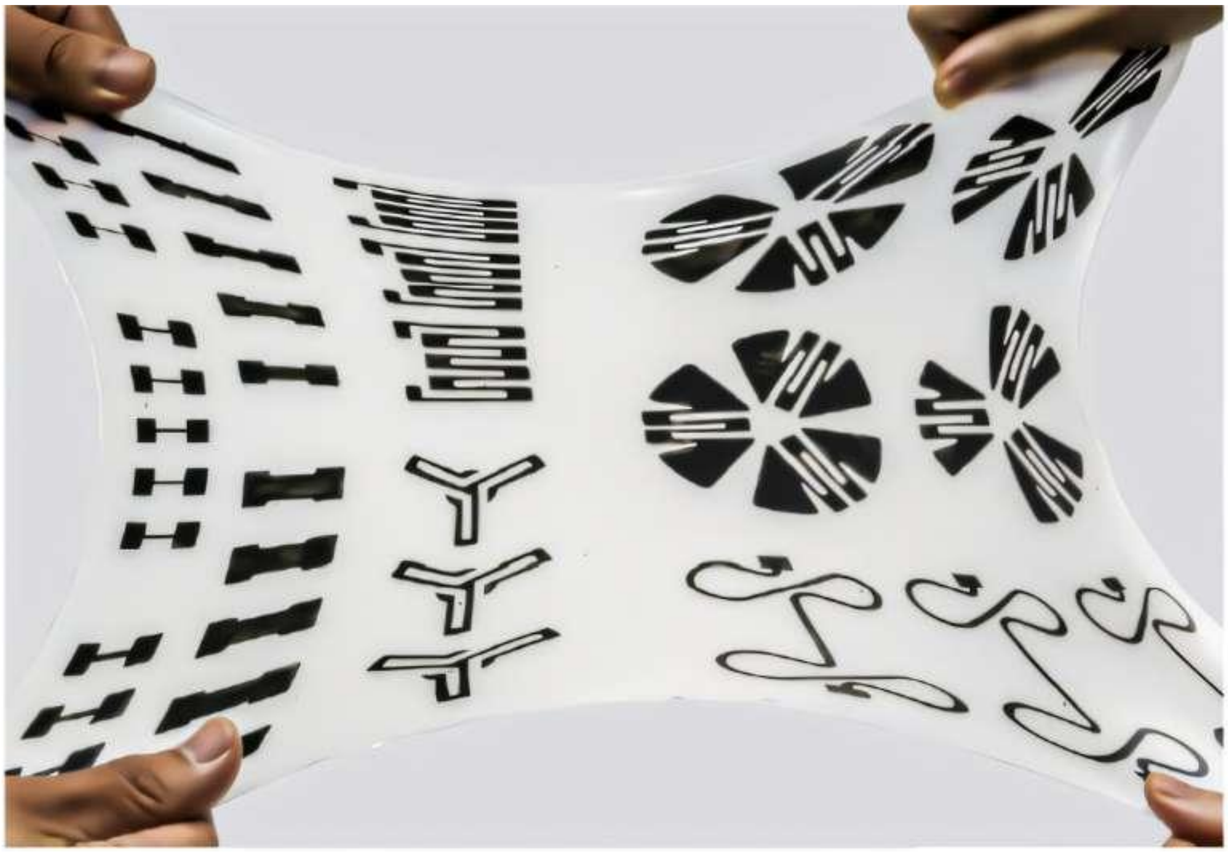
The resulting battery has longer and shorter rectangular holes of the right size and placement. Testing showed it was capable of holding a charge when folded 180 degrees, and could be stretched by as much as 10% of its length. The researchers also found that it held up without fail after 100 folds/unfolds, was twice as breathable as cotton, and that the holes served to dissipate heat.

More information: Lin Xu et al, Stretchable, breathable, wearable batteries using a holey design, *Matter* (2025). DOI: 10.1016/j.matt.2025.101959
Journal information: Matter

JANUARY 23, 2025

A new method to fabricate soft electronics via particle engulfment printing

by Ingrid Fadelli , Tech Xplore



Soft sensors engulfed on A4-size elastomer. Credit: Rongzhou Lin.

The electronics industry has been rapidly advancing over the past few decades, leading to the development of countless devices of different sizes and shapes, which are designed for a variety of applications.

These include stretchable electronics, which are sensors and other devices that can be used to create smart watches, fitness trackers, bio-medical sensors to monitor specific health conditions and soft robots.

Flexible electronics are typically made using soft polymers, elastic materials comprised of long molecular chains that can undergo significant deformation without breaking. To broaden their functions or boost their performance, these polymers are often combined with microscale or nanoscale particles that have specific optoelectronic or magnetic properties, also known as functional particles.

Most existing approaches to introducing functional particles in polymers work by dispersing the particles into liquid molecules that bond with other molecules to form a polymer before the material is solidified. Yet many of these strategies are only applicable to some polymer-particle combinations or are difficult to implement on a large scale.

Prof. John Ho's research group at the National University of Singapore and Prof. Yong Lin Kong's group at Rice University recently introduced a new method for fabricating soft electronics, which is outlined in a paper in *Nature Electronics*.

The first author of this paper is Dr. Rongzhou Lin, who was a post-doctoral scholar at the time and is now a faculty member at the South China University of Technology.

The new approach developed by the researchers leverages a soft matter physics phenomenon called 'particle engulfment' to embed particles into a soft polymer. Particle engulfment is a spontaneous process that occurs when the so-called elastocapillary length of a polymer's matrix surpasses the characteristic length of particles.

"Elastocapillary length is the length scale at which the surface stress becomes important over bulk elastic stresses," Prof.Yong Lin Kong, the co-corresponding author of the paper, told Tech Xplore.

"For example, when a particle with a size smaller than the elastocapillary length (e.g., a very soft substrate) is left on the surface, the surface stress of the substrate can dominate, so much so that it becomes energetically favorable for the particle to be 'subsumed' by the solid substrate itself.

"This phenomenon itself is not new and was already studied by others within the soft matter physics community, including as part of a beautiful work by Prof. Eric Dufresne at Cornell University. However, prior work studied particle engulfment with a few particles and it had so far not been employed to fabricate electronics."

While they were trying to create an effective soft strain sensor, the researchers found that existing approaches to disperse CNT particles into polymer solutions did not reliably produce the conductive polymers needed for high-performance stretchable sensors. Yet accidentally, they discovered the advantages of leveraging particle engulfment to create these conductive polymers for stretchable electronics.

"Conventional methods for creating strain sensors using carbon nanotube (CNT) typically involve dispersing CNTs into a polymer precursor with the use of solvents," Rongzhou Lin, first author of the paper, told Tech Xplore.

"However, we encountered challenges in producing conductive composites using this approach. Unexpectedly, we discovered that applying rubber CNTs onto cured silicone resulted in the easy formation of conductive composites."

When they investigated this phenomenon further, the researchers found that nanomaterials can spontaneously embed themselves into the polymer matrix via the particle engulfment phenomenon. They then integrated this approach with a printing set-up, using a stencil mask to control the exposed areas, which was found to successfully incorporate a broad range of functional particles into soft polymers.

To demonstrate the potential of their proposed method, the team used it to create elastic electronics with multiple layers incorporating various materials. The devices they fabricated could be suitable for different real-world applications, as they were found to possess wireless sensing, communication and power transfer capabilities.

"To the best of our knowledge, this was the first successful use of particle engulfment to make soft electronics," Lin said.

In addition to demonstrating the possibility of using particle engulfment to develop system-level electronics with tissue-like properties, this study also opens up new possibilities for soft matter physics research. Future studies could leverage the methods employed by the team to further study the physics underpinning particle engulfment.

"As this is the first experimental study on the engulfment of high concentrations of particles, our experimental data can potentially unravel new physical insights that have not been previously explored," Kong added.

"Our intriguing observations open new questions in soft matter physics, such as multi-layer engulfment of particles that could inspire future applications."

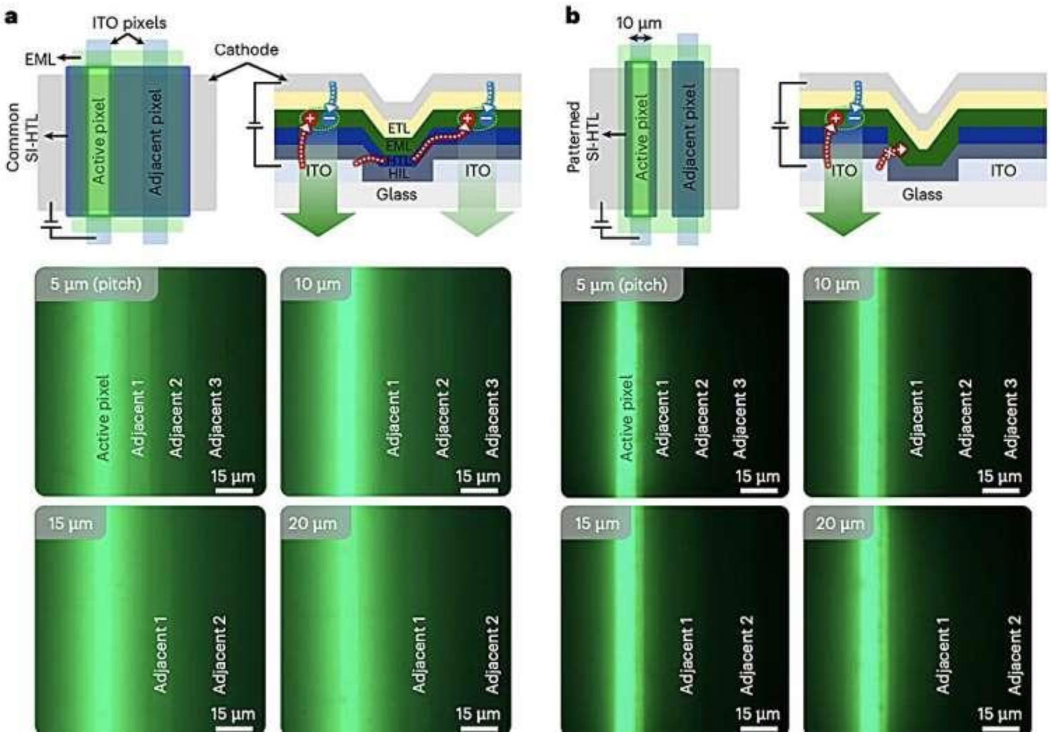
As the new strategy devised by the researchers is both scalable and reliable, it could soon also be employed by other teams, contributing to the further advancement of the electronics industry.

In the future, it could be used to fabricate a broader range of electronics, including electronic skins for robots and stretchable sensors for wearable devices.

More information: Rongzhou Lin et al, Soft electronics based on particle engulfment printing, *Nature Electronics* (2025). DOI: 10.1038/s41928-024-01291-0.
Journal information: Nature Electronics

FEBRUARY 7, 2025

High-definition organic LED microdisplays with reduced electrical crosstalk could enhance VR and AR experiences



Evaluation of electrical pixel crosstalk in OLEDs with micro-patterned SI-HTL. Credit: *Nature Electronics* (2025). DOI: 10.1038/s41928-024-01327-5

The rapid advancement of the electronics industry is opening new possibilities for the development of increasingly advanced device components, including displays. Many of the most widely used and highly performing displays developed to date are based on organic light-emitting diodes (OLED), devices based on organic materials that emit light when an electric current is applied to them.

Compared to conventional displays based on liquid crystals, OLED-based displays do not require a backlight and can thus consume significantly less power. Despite their energy-efficiency, the performance of OLEDs, in terms of image quality and color rendition, has been found to decline as the density of pixels increases, due to undesired interactions between adjacent pixels referred to as electrical crosstalk.

Electronics engineers have devised various strategies to overcome this limitation, most of which entail increasing the thickness of an OLED component known as the hole transport layer (HTL), which facilitates the movement of holes in the devices. Yet these strategies can compromise a display's energy-efficiency, due to increases in the devices' driving voltages.

Researchers at Hanyang University, Yonsei University and Sogang University in South Korea recently introduced an alternative approach to reduce electrical crosstalk between pixels, which could in turn boost the performance and efficiency of OLED displays.

Their proposed solution, presented in a paper published in *Nature Electronics*, involves the use of a silicon-integrated small-molecule hole transport layer (SI-HTL) patterned using microlithography, a well-established technique to precisely structure materials on a microscopic scale.

"High-density displays are required for the development of virtual and augmented reality devices," Hyukmin Kweon, Seonkwon Kim and their colleagues wrote in their paper. "However, increasing the pixel resolution can lead to higher electrical pixel crosstalk, primarily due to a shared hole transport layer. We show that a silicone-integrated small-molecule hole transport layer can be patterned at the wafer scale with microlithography to mitigate electrical pixel crosstalk."

Using microlithography, the researchers created the SI-HTL layer and integrated it in OLEDs. They then created micro-patterned OLED arrays and tested their performance in a series of tests.

Notably, they found that the hole transport layer they created exhibited an improved performance. The prototype display they created was found to enable remarkable pixel resolutions, while also retaining a good energy efficiency.

"With this approach, we create high-fidelity micro-pattern arrays with a resolution of up to 10,062 pixels per inch on a six-inch wafer," wrote Kweon, Kim and their colleagues. "The silicone-integrated small-molecule hole transport layer can effectively modulate charge balance within the emission layers, improving the luminance characteristics of organic light-emitting diodes.

"We also show that organic light-emitting diodes integrated with micro-patterned silicone-integrated small-molecule hole transport layers have a reduced electrical pixel crosstalk compared with organic light-emitting diodes with a typical hole transport layer."

This recent study by Kweon, Kim and their colleagues opens new possibilities for the development of high-definition OLED displays that also exhibit excellent energy-efficiencies. These displays could be integrated into a wide range of electronic devices, including virtual reality (VR) or augmented reality (AR) headsets, smart glasses, wearable technologies, smart phones, and many other electronics.

More information: Hyukmin Kweon et al, Microlithography of hole transport layers for high-resolution organic light-emitting diodes with reduced electrical crosstalk, *Nature Electronics* (2025). DOI: 10.1038/s41928-024-01327-5
Journal information: Nature Electronics

Stretchy, self-healing 'jelly batteries' could revolutionize medical implants

In a nutshell

- Cambridge scientists have created stretchy, self-healing "jelly batteries" that can extend to 15 times their length while maintaining electrical conductivity – a combination never achieved before in a single material
- The materials repair themselves within hours of damage and could revolutionize medical implants, as they match human tissue properties and are less likely to be rejected by the body
- Inspired by electric eels, these hydrogels can generate power like a battery (about 1/10th of a AA battery's voltage) and maintain stable performance even when stretched 50% – five times better than previous versions

CAMBRIDGE, England — The next generation of medical devices won't just interact with the human body, they'll move and flex with it. University of Cambridge researchers have created remarkable "jelly batteries" that stretch, conduct electricity, and even heal themselves, potentially revolutionizing everything from brain implants to wearable health monitors.

Unlike traditional electronics, which rely on rigid metal components and wires, these new materials are primarily water-based and can stretch to more than 15 times their original length without losing their ability to conduct electricity. The breakthrough, published in *Science Advances*, overcomes a fundamental challenge in materials science.

"It's difficult to design a material that is both highly stretchable and highly conductive since those two properties are normally at odds with one another," explains lead author Stephen O'Neill from Cambridge's Yusuf Hamied Department of Chemistry, in a statement. "Typically, conductivity decreases when a material is stretched."

A research team from the University of Cambridge solved this challenge by creating special *hydrogels*, which are materials composed of 3D networks of *polymers* containing over 60% water. These hydrogels use the same principle as our own bodies to conduct electricity, carrying charges through ions rather than electrons like traditional electronics.

"Normally, hydrogels are made of polymers that have a neutral charge, but if we charge them, they can become conductive," says co-author Dr. Jade McCune. "And by changing the salt component of each gel, we can make them sticky and squish them together in multiple layers, so we can build up a larger energy potential."

The secret to these materials' remarkable properties lies in their molecular structure. The researchers developed a system using special barrel-shaped molecules called *cucurbiturils*, which act like molecular handcuffs to bind different layers of the material together. These bonds can repeatedly break and reform, allowing the material to stretch, compress, and even heal itself when damaged.

This self-healing capability is particularly impressive. When the material is cut, it can repair itself within minutes. Tests showed that after just two hours of healing time, the material recovers 90% of its original stretchability. The team demonstrated this by cutting samples in half and watching them fuse back together, tracking the healing process using fluorescent dyes under a microscope.

Taking inspiration from electric eels, which stun their prey using special cells called *electrocytes*, the researchers created a working prototype of a soft, stretchable power source. By stacking different types of their conductive gels together in layers, they built a device that generates electricity through ion concentration gradients, similar to how electric eels produce their shock.

The device produces about 115-125 *millivolts* (roughly a tenth of an AA battery's voltage), and by connecting two cells in series, they could double this to around 248 millivolts. Most importantly, it maintains stable performance even when stretched up to 50%, which is about the same amount human skin can stretch. Previous attempts at similar devices would fail at just a 10% stretch.

"We can customize the mechanical properties of the hydrogels so they match human tissue," explains Professor Scherman. "Since they contain no rigid components such as metal, a hydrogel implant would be much less likely to be rejected by the body or cause the build-up of scar tissue."

Beyond medical applications, these materials could revolutionize soft robotics, machines designed to interact safely with humans or handle delicate objects. The combination of flexibility, conductivity, and durability could enable robots that move more naturally and adapt better to their environment.

The materials are remarkably resilient in other ways, too. They can be compressed by more than 90% without permanently losing their shape, and they bounce back within 30 seconds, though some variations show minor delays in full recovery. This level of durability, combined with their self-healing properties, suggests they could last longer than traditional electronic components in many applications.

This invention is a significant step forward in creating electronics that adapt to humans rather than forcing humans to adapt to electronics. As testing continues, they could fundamentally change our approach to everything from medical implants to wearable devices.

Paper Summary

Methodology

The researchers created these hydrogels by combining water-based polymers with specially designed molecular structures that can form reversible bonds. The key innovation was using barrel-shaped molecules called cucurbiturils as tiny molecular containers that can hold and release other molecules, creating dynamic links between polymer chains. They tested several types of charged molecules to create different versions of the hydrogel, each with unique properties. The team used multiple testing methods including mechanical stretching tests, electrical conductivity measurements, and microscopic imaging with fluorescent dyes to analyze how the materials performed.

Results

The hydrogels achieved several breakthrough properties: they could stretch to more than 15 times their original length, compress by over 90%, and conduct electricity at levels up to 0.1 Siemens per centimeter. They demonstrated rapid self-healing abilities, recovering most of their strength within hours of being damaged. When used as a power source, the materials maintained consistent voltage even when stretched to 50% – five times more than previous versions. The team also proved these materials could stick strongly to each other without separating under strain.

Limitations

While the research shows promise, several challenges remain. The materials show some trade-off between stretchability and immediate elastic recovery – meaning they don't snap back to their original shape as quickly as some applications might require. The power output, while stable, remains relatively low compared to conventional batteries. Additionally, more testing is needed to fully understand how these materials would perform in long-term use, particularly in medical applications.

Discussion and Takeaways

This research represents a significant advance in creating electronics that can better integrate with biological systems. The combination of stretchability, conductivity, and self-healing properties could enable new applications in medicine and robotics that weren't previously possible. The approach of using reversible molecular bonds provides a framework for developing other advanced materials with similar properties. The biocompatibility of these materials makes them particularly promising for medical implants and devices that need to interface directly with human tissue.

Funding and Disclosures

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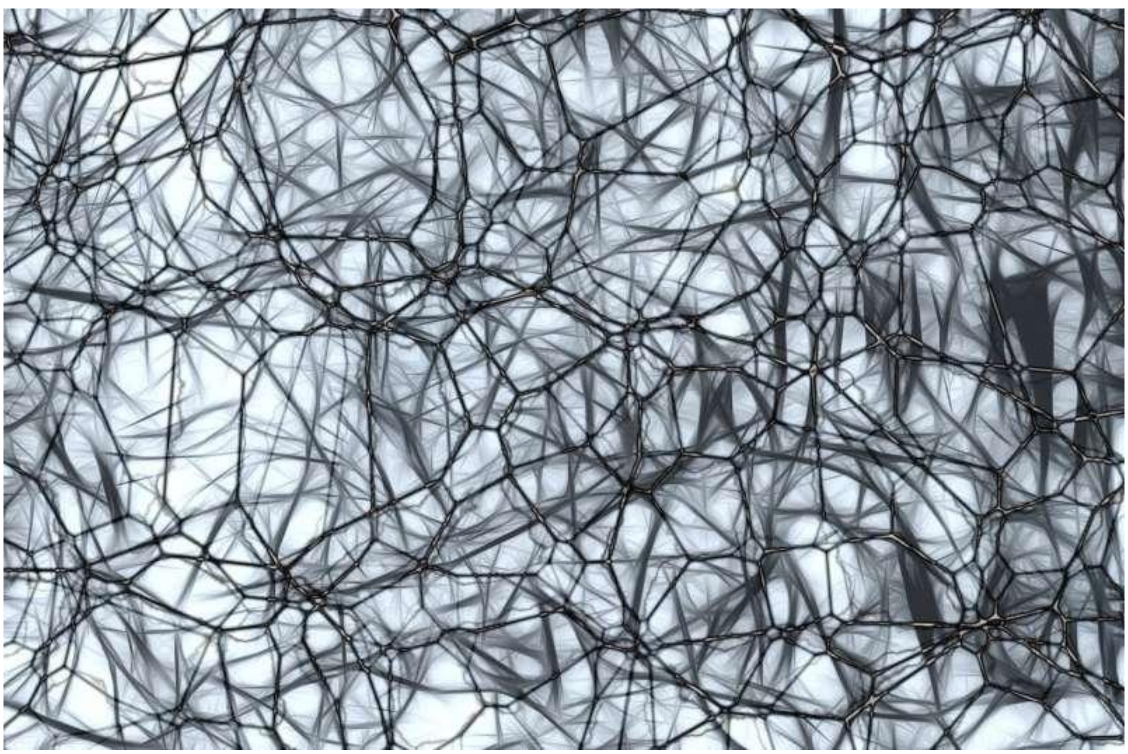
Publication Information

This research paper, "Highly stretchable dynamic hydrogels for soft multilayer electronics," was published in *Science Advances* on July 17, 2024. The study was conducted by researchers at the University of Cambridge's Melville Laboratory for Polymer Synthesis and the Electrical Engineering Division, in collaboration between the Yusuf Hamied Department of Chemistry and the Department of Engineering.

FEBRUARY 8, 2025

Brain cells mimic muscle signaling to enhance learning and memory

by Howard Hughes Medical Institute



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Our biceps and our brain cells may have more in common than previously thought.

New research led by the Lippincott-Schwartz Lab shows that a network of subcellular structures similar to those responsible for propagating molecular signals that make muscles contract are also responsible for transmitting signals in the brain that may facilitate learning and memory.

"Einstein said that when he uses his brain, it is like he is using a muscle, and in that respect, there is some parallel here," says Janelia Senior Group Leader Jennifer Lippincott-Schwartz. "The same machinery is operating in both cases but with different readouts."

The first clue about the possible connection between brain and muscle cells came when Janelia scientists noticed something strange about the endoplasmic reticulum, or ER—the membranous sheets and folds inside cells that are crucial for many cellular functions.

Lorena Benedetti, a research scientist in the Lippincott-Schwartz Lab, was tracking molecules at high resolution along the surface of the ER in mammalian neurons when she saw that the molecules were tracing a repeating, ladder-like pattern along the entire length of the dendrites—the branch-like extensions on brain cells that receive incoming signals.

Around the same time, Senior Group Leader Stephan Saalfeld alerted Lippincott-Schwartz to high-resolution 3D electron microscopy images of neurons in the fly brain where the ER was also forming regularly spaced, transversal structures.

The ER normally appears like a huge, dynamic net, so as soon as Lippincott-Schwartz saw the structures, she knew her lab needed to figure out what they were for.

"In science, structure is function," says Lippincott-Schwartz, who also heads Janelia's 4D Cellular Physiology research area. "This is an unusual, beautiful structure that we are seeing throughout the whole dendrite, so we just had this feeling that it must have some important function."

The researchers, led by Benedetti, started by looking at the only other area of the body known to have similar, ladder-like ER structures: muscle tissue. In muscle cells, the ER and the plasma membrane—the outer membrane of the cell—meet at periodic contact sites, an arrangement controlled by a molecule called junctophilin.

New research details the subcellular structures in neurons that enable signals to be transmitted from where they are received at specific sites on dendrites to the decision-making cell body located hundreds of micrometers away. The new research finds that the endoplasmic reticulum and the plasma membrane form contact sites where specialized molecules control the release of calcium, which regulates the signals sent along the dendrite to the soma. This movie shows 3D renderings of these structures in high-resolution 3D electron microscopy images of fruit fly neurons. The endoplasmic reticulum (green), plasma membrane (blue), mitochondria (pink), microtubules (tan), and ER-plasma membrane contacts (magenta) are segmented from FIB-SEM datasets of a Drosophila melanogaster MBON1 neuron. Credit: Benedetti et al.
Using high-resolution imaging, the researchers discovered that dendrites also contain a form of junctophilin that controls contact sites between their ER and plasma membrane. Further, the team found that the same molecular machinery controlling calcium release at muscle cells' contact sites—where calcium drives muscle contraction—was also present at dendrite contact sites—where calcium regulates neuronal signaling.

Because of these clues, the researchers had a hunch that the molecular machinery at the dendritic contact sites must also be important for transmitting calcium signals, which cells use to communicate. They suspected that the contact sites along the dendrites might act like a repeater on a telegraph machine: receiving, amplifying, and propagating signals over long distances. In neurons, this could explain how signals received at specific sites on dendrites are relayed to the cell body hundreds of micrometers away.

"How that information travels over long distances and how the calcium signal gets specifically amplified was not known," says Benedetti. "We thought that ER could play that role, and that these regularly distributed contact sites are spatially and temporally localized amplifiers: they can receive this calcium signal, locally amplify this calcium signal, and relay this calcium signal over a distance."

The researchers found that this process is triggered when a neuronal signal causes calcium to enter the dendrite through voltage-gated ion channel proteins, which are positioned at the contact sites. Although this initial calcium signal dissipates quickly, it triggers the release of additional calcium from the ER at the contact site.

This influx of calcium at the contact site attracts and activates a kinase called CaMKII, a protein known to be important in memory. CaMKII alters the plasma membrane's biochemical properties, changing the strength of the signal that is passed down the plasma membrane.

This process continues from contact site to contact site all along the dendrite to the cell body, where the neuron decides how it will communicate with other neurons.

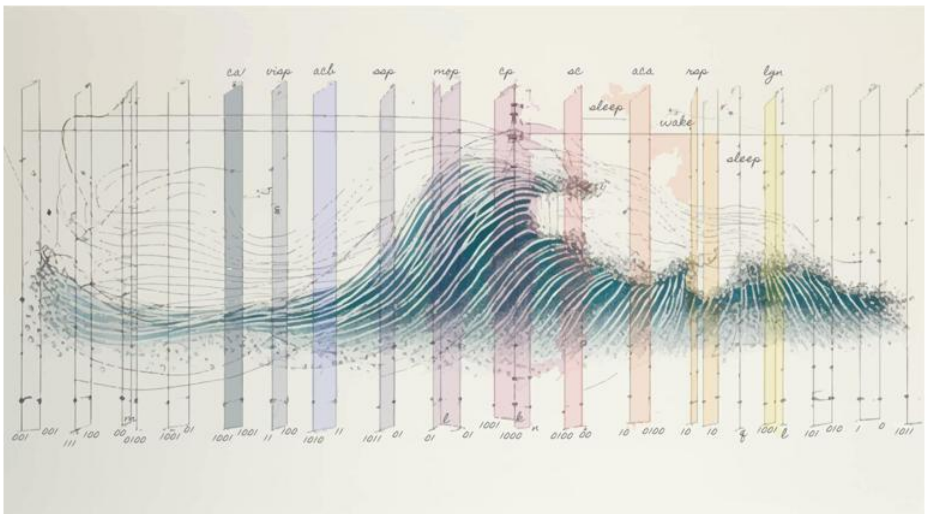
The new research reveals a novel mechanism for signal transmission in brain cells and helps answer an open question in neuroscience about how intracellular signals travel over long distances in neurons, enabling information received at specific sites on dendrites to be processed in the brain.

It also sheds light on the molecular mechanisms underlying synaptic plasticity—the strengthening or weakening of neuronal connections that enables learning and memory. Figuring out this process at the molecular level could increase understanding of how the brain works normally and in diseases where these processes go awry, like Alzheimer's.

"We are showing that a structure—a beautiful structure—operating at a level of subcellular organization is having a huge effect on the way the entire neuronal system is operating vis-à-vis calcium signaling," Lippincott-Schwartz says. "This is a great example of how, in doing science, if you see a beautiful structure, it can take you into a whole new world."

More information: Lorena Benedetti et al, Periodic ER-plasma membrane junctions support long-range Ca2+ signal integration in dendrites, *Cell* (2024). DOI: 10.1016/j.cell.2024.11.029
Journal information: Cell
Provided by Howard Hughes Medical Institute

Scientists find small regions of the brain can take micro-naps while the rest of the brain is awake and vice versa



Hengen's artistic interpretation of the varied brain wave patterns that produce the fundamental states of sleep and wake. Credit: Keith Hengen© Provided by Medical Xpress

Sleep and wake: They're totally distinct states of being that define the boundaries of our daily lives. For years, scientists have measured the difference between these instinctual brain processes by observing brain waves, with sleep characteristically defined by slow, long-lasting waves measured in tenths of seconds that travel across the whole organ.

For the first time, scientists have found that sleep can be detected by patterns of neuronal activity just milliseconds long, 1,000 times shorter than a second, revealing a new way to study and understand the basic brain wave patterns that govern consciousness. They also show that small regions of the brain can momentarily "flicker" awake while the rest of the brain remains asleep, and vice versa from wake to sleep.

These findings, described in a new study published in the journal *Nature Neuroscience*, are from a collaboration between the laboratories of Assistant Professor of Biology Keith

Hengen at Washington University in St. Louis and Distinguished Professor of Biomolecular Engineering David Haussler at UC Santa Cruz. The research was carried out by Ph.D. students David Parks (UCSC) and Aidan Schneider (WashU).

Over four years of work, Parks and Schneider trained a neural network to study the patterns within massive amounts of brain wave data, uncovering patterns that occur at extremely high frequencies that have never been described before and challenge foundational, long-held conceptions of the neurological basis of sleep and wake.

"With powerful tools and new computational methods, there's so much to be gained by challenging our most basic assumptions and revisiting the question of 'what is a state?'" Hengen said. "Sleep or wake is the single greatest determinant of your behavior, and then everything else falls out from there. So if we don't understand what sleep and wake actually are, it seems like we've missed the boat."

"It was surprising to us as scientists to find that different parts of our brains actually take little naps when the rest of the brain is awake, although many people may have already suspected this in their spouse, so perhaps a lack of male-female bias is what is surprising," Haussler quipped.

Understanding sleep

Neuroscientists study the brain via recordings of the electrical signals of brain activity, known as electrophysiology data, observing voltage waves as they crest and fall at different paces. Mixed into these waves are the spike patterns of individual neurons.

The researchers worked with data from mice at the Hengen Lab in St. Louis. The freely-behaving animals were equipped with a very lightweight headset that recorded brain activity from 10 different brain regions for months at a time, tracking voltage from small groups of neurons with microsecond precision.

This much input created petabytes—which are one million times larger than a gigabyte—of data. David Parks led the effort to feed this raw data into an artificial neural network, which can find highly complex patterns, to differentiate sleep and wake data and find patterns that human observation may have missed. A collaboration with the shared academic computer infrastructure located at UC

San Diego enabled the team to work with this much data, which was on the scale of what large companies like Google or Facebook might use.

Knowing that sleep is traditionally defined by slow-moving waves, Parks began to feed smaller and smaller chunks of data into the neural network and asked it to predict whether the brain was asleep or awake.

The team found that the model could differentiate between sleep and wake from just milliseconds of brain activity data. This was shocking to the research team—it showed that the model couldn't have been relying on the slow-moving waves to learn the difference between sleep and wake. Just as listening to a thousandth of a second of a song couldn't tell you if it had a slow rhythm, it would be impossible for the model to learn a rhythm that occurs over several seconds by just looking at random isolated milliseconds of information.

"We're seeing information at a level of detail that's unprecedented," Haussler said. "The previous feeling was that nothing would be found there, that all the relevant information was in the slower frequency waves. This paper says, if you ignore the conventional measurements, and you just look at the details of the high frequency measurement over just a thousandth of a second, there is enough there to tell if the tissue is asleep or not. This tells us that there is something going on a very fast scale—that's a new hint to what might be going on in sleep."

Hengen, for his part, was convinced that Parks and Schneider had missed something, as their results were so contradictory to bedrock concepts drilled into him over many years of neuroscience education. He asked Parks to produce more and more evidence that this phenomenon could be real.

"This challenged me to ask myself, 'To what extent are my beliefs based on evidence, and what evidence would I need to see to overturn those beliefs?'" Hengen said. "It really did feel like a game of cat and mouse, because I'd ask David [Parks] over and over to produce more evidence and prove things to me, and he'd come back and say, 'Check this out.' It was a really interesting process as a scientist to have my students tear down these towers brick by brick, and for me to have to be okay with that."

Local patterns

Because an artificial neural network is fundamentally a black box and does not report back on what it learns from, Parks began stripping away layers of temporal and spatial information to try to understand what patterns the model could be learning from.

Eventually, they got down to the point where they were looking at chunks of brain data just a millisecond long and at the highest frequencies of brain voltage fluctuations.

"We'd taken out all the information that neuroscience has used to understand, define, and analyze sleep for the last century, and we asked, 'Can the model still learn under these conditions?'" Parks said. "This allowed us to look into signals we hadn't understood before."

By looking at this data, they were able to determine that the hyperfast pattern of activity between just a few neurons was the fundamental element of sleep that the model was detecting. Crucially, such patterns cannot be explained by the traditional, slow and widespread waves. The researchers hypothesize that the slow-moving waves may be acting to coordinate the fast, local patterns of activity, but ultimately reached the conclusion that the fast patterns are much closer to the true essence of sleep.

If the slow-moving waves traditionally used to define sleep are compared to thousands of people in a baseball stadium doing the wave, then these fast-moving patterns are the conversations between just a few people deciding to participate in the wave. Those conversations occurring are essential for the overall larger wave to take place, and are more directly related to the mood of the stadium—the wave is a secondary result of that.

Observing flickers

In further studying the hyperlocal patterns of activity, the researchers began to notice another surprising phenomenon.

As they observed the model predicting sleep or wake, they noticed what looked at first like errors, in which for a split second the model would detect wake in one region of the brain while the rest of the brain remained asleep. They saw the same thing in wake states: For a split second, one region would fall asleep while the rest of the regions were awake. They call these instances "flickers."

"We could look at the individual time points when these neurons fired, and it was pretty clear that [the neurons] were transitioning to a different state," Schneider said. "In some cases, these flickers might be constrained to the area of just an individual brain region, maybe even smaller than that."

This compelled the researchers to explore what flickers could mean about the function of sleep, and how they affect behavior during sleep and wake.

"There's a natural hypothesis there; let's say a small part of your brain slips into sleep while you're awake—does that mean your behavior suddenly looks like you're asleep? We started to see that that was often the case," Schneider said.

In observing the behavior of mice, the researchers saw that when a brain region would flicker to sleep while the rest of the brain was awake, the mouse would pause for a second, almost like it had zoned out. A flicker during sleep (one brain region "wakes up") was reflected by an animal twitching in its sleep.

Flickers are particularly surprising because they don't follow established rules dictating the strict cycle of the brain moving sequentially between wake to non-REM sleep to REM sleep.

"We are seeing wake to REM flickers, REM to non-REM flickers—we see all these possible combinations, and they break the rules that you would expect based on a hundred years of literature," Hengen said. "I think they reveal the separation between the macro-state—sleep and wake at the level of the whole animal, and the fundamental unit of state in the brain—the fast and local patterns."

Impact

Gaining a deeper understanding of the patterns that occur at high-frequencies and the flickers between wake and sleep could help researchers better study neurodevelopmental and neurodegenerative diseases, which are both associated with sleep dysregulation. Both Haussler and Hengen's lab groups are interested in understanding this connection further, with Haussler interested in further studying these phenomena in cerebral organoid models, bits of brain tissue grown on a laboratory bench.

"This gives us potentially a very, very sharp scalpel with which to cut into these questions of diseases and disorders," Hengen said. "The more we understand fundamentally about what sleep and wake are, the more we can address pertinent clinical and disease related problems."

On a foundational level, this work helps push forward our understanding of the many layers of complexity of the brain as the organ that dictates behavior, emotion, and much more.

More information: David F. Parks et al, A nonoscillatory, millisecond-scale embedding of brain state provides insight into behavior, *Nature Neuroscience* (2024). DOI: 10.1038/s41593-024-01715-2

Provided by University of California - Santa Cruz

'Flow state' uncovered: We finally know what happens in the brain when you're 'in the zone'

any people know the feeling of being "in the zone": As they're fully immersed in a task, the background noise of the world fades and they may not notice time passing. Gymnasts may enter this all-consuming mental state as they're refining a floor routine, an artist might find "the zone" when adding delicate brushstrokes to a painting and a writer might enter it as they're crafting the climax of a chapter.

This state, known in psychology as a "flow state," is pursued by those who want to be more productive and creative in an enjoyable way. What happens in the brain during this state, however, has been under debate for more than four decades.

Now, in research published March 4 in the journal Neuropsychologia, scientists may have settled the debate. They conducted a new brain-scan study that has finally revealed which regions of the brain are activated in the midst of a creative flow state.

Their findings contradict one popular theory of flow while supporting another, and they seem to reveal the key ingredients needed to get "in the zone."

Related: What happens in our brains when we 'hear' our own thoughts?

The competing hypotheses of flow

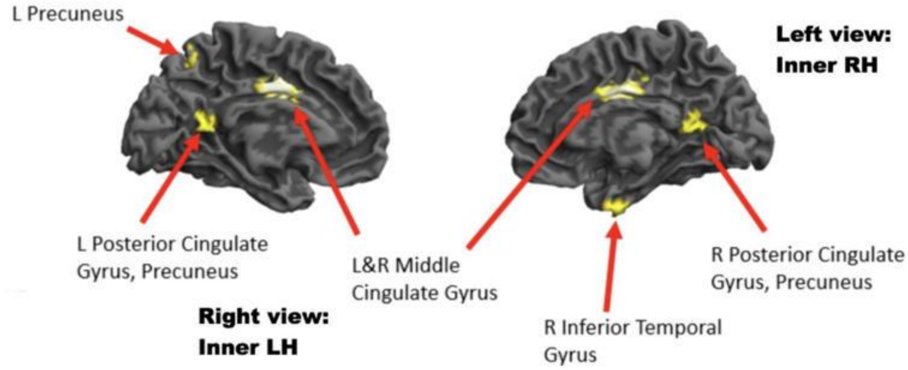
Two brain networks have historically been studied during tasks that could unlock flow. One is the default mode network (DMN), a circuit of connected brain areas associated with daydreaming whose activity spikes when people are not engaged in a specific task. The second is the executive control network (ECN), which supports complex cognitive processes, like problem-solving, and tunes out distractions.

Both networks can act independently, but they've also been shown to display certain levels of connectivity and to interact dynamically, especially during the creative process.

Researchers have proposed two main theories for how the flow state affects the brain. The first posits it's a state of hyperfocus in which ECN activity increases and guides the DMN to maintain focus on a task, to help generate relevant ideas, said Dmitri van der Linden, a professor of work and organizational psychology at Erasmus University Rotterdam who was not involved in the new study.

"It has been hypothesized that during flow, which is characterized by an intense task focus, DMN activity is relatively low," van der Linden told Live Science in an email. DMN activity is linked to "creative production," though, which is needed to generate ideas and improvise, he noted. With that in mind, this first hypothesis implies that both the ECN and the DMN are active and play off each other during flow, respectively contributing attention and creativity.

The alternative theory of flow, however, says that the expertise a person gains in a task through practice forges its own neural processing network that does not require ECN supervision or DMN involvement.



The researchers studied jazz guitarists in the study. This image highlights areas of reduced brain activity when experienced musicians were in a high-flow state, compared to a low-flow state. These areas include key nodes of the default mode network. (Image credit: Image provided by John Kounios, PhD, of Drexel University)© Provided by Live Science

If you don't know, you can't flow

To pit these hypotheses against each other, John Kounios, a professor of psychology at Drexel University and senior author of the study, and his team studied 32 jazz guitarists, some highly experienced and some less-experienced. Creative tasks like improvisational jazz lend themselves well to triggering a flow state.

The researchers scanned the musicians' brains using electroencephalogram caps, fitted caps studded with electrodes that track the brain's electrical activity. They examined activity in areas related to the DMN and the ECN and compared flow and non-flow states, which they evaluated with a questionnaire about the musicians' experiences while improvising.

Experienced musicians in a flow state showed decreased activity in the ECN and the DMN and increased activity in regions that process auditory, visual and movement information. This suggests that, during flow, individuals "let go" or switch into "autopilot" and experience less conscious control.

Moreover, experienced musicians in a flow state didn't seem to rely on the DMN to generate ideas, since its activity was down. Instead, they used the networks they had formed throughout their lives while honing their craft — in other words, networks involved in hearing and playing guitar, the researchers concluded.

Meanwhile, less-experienced musicians showed little change in the baseline activity of their ECNs, DMNs, or other processing centers while improvising in either low- or high-flow states. This suggests that only through gaining expertise and "letting go" can a person hope to achieve a high state of flow.

According to van der Linden, these findings address key questions in neuroscience and are especially impactful because they looked at brain activity during a real-life creative task rather than one invented for a study.

"This can be the basis for new techniques for instructing people to produce creative ideas," Kuonios said in a statement. In future work, the group hopes to confirm their theory with other creative tasks, such as drawing, while replicating the findings with higher-resolution brain-scanning techniques.

Unique Flow of Information Identified in The Human Brain

"What's new in our study is the use of multimodal data in a single model combining two branches of mathematics: graph theory, which describes the polysynaptic roadmaps; and information theory, which maps information transmission (or traffic) via the roads," says Alessandra Griffa, a biomedical engineer from EPFL.

"The basic principle is that messages passed from a source to a target remain unchanged or are further degraded at each stop along the road, like the telephone game we played as children."

To use another analogy, the information traffic moving around the brain is like traffic traveling down a road with multiple stops along the way. Our brains seem to be wired to simultaneously use multiple roads to get the convoy of signals to its destination.

What's more, the researchers discovered that these parallel pathways are as unique as fingerprints: studying the particular way that information flows around a brain can distinguish individual nervous systems.

"Such parallel processing in human brains has been hypothesized, but never observed before at a whole-brain level," says Griffa.

How these multiple channels affect thought processing, and why we have them when other animals don't, is beyond the scope of this study. However, the researchers think our larger brains have enabled more complex patterns of connectivity.

It might also add some level of resilience to the human brain, the researchers suggest. If one channel gets blocked or damaged, then it's possible that information can be rerouted through another channel instead.

Further down the line, the research could help us determine how damage from brain injuries could be repaired, or how we might be able to guard against the development of conditions such as dementia.

"We could hypothesize that these parallel information streams allow for multiple representations of reality, and the ability to perform abstract functions specific to humans," says Griffa.

"We looked at how information travels, so an interesting next step would be to model more complex processes to study how information is combined and processed in the brain to create something new."

The research has been published in *Nature Communications*.

Study provides first anatomical, functional representation of the ocular surface in the central nervous system

Nerve fibers on the eye surface are involved in many relevant physiological processes, from detecting and transmitting external stimuli to maintaining the integrity of the cornea. However, research on the sensory system of the ocular surface has focused mainly on the peripheral axons of the trigeminal ganglia neurons, leaving information processing in the central nervous system unknown.

Now, a new study carried out by the Institute for Neurosciences (IN), a joint center of the Miguel Hernández University (UMH) of Elche and the Spanish National Research Council (CSIC), together with the National Hospital for Paraplegics-SESCAM of Toledo, has characterized, for the first time, the neurons of the thalamus and cerebral cortex that respond to stimulation of the ocular surface.

The work, published in *The Journal of Physiology*, reveals that along the somatosensory pathway, there are neurons capable of responding to different types of stimuli applied to the eye surface and that their functional diversity increases as progress from the peripheral system to higher levels of the central nervous system.

The eye surface is sensitive to external stimuli that cause discomfort, such as irritation, dryness, or a feeling of sand in the eyes. Although these are the most relevant symptoms of many ocular pathologies, little is currently known about the central nervous system circuits involved in these perceptions.

"Until relatively recently, ocular sensitivity and pain had not been the subject of attention because these symptoms barely existed in the field of ophthalmology," explains Juana Gallar, co-director of the Ocular Neurobiology Laboratory at the IN together with Mª Carmen Acosta, who also has participated in the study.

"It has been the arrival of some social changes such as the habitual presence of air conditioning in many places, the high levels of environmental pollution or the introduction of refractive surgery, which has led to focusing on this issue," says the researcher.

The study shows the precise location of the thalamic and cortical neurons that receive information from the ocular surface and analyzes how the activity caused by stimuli of different types is integrated, which is transmitted from the trigeminal sensory neurons to the thalamus and, subsequently, the cerebral cortex.

"Until now, the primary sensory neurons have been characterized, which are those in the trigeminal ganglion, but this is the first time that it has been analyzed which stimuli activate the neurons of the thalamus and the cerebral cortex," says researcher Enrique Velasco, first author of the article.

Multimodal neurons

The peripheral nerves found on the ocular surface are composed of axons of unimodal neurons, which respond to a single stimulus modality, and polymodal neurons, which respond to stimuli from several modalities. As the authors describe, there are different degrees of sensory multimodality, so there are neurons that activate in response to multiple modalities of stimuli and others that respond to a smaller number.

Researchers have discovered that, although in the peripheral nervous system, some sensory nerves act as detectors of a single class of stimuli, this unimodality is practically non-existent in the brain.

"In the detectors of our eye, cold, heat and touch are totally separate," says Velasco. "However, in the central nervous system we find neurons that respond to various stimuli, which tells us that information from the periphery converges as it progresses through the nervous system and is compared one with another to give rise to conscious sensations that we perceive when we are exposed to a stimulus."

Furthermore, investigators have observed that both the degree of multimodality of neurons and the percentage of highly multimodal neurons increase along the somatosensory pathway: it is lowest in the trigeminal, intermediate in the thalamus, and maximum in the cerebral cortex.

This distribution implies that different stimuli can activate the same neuron, and conversely, the same stimulus can activate many different neurons, so the perceptions they produce are intermixed.

"In the case of the skin, we can clearly distinguish between a cold, hot, mechanical, or other type of stimulus. However, in the case of the cornea, we are not able to describe the sensations with that precision. This happens because most neurons that are part of the somatosensory pathway of the ocular surface are multimodal and, therefore, the information collected by these receptors on the eye surface converges and is intermixed along the pathway," explains Gallar.

To carry out this study, the researchers used electrophysiology techniques, which allowed them to explore the physiology of tissues and synaptic connections in living beings. To observe trigeminal, thalamic, and cortical activity in response to different stimulation modalities, the authors took recordings of rats while they administered eye drops of different temperatures, which allowed them to test five sensory modalities: intense cold, light cold, neutral temperature, light heat, and intense heat, the later capable of causing a sensation of pain.

Regarding the evolutionary significance of these results, experts consider that "the high functional diversity of these ocular neurons in the cerebral cortex guarantees that any kind of stimulus that we receive in the eyes produces a conscious perception," says Gallar.

"This allows us to be alert regarding our eyes to be able to react quickly in the case of harmful stimuli and, in addition, launch fundamental mechanisms to protect vision, such as increased tear production and blinking itself. The flip side is that we can not differentiate the types of stimuli with precision, or define their exact location on the ocular surface."

Along these lines, Gallar explains that this diversity of neurons constitutes the basis of the very characteristic sensations that are perceived on the surface of the eye.

"When we feel discomfort on the ocular surface we usually say that we have 'something' in the eye (the so-called foreign body sensation), grittiness, dryness, etc., but generally we do not use the word pain, although in reality what we are doing is using different terms to describe the different kinds of discomfort and pain that the neurons on our ocular surface are capable of processing," says the researcher. **More information:** Enrique Velasco et al, Ocular surface information seen from the somatosensory thalamus and cortex, *The Journal of Physiology* (2024). DOI: 10.1113/JP285008Provided by Miguel Hernandez University of Elche

Tiny eye movements are the key to making your vision sharper

BONN, Germany — Even when you think your eyes are perfectly still while reading these words, they're actually making tiny, unconscious movements. As it turns out, these seemingly random twitches serve a critical purpose: they help you see the world more clearly, according to new research from Germany.

The study, published in the journal *eLife*, reveals that these microscopic eye movements work in perfect harmony with the arrangement of light-sensing cells in our eyes, automatically adjusting to help us achieve the sharpest possible vision.

"Unlike a camera, our eyes are constantly and unconsciously in motion," explains Dr. Wolf Harmening, who leads the AOVision laboratory at the University Hospital Bonn's Department of Ophthalmology, in a media release.

These minuscule movements continue even when we're trying our hardest to stare at a fixed point.

How do our eyes create sharp vision?

At the center of each eye lies a tiny region called the fovea – a densely packed area of color-sensing cells known as cones. To put its size in perspective, this crucial region is about 200 times smaller than a quarter coin, yet it contains an astounding 200,000 cone cells per square millimeter. These cells are responsible for our ability to see fine details and vivid colors.

Unlike the uniform grid of pixels in your smartphone's camera, however, these cone cells aren't evenly distributed. Each person has their own unique pattern of cone density in their fovea, like a fingerprint for vision. What makes this new research particularly fascinating is how our unconscious eye movements – specifically, a type called "drift" – work in concert with this irregular arrangement of cells.

The research team used a specialized instrument called an Adaptive Optics Scanning Light Ophthalmoscope – the only one of its kind in Germany – to conduct their investigation. This high-tech device allowed them to observe both the precise arrangement of cone cells in participants' eyes and track their minute eye movements simultaneously.

The team studied 16 healthy volunteers, measuring their visual acuity during challenging vision tests while recording exactly how their eyes moved, and which photoreceptor cells were being used. What they found was remarkable: people could actually see finer details than what should have been possible based on the density of their cone cells alone.

The secret is in those tiny, drifting eye movements. Lead author Jenny Witten, a doctoral student at the University of Bonn, found that these movements weren't random at all.

"The drift movements repeatedly brought visual stimuli into the region where cone density was highest," explains Witten.

In other words, your eyes automatically drift in patterns that maximize the use of your highest-density cone regions, enhancing your ability to see detail.

The future of better vision

This discovery isn't just interesting for scientists and eye doctors – it could have important practical applications. Dr. Harmening's team suggests that understanding how these unconscious eye movements optimize vision could lead to better treatments for various eye disorders and improvements in artificial vision technologies, such as retinal implants.

The next time you find yourself marveling at your ability to read tiny print or appreciate the intricate details in a painting, remember: it's not just your eyes that are doing the work, but also those constant, invisible movements that help you see the world in crystal clarity.

Paper Summary

Methodology

This study explored how tiny movements of our eyes, called "fixational drift," influence how clearly we see very fine details. The researchers used special high-resolution imaging equipment to look closely at the center of participants' retinas (the area responsible for our sharpest vision). During the experiment, participants were asked to identify the orientation of a small letter "E" on a screen.

While they looked at the letter, the equipment recorded their eye movements and how different parts of the retina were involved in seeing the image. By analyzing these recordings, the researchers examined how eye movements could help us see even finer details than previously thought possible.

Key Results

The study found that small, controlled eye movements (fixational drift) helped participants see details smaller than a single photoreceptor cell (the tiny light-sensitive cells in the eye). The results showed that these eye movements are not random but are directed toward areas with the highest concentration of these photoreceptor cells. This adaptation allowed participants to see finer details than if their eyes remained still, suggesting that the human visual system uses both eye movement and retinal structure to enhance vision.

Study Limitations

One limitation is that the study was conducted under controlled laboratory conditions using specialized imaging technology, which may not fully represent natural viewing conditions. Additionally, the participants were limited in number, and all had normal vision without significant eye issues, which may not apply to those with vision impairments. Finally, the findings on eye movement patterns may vary among individuals and may not apply equally across different age groups or people with visual conditions.

Discussion & Takeaways

This research highlights how our eyes make subtle adjustments to enhance our ability to see fine details, especially during tasks that require high precision. These findings may help us better understand vision-related conditions and inform potential treatments, as they reveal that vision is a dynamic process involving not just our eyes' structure but also controlled eye movements. The study suggests that similar principles could apply in developing technologies to assist people with vision impairments or to enhance image quality in visual devices.

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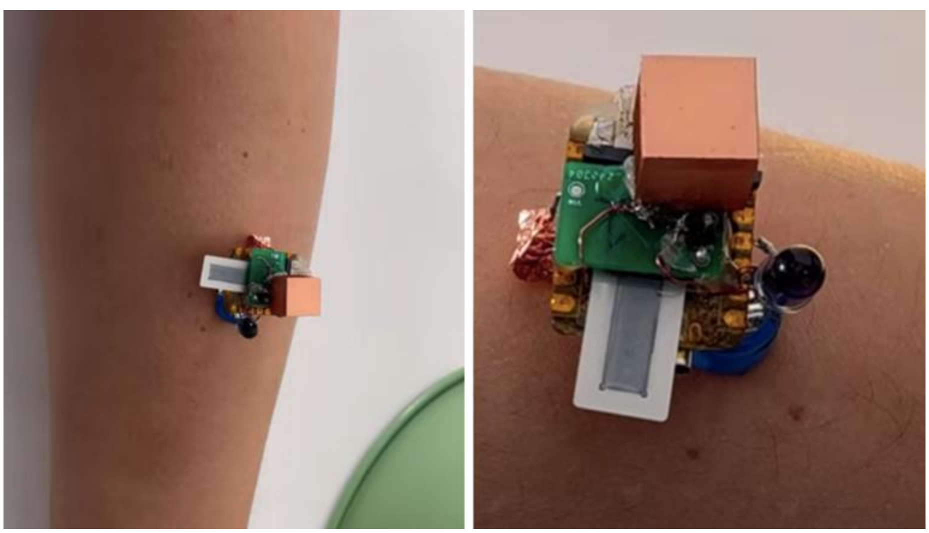
Human skin powers devices using intra-body RF energy, method eliminates battery needs



Human skin powers devices using intra-body RF energy, method eliminates battery needs

Researchers at Carnegie Mellon University have claimed that they have powered wearables using the human body. Called power-over-skin technology, the method used the human body to deliver power to many distributed, battery-free, worn devices.

Researchers claimed that they tested power delivery from on-body distances as far as from head-to-toe, with sufficient energy, to power microcontrollers capable of sensing and wireless communication.

Researchers stated that the human body could be modeled as a complex RC circuit.

Human body circuit

"Since we wish to have only one connection point to the body on the transmit and receive side, we must rely on the body's capacitance and use high-frequency AC waves (RF) to conduct energy," said researchers.

"Though the precise values of the human body circuit vary from person to person, this variation is negligible at the higher frequencies we need to use."

The power-over-skin technology is claimed to be a refinement upon past intra-body power transfer (IBPT) systems for energizing battery-free receiver devices worn across the body.

More than a dozen experiments performed

This required improvements across every aspect of the system, including circuit design, component choice, and measurement apparatus.

Researchers documented over a dozen experiments to inform their system design, which they believe will be invaluable to future researchers. A key result was maintaining power delivery over a diversity of on-body locations and distances in spite of our small receiver board, according to researchers.

"This power was enough to run microprocessors and sensors, display output, and perform wireless communication at various worn locations. We believe this capability enables a wide range of new and interesting on-body applications."

Researchers claimed that power-over-skin has the potential to increase the practicality and lifespan of many systems, as well as allowing for

novel body placements.

Several devices prove efficacy of technical approach

They created several example devices to convey the efficacy of their technical approach.

"As discussed previously, our transmitter can be comparatively large, as it contains the only battery in our system; the power-receiving devices can then be small and lightweight," said researchers.

They created an earring with a decorative ground and an LED.

"Blink rate is controlled by our power management IC, which discharges the storage capacitor across an LED when enough power is stored. The transmitter is contained in a hairband, which can accommodate the weight of batteries better than a small earring," added researchers.

Power-over-skin is particularly suitable for longitudinal health sensing

Researchers claimed that the power-over-skin is particularly suitable for longitudinal health sensing, since changes in bio-signals happen over minutes to hours (as opposed to real-time responsivity, e.g. ring joystick).

Their receiver can store plenty of energy, allowing us to power a microcontroller for an extended sensing operation (e.g., ECG heartrate) and perform a wireless transmission to another device which persists the data. This also means the transmitter can sit further away — for example, in a shoe or phone, according to researchers.

“As a simple example, we built a patch which senses body temperature and transmits the measurement over BLE to a laptop,” said researchers.

Wearable ‘smart’ patch works with smartphone to detect health issues

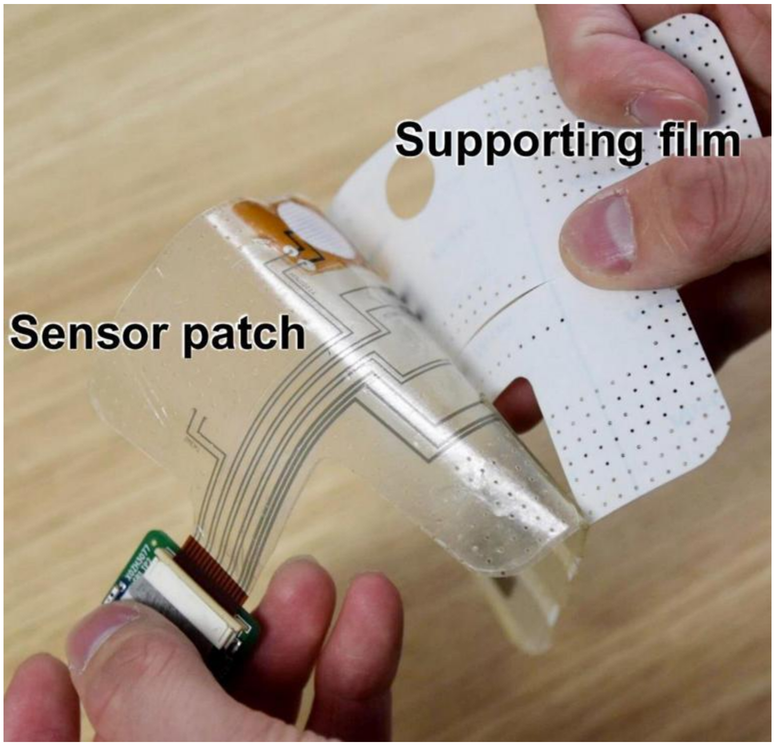
A new wearable "smart" sensor patch can detect health symptoms early via a smartphone.

The innovative device is able to spot an abnormal heart rhythm as well as coughs and falls, say Japanese scientists.

They explained that the sensors generate large amounts of data, and that data must be processed to be understood.

The field of computing dealing with processing the data on the sensor or a device that the sensor is connected to - rather than at a remote server on the cloud - is called edge computing.

The research team - led by Professor Kuniharu Takei at Hokkaido University and Associate Professor Kohei Nakajima at The University of Tokyo - says edge computing is a "key" element in wearable sensor technology.



The smart sensor patch is fabricated on a supporting film so that it may be peeled off and stuck onto the skin.

They have made a flexible wearable sensor patch and developed edge computing software that is capable of detecting arrhythmia, coughs and falls in volunteers.

The sensor uses a smartphone as the edge computing device.

Takei said: “Our goal in this study was to design a multimodal sensor patch that could process and interpret data using edge computing, and detect early stages of disease during daily life.”

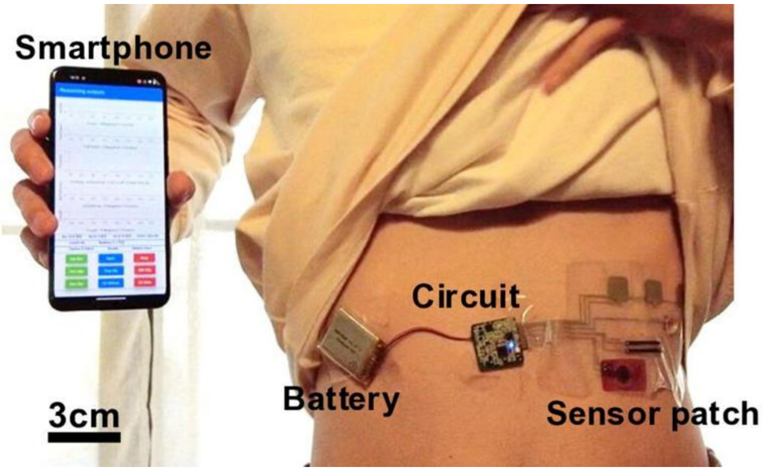
The team created sensors that monitor cardiac activity via electrocardiogram (ECG), respiration, skin temperature, and humidity caused by perspiration.

After confirming their suitability for long-term use, the sensors were integrated into a flexible film that adheres to human skin.

The sensor patch also included a Bluetooth module to connect to a smartphone.

The team first tested the capability of the sensor patch to detect physiological changes in three volunteers, who wore it on their chests.

The sensor patch, described in the journal Device, was used to monitor vital signs in the volunteers under wet-bulb globe temperatures - used to determine the likelihood of heat stress- of 22°C and over 29°C.



The sensor patch is connected to a processor (circuit) that includes a Bluetooth module and is powered by a battery.

Takei said: “Although our test group was small, we could observe their vital signs change during time-series monitoring at high temperatures.

"This observation may eventually lead to the identifying symptoms of early-stage heat stress.”

The team developed a machine learning program to process the recorded data to detect other symptoms such as heart arrhythmia, coughing and falls.

Nakajima said: “In addition to performing the analysis on a computer, we also designed an edge computing application for smartphones that could perform the same analysis.

"We achieved prediction accuracy of over 80%.”

Takei added: “The significant advance of this study is the integration of multimodal flexible sensors, real-time machine learning data analyses, and remote vital monitoring using a smartphone.

“One drawback of our system is that training could not be carried out on the smartphone, and had to be done on the computer.

"However, this can be solved by simplifying the data processing.”

The post Wearable 'smart' patch works with smartphone to detect health issues appeared first on Talker.

What is wearable neurotech and why might we need it?

The wearables category already contains multitudes, from exercise-focused smart watches and sleep tracking smart rings to smart femtech and semi-invasive blood glucose monitors — to name a few of the gizmos we've tracked over roughly a decade of novel personal hardware launches. But the space is set to get even more active, with a new wave of neurotech: wearable devices targeting the brain.

The neurotechnology category tends to be associated with brain implants. But wearable neurotech refers to therapeutic medical devices that apply brain stimulation from outside the body — through the skin and skull — not via any physically invasive process as a treatment for a range of chronic health issues.

Think head-mounted wearables that allow the user to self-administer treatment for psychological conditions such as depression (Flow Neuroscience) or period pain & PMS (Samphire Neuroscience). Other target applications include anxiety, insomnia and even post traumatic stress disorder (PTSD). Metabolic disorders like obesity and Type II diabetes could even be treated using wearable neurotech.

Both are applications on the roadmap of Neurovalens, a U.K.-based startup that's been developing its non-invasive brain-stimulating technology for over a decade.

The market for wearable medtech remains small but it looks to be on the cusp of a growth spurt over the next few years as long-running efforts to commercialize

R&D are poised to translate into a pipeline of products — assuming the necessary regulatory approvals flow.

A different kind of treatment

One big promise of non-invasive neurotech is that it could offer an alternative treatment for conditions like depression that don't always respond well to drugs. But how can an electronic device have a therapeutic effect on the human brain? The basic theory is that stimulating the brain's activity in a targeted way can influence how a person feels by changing the electric signals that brain cells use to talk to each other.

"Brain cells communicate with electrochemicals," explains Cambridge University's Dr. Camilla Nord, an assistant professor, head of the university's Mental Health Neuroscience Lab and author of a book (The Balanced Brain) on the science of mental health. "So one way we can change activity in the brain — and thereby someone's thoughts, mood [etc]… is by changing the chemistry. That's what drugs like antidepressants, antipsychotics do.

"The second way we can change it is by changing their electrical signals — and that, in varying ways, is what brain stimulation does."

While pharmaceuticals are a more established pathway for influencing mood and mental health, there are many drawbacks to taking medication — from ongoing cost; to not easily/being able to stop once you start; to a whole host of potential side-effects.

Drugs also aren't equally effective for everyone, if they work at all. And, even if they do, no one wants to have to be taking any form of medication, even a painkiller, forever – unless they literally have no choice. So the case for neurotech wearables to expand treatment options looks strong — provided device makers can demonstrate that their products are safe and effective.

To the uninitiated, the idea of applying electricity to the brain might sound a bit scary. But, asked about potential risks, Nord says the amount of neurostimulation used in commercial devices is so mild it shouldn't be a cause for concern.

"My understanding of the level of brain stimulation used in these commercial devices [is] they are not something to have safety concerns about," she suggests. "These are very, very low levels of electrical brain stimulation – if they're changing neuronal activity it's likely to be at safe levels if you're using them for a short amount of time, which is how they're recommended for use."

Whether there might be any risks related to usage duration – i.e. using non-invasive neurostimulators for long periods of time – is less clear. "To some degree, we can never fully know," she posits. But long term drug use may have its own risks, too.

Another big potential plus-point for neurotech vs pharmaceuticals is that a treatment that's lower risk can be tried earlier — before resorting to prescribing medication. Drugs may also require a full diagnosis before they can be dispensed. Whereas wearable neurotech could open up a market for earlier health interventions — allowing treatment to be applied sooner in a disease's progression with the chance of better outcomes for patients.

Technical & regulatory complexity

While neurotech has clear potential, there is a lot of complexity attached to this kind of medtech. Part of the reason the neurotech landscape is so complex is the variety of techniques that can be used to influence the brain's activity. Broadly speaking this includes transcranial magnetic stimulation (TMS), electrical current stimulation (CES), and even – research indicates – ultrasound (TUS).

So far, most commercial activity has focused on a form of CES called transcranial electrical current stimulation (aka tDCS). But there are several other electrical approaches being explored. Applications for non-invasive brain stimulation are also growing – but the main areas of interest so far are mental health and neurological issues.

Commercializing neurotech research into medical devices is far from simple due to a fragmented regulatory environment, too: In the U.S., the Food and Drug Administration (FDA) is an overloaded one-stop shop, while in Europe a decentralized system of private accredited bodies handle safety testing and audits. The rules for how medical devices are prescribed and reimbursed also differ between markets.

On top of that, there is some historical baggage to contend with – as a result of brain stimulation having a long but not always illustrious history. Legacy devices unsupported by science do explain some of the lingering scepticism about non-invasive neurotech therapy. But in recent years, the FDA has been looking to tighten up its rules for approving electrical neurostimulation for certain applications.

This is a course corrector for earlier waves of products that were brought to market in the U.S. from the late 1970s onwards under less rigorous standards. In 2019 the FDA finalized a reclassification of CES for treating insomnia and anxiety — moving these use-cases to a lower risk category (Class II) but also applying some special controls.

The 2019 FDA order also addressed CES devices targeting depression. These were maintained as Class III (high risk) under its revised rules but there's now a more involved pathway to get to market, known as Premarket Approval (PMA). Device makers must amass U.S. clinical evidence that will be reviewed, and ensure the hardware meets safety standards, before they can seek approval for a commercial launch.

A full PMA application process can take years. And while some devices targeting anxiety and insomnia have been cleared by the FDA since the 2019 rule changes, the regulator has yet to approve any CES devices for depression under its revised pathway.

Safe to say, the first depression-targeting neurotech wearable that gains FDA approval will be able to lay claim to a major credibility boost.

Modernized and strengthened rules for approving neurotech medical devices set the category up for a reputational reboot – provided startups can deliver to the upgraded standards.

Getting regulatory sign-off is not the end of the journey, though. Healthcare supply systems also assess novel treatments with a focus on costs — meaning they need to be able to demonstrate value for money. Again, different markets and healthcare systems may approach these cost-benefit assessments very differently, amping up the admin work for startups wanting to sell to multiple markets.

The U.K.'s publicly-funded National Health Service (NHS), for example, relies on a body called NICE (the National Institute for Health and Care Excellence) to evaluate both clinical efficacy and cost effectiveness of potential treatments. While the U.S. has a far more fragmented cost assessment process as a result of the larger role private healthcare plays.

Achieving reimbursement is the holy grail for a medical device maker as it unlocks the opportunity to reach serious scale. But there's no shortcut to get there.

Since March last year Flow's wearable has been made available to patients and clinicians in the U.K.'s NHS via a series of pilot programs. It's also started to have its hardware reimbursed in some European markets.

Co-founder and CEO Erik Rehn won't be drawn into predicting how long the next big step for Flow, of FDA approval, might take to obtain. But he credits the startup's initial B2C approach – of selling its wearable to interested consumers in Europe (where it has obtained a CE mark under regional medical device rules) – with giving it enough runway to work towards heading over the pond as a reimbursable medical device in the future.

"There's this big gap between getting regulatory approval and reimbursement," Rehn tells TechCrunch. "A lot of companies have a medical device idea, they develop it, they run the clinical trials to get approval, but then what? It can take years from that point to actually get it to a reimbursed state to actually earn money. And how do you survive that?

"We solved that by having a strategy where we could sell directly to consumers. But that's not possible in all cases. It might need to be a prescription device…. depend[ing] on the indication you're using it for – but also the technology, and also the regulatory framework on the market where you are."

"To have the really big impact in the long term we need to go B2B," he adds. "We'd need to get reimbursement. We'd need to get this as a first line of treatment. And that's much harder than just having the medical device approved."

Flow's strategy requires the startup to execute a long, slow switch from B2C to B2B – as it amasses usage data, traction and evidence for its novel wearable — to gain buy-in from healthcare systems far more accustomed to pushing pills on patients than head-mounted gadgets.

"It's taken a long time," admits Rehn. "I hoped it [would] be much faster. But I think, realistically, this is how long it takes to change how something is treated."

Beyond placebo

Whether the sense of relaxation the person we spoke to earlier, Alex, was able to achieve within a few weeks of trying Flow's non-invasive neurostimulation is a direct result of the therapeutic electricity the device applies or whether some kind of placebo effect could be involved — including as a result of mindful product design (Flow's app encourages the user to get into a routine of reflective self-focus, for example) — is harder to determine.

Placebo is a phenomenon that refers to the brain's ability to change a person's experience with expectations.

Alex told us they believe Flow's product worked for them. But they also wondered aloud whether it was placebo?

Rehn says Flow is able to demonstrate the product's efficacy in trials that control for the placebo effect. And — specifically — he says it can demonstrate that it's the electrical brain stimulation component which is having a therapeutic effect.

"So far we only looked at the brain stimulation — there's no CBT [cognitive behavioral therapy], involved [in our clinical trials]," he stresses. "Because it's the headset that we sell. So we want to be really sure that we have evidence for the treatment.

"That's the kind of evidence that we're going to the regulators with."

Discussing the role placebo might play in non-invasive brain stimulation, Dr Nord confirms there is no way for regular users to be sure. "These forms of brain simulation that are being used [commercially] – for the majority – they have a basis in science. They have the potential [to make] these changes in the brain. And then, therefore, a potential to have the effects that they claim to be having.

"But when you personally have experienced these effects – no, you can't say whether it has happened through that [placebo] pathway," she says.

A person experiencing relief from a debilitating condition like depression may not much care about the exact mechanism making it happen – whether it's their own neurons convincing them to shift perspective or a legit change in brain activity flowing from active neurostimulation. But for healthcare systems and regulators – and therefore for medical device builders – it obviously does matter.

Knowing a treatment is better than placebo is a standard clinical requirement that enables healthcare service providers to take decisions that properly consider risks and costs. So a direct-to-consumer strategy can only be a stepping-stone for any medtech startup.

Add to that, the really big prize this new wave of wearable neurotech builders are shooting for is to get their devices established as therapeutics within traditional healthcare supply systems where they can scale impact and have the chance to drive a more proactive approach to tackling complex concerns.

What about consumer neurotech?

There's another bundle of brain-targeting wearables to consider which sit outside the medtech category — in a broader but fuzzier wellness device space. These are lifestyle products, marketed and sold directly to consumers, typically with some brain training or tracking pitch. But with no regulatory oversight of claimed benefits it's harder to understand and verify impact.

While we've seen startups experimenting with consumer neurotech plays for years, there are signs the category might be heating up again – judging by recent device launches.

For example, Netherlands-based Alphabeats – which launched its first product in the U.S. in May – is combining an EEG (electroencephalography) brainwave detecting headband with music and other in-app visuals for a focus-tracking and focus-training pitch that's geared towards professional athletes and sportspeople.

The product is based on research originally conducted by the electronics giant Philips, along with researchers at the University of Tilburg in the Netherlands, according to co-founder Jorrit DeVries, who was also president & chief commercialization officer at the startup when we spoke to him (but has since taken over the CEO role).

Another consumer player that's set to launch its debut brain-targeting device in the U.S. shortly is Neurable. The Boston-based startup has actually been grinding away in the category for years – spinning out of the PhD research of founder and CEO, Ramses Alcaide.

After years developing algorithms to boost an EEG signal from brain-scanning hardware that's small enough to be housed in a standard-looking pair of headphone cups, Neurable's first consumer device is finally headed to market — via a partnership with premium audio brand, Master & Dynamic. The resulting product is a pair of premium smart headphones that will be marketed as an attention-tracking (and focus training) tool for information workers wanting to optimize their productivity.

Brain training itself isn't a new idea of course. Games claiming to up your mental agility have been touted and sold for years. But such apps don't have the best reputation, with limited evidence of utility beyond such stuff being good for improving users' ability to play brain training games.

Startups like Alphabeats and Neurable are hoping to reboot the category thanks to pulling in brain activity data via EEG. Their pitches push the notion that consumers can use their apps to track their brain activity in real-time and get feedback to support them to positively rewire mental habits.

Why does DeVries think the time is right to sell consumers on a wearable for training mental game?

"I think the stigma [around mental health and seeking support for it] is being removed quite rapidly," he suggests. "Role models like Simone Biles, for example, or Michael Phelps, or all these key athletes that that talk about mental performance and the importance of mental health – so that helps the market tremendously to be able to tap into to a bigger cohort of people that is not worried about what a lot of people think about it."

Another big change he flags vs earlier consumer neurotech plays is refinements to the wearable technology itself: Alphabeats is bundling a pretty slender headband with its app, which is made by a third party company (BrainBit), also helping it trim product costs.

"The form factor is getting smaller and smaller and more accessible. Prices are being driven down by competition," he says, adding: "Years ago there were headbands in the market that were at least $1,000 and now we're offering Alphabet for $499 including 12 months of the service."

"In five to 10 years from now, it will be very common to get EEG out of earbuds," DeVries also predicts. "So we want to focus on this platform to become the companion – the mental performance companion – for anybody that needs it."

In Neurable's case the U.S. startup kicked off with what Alcaide admits was a "bad strategy" – of focusing on targeting the tech at users of AR and VR. The new product positioning now has the startup leaning into the wellness trend.

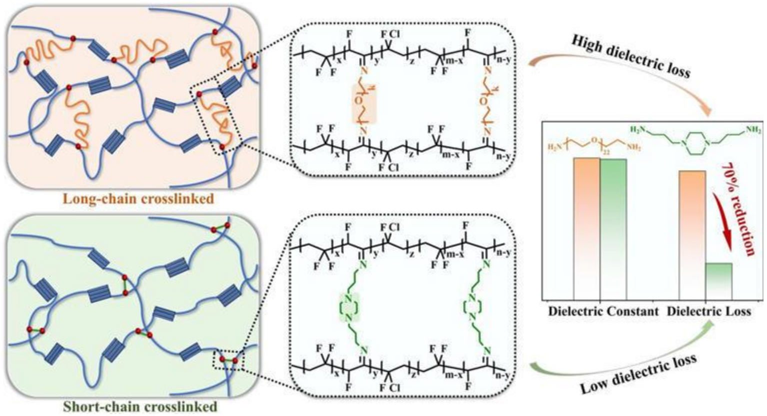
Neurable talks in terms of its smart headphones enabling users to take care of their "mental hygiene" – so there's a clear push to connect to the broader wearables space (which encompasses products like Apple's Watch, the Oura Ring or the Whoop band, to name a few), where health tracking has been a key selling point.

"We're definitely going to go the same path as Apple does," emphasizes Alcaide. "We're not going to make a medical device anytime soon – we're just going to help people better understand themselves and their data."

What else might brain-focused wearables end up targeting down the line? Research continues to turn up some tingling possibilities. A recent study suggested neurostimulation could even be used to dull the emotional pain of heartbreak. So maybe future consumers of neurotech wearables will be weighing the pros & cons of whether they want to give themselves a dose of *Eternal Sunshine of the Spotless Mind*.

A headband for heartbreak remains science fiction for now — but, well, it's quite a thought!

High-dielectric-constant elastomer with low dielectric loss improves performance of smart wearables



Intrinsic ferroelectric elastomer with a high dielectric constant and low dielectric loss. Credit: NIMTE

High-dielectric-constant elastomers possess outstanding softness and stretchability. They allow a fast response and have a high reliability, and thus have been widely applied to wearable electronics.

Prof. Hu Benlin's team at the Ningbo Institute of Materials Technology and Engineering (NIMTE) of the Chinese Academy of Sciences, has developed an intrinsic ferroelectric elastomer with a high dielectric constant and a low dielectric loss, which can effectively improve the performance and stability of smart wearables.

The study is published in *Advanced Materials*.

By introducing soft long-chain crosslinking structures into ferroelectric polymer materials with a "slight crosslinking" method, Hu's team had earlier achieved an intrinsic elastomer with high dielectric constants up to 35.4 at 1 kHz (54.2 at 100 Hz) that balances ferroelectricity and elasticity.

However, the dielectric relaxation and high mobility of the introduced soft long chains under alternating electric fields can trigger serious energy dissipation, leading to substantial dielectric loss.

In their new study, the NIMTE researchers integrated a rigid short-chain crosslinker with the relaxor ferroelectric P(VDF-TrFE-CFE). The obtained intrinsic ferroelectric elastomer showed a low dielectric loss of ~0.09 while maintaining a high dielectric constant of ~35 at 1 kHz and 25°C.

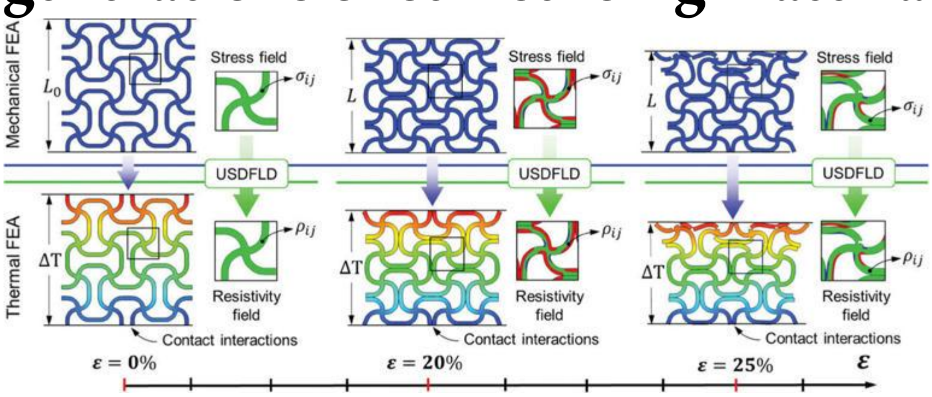
Compared with the soft long-chain crosslinking method, the rigid short-chain crosslinking approach reduced dielectric loss by more than 70%.

In addition to great ferroelectricity, piezoelectricity, and thermal stability, the obtained intrinsic ferroelectric elastomer achieved a high elastic recovery ratio exceeding 70% under 60% strain. The fabricated elastic devices based on the obtained intrinsic ferroelectric elastomer showed stable ferroelectric responses and relaxor characteristics even under 80% strain.

The study provides an effective approach to reducing the dielectric loss of high-dielectric-constant intrinsic elastomers, broadening their applications in wearable electronics, actuation, sensing, information processing, and energy storage.

More information: Fangzhou Li et al, Reducing Dielectric Loss of High-Dielectric-Constant Elastomer via Rigid Short-Chain Crosslinking, *Advanced Materials* (2024). DOI: 10.1002/adma.202411082

Modeling system could enable future generations of self-sensing materials



Methodology for the piezoresistive finite element analysis. Credit: Advanced Functional Materials (2024). DOI: 10.1002/adfm.202411975

Research that eliminates the guesswork in developing advanced 3D printed materials could help accelerate the development of new forms of "self-sensing" airplanes, robots, bridges and more.

A team of engineers led by researchers from the University of Glasgow have developed the first system capable of modeling the complex physics of 3D-printed composites capable of detecting strain, load, and damage using nothing more than a measure of electrical current.

By allowing material scientists to predict in advance for the first time how new structures can be fine-tuned to produce specific combinations of strength, stiffness, and self-sensing properties, it could help catalyze the development of revolutionary new applications for the technology.

In the aerospace and automotive sectors, new materials produced using the team's insights could enable real-time monitoring of structural integrity in aircraft, spacecraft, and vehicle components, enhancing safety and maintenance efficiency.

For civil engineering, these materials could enable developments in smart infrastructure by providing continuous assessment of the structures of bridges, tunnels, and high-rise buildings, highlighting problems long before they lead to collapse. They could offer similar benefits for robots at work in automated manufacturing, or even help soldiers on the battlefield keep tabs on the integrity of their body armor plates.

3D printing, also known as additive manufacturing, enables the creation of complex structures by building them layer by layer from materials like plastics, metals, or ceramics.

As technology has developed, researchers have been able to create increasingly complex materials with unique properties. Introducing a lattice of honeycomb-like chambers to the structure's interiors, for example, can allow materials to delicately balance weight with structural strength.

Weaving fine strands of carbon nanotubes throughout materials can allow them to carry an electrical current, imbuing them with the ability to monitor their own structural integrity through a phenomenon called piezoresistivity. When the readout of the current changes, it can indicate that the material has been crushed or stretched, allowing action to be taken to address the fault.

Professor Shanmugam Kumar, of the University of Glasgow's James Watt School of Engineering led the research, which is published in the journal *Advanced Functional Materials*. He said, "Imparting piezoresistive behavior to 3D-printed cellular materials gives them the ability to monitor their own performance without any additional hardware.

That means we can imbue cheap, relatively easy-to-manufacture materials with the remarkable ability to detect when they have been harmed and measure just how damaged they are. These types of lattice materials, which we call autonomous sensing architected materials, hold significant untapped potential to create advanced applications across various fields.

"While researchers have known about these properties for some time now, what we've not been able to do is provide a way to know in advance how effective new attempts at creating novel self-sensing materials will be. Instead, we have often relied on trial and error to determine the optimal approach for developing these materials, which can be both time-consuming and costly."

In the paper, the researchers describe how they developed their system through a rigorous set of lab experiments combined with modeling.

They used a plastic known as polyetherimide (PEI) mixed with carbon nanotubes to create a series of four different lightweight lattice structure designs. These designs were then tested for their stiffness, strength, energy absorption and self-sensing capabilities.

Using sophisticated computer modeling, they developed a system aimed at predicting how the materials would respond to a varied set of loads. They then validated their multiscale finite element model's predictions by subjecting the materials to intense analysis under real-world conditions, utilizing infrared thermal imaging to visualize electrical current flowing through the materials in real-time, leveraging the analogy between heat and current flow within these materials.

They found that their models could accurately predict how the materials would respond to various combinations of stress and strain, and how their electrical resistance would be affected. The results could help underpin future developments in additive manufacturing by providing insights into how proposed new materials will perform before the first real-world prototype is printed.

The research builds on previous developments from the team, who recently published a paper showcasing another approach to modeling which enables researchers to predict how additive manufacturing-induced flaws can affect the structural integrity of any new design.

Professor Kumar added, "With this study, we have developed a comprehensive system capable of modeling the performance of self-sensing, 3D-printed materials. Informed by rigorous experimentation and theory, it represents the first system of its kind that enables the modeling of 3D-printed materials across multiple scales and incorporates multiple types of physics."

"While we focused on PEI materials with embedded carbon nanotubes in this paper, the multiscale finite element modeling our results are based on could be easily applied to other materials which can be created through additive manufacturing too.

"We hope this approach encourages other researchers to develop new autonomous sensing architected materials, unlocking the full potential of this methodology in material design and development across a wide range of industries."

More information: Mattia Utzeri et al, Autonomous Sensing Architected Materials, *Advanced Functional Materials* (2024). DOI: 10.1002/adfm.202411975

Provided by University of Glasgow

LG's bizarre but impressive stretchable prototype display has the 'highest rate of elongation in the industry,' a measurement I had no idea existed

LG's bizarre but impressive stretchable prototype display has the 'highest rate of elongation in the industry,' a measurement I had no idea existed© LG Display

Flexibility could be the next bleeding edge for hardware to thread. Besides the bendy CPU whose performance leaves much to be desired outside its one party trick, monitor manufacturers are experimenting with pliable projects.

LG Display is the latest name to explore something with this technical twist, unveiling a stretchy screen prototype that can be expanded by up to 50% with a good tug (via Tom's Hardware). A prototype demonstration took place in Seoul at LG Science Park as part of a stretchable display national project during an event involving around 100 other South Korean tech stakeholders on November 8th.

This is far from the first bendy screen we've seen, with American company Corsair releasing the Xeneon Flex OLED Monitor a few years back. The big difference with LG's prototype is that it does a bit more than stretch; you can scrunch it, pull it, and twist it (though there's no word yet on whether you can bop it).

Dated reference aside (does Gen Z know the crushing low of flicking it when you mean to bop it?) LG's prototype is also a darn sight smaller than that Corsair monitor. LG's flexible display first presents RGB colour and 100 PPI at 12 inches, but can then expand up to 18-inches—which LG is quick to note in their press release exceeds "the original national project’s target of 20% elongation," and is "the highest rate of elongation in the industry."

As impressive as all of that is, I just can't get past how wrong the idea of scrunching up expensive tech feels; monitors may be hardware but they're historically not the hardiest of wares in the face of, say, a flung controller. Furthermore, in the case of the Corsair monitor, it's not just the fact you've really got to give it some welly to expand the display, but also the horrible sounds of protestation made by the frame that all contribute to the feeling of 'there's something wrong with this picture.'

Besides that, isn't the pliability of LG's prototype and its array of potential form factors just introducing heaps of new points of failure?

On the subject of durability, LG's press release states, "By using a micro-LED light source of up to 40 µm (micrometers), the new prototype’s strengthened durability means it can be repeatedly stretched over 10,000 times, maintaining clear image quality even in extreme environments such as exposure to low or high temperatures and external shocks." That might be a bold claim but, if this prototype ever makes it to market in some form, it could mean cracked phone screens may one day be a thing of the past.

The LG Display prototype remains a ways off any kind of consumer environment, but the company also shared a handful of conceptual use cases. In a bid to further highlight both the prototype's durability and pliability, LG proposed a wearable application where a stretchable display panel attached to a firefighter's uniform could provide a real-time feed of information. While that could end up being a pipe dream, a wearable that actually achieves some real world good would certainly make a change.

How the brain structure that produces norepinephrine also helps control visual attention

The locus coeruleus (LC) is a small region of the brainstem that produces norepinephrine, a chemical with powerful effects on arousal and wakefulness which plays an important role in the body's response to stress or panic. Now, research from the University of Chicago shows it plays a specific role in visual sensory processing as well.

In a study, titled "Locus coeruleus norepinephrine selectively controls visual attention" and published in *Neuron*, neuroscientists artificially increased neuronal activity in the LC by briefly shining light on genetically modified neurons. They saw that this manipulation selectively enhanced performance in non-human primates performing a visual attention task, underscoring the crucial role that attention plays in sensory perception.

"We want to understand what changes in your brain when you pay attention to something in the environment, because attention greatly affects your ability to discern stimuli," said John Maunsell, Ph.D., the Albert D. Lasker Distinguished Service Professor of Neurobiology and Director of the Neuroscience Institute at the University of Chicago, and co-author of the study.

"Now we have found a brain structure that has strong signals related to whether the subjects are paying attention to a stimulus or not, and we see big differences in how its neurons respond depending on where that attention is directed."

Maunsell and co-author Supriya Ghosh, Ph.D., a postdoctoral researcher, focus their studies on how neurons in different areas of the brain change to represent sensory input when a subject is paying attention to a stimulus or not. For example, activity of neurons in the cerebral cortex may increase by 10–25% when a subject pays attention to the stimuli those neurons represent.

Previous research has shown that LC activation, coupled with its ensuing norepinephrine production, might improve performance on tasks that require attention to discern between visual stimuli.

Ghosh, who specializes in subcortical brain structures, suggested that the LC might be a good candidate to study for these effects. The team trained two monkeys to perform a visual task in which they paid attention to the left or right side of a screen. First, a sample image would appear on both sides of the screen.

Next, after a delay, a test image would appear on one side of the screen. The monkey would report if that image was oriented differently than the sample shown earlier on that side of the screen by moving its eyes to one of two targets. The researchers recorded neuron activity in the LC during the task and saw that activity increased greatly—and only—when the animal attended to the image that appeared on the side of the screen monitored by those neurons.

To see if there was a causal relationship between this increased activity and performance, they also used a method called optogenetics to increase activity in the LC while the animals were performing the task. Optogenetics allows researchers to selectively control the activity of norepinephrine-expressing cells via light.

First, they introduce a genetic modification that causes neurons to produce a light-sensitive protein called opsin, the same type of protein that photoreceptors in the eye use to detect light. When they shine a special light on these neurons, the opsin causes the neurons to fire.

Optogenetically boosting the responses of the neurons drastically improved the animals' ability to differentiate the shapes on the corresponding half of the screen, without affecting motor processing.

"This kind of artificial enhancement of that activity did not interfere with other cognitive factors either, such as motor actions or decision-related activities," Ghosh said. "So, it could selectively contribute to the perceptual sensitivity in a very precise way."

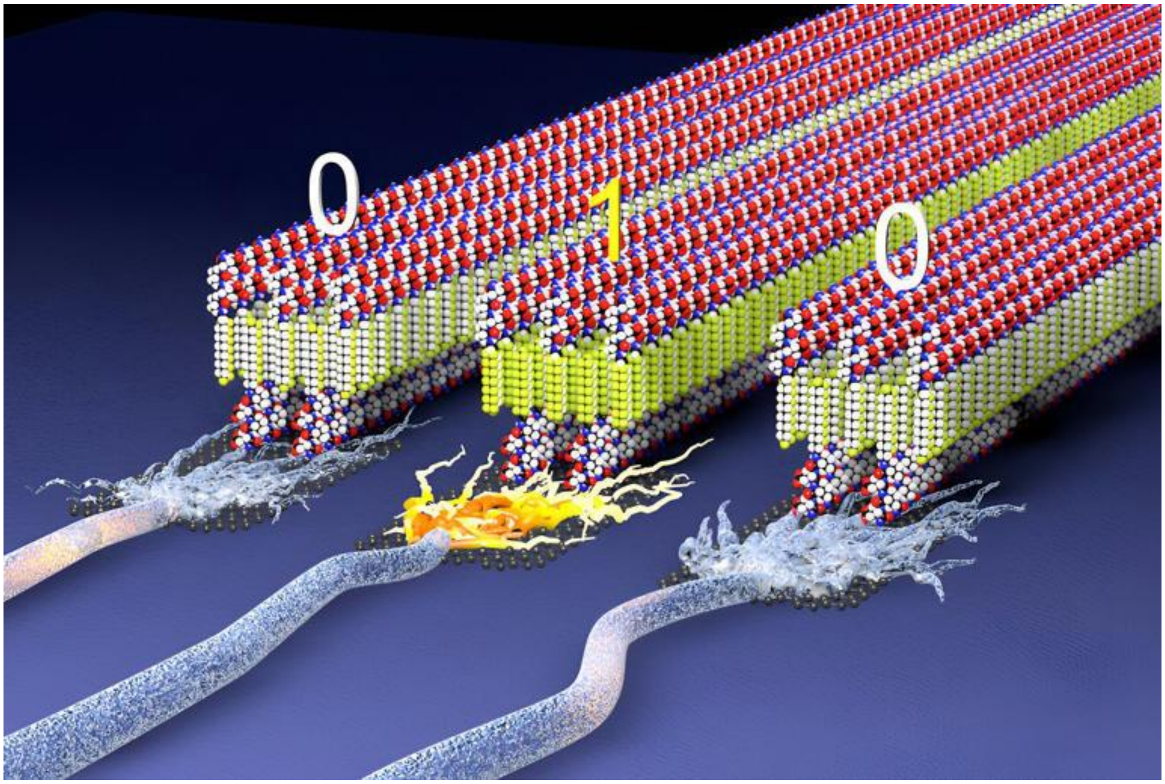
Distinguishing the effects of attention from other factors, like decision-making or motor movements, is crucial, Ghosh said. Those processes take place in other parts of the brain, and can contribute to performance independently. Understanding how a relatively small brain structure like the LC impacts such an important function as attention is also one step toward solving the overall puzzle of the brain.

"Every time we get more information about the likely contribution of a given brain structure, or how broad the range of functions of a given structure might be, that gives us much more power to understand the relationships among them," Maunsell said. "No one part of the brain does interesting behaviors by itself."

More information: Locus coeruleus norepinephrine contributes to visual spatial attention by selectively enhancing perceptual sensitivity, *Neuron* (2024). DOI: 10.1016/j.neuron.2024.04.001. www.cell.com/neuron/fulltext/S0896-6273(24)00239-3

Provided by University of Chicago

Peptides and plastics combine for energy-efficient materials



This illustration shows a future vision of assemblies of molecules formed by peptides and miniature molecular segments from a plastic material to create ferroelectric structures that switch polarity to store digital information or signal neurons. Credit: Mark Seniw/Center for Regenerative Medicine/Northwestern University

Step aside hard, rigid materials. There is a new soft, sustainable electroactive material in town—and it's poised to open new possibilities for medical devices, wearable technology and human-computer interfaces.

Using peptides and a snippet of the large molecules in plastics, Northwestern University materials scientists have developed materials made of tiny, flexible nano-sized ribbons that can be charged just like a battery to store energy or record digital information.

Highly energy efficient, biocompatible and made from sustainable materials, the systems could give rise to new types of ultralight electronic devices while reducing the environmental impact of electronic manufacturing and disposal.

The study, "Peptide programming of a supramolecular vinylidene fluoride ferroelectric phase," was published on Oct. 9 in the journal *Nature*.

With further development, the new soft materials could be used in low-power, energy-efficient microscopic memory chips, sensors and energy storage units. Researchers also could integrate them into woven fibers to create smart fabrics or sticker-like medical implants.

In today's wearable devices, electronics are clunkily strapped to the body with a wristband. But, with the new materials, the wristband itself could have electronic activity.

"This is a wholly new concept in materials science and soft materials research," said Northwestern's Samuel I. Stupp, who led the study.

"We imagine a future where you could wear a shirt with air conditioning built into it or rely on soft bioactive implants that feel like tissues and are activated wirelessly to improve heart or brain function.

"Those uses require electrical and biological signals, but we cannot build those applications with classic electroactive materials. It's not practical to put hard materials into our organs or in shirts that people can wear. We need to bring electrical signals into the world of soft materials. That is exactly what we have done in this study."

Stupp is the Board of Trustees Professor of Materials Science and Engineering, Chemistry, Medicine and Biomedical Engineering at Northwestern.

He has also served over the past decade as director of the U.S. Department of Energy-supported Center for Bio-Inspired Energy Science, where this research began. Stupp has appointments in the McCormick School of Engineering, Weinberg College of Arts and Sciences and Northwestern University Feinberg School of Medicine. Yang Yang, a research associate in Stupp's laboratory, is the paper's first author.

Peptides meet plastics for true innovation

The secret behind the new material is peptide amphiphiles, a versatile platform of molecules previously developed in Stupp's laboratory. These self-assembling structures form filaments in water and have already demonstrated promise in regenerative medicine. The molecules contain peptides and a lipid segment, which drives the molecular self-assembly when placed in water.

In the new study, the team replaced the lipid tail with a miniature molecular segment of a plastic called polyvinylidene fluoride (PVDF). But they kept the peptide segment, which contains sequences of amino acids. Commonly used in audio and sonar technologies, PVDF is a plastic with unusual electrical properties.

It can generate electrical signals when pressed or squeezed—a property known as piezoelectricity. It is also a ferroelectric material, which means it has a polar structure that can switch orientation by 180 degrees using an external voltage. The dominant ferroelectrics in technology are hard materials and often include rare or toxic metals, such as lead and niobium.

"PVDF was discovered in the late 1960s and is the first known plastic with ferroelectric properties," Stupp said.

"It has all the robustness of plastic while being useful for electrical devices. That makes it a very high-value material for advanced technologies. However, in pure form, its ferroelectric character is not stable, and, if heated above the so-called Curie temperature, it loses its polarity irreversibly."

All plastics, including PVDF, contain polymers, which are giant molecules typically composed of thousands of chemical structural units. In the new study, the Stupp laboratory precisely synthesized miniature polymers with only 3 to 7 vinylidene fluoride units. Interestingly, the miniature segments with 4, 5 or 6 units are programmed by nature's beta-sheet structures, which are present in proteins, to organize into a stable ferroelectric phase.

"It was not a trivial task," Stupp said. "The combination of two unlikely partners—peptides and plastics—led to a breakthrough in many respects."

Not only were the new materials equally ferroelectric and piezoelectric as PVDF, but the electroactive forms were stable, with the ability to switch polarity using extremely low external voltages. This opens the door for low-power electronics and sustainable nanoscale devices.

The scientists also envision developing new biomedical technologies by attaching bioactive signals to the peptide segments, a strategy already used in Stupp's regenerative medicine research. This offers the unique combination of electrically active materials that are also bioactive.

Just add water

To create the sustainable structures, Stupp's team simply added water to trigger the self-assembly process. After dunking the materials, Stupp was amazed to find that they achieved the highly sought-after ferroelectric properties of PVDF.

In the presence of an external electric field, ferroelectric materials flip their polar orientation—similar to how a magnet can be flipped from north to south and back again. This property is a key ingredient for devices that store information, an important feature for artificial intelligence technologies.

Surprisingly, the investigators found that "mutations" in the peptide sequence could tune properties related to ferroelectricity or even transform the structures into materials that are ideal for actuation or energy storage known as "relaxor phases."

"Peptide sequence mutations in biology are the source of pathologies or biological advantages," Stupp said. "In the new materials, we mutate peptides to tune their properties for the physical world.

"Using nanoscale electrodes, we could potentially expose an astronomical number of self-assembling structures to electric fields. We could flip their polarity with a low voltage , so one serves as a 'one,' and the opposite orientation serves as a 'zero.' This forms binary code for information storage. Adding to their versatility, and in great contrast to common ferroelectrics, the new materials are 'multiaxial'—meaning they can generate polarity in multiple directions around a circle rather than one or two specific directions."

Record-breaking low power

To flip their polarity, even soft ferroelectric materials like PVDF or other polymers typically require a substantial external electric field. The new structures, however, require incredibly low voltage.

"The energy required to flip their poles is the lowest ever reported for multiaxial soft ferroelectrics," Stupp said. "You can imagine how much energy this will save in increasingly energy-hungry times."

The new materials also have innate environmental benefits. Unlike typical plastics, which linger in the environment for centuries, the Stupp laboratory's materials could be biodegraded or reused without the use of harmful, toxic solvents or high-energy processes.

"We are now considering the use of the new structures in non-conventional applications for ferroelectrics, which include biomedical devices and implants as well as catalytic processes important in renewable energy," Stupp said.

"Given the use of peptides in the new materials, they lend themselves to functionalization with biological signals. We are very excited about these new directions."

More information: Samuel Stupp, Peptide programming of supramolecular vinylidene fluoride ferroelectric phases, *Nature* (2024). DOI: 10.1038/s41586-024-08041-4. www.nature.com/articles/s41586-024-08041-4

Provided by Northwestern University

Fascinating neuroscience research reveals a key mechanism underlying human cognition

How does the brain adapt to different levels of mental challenge? A new neuroimaging study reveals that when we engage in more complex cognitive tasks, our brain activity becomes not only richer in detail but also more streamlined. The findings suggest that the brain adjusts its patterns of activity to match the demands of the task, allowing for more efficient processing during mentally challenging activities.

The study, published in the *Proceedings of the National Academy of Sciences*, was driven by a desire to understand how the brain manages different cognitive demands. Previous research by the same team had revealed the brain's remarkable ability to reconstruct missing data from minimal measurements, raising questions about why the brain can generate such detailed and efficient activity patterns with limited input.

"Several years ago, my co-author and graduate student at the time, Lucy Owen, and I came out with a precursor to this study, where we found something very surprising," explained study author Jeremy Manning, an associate professor of psychological and brain sciences at Dartmouth College and director of the Contextual Dynamics Lab.

"At the time, we were working with neurosurgical patients who had electrodes implanted in their brains to monitor for seizure activity. A challenge with working with those recordings is that our brains contain roughly a hundred billion neurons, but we can only safely implant around a few hundred wires into someone's brain. So there is a massive undersampling problem: for every measurement we take, we miss roughly a billion others! We wanted to understand how much of that 'missing' data we could reliably and accurately reconstruct using statistical 'hacks.'"

"We were very surprised to find that just a few hundred measurements from an essentially random sampling of locations throughout someone's brain could give us enough information to fill in an accurate guess about activity patterns throughout their entire brain, at millimeter-scale resolutions (roughly on par with the best fMRI available today), but at millisecond-scale sampling rates (roughly 1000 times faster than fMRI)," Manning said. "If human language was similarly efficient, I'd be able to tell you the details of every Wikipedia article just by speaking a dozen or so words."

"In that initial study, we were primarily concerned with the 'how' and 'what' aspects of our approach: in other words, we reported how we built our model and generated guesses, how we validated the guesses, and the circumstances that affected accuracy, and so on. But it left us with a much deeper question that we weren't able to answer back then: why is it possible to reconstruct what nearly our entire brain is doing at a given moment, using a comparatively miniscule number of measurements? That led us down a rabbit hole of additional questions about the fundamental properties of brain activity patterns. Our findings are reported in this new study."

To answer these deeper questions about how the brain adjusts its activity to match cognitive demands, the researchers examined a dataset collected from previous neuroimaging experiments. These experiments involved functional magnetic resonance imaging (fMRI) scans of participants as they listened to different audio recordings.

Some participants listened to a coherent, seven-minute story, while others listened to a scrambled version of the story, in which either the paragraphs or individual words were randomly ordered. A final group underwent a resting state scan with no auditory stimulus, meant to simulate a condition of minimal cognitive engagement.

The goal was to analyze how the brain's activity changed under these varying levels of cognitive demand. In a high-demand task—following a coherent story—the brain has to actively process and organize information to make sense of the narrative. In contrast, during the scrambled story conditions, the brain's task is less cognitively challenging because the information is less meaningful. The resting state condition provided a baseline measure of brain activity in the absence of any specific cognitive task.

The authors sought to investigate two properties of brain activity: informativeness and compressibility. The authors hypothesized that these properties might shift depending on the complexity of a task, allowing the brain to strike a balance between flexibility and efficiency.

To assess the informativeness and compressibility of brain activity, the researchers used advanced computational techniques. They measured informativeness by analyzing how much specific information about the task was reflected in participants' brain activity. Compressibility, on the other hand, was evaluated by examining how efficiently the brain's activity patterns could be represented using fewer components or data points. A highly compressible brain pattern is one in which fewer pieces of information are needed to reconstruct the full activity.

"In the world of machine learning, the ability to reconstitute a detailed pattern from its parts is called 'compression,'" Manning told PsyPost. "Highly compressible patterns can be accurately rebuilt from just a tiny sliver, like reconstructing the complete text of a novel from just a single word. Another related property is called 'informativeness.' This refers to how 'expressive' a sequence of patterns is– akin to the length of a novel."

The researchers uncovered two key findings. First, brain activity was more informative and compressible when participants engaged in the more demanding task of listening to a coherent story compared to the scrambled story or resting conditions. This suggests that during higher-level cognitive tasks, the brain produces detailed, information-rich activity that is also organized efficiently. In simpler tasks, or during rest, the brain's activity is less organized and contains less specific information.

Second, the study found that these brain patterns became more informative and compressible over time as participants continued to listen to the coherent story. As the narrative unfolded, the brain seemed to adapt by refining and optimizing its activity patterns. This pattern was less pronounced in the scrambled conditions, where the lack of a coherent structure in the story likely led to less mental engagement and, consequently, less organization in the brain's activity.

"Going into this study, we would have guessed that 'compression' and 'informativeness' would have changed in opposite directions," Manning said. "That would be analogous to either being able to reconstruct short novels from just a few words (perhaps under certain cognitive circumstances — representing high compressibility but low informativeness), or being able to reconstruct longer novels from more words (perhaps under different circumstances — representing low compressibility and high informativeness). Finding that compression and informativeness change in the same direction helped us to understand that these two aspects of how our brains respond can vary independently from each other."

The researchers also took a closer look at different brain networks to see if certain regions were more affected by task complexity than others. They found that higher-order brain networks, which are typically associated with complex functions like decision-making and memory, showed more pronounced changes in informativeness and compressibility than lower-order networks, which are primarily involved in basic sensory processing. This supports the idea that the brain's ability to adjust its activity is not uniform across all regions; instead, areas involved in more complex cognitive functions are especially responsive to task demands.

“We have known for a long time that our ‘thoughts’ come from patterns of electrical activity in our brains,” Manning told PsyPost. “What we found is that our brains seem to change the ‘language’ that those patterns are expressed in according to what we are doing. When we are highly engaged or thinking ‘deeply’ about what we are doing, our brains move into a mode where the activity patterns become both highly compressible and highly informative.”

“In other words, our brains start representing what we are doing or thinking about in a very efficient way that is also incredibly robust to data corruption. That helped us understand why, under the right circumstances, it becomes possible to accurately guess what someone’s entire brain is doing from just a few hundred measurements.”

“When we stop being engaged, or when we think more ‘shallowly’ about what we are doing, our brains switch into a much less efficient mode, where the activity patterns become less structured, less informative, and more idiosyncratic,” Manning continued. “We’re not totally sure why this happens, but we go through some speculations in our paper.”

The research provides valuable insights into the fundamental mechanisms of human cognition. But the study, like all research, has limitations. The study only examined a specific set of tasks and stimuli, which means that the results may not apply to all types of mental activities. Additionally, the researchers used one method of measuring brain activity—fMRI—which provides a detailed view of brain activity but is limited by its relatively slow sampling rate compared to other techniques.

“We looked at data from a little over 100 participants, using one set of experimental conditions, and using one method for measuring brain activity,” Manning noted. “Although it is tempting to generalize to ‘all humans and circumstances,’ the true test of these findings, as with any study, will be in how well they replicate and generalize.”

The researchers suggest that future studies could examine how the brain’s ability to adjust informativeness and compressibility might apply to other cognitive processes, such as decision-making, problem-solving, or creativity.

Understanding how these brain properties change in different contexts could offer new insights into the nature of cognition and how the brain adapts to a wide range of mental challenges.

Despite its limitations, the study provides a compelling look at how the brain organizes itself to meet the demands of complex tasks. The findings suggest that the brain's ability to adapt is not just a matter of activating more areas or working harder, but rather involves fine-tuning its activity patterns to balance flexibility and efficiency.

In the long term, this line of research could help scientists better understand how the brain supports higher-level cognitive functions and what happens when these processes break down, such as in conditions like dementia or traumatic brain injury. By identifying the mechanisms that allow the brain to optimize its activity for different tasks, researchers may eventually develop new interventions or treatments to support cognitive health and recovery.

"We are deeply curious about understanding fundamental questions about how our brains work, and what makes us 'us.' This line of work is a tiny part of a much broader literature aimed at uncovering the neural basis of thought," Manning said. "My website is www.context-lab.com. It has links to all of my lab's publications, data, and software, along with some open courses that could be of interest to people who want to learn more about this stuff."

The study, "High-level cognition is supported by information-rich but compressible brain activity patterns," was authored by Lucy L. W. Owen and Jeremy R. Manning.

Beyond reward: A new study offers a glimpse into how the brain learns

- Learning involves acquiring knowledge through experiences and adapting behaviors based on rewards or consequences.
- Dopamine plays a pivotal role in the brain's learning and decision-making processes.

- A new study in animals uses light to peer into cells, linking specific mouse actions to real-time dopamine release.

Learning is essential for survival and intelligence. It enables living things to navigate their world, make wise choices, and adjust their behaviors based on past experiences.

Learning is, among other things, about getting new information, abilities, or behavior patterns using experiences, research, or teaching. Trial and error helps organisms learn which behaviors get rewarded and which do not.

A critical part of learning is how our brains give value or importance to particular actions or behaviors based on their outcomes. This process is known as credit assignment and is a critical part of learning.

Understanding credit assignment is crucial for comprehending how organisms learn from their experiences, make decisions, and adapt their behavior to maximize positive outcomes.

A new study published in *Nature* by a group of scientists from Allen Institute, the Champalimaud Centre for the Unknown, Columbia University's Zuckerman Mind Brain Behavior Institute, and Seattle Children's Research Institute explores this phenomenon in mice.

The researchers conducted a comprehensive study to understand how dopamine influences credit assignment in mice. In particular, they wanted to explore how the neurotransmitter shapes learning and behavior by reinforcing specific actions.

Understanding credit assignment in behavioral psychology is vital for understanding how organisms adapt, learn, and optimize behavior based on experiences. This process has implications for decision-making, skill acquisition, and potential clinical applications.

The role of dopamine

Dopamine, often referred to as the "feel-good" neurotransmitter in the brain, contributes to mood changes when its levels vary.

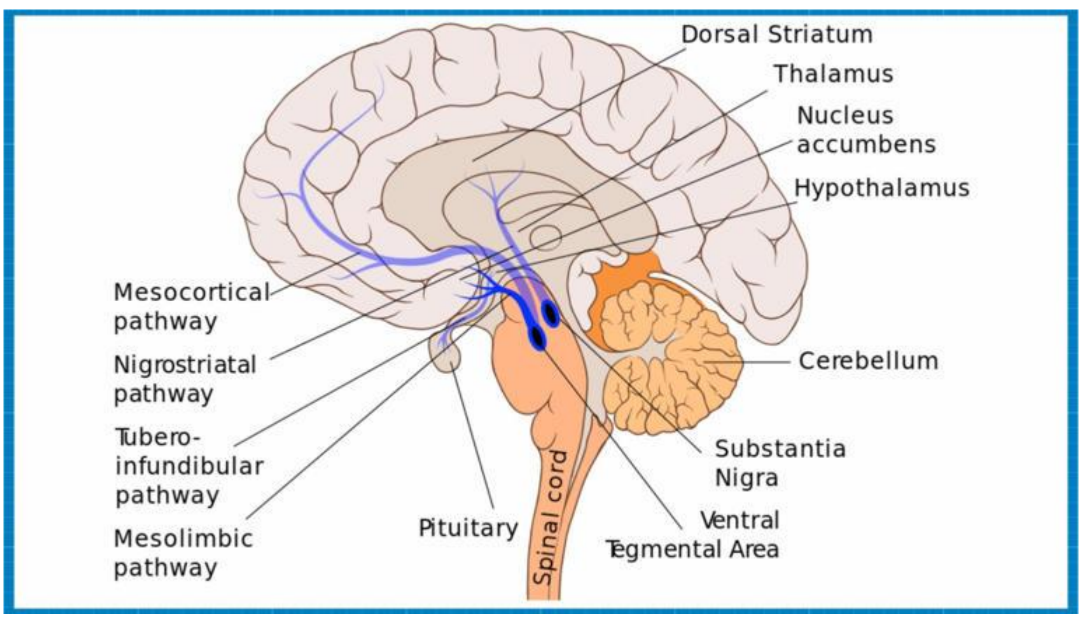
Dopamine originates in various parts of the brain, such as the substantia nigra and the ventral tegmental area. It is linked to motivation and pleasure and plays a major role in the brain's reward system.

For instance, when encountering pleasurable or rewarding experiences, like savoring a delightful meal or accomplishing a goal, dopamine is released. This release of dopamine reinforces the behaviors or actions that led to the positive experience, encouraging the individual to repeat those actions.

Dopamine is also involved in various cognitive processes, including learning, memory, and decision-making.

In the context of learning, the attribution of credit is fundamental for organisms to adapt their behavior and optimize their chances of experiencing favorable outcomes.

For example, when learning to play the guitar, actions like pressing the correct strings lead to positive outcomes, creating an association. The brain recognizes and reinforces these actions linked to favorable results through credit assignment.



The dopaminergic mesolimbic pathway in the brain. (Source: Slashme/Patrick J. Lynch/Fvasconcellos)© Provided by Interesting Engineering

Now that we have established what credit assignment is, let's go back to the research question: How does dopamine contribute to the assignment of credit for specific actions?

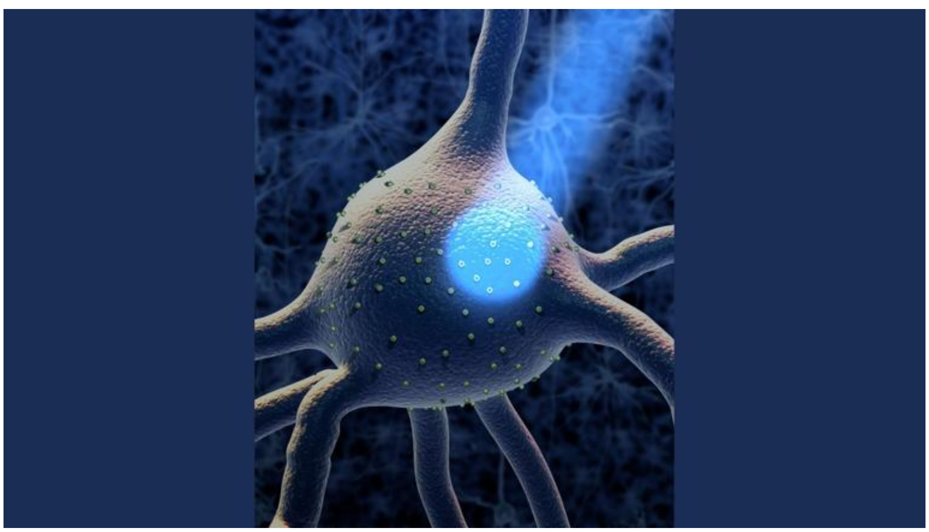
You might assume this is a purely academic pursuit. However, assigning credit accurately to actions allows organisms to learn from their experiences, make informed decisions, and modify their behavior to maximize positive outcomes.

What is closed-loop optogenetics?

To observe and manipulate the mice, the researchers used a closed-loop system that linked specific actions to dopamine release in real time. These mice were equipped with wireless sensors to monitor their behavior or movement.

The researchers used a technique called optogenetics to stimulate the dopamine neurons in mice. In simple terms, they used light to control the neurons.

By stimulating the dopamine neurons, the researchers were able to observe the mice's responses to the release of dopamine triggered by specific "target actions" (or specific outcomes).



Optogenetics involves controlling neurons with light. (Source: statenews website / hayadan website)© Provided by Interesting Engineering

The researchers used two distinct target actions (A and B) to study how the mice adjusted their behavior based on changes in the contingency between actions and closed-loop dopamine stimulation.

Closed-loop optogenetics gave the researchers a distinct edge by giving real-time feedback and control to them. This provided a more detailed understanding of how the brain refines behavior in response to reinforcement.

Reward and behavior

Learning action-reward contingencies

The researchers observed that the mice adapted to changes in action-reward contingencies by refining their behavioral repertoire. This means that in response to altered circumstances or learning experiences, the mice adjusted and improved their range of behaviors to optimize the likelihood of receiving rewards, especially dopamine release.

Temporal dynamics of reinforcement

The time between the mice's actions and dopamine release was crucial in shaping their behavioral repertoire dynamics. This means that the specific time relationship between actions and rewards significantly influenced how mice adjusted their behavior.

Furthermore, the study found that behavioral similarity and baseline temporal proximity were the main factors in predicting the type of action dynamics observed after reinforcement.

Behavioral similarity refers to the likeness or resemblance between different actions, and baseline temporal proximity relates to the time intervals between actions.

Overall, this emphasizes the importance of time-related factors in how mice adapt their behavior to dopamine stimulation.

Individual learning differences

Among the mice in the study, there were differences in how quickly they learned. The speed of learning was correlated with the initial time gap between triggers (stimuli that led to dopamine release).

Mice with different learning speeds also showed distinct patterns in their behavioral response refinement.

Credit assignment for action sequences

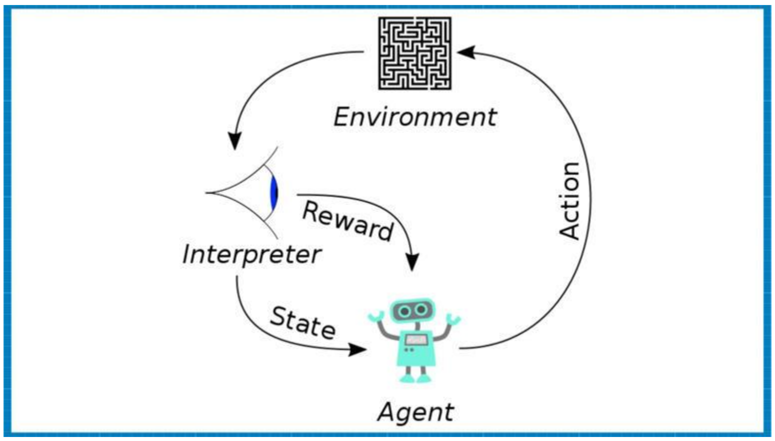
The researchers found that the mice could learn sequences of actions, which led to dopamine stimulation.

This finding emphasizes the complexity of learning action sequences and the influence of dopamine in reinforcing specific behavioral patterns.

Retrospective reinforcement

The study supported the concept of retrospective reinforcement, where behavior leading to dopamine stimulation was reinforced even if it was delayed.

Retrospective reinforcement contributed to the gradual refinement of behavioral repertoires over time.



A typical reinforcement learning system. (Source: Megajuice)© Provided by Interesting Engineering

"When you reinforce behavior, we often think it's just that action. But no: you're changing the entire behavioral structure. And what was really surprising was how rapid it was," said Dr. Rui Costa, the President and CEO of the Allen Institute, in a press release.

Conclusion

So there we have it; rewards don't just reinforce certain actions; they completely change how we behave, and quickly so!

The observed dynamic adaptation to changing action-reward dependencies provides a peek into neural plasticity. This prompts further investigation into the cellular and synaptic mechanisms at play.

Beyond the lab setting, these findings could have wide-ranging implications in behavioral psychology. They offer a valuable perspective on human and animal behavior in reward-based learning.

The use of closed-loop optogenetics introduces a new approach, providing unmatched control over neural circuits. Looking forward, this technology invites further exploration into various aspects of neural modulation and behavior.

On the clinical front, the study has revealed promising insights into dopamine-mediated reinforcement. They could contribute to a better understanding of neurological and psychiatric disorders linked to dopamine dysregulation, potentially guiding future research on therapeutic interventions.

The researchers suggest a potential impact on education by emphasizing exploration and gradual refinement aligned with natural learning processes.

Additionally, replicating biological learning could enhance the adaptability of artificial intelligence systems to new data and situations, fostering more sophisticated learning mechanisms.

Humans have a magnetic sensor in our eyes, but can we detect magnetic fields?

Many birds have a compass in their eyes. Their retinas are loaded with a protein called cryptochrome, which is sensitive to the Earth's magnetic fields. It's possible that the birds can literally *see* these fields, overlaid on top of their normal vision. This remarkable sense allows them to keep their bearings when no other landmarks are visible.

But cryptochrome isn't unique to birds – it's an ancient protein with versions in all branches of life. In most cases, these proteins control daily rhythms. Humans, for example, have two cryptochromes – CRY1 and CRY2 – which help to control our body clocks. But Lauren Foley from the University of Massachusetts Medical School has found that CRY2 can double as a magnetic sensor.

Foley worked with *Drosophila* flies, which can normally sense magnetic fields using cryptochome. You can show this by placing them in an artificial magnetic field and training them to head in a specific direction in search for food. Normal flies can do this easily. Mutants that don't have the *cry* gene, which makes the cryptochrome protein, lose their ability to find their meal.

To restore their internal compass, Foley simply has to give the mutant flies extra copies of *cry*. But she found that the human version of the gene works just as well. When she loaded her mutants flies with human CRY2, she found that they could sense magnetic fields like their normal peers. Foley also found that human cryptochrome is sensitive to blue light. It only managed to restore the magnetic sense of flies when they were bathed in this colour.

These simple experiments show that human cryptohrome *can* act as a magnetic sensor. This doesn't mean that it does, much less that humans can sense magnetic fields. Plugging human cryptochrome into an alien environment like the body of a fly tells you very little about what it does in its native surroundings.

Roswitha Wiltschko, one of the scientists who first discovered the magnetic sense of birds, says, "To sense the magnetic field, one does not only need a molecule like cryptochrome, but also an apparatus that picks up the changes in that molecule and mediates it to the brain. *Drosophila* obviously has this apparatus, but humans? I have my doubts." Steven Reppert, who led the new study, is also cautious. However, he notes that Cry2 is heavily active in the human retina. "It's beautifully poised to sense light but we don't know if it has the downstream pathways that communicate magnetic information to the brain. The possibility exists."

A radical idea

The connections between light, cryptochrome and a magnetic sense were laid out by Klaus Schulten and Thorsten Ritz in 2000, in a bravura paper that united biology and quantum physics. They suggested that when cryptochrome is struck by blue light, it transfers one of its electrons across to a partner molecule called FAD. Electrons normally waltz around in pairs, but thanks to the light, cryptochrome and FAD now have lone electrons. They are known as a "radical pair".

Electrons also have a property called "spin". In a radical pair, the spins of the two solo electrons are linked – they can either spin together or in opposite directions. These two states have different chemical properties, the radical pair can flip between them, and the angle of the Earth's magnetic field can influence these flips. In doing so, it can affect the outcome or the speed of chemical reactions involving the radical pair. This is one of the ways in which the Earth's magnetic field can affect living cells. It explains why the magnetic sense of animals like birds is tied to vision – after all, cryptochrome is found in the eye, and it's converted into a radical pair by light.

Several experiments in the past few decades have support Schulten and Ritz's theory. Foley's work also seems to fit – human cryptochrome can support a magnetic sense in flies, in a way that depends on blue light. But Wiltschko thinks that using the human protein is a red herring. "All cryptochromes should be light-sensitive and since they form radical pairs, they should be sensitive to magnetic fields. The authors are describing intrinsic properties of cryptochrome. Using human cryptochrome is a nice gag!"

Indeed, Reppert says, "Of all the cryptochromes one could think of, the human one seemed the most interesting. We thought that if it did work, it might reignite some interest in magnetoreception in humans, which has waned down to virtually nothing."

Can humans sense magnetic fields?

The current consensus is that humans cannot sense magnetic fields. Birds can do it, as can bats, turtles, ants, mole rats, sharks, rays, and more. Recently, Czech scientists have suggested that foxes, cows and deer also have the same ability. But look at all the recent reviews in this field, and you'll see very little mention of our own species. A decade ago, a German group showed that our vision is slightly more sensitive in some directions than in others, but the results have not caught on.

It wasn't always like this. In the 1980s, Robin Baker from the University of Manchester carried out a series of experiments which seemed to show that humans could sense magnetic fields. He took busloads of blindfolded volunteers on winding journeys for several kilometres before asking them to point their way back home. They did so more often than expected, and if they wore magnets on their heads, their accuracy dropped.

The results were published in *Science*were published in *Science* and you can read Baker's own description of his study in this 1980 issue of New Scientist. He even wrote a book about it. At the time, Baker said, "Whatever the repercussions, we have no alternative but to take seriously the possibility that Man has a magnetic sense of direction."

Unfortunately, the main repercussion was a fierce series of rebuttals. Over the next decade, several groups around the world failed to repeat Baker's results, even though Baker himself had no problems in doing so. He argued that their failure could have been due to local magnetic anomalies or brief changes in the strength of the magnetic field due to solar activity.

An American duo – Gould and Able – charitably suggested that Baker's British students "either had cues available to them which were absent in our experiments, or are dramatically better than Americans in using whatever cues may be involved." Max Westby and Karen Partridge, who failed to replicate Baker's results in Sheffield, were less kind. "Perhaps it depends on which side of the Pennine Hills the experiments are conducted?" they asked. "It is obviously extremely difficult to counter all conceivable explanations for a negative result but we are forced to wonder about the ecological importance of a magnetic sense, the existence of which is so difficult to demonstrate."

In the end, Baker relented and he moved on to the science of sperm. When I talked to him about the new study, he confesses that he hasn't kept up with the field. "I'd spent nearly a decade, tested thousands of people under all sorts of conditions, and had absolutely no doubt. Then people did a few tests here and there and claimed the experiments didn't replicate," he says. "Even after I'd collected everybody else's results and published that taken together, they did in fact constitute successful replication, nobody wanted to know. There was an element of 'Sod them, then'."

Reppert thinks that Baker's story was an unfortunate one, especially since he stopped just when others were starting to discover light-based magnetic sensors. "I think Baker's work was very good work but a lot of people had trouble reproducing aspects of it," says Reppert. "It's just very hard to do these sorts of behavioural experiments in humans."

The hardest sense

Magnetoreception has to be one of the hardest of all animal senses to study. Thorsten Ritz says, "Basic things that you do in other senses don't make sense when it comes to magnetoreception. Almost every other sense is linked to an opening in bone structure – eyes, ears and so on. The magnetic sense could sit anywhere in the body because the magnetic field penetrates the body."

To complicate matters, we don't really know what a magnetic sense would be used for. For birds and turtles, it seems obvious that an internal compass would help them to navigate over long migrations. But that doesn't really apply to humans, and we know that lost humans tend to go round in circles when other landmarks are unavailable.

But navigation isn't the only use for a magnetic sense. Recently, John Philips has suggested that animals could use magnetic fields to estimate distances over much smaller scales. Indeed, it's possible that foxes could use a magnetic range finder to gauge the distance of their pounces, when their prey is hidden by snow.

It's clear that magnetic senses will remain alluring and controversial for many years to come. Baker has left the field behind, but he is still intrigued by it. "I would be really thrilled if somebody managed to vindicate those ten years of work, because I still have no doubt that there is a real phenomenon there," he says. "This new paper is a very long way from being vindication, but just to read somebody saying that human magnetoreception deserves another look did give me a brief surge of satisfaction."

Reference: Foley, Gegear & Reppert. 2011. Human cryptochrome exhibits light-dependent magnetosensitivity. Nature Communications http://dx.doi.org/10.1038/ncomms1364

Scientists discover a framework in the brain for organizing the order of things

Scientists at NTNU's Kavli Institute for Systems Neuroscience in Norway have discovered a pattern of activity in the brain that serves as a template for building sequential experiences.

"I believe we have found one of the brain's prototypes for building sequences," says Professor Edvard Moser. He describes the activity pattern as "a fundamental algorithm that is intrinsic to the brain and independent of experience."

The breakthrough discovery was published in *Nature*.

The ability to organize elements into sequences is a fundamental biological function essential for our survival. Without it, we would not be able to communicate, keep track of time, find our way, or even remember what we are in the process of doing. The world would cease to present itself to us in meaningful experiences, as every event would be fragmented into an erratic series of random happenings.

The NTNU researchers' discovery of a rigid sequence pattern in the brain provides new insights into how we organize experiences into a temporal order.

The sequential nature of memory

Have you ever heard memories described as snapshots? That is not a very faithful description, according to Professor Edvard Moser. "It is more helpful to think of memories as videos," he says.

"All your experiences in the world extend over time," says Professor May-Britt Moser. "One thing happens, then another thing, then a third."

Your brain has the remarkable ability to mentally capture and organize selected events into the chronological order in which they occurred, and to link them together as meaningful experiences. This sequence-building activity takes place on the timescale in which you interact in the situation. When you recall this memory, the process of reliving the sequence of events in your mind also takes time.

"How is the brain able to generate and store all these unique and lengthy sequences of information on the fly?" asks Edvard Moser.

"There has to exist a foundational mechanism for sequence formation there."

"There is a mismatch in neuroscience between the timescales at which brain activity is typically studied, in the millisecond regime, and the timescales at which many of our most important brain functions occur, in the tens of seconds to several minutes range," says Soledad Gonzalo Cogno, Kavli Research Group Leader and first author of the paper, expanding on the motivation behind this study.

The team set out to identify this fundamental mechanism for sequence formation, which occurs on very slow timescales as most of our brain functions do.

The experiment

To uncover how neurons coordinate at the slow timescales at which many of our brain functions unfold, the Kavli researchers focused on the medial entorhinal cortex (MEC), a brain area that supports brain functions that depend on sequence formation, such as navigation and episodic memory, which unfold very slowly in time.

The sheer volume of information about the outside world being processed in the brain at any one time posed a challenge to the pursuit. Any baseline signal from structured and recurrent neural algorithms would risk drowning in the "noise" of incoming experience.

To get around this, the researchers created an experimental environment that was almost devoid of sensory inputs. They let a mouse run in complete darkness, with no task to complete and no reward to earn. The mouse could run or rest as it pleased for as long as the session lasted.

At the same time, the researchers recorded what was happening in the entorhinal cortex of the mouse's brain while its orchestra of nerve cells remained in this soft-spoken standby position.

A fundamental brain mechanism for sorting information into sequences

"This is what we found," says Soledad Gonzalo Cogno, pointing to a zebra-striped figure before her.

The pattern is made up of thousands of dots clustered together. Each dot is a neural signal. We can see that the neural activity moves through all the cells from bottom to top along the Y-axis as time progresses along the X-axis. The clustering tells us that the activity is coordinated as waves running through the network, like rhythms in a symphony.

The sequences are ultra-slow, meaning that it takes two minutes for the wave to travel through the neural network, before the whole process repeats again, sometimes for as long as the duration of the test session, over periods of up to an hour.

The figure shows several hundred mouse entorhinal cortex neurons oscillating at ultra-slow frequencies, spanning time windows ranging from tens of seconds to several minutes. The dynamic that excited the researchers, even more, is that as each cell oscillates, the cells also organize themselves into sequences, with cell A firing before cell B, cell B firing before cell C, and so on, until they have completed a full loop and return to cell A, where the cycle repeats.

This highly structured activity overlaps with the timescale of events that we encode into our memories and provides the perfect template for building the sequential structure that forms the basis of episodic memories.

These waves of coordinated activity did not travel straight from one end of the brain tissue to the other. Instead, the waves travel along the thin synaptic connections between cells that talk to each other in the network. Cells can talk to other cells far away and to their nearest neighbors. The anatomical tangle makes it difficult to see coordinated activity with the naked eye without first locating the cells from the raster plot.

Zebra-stripes, spiral, and ring

The zebra-striped raster plot shows the slow waves of activity through the whole network over a period of time. "If you fold the raster plot into a tube so that the top and the bottom of the figure overlap, you will see that the diagonal stripes connect to form a coherent spiral," explains May-Britt Moser. "The spiral represents the network activity over time."

You will see a ring if you rotate the spiral by 90 degrees. All the cells in the network have their set time to fire, distributed across the surface of this ring. The signal travels through the entire ring structure before returning to the same cell.

"This ring is a signature for coordination patterns in the form of repetitive sequences, which is what we found in the MEC," says Soledad Gonzalo Cogno. "Other brain areas have different coordination patterns."

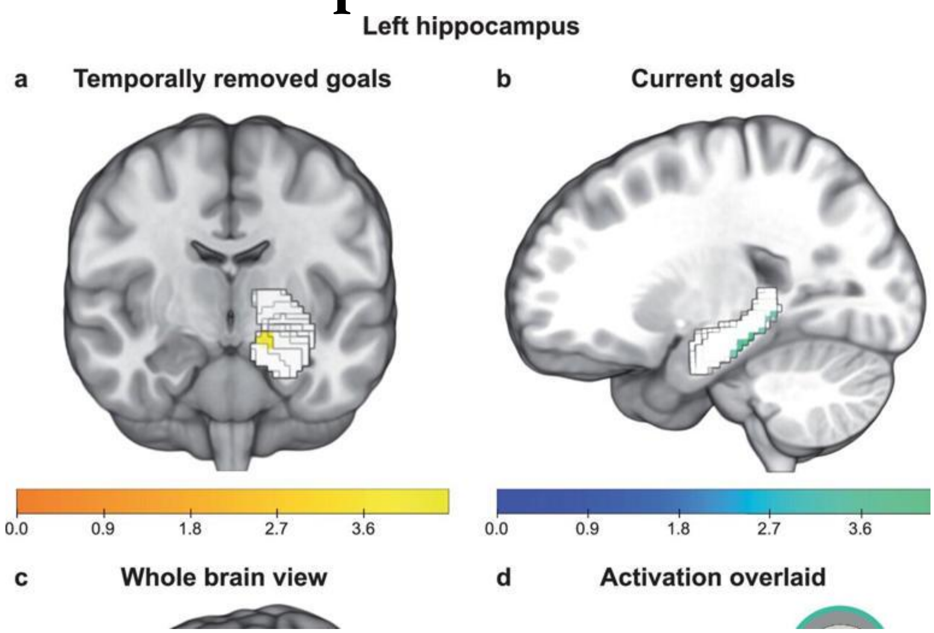
Your brain may already be equipped with this ring before you experience anything in this world. It is acquired through evolution and may be specified in our genes.

"What excites me most about this discovery is the prospect that these sequences may open up for new ways of understanding the brain," says Gonzalo Cogno. "The discoveries that follow may challenge the way we think about coordination throughout the brain. Cells that are so different still seem to be coordinated and work together on different timescales."

More information: Edvard Moser, Minute-scale oscillatory sequences in medial entorhinal cortex, *Nature* (2023). DOI: 10.1038/s41586-023-06864-1. www.nature.com/articles/s41586-023-06864-1

Provided by Norwegian University of Science and Technology

Scientists show how the hippocampus is activated to prioritize our activities



Temporally removed goals activated the left anterior hippocampus and current goals activated the left posterior hippocampus. a Activation maps for the contrasts comparing the remote (distant future + near future + distant past + near past) > current are overlaid in yellow. b Activation maps for the contrasts comparing the current > remote are overlaid in green. c Activation for the temporally removed goals (yellow) and the current goals (green) shown concurrently on the brain. d The same goal, for instance fixing the space helmet, was anatomically dissociated along the longitudinal axis based on whether it was currently relevant, or relevant at a point removed in time. The left hippocampal region of interest (ROI) is displayed in white. Credit: Nature Communications (2024). DOI: 10.1038/s41467-024-48648-9© Provided by Medical Xpress

How does our brain distinguish between urgent and less urgent goals?

Researchers at the University of Geneva (UNIGE) and the Icahn School of Medicine in New York have explored how our brain remembers and adjusts the goals we set for ourselves on a daily basis.

Their study reveals differences in the way we process immediate and distant goals, at both behavioral and cerebral levels. These discoveries, published in the journal *Nature Communications*, could have significant implications for understanding psychiatric disorders, particularly depression, which can hamper the formulation of clear goals.

Throughout the day, we set ourselves goals to achieve: picking up the children from school in an hour, preparing dinner in three hours, making a doctor's appointment in five days or mowing the lawn in a week. These goals, both urgent and less urgent, are constantly redefined according to the events that occur throughout the day.

Researchers from the UNIGE and the Icahn School of Medicine at Mont Sinai Hospital in New York have studied how the brain memorizes and updates the goals to be achieved. More specifically, how the brain sorts out which goals require immediate attention and which do not.

Their study focused on a particular region of the brain, the hippocampus, because of its established role in episodic memory. This is responsible for encoding, consolidating and retrieving personally experienced information, integrating its emotional, spatial and temporal context.

An imaginary mission to Mars, in the time of an MRI scan

Neuroscientists asked 31 people to project themselves into an imaginary 4-year space mission to Mars, requiring them to achieve a series of objectives crucial to their survival (taking care of their space helmet, doing exercise, eating certain foods, etc.). The mission objectives varied according to when they had to be achieved, with different tasks for each of the four years of the journey.

As participants progressed through the mission, they were presented with the same objectives. They were then asked to indicate whether these were past, present or future goals.

As the participants moved forward in time, the relevance of these objectives changed: Objectives initially planned for the future became current needs, while current needs became past objectives.

In this way, participants had to manage several objectives at different distances in time and update their priorities as their mission progressed.

Prioritizing immediate objectives

The team observed the reaction times of each individual to determine whether the task was to be achieved in the present, the past or the future. "Goals to be achieved immediately are recognized more quickly than those to be achieved in the distant future. This different processing of stored information reveals the priority given to needs in the present over those in the distant future.

"It takes extra time to mentally travel back in time to retrieve past and future goals," explains Alison Montagrin, research and teaching fellow in the Department of Basic Neurosciences at the UNIGE Faculty of Medicine, former post-doctoral fellow at the Icahn School of Medicine, and first author of the study.

The scientists also investigated whether differences were also apparent at the cerebral level. Images obtained using very high-resolution MRI revealed that, when retrieving information about the present, the hippocampus is activated in its posterior region. On the other hand, when recalling past goals or goals to be achieved in the future, the anterior region is activated.

"These results are particularly interesting because previous studies have shown that when we call on our episodic memory or our spatial memory, the anterior region of the hippocampus is involved in retrieving general information, while the posterior part deals with details.

"It will therefore be interesting to explore whether—unlike immediate goals—projection into the future or recall of a past goal do not require specific details, but a general representation is sufficient," concludes the researcher.

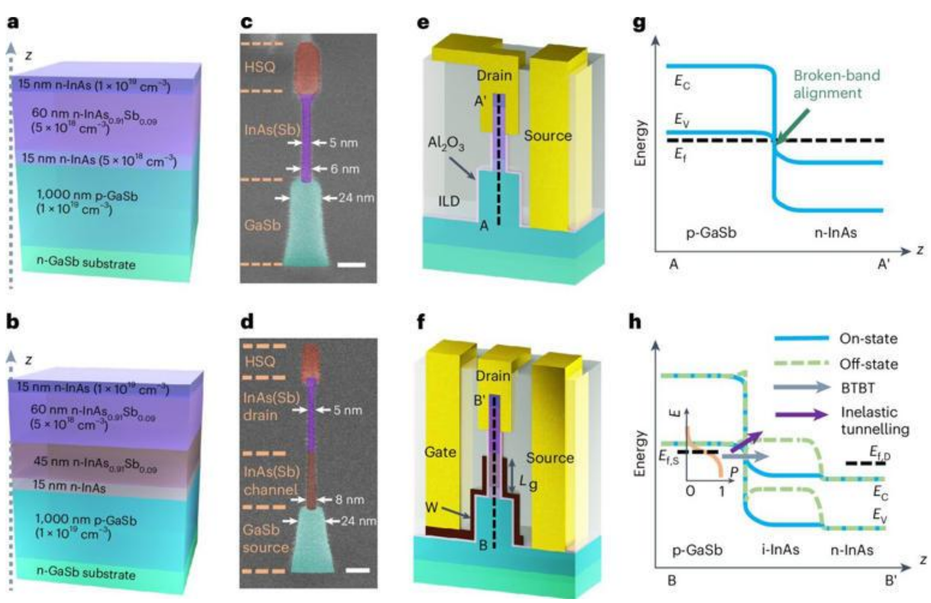
This research shows that the time scale plays a crucial role in the way people set personal goals. This could have important implications for understanding psychiatric disorders such as depression. Indeed, people suffering from depression may present difficulties in forming specific goals and envisage more obstacles in reaching their objectives.

Investigating whether these people perceive the distance to their goals differently—which could make them pessimistic about their chances of success—could open up a therapeutic avenue.

More information: Alison Montagrin et al, The hippocampus dissociates present from past and future goals, *Nature Communications* (2024). DOI: 10.1038/s41467-024-48648-9

Provided by University of Geneva

Nanoscale transistors could enable more efficient electronics



Ultra-scaled vertical-nanowire device design. Credit: Nature Electronics (2024). DOI: 10.1038/s41928-024-01279-w

Silicon transistors, which are used to amplify and switch signals, are a critical component in most electronic devices, from smartphones to automobiles. But silicon semiconductor technology is held back by a fundamental physical limit that prevents transistors from operating below a certain voltage.

This limit, known as "Boltzmann tyranny," hinders the energy efficiency of computers and other electronics, especially with the rapid development of artificial intelligence technologies that demand faster computation.

In an effort to overcome this fundamental limit of silicon, MIT researchers fabricated a different type of three-dimensional transistor using a unique set of ultrathin semiconductor materials. The research appears in *Nature Electronics*.

Their devices, featuring vertical nanowires only a few nanometers wide, can deliver performance comparable to state-of-the-art silicon transistors while operating efficiently at much lower voltages than conventional devices.

"This is a technology with the potential to replace silicon, so you could use it with all the functions that silicon currently has, but with much better energy efficiency," says Yanjie Shao, an MIT postdoc and lead author of a paper on the new transistors.

The transistors leverage quantum mechanical properties to simultaneously achieve low-voltage operation and high performance within an area of just a few square nanometers. Their extremely small size would enable more of these 3D transistors to be packed onto a computer chip, resulting in fast, powerful electronics that are also more energy-efficient.

"With conventional physics, there is only so far you can go. The work of Yanjie shows that we can do better than that, but we have to use different physics. There are many challenges yet to be overcome for this approach to be commercial in the future, but conceptually, it really is a breakthrough," says senior author Jesús del Alamo, the Donner Professor of Engineering in the MIT Department of Electrical Engineering and Computer Science (EECS).

They are joined on the paper by Ju Li, the Tokyo Electric Power Company Professor in Nuclear Engineering and professor of materials science and engineering at MIT; EECS graduate student Hao Tang; MIT postdoc Baoming Wang; and professors Marco Pala and David Esseni of the University of Udine in Italy.

Surpassing silicon

In electronic devices, silicon transistors often operate as switches. Applying a voltage to the transistor causes electrons to move over an energy barrier from one side to the other, switching the transistor from "off" to "on." By switching, transistors represent binary digits to perform computation.

A transistor's switching slope reflects the sharpness of the "off" to "on" transition. The steeper the slope, the less voltage is needed to turn on the transistor and the greater its energy efficiency.

But because of how electrons move across an energy barrier, Boltzmann tyranny requires a certain minimum voltage to switch the transistor at room temperature.

To overcome the physical limit of silicon, the MIT researchers used a different set of semiconductor materials—gallium antimonide and indium arsenide—and designed their devices to leverage a unique phenomenon in quantum mechanics called quantum tunneling.

Quantum tunneling is the ability of electrons to penetrate barriers. The researchers fabricated tunneling transistors, which leverage this property to encourage electrons to push through the energy barrier rather than going over it.

"Now, you can turn the device on and off very easily," Shao says.

But while tunneling transistors can enable sharp switching slopes, they typically operate with low current, which hampers the performance of an electronic device.

Higher current is necessary to create powerful transistor switches for demanding applications.

Fine-grained fabrication

Using tools at MIT.nano, MIT's state-of-the-art facility for nanoscale research, the engineers were able to carefully control the 3D geometry of their transistors, creating vertical nanowire heterostructures with a diameter of only 6 nanometers. They believe these are the smallest 3D transistors reported to date.

Such precise engineering enabled them to achieve a sharp switching slope and high current simultaneously. This is possible because of a phenomenon called quantum confinement.

Quantum confinement occurs when an electron is confined to a space that is so small that it can't move around. When this happens, the effective mass of the electron and the properties of the material change, enabling stronger tunneling of the electron through a barrier.

Because the transistors are so small, the researchers can engineer a very strong quantum confinement effect while also fabricating an extremely thin barrier.

"We have a lot of flexibility to design these material heterostructures so we can achieve a very thin tunneling barrier, which enables us to get very high current," Shao says.

Precisely fabricating devices that were small enough to accomplish this was a major challenge.

"We are really into single-nanometer dimensions with this work. Very few groups in the world can make good transistors in that range. Yanjie is extraordinarily capable to craft such well-functioning transistors that are so extremely small," says del Alamo.

When the researchers tested their devices, the sharpness of the switching slope was below the fundamental limit that can be achieved with conventional silicon transistors. Their devices also performed about 20 times better than similar tunneling transistors.

"This is the first time we have been able to achieve such sharp switching steepness with this design," Shao adds.

The researchers are now striving to enhance their fabrication methods to make transistors more uniform across an entire chip. With such small devices, even a 1-nanometer variance can change the behavior of the electrons and affect device operation.

They are also exploring vertical fin-shaped structures, in addition to vertical nanowire transistors, which could potentially improve the uniformity of devices on a chip.

More information: Yanjie Shao et al, Scaled vertical-nanowire heterojunction tunnelling transistors with extreme quantum confinement, *Nature Electronics* (2024). DOI: 10.1038/s41928-024-01279-w

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Provided by Massachusetts Institute of Technology

Brain waves found to travel in one direction when memories are made and the opposite when recalled

Traveling wave propagation directions in the memory task reveal how the brain quickly coordinates activity and shares information across multiple regions. Credit: Honghui Zhang© Provided by Medical Xpress

In the space of just a few seconds, a person walking down a city block might check their phone, yawn, worry about making rent, and adjust their path to avoid a puddle. The smell from a food cart could suddenly conjure a memory from childhood, or they could notice a rat eating a slice of pizza and store the image as a new memory.

For most people, shifting through behaviors quickly and seamlessly is a mundane part of everyday life.

For neuroscientists, it's one of the brain's most remarkable capabilities. That's because different activities require the brain to use different combinations of its many regions and billions of neurons. How it manages to do this so rapidly has been an open question for decades.

In a paper published March 8 in *Nature Human Behaviour*, a team of researchers, led by Joshua Jacobs, associate professor of biomedical engineering at Columbia Engineering, shed new light on this question. By carefully monitoring neural activity of people who were recalling memories or forming new ones, the researchers managed to detect how a newly appreciated type of brainwave—traveling waves—influences the storage and retrieval of memories.

"Broadly, we found that waves tended to move from the back of the brain to the front while patients were putting something into their memory," said the paper's co-author Uma R. Mohan, a postdoctoral researcher at NIH and former postdoctoral researcher in the Electrophysiology, Memory, and Navigation Laboratory at Columbia Engineering.

"When patients were later searching to recall the same information, those waves moved in the opposite direction, from the front towards the back of the brain," she said.

In the brains of some of the study's 93 participants, waves traveled in other directions.

"There was a lot of diversity across patients, so we implemented a framework based on the direction an individual's oscillations 'preferred' to travel," Mohan said.

The researchers say these findings advance fundamental neuroscience research and point toward diagnostic and therapeutic approaches for memory-related disorders.

"We think the work may lead to new approaches for interfacing with the brain. By measuring the direction that a person's brain waves move, we may be able to predict their behavior," Jacobs said.

Brain waves are patterns of electrical oscillations that reflect the state of hundreds or thousands of individual neurons at a particular moment. One major question, which remains unsettled, is whether brain waves drive activity or simply occur as a byproduct of neural activity that was already happening. Researchers who study brain waves have tended to treat them as a stationary phenomenon that occurs in a particular region, noting when oscillations in multiple regions seem synchronized.

In this study, Mohan and her colleagues contribute to a growing understanding of these oscillations differently, as "traveling waves" that spread across the brain's cortex, the outermost layer that supports higher cognitive processing. Mohan compares the traveling waves to the ripples that would spread outward after a pebble was thrown into a pond.

"We're looking at neural oscillations not as independent stationary things but as things that are constantly and spontaneously moving across the brain in a dynamic way," Mohan said.

This relatively new way of understanding brain waves is an exciting step in neuroscience because it offers a pathway to explaining how the brain quickly coordinates activity and shares information across multiple regions.

The study drew on data from participants who were being treated for drug-resistant epilepsy at hospitals across the United States. The experiments occurred while the participants had grids or strips of electrodes temporarily implanted on the surface of the brain, beneath the skull, to determine where the patients' seizures arise. For the researchers, these electrodes offer the chance to perform experiments that wouldn't otherwise be feasible.

"It's a rare opportunity to be able to see what's going on directly from the brain while the participants are engaged in different cognitive behaviors," Mohan said.

During the experiments, researchers recorded the participants' brain activity while they performed tasks that required memorizing and recalling lists of words or letters.

After the experiments, the researchers analyzed the brain activity from each participant in the context of what they were doing in the memory task and how well they performed.

"I implemented a method to label waves traveling in one direction as basically 'good for putting something into memory." Then we could see how the direction switched over the course of the task," Mohan said. This method builds on previous research from the Jacobs lab by expanding the mathematical framework used to make sense of the vast quantities of data these experiments produced.

"The waves tended to go in the participant's encoding direction when that participant was putting something into memory and in the opposite direction right before they recalled the word," she said. " Overall, this new work links traveling waves to behavior by demonstrating that traveling waves propagate in different directions across the cortex for separate memory processes."

The data also showed that participants tended to perform the memory task more accurately when the traveling waves were moving in the appropriate direction for memory storage and recall.

"These findings shed light on the mechanisms that underlie memory processing. More broadly, they help us better understand how the brain supports a wide range of behaviors that involve precisely coordinated interactions between brain regions," Mohan said.

Potential impact and future directions

As traveling waves are increasingly well understood, they could be the basis for a new class of diagnostic tools that recognize abnormal patterns in brain activity.

There is also significant therapeutic potential.

"If someone's waves are moving in the wrong direction when they're about to try to remember something, that might put them in a poor memory state," Mohan explained. "If you could apply stimulation in the right way, you could maybe push those waves to move in a different direction, bringing about a fundamentally different memory state."

Advances in understanding traveling waves offer significant potential for human-computer interaction.

In terms of both research and application, Mohan notes that memory is just the starting point.

"I am interested in how characteristics of cortical traveling waves change to support a wide range of cognitive functions, including attention and associative memory," she said.

"The direction of traveling wave propagation may tell us where information is moving across the brain at each moment, showing us how different parts of the brain transfer information during behavior," Jacobs said.

More information: The direction of theta and alpha travelling waves modulates human memory processing, *Nature Human Behaviour* (2024). DOI: 10.1038/s41562-024-01838-3. www.nature.com/articles/s41562-024-01838-3

Provided by Columbia University School of Engineering and Applied Science

Imagine using a computer with your thoughts. No more typing and scrolling, you just think about sending an email and off it goes.

This kind of technological telepathy is the broad idea behind the brain-computer interface (BCI).

Also known as a brain-machine interface, these devices are intended to bypass our typical modes of interacting with computers – hands, fingers, and voices – in favour of capturing and interpreting signals directly from the brain.

The possibilities of this technology are so wide-reaching to the point where we could have near-instant communication with anyone on Earth using just our minds.

These devices could also let you control robotic limbs or pilot drones and, as virtual reality continues to develop, you may be able to move around digital worlds without lifting a finger.

In scientific literature, the concept of BCIs goes back at least as far as a 1973 paper from Jacques Vidal of the University of California's Brain Research Institute who pondered whether brain signals captured by an electroencephalogram (EEG) could be used "for the purpose of controlling such external apparatus as prosthetic devices or spaceships".

Vidal described an early BCI built on the "conviction" that EEG signals "contain usable concomitances of conscious and unconscious experiences" that – though largely consisting of noise – still "reflects underlying neural events".

BCIs could do more than read brainwaves – they may be able to write them as well, letting you 'see' a user interface where there is none, or even giving you a consistently calm mental state with the kind of direct brain access pharmaceutical companies could only dream of achieving.

These are just some of the potential future use-cases for BCIs. They may sound like fantastical ideas ripped from the pages of science fiction novels, and that's because much of this technology lies at the bleeding edge where science fiction meets science fact.

At the heart of modern BCI research and development is a striving for greater inclusivity. People living with disabilities and chronic health conditions are the immediate beneficiaries of this technology as they find new ways of communicating and interacting with the world and other people.

The foundations being laid in the name of creating a more inclusive world could one day lead to a general computing revolution that has implications for how we define autonomy and free will, how we preserve the privacy of our inner-most thoughts and feelings, and what it means to be human.

An unreal vision

It's a technology that, like much of the bleeding edge, involves billionaire Elon Musk and his outrageous, sci-fi promises.

In March 2017, early reports of Musk's company Neuralink surfaced. When he began to speak publicly about the idea behind Neuralink, Musk mentioned the devices as a way of creating "symbiosis with artificial intelligence" in order to give people "superhuman cognition" and mitigate the "existential risk" Musk and other long-termist adherents believe is inherent in AI development.

Neuralink's soft launch was nudged along with a long explainer from blogger Tim Urban about how BCIs could usher in a future where humans collectively and telepathically make decisions – something Musk insists is necessary lest humans become "effectively useless or like a pet" to AI.

"If we achieve tight symbiosis [with AI through BCIs], the AI wouldn't be 'other'," Musk said. "It would be you and with a relationship to your cortex analogous to the relationship your cortex has with your limbic system."

To get to this point, Musk wants to implant Neuralink devices into willing customers in order to both "report from and stimulate spikes in neuron activity".

"It will be safe enough that it's not a major operation and will be equivalent to LASEK surgery," Musk previously said.

One day, Musk claims, the device will even let people "save and replay memories".

As with many of his business ventures, Musk's intended future state of Neuralink is as ambitious as it is divorced from the current technological reality.

Neuralink has yet be approved for human trials and has been plagued by reports of animal cruelty during testing.

One of the few glimpses we have seen of Neuralink involve a monkey playing the video game Pong with its mind which, while impressive in its own right, failed to demonstrate new developments in the BCI space.

In mid-2004, researchers with the BrainGate project conducted human trials of its technology that gave a handful of patients who had spinal cord injuries or motor neurone disease. They were able to control a computer cursor and even issue simple commands to a prosthetic hand using their minds.

Leaving the lab

Today, much of the effort in BCI development is about taking the technologies out of the lab, according to Professor David Grayden, Clifford Chair of Neural Engineering at the University of Melbourne.

He told *Information Age* there has "been a lot of work trying to understand the [brain] signals, decode them, and use AI to interpret the signals, but with systems that are sort of unusable in the home".

Moving BCI technologies into people's homes will be a game changer for the people who use them and is part of a gradual adoption curve.

There are a few different ways for extracting your thoughts, Professor Grayden said, including the EEG technology explored 50 years ago by Jacques Vidal.

"[The electrodes] don't need surgery to put on so it's about trying to get the best possible signal from those," he told *Information Age*.

"This is really difficult because the signal is attenuated a lot by the skull and the scalp so you really only get the low frequencies."

Maximising the fidelity and interpretation of brain signals using EEG could be an important step toward broader BCI adoption and use because of its non-invasive nature.

You could imagine buying a consumer-grade headset with powerful enough electrodes to read signals via processing that happens on-board or on a nearby device.

Back in 2019, Meta (then Facebook) told the world about its own experiments with BCI technology in a blog post that described its research into decoding words and phrases captured from invasive electrocorticography (ECoG).

Meta's researchers used this data to train a neural network that could interpret a "sentence-length sequence of neural activity" into language.

Incredibly, the researchers claimed in an article subsequently published in *Nature Neuroscience*, that the model could decode brain activity "with high accuracy and at natural-speech rates".

Meta posed a possible future in which you could have the "hands-free convenience and speed" of using your voice to control your phone, tablet, laptop "with the discreteness of typing".

Aside from EEG, Meta also spoke about how it tested measuring changes in oxygen levels in the brain that correspond to activity.

Combined with its research on decode brain activity, Meta suggested that the ability "to recognise even a handful of imagined commands, like 'home,' 'select,' and 'delete' would provide entirely new ways of interacting with today's VR [virtual reality] systems – and tomorrow's AR [augmented reality] glasses".

Here you can see the potential for consumer-grade BCIs with rudimentary mind-reading technology for walking around virtual worlds or controlling AR glasses.

But so far, the best way to control a computer with your mind is to have electrodes placed directly onto brain tissue.

"If you're inside the skull, you can get higher frequencies and a better localisation of the signal," Professor Grayden said.

"This involves putting penetrating electrodes down into people's heads, kind of like a bed of nails that just gets pushed into the brain.

“Those electrodes are so small and they're so close to the neurons that they can record even individual neuron activity.”

Localisation is important given how our brains process different information in different areas of tissue.

It’s an imperfect description of how brains work – there is plenty of overlap with activity that activates neurons in different sections of the brain – but is nonetheless useful when trying to target specific areas or functions like in the motor cortex, which controls voluntary movements.

The more invasive the BCI technology, the better the signal and localisation – but implanting anything onto the brain is fraught with difficulty.

In part two of this series, we will look at the limitations for the development of BCIs, an Australian company that has taken a novel approach, and some of the real-world uses of BCIs today.

Scientists Prove That Telepathic Communication Is Within Reach

An international research team develops a way to say “hello” with your mind

In a recent experiment, a person in India said “hola” and “ciao” to three other people in France. Today, the Web, smartphones and international calling might make that not seem like an impressive feat, but it was. The greetings were not spoken, typed or texted. The communication in question happened between the brains of a set of study subjects, marking one of the first instances of brain-to-brain communication on record.

The team, whose members come from Barcelona-based research institute Starlab, French firm Axilum Robotics and Harvard Medical School, published its findings earlier this month in the journal *PLOS One*. Study co-author Alvaro Pascual-Leone, director of the Berenson-Allen Center for Noninvasive Brain Stimulation at Beth Israel Deaconess Medical Center and a neurology professor at Harvard Medical School, hopes this and forthcoming research in the field will one day provide a new communication pathway for patients who might not be able to speak.

“We want to improve the ways people can communicate in the face of limitations—those who might not be able to speak or have sensory impairments,” he says. “Can we work around those limitations and communicate with another person or a computer?”

Pascual-Leone’s experiment was successful—the correspondents neither spoke, nor typed, nor even looked at one another. But he freely concedes that the test was more a proof of concept than anything else, and the technique still has a long way to go. “It’s still very, very early,” he says, “[but] we can show that this is even possible with technology that’s available. It’s the difference between talking on the phone and sending Morse code. To get where we’re going, you need certain steps to be taken first.”

Indeed, the process was drawn out, if not downright inelegant. First, the team had to establish binary-code equivalents of letters; for example “h” is “0-0-1-1-1.” Then, with EEG (electroencephalography) sensors attached to the scalp, the sender moved either his hands or feet to indicate a 1 or a 0. The code then passed to the recipient over email. On the other end, the receiver was blindfolded with a transcranial magnetic stimulation (TMS) system on his head. (TMS is a non-invasive method of stimulating neurons in the brain; it’s most commonly used to treat depression.) The TMS headset stimulated the recipient’s brain, causing him to see quick flashes of light. A flash was equivalent to a “1” and a blank was a “0.” From there, the code was translated back into text. It took about 70 minutes to relay the message.

Grau, C., et al. PLOS ONE 2014

There is a bit of contention about the degree to which this approach was actually novel. *IEEE Spectrum* reports that this recent study is quite similar to one conducted at the University of Washington last year. In that study, researchers used the same EEG-to-TMS setup, but rather than pulsed light, stimulated the brain’s motor cortex to subconsciously cause the recipient to strike a key on a keyboard. Pascual-Leone contends, however, that his work is notable because the recipient was conscious of the communication.

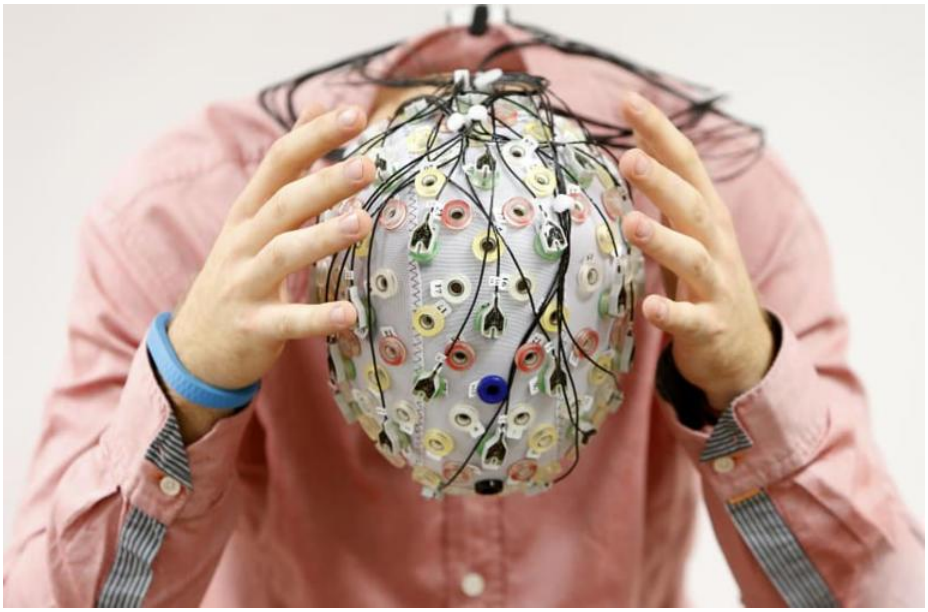
Both studies represent only a small step toward engineering telepathy, which might take years—or decades—to perfect. Ultimately, the goal is to remove the computer middleman from the transmission equation and allow direct brain-to-brain communication between people. “We’re still a long way from that,” Pascual-Leone admits, “but in the end, I think it’s a pursuit worthy of the effort.”

Outside of medicine, brain-to-brain communication could find applications across many disciplines. Soldiers, for instance, could use the technology on the battlefield, sending commands and warnings to one another. Civilians might benefit, as well; businesspeople could use it to send cues to partners during negotiations, or pitchers and catchers could avoid sign-stealing during baseball games.

Still, telepathic communication that works like a sort of futuristic walkie-talkie will involve major advances in sensing, emitting and receiving technologies—and perhaps even a slight retraining of the human brain. At the same time, Pascual-Leone cautions that scientists must also keep in mind the ethics of telepathy.

“Could there be potential for sending someone a thought that’s not desirable to them?” he says. “Those kinds of things are theoretically in the realm of possibility."

Two-stage brain coding explained by University of Haifa study


Test person Niklas Thiel poses with an electroencephalography (EEG) cap which measures brain activity, at the Technische Universitaet Muenchen (TUM) in Garching near Munich© (photo credit: REUTERS/Michaela Rehle)

Understanding how the brain encodes information is important to understand how parts of the body "communicate" with the brain – for example, if doctors want to connect a prosthetic hand or leg to the brain and let the brain operate it.

"Understanding the language that the brain uses to speak to itself will enable us to better understand how to transfer information to and from the brain with a high degree of precision," according to Prof. Eran Stark of the Sagol neurobiology department at the University of Haifa who led a study just published in the prestigious journal *Science* under the title "Local activation of CA1 pyramidal cells induces theta-phase precession."

To encode new information, brain cells in the hippocampus – a complex brain structure embedded deep into the temporal lobe that has a major role in learning and memory – activate a mechanism that triggers an increase in the firing rate and influences the precise timing of the firing.

The importance of understanding the brain

“The new study shows us that local circuits in the brain are more sophisticated than we might have thought. The brain can encode information in two different ways, one of which causes the other,” Stark explains.

The question of how the brain encodes new information it receives is one of the most important and complex issues in understanding processes of learning, memory, and more.

One of the main problems involved in understanding coding mechanisms concerns the difficulty in “controlling” neurons and making them act in a particular manner.

Until now, neurobiologists knew that during the encoding of new information (specifically, the identification by mice of new places within space), neurons in the hippocampus participate in two processes.

What are the two processes that occur?

The first process entails an increase in the firing rate of the individual cell.

In simple terms, the cell fires more times within a given period of time. The second process is a change in the timing mechanism. Theta waves with a frequency of 8 Hertz occur in the hippocampus, and it is possible to measure precisely when within the shape of the theta wave the cell fires – at what timing (phase) “along the wave.”

In the second process, when entering a new place in space, the neurons initially fire at the peak of the wave, then at an earlier phase, and on leaving the new place, they again fire close to the peak of the wave – a process known as phase precession.

According to the current state of knowledge, both of these processes occur simultaneously in the same cell in mice during the encoding of new information concerning spatial location.

Until now, however, it was not known whether there is a causal relationship between the two processes – does one cause the other or do they operate independently? In addition, if there is a causal dependence between the two processes, it has been unclear what mechanism promotes the conversion of the code for the firing rate into a temporal code for phase precession, causing the two to operate simultaneously.

Over the years, six groups of mathematic models were proposed, each assuming a different mechanism for the relationship between the two processes.

A new study at Tel Aviv University

In the new study – which was headed by Stark while he was the head of the Center of Excellence for the Study of the Neural Code underlying Cognition at Tel Aviv University TAU, the researchers used optogenetic technology that uses a special protein channel that reacts to light: each time the protein is exposed to blue light, the electric potential inside the neuron changes and it fires.

The researchers implanted miniaturized optoelectronic devices in the brains of freely moving mice and, using closed-loop feedback methods, caused an individual cell in the hippocampus to increase its firing rate artificially – the condition for the first process of information encoding.

The researchers monitored the mouse as it moved back and forth along a track – as it used coding mechanisms for spatial recognition.

In some track crossings, the researchers caused an increase in the firing rate of the examined cell in the hippocampus, and in others, they did not.

This allowed them to examine the effect of the artificial constraint on the firing rate at different points and times and under different conditions and thereby compare their results to "control" instances.

The findings showed that when the researchers increased the cell firing rate and created a new rate code, a change occurred in the precise timing of firing, and a phase code emerged. When the firing rate was not increased, no change in timing was observed. Thus, a clear causal relationship could be seen, whereby increasing the rate causes a change in timing.

“Firstly, it is important to clarify that although we examined the six existing model groups, there may, of course, be additional explanations we did not consider that are correct,” Stark stressed.

“If we wish to elaborate the model that explains the observations, we need to understand where the additional wave that causes interference comes from. For there to be a new wave, there must be an additional oscillator – something that creates the oscillations that form the faster waves," Stark added.

"Regarding the practical ramifications of understanding the brain mechanism for the first time, Stark said that for us to communicate effectively with the brain, we need to use its own language (code). Before our study, it might have been assumed that the brain uses several separate systems to operate the two codes simultaneously –that the brain uses several languages. But now we know that at least in one area of the brain, one code – the rate code – can be automatically converted into a code for precise timing that may be better suited to the transmission of information between the cells but is harder to implement artificially. So, if we want to elaborate the model that explains the observations, we need to understand where the additional wave that causes interference comes from,” he concluded.

Study discovers a 'brain thesaurus' that lets neurons derive meaning from spoken words

Using a novel technology for obtaining recordings from single neurons, a team of investigators at Massachusetts General Hospital, a founding member of the Mass General Brigham health care system, discovered a microscopic "thesaurus" that reflects how word meanings are represented by neurons in the human brain.

The research, which is published in *Nature*, opens the door to understanding how humans comprehend language and provides insights that could be used to help individuals with medical conditions that affect speech.

"Humans possess an exceptional ability to extract nuanced meaning through language—when we listen to speech, we can comprehend the meanings of up to tens of thousands of words and do so seamlessly across remarkably diverse concepts and themes," said senior author Ziv Williams, MD, a physician-investigator in the department of Neurosurgery at Massachusetts General Hospital and an associate professor of Neurosurgery at Harvard Medical School.

"Yet, how the human brain processes language at the basic computational level of individual neurons has remained a challenge to understand."

Williams and his colleagues set out to construct a detailed map of how neurons in the human brain represent word meanings—for example, how we represent the concept of animal when we hear the word cat and dog, and how we distinguish between the concept of a dog and a car.

"We also wanted to find how humans are able to process such diverse meanings during natural speech and through which we are able to rapidly comprehend the meanings of words across a wide array of sentences, stories, and narratives," Williams said.

To start addressing these questions, the scientists used a novel technology that allowed them to simultaneously record the activities of up to a hundred neurons from the brain while people listened to sentences (such as, "the child bent down to smell the rose") and short stories (for example, about the life and times of Elvis Presley).

Using this new technique, the investigators discovered how neurons in the brain map words to particular meanings and how they distinguish certain meanings from others.

"For example, we found that while certain neurons preferentially activated when people heard words such as 'ran' or 'jumped,' which reflect actions, other neurons preferentially activated when hearing words that have emotional connotations, such as 'happy' or 'sad,'" said Williams.

"Moreover, when looking at all of the neurons together, we could start building a detailed picture of how word meanings are represented in the brain."

To comprehend language, though, it is not enough to only understand the meaning of words, but also to accurately follow their meanings within sentences. For example, most people can rapidly tell the correct meaning of words such as "sun" and "son" or "see" and "sea" when used in a sentence, even though the words sound exactly the same.

"We found that certain neurons in the brain are able to reliably distinguish between such words, and they continuously anticipate the most likely meaning of the words based on the sentence contexts in which they are heard," said Williams.

Lastly, and perhaps most excitingly, the researchers found that, by recording a relatively small number of brain neurons, they could reliably predict the meanings of words as they were heard in real-time during speech. That is, based on the activities of the neurons, the team could determine the general ideas and concepts experienced by an individual as they were being comprehended during speech.

"By being able to decode word meaning from the activities of small numbers of brain cells, it may be possible to predict, with a certain degree of granularity, what someone is listening to or thinking," said Williams.

"It could also potentially allow us to develop brain-machine interfaces in the future that can enable individuals with conditions such as motor paralysis or stroke to communicate more effectively."

More information: Mohsen Jamali et al, Semantic encoding during language comprehension at single-cell resolution, *Nature* (2024). DOI: 10.1038/s41586-024-07643-2

Quantum Entanglement Communicator

The Quantum Entanglement Communicator represents a monumental leap in global communication technology, inspired by the advanced systems featured in *Ender's Game*. This groundbreaking device harnesses the principles of quantum entanglement to enable instantaneous communication across vast distances, eliminating the delays associated with traditional systems.

By utilizing entangled particles, this communicator ensures that messages are transmitted instantly, regardless of physical barriers. Its secure, nearly unhackable nature provides a significant tactical advantage, allowing for strategic discussions without the risk of interception.

As the Quantum Entanglement Communicator bridges the gaps of time and space, it transforms not only military operations but also the very fabric of global connectivity, paving the way for a future where communication knows no bounds.

Jarvis AI is real – Google accidentally leaks its AI agent that browses the web for you

- **Google has accidentally leaked its Jarvis AI**
- **Jarvis AI browses Chrome for you**
- **It's expected to be officially unveiled in December**

Google has accidentally leaked its upcoming AI agent, Jarvis AI, which will browse the web for you in Chrome.

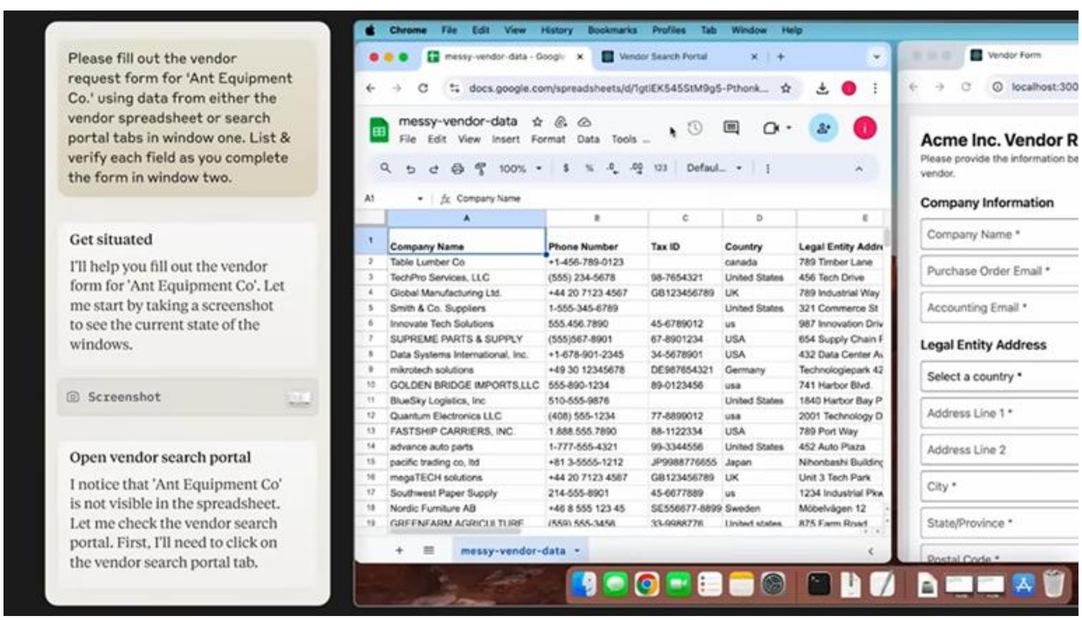
According to The Information, Google posted an internal preview of the product, codenamed Jarvis, on the Chrome extension store but was quick to remove the prototype before too many users noticed.

The listing read "a helpful companion that surfs the web with you." which lines up with the news from October that Google was developing Jarvis, the AI agent that would help you shop online and even be able to book your next vacation.

Those who managed to download the Jarvis AI prototype before it was pulled from Chrome's extension store were unable to use it as the program required specific access permissions.

With The Information reporting Google plans to officially unveil Jarvis in December, this leak confirms that we won't have long to wait.

Christmas shopping for me



Anthropic released the 'computer use' feature (above) for its Claude AI, which similarly lets it interact with your computer. (Image credit: Anthropic)

Jarvis AI is expected to allow users to automate web browsing tasks from within Google Chrome so they can focus on more important things while the AI agent shops or even books flights for you.

For example, think of how great this could be for mundane Christmas shopping – after all, nothing says 'I love you' more than a gift purchased by AI.

AI agents, which are systems that can complete tasks without your supervision, are starting to pop up increasingly with companies like Anthropic releasing a product similar to Jarvis last month. It's also reported that OpenAI could be working on an agent too, although we're yet to see how that would differ from Google's upcoming product.

AI development is booming with companies releasing new tools almost daily. Just last week ChatGPT Search became available to Plus subscribers ushering in a new era for AI search engines. With Jarvis AI, however, we might not even need to do the searching ourselves.

Memories are not only in the brain, human cell study finds

An NYU researcher administers chemical signals to non-neural cells grown in a culture plate. Credit: Nikolay Kukushkin

It's common knowledge that our brains—and, specifically, our brain cells—

store memories. But a team of scientists has discovered that cells from other parts of the body also perform a memory function, opening new pathways for understanding how memory works and creating the potential to enhance learning and to treat memory-related afflictions.

"Learning and memory are generally associated with brains and brain cells alone, but our study shows that other cells in the body can learn and form memories, too," explains New York University's Nikolay V. Kukushkin, the lead author of the study, which appears in the journal *Nature Communications*.

The research sought to better understand if non-brain cells help with memory by borrowing from a long-established neurological property—the massed-spaced effect—which shows that we tend to retain information better when studied in spaced intervals rather than in a single, intensive session—better known as cramming for a test.

In the research, the scientists replicated learning over time by studying two types of non-brain human cells in a laboratory (one from nerve tissue and one from kidney tissue) and exposing them to different patterns of chemical signals—just like brain cells are exposed to patterns of neurotransmitters when we learn new information.

In response, the non-brain cells turned on a "memory gene"—the same gene that brain cells turn on when they detect a pattern in the information and restructure their connections in order to form memories.

To monitor the memory and learning process, the scientists engineered these non-brain cells to make a glowing protein, which indicated when the memory gene was on and when it was off.

The results showed that these cells could determine when the chemical pulses, which imitated bursts of neurotransmitter in the brain, were repeated rather than simply prolonged—just as neurons in our brain can register when we learn with breaks rather than cramming all the material in one sitting.

Specifically, when the pulses were delivered in spaced-out intervals, they turned on the "memory gene" more strongly, and for a longer time, than when the same treatment was delivered all at once.

"This reflects the massed-space effect in action," says Kukushkin, a clinical associate professor of life science at NYU Liberal Studies and a research fellow at NYU's Center for Neural Science. "It shows that the ability to learn from spaced repetition isn't unique to brain cells, but, in fact, might be a fundamental property of all cells."

The researchers add that the findings not only offer new ways to study memory, but also point to potential health-related gains.

"This discovery opens new doors for understanding how memory works and could lead to better ways to enhance learning and treat memory problems," observes Kukushkin.

"At the same time, it suggests that in the future, we will need to treat our body more like the brain—for example, consider what our pancreas remembers about the pattern of our past meals to maintain healthy levels of blood glucose or consider what a cancer cell remembers about the pattern of chemotherapy."

The work was jointly supervised by Kukushkin and Thomas Carew, a professor in NYU's Center for Neural Science. The study's authors also included Tasnim Tabassum, an NYU researcher, and Robert Carney, an NYU undergraduate researcher at the time of the study.

More information: N. V. Kukushkin et al, The massed-spaced learning effect in non-neural human cells, *Nature Communications* (2024). DOI: 10.1038/s41467-024-53922-x Provided by New York University

Study discovers a 'brain thesaurus' that lets neurons derive meaning from spoken words

Using a novel technology for obtaining recordings from single neurons, a team of investigators at Massachusetts General Hospital, a founding member of the Mass General Brigham health care system, discovered a microscopic "thesaurus" that reflects how word meanings are represented by neurons in the human brain.

The research, which is published in *Nature*, opens the door to understanding how humans comprehend language and provides insights that could be used to help individuals with medical conditions that affect speech.

"Humans possess an exceptional ability to extract nuanced meaning through language—when we listen to speech, we can comprehend the meanings of up to tens of thousands of words and do so seamlessly across remarkably diverse concepts and themes," said senior author Ziv Williams, MD, a physician-investigator in the department of Neurosurgery at Massachusetts General Hospital and an associate professor of Neurosurgery at Harvard Medical School.

"Yet, how the human brain processes language at the basic computational level of individual neurons has remained a challenge to understand."

Williams and his colleagues set out to construct a detailed map of how neurons in the human brain represent word meanings—for example, how we represent the concept of animal when we hear the word cat and dog, and how we distinguish between the concept of a dog and a car.

"We also wanted to find how humans are able to process such diverse meanings during natural speech and through which we are able to rapidly comprehend the meanings of words across a wide array of sentences, stories, and narratives," Williams said.

To start addressing these questions, the scientists used a novel technology that allowed them to simultaneously record the activities of up to a hundred neurons from the brain while people listened to sentences (such as, "the child bent down to smell the rose") and short stories (for example, about the life and times of Elvis Presley).

Using this new technique, the investigators discovered how neurons in the brain map words to particular meanings and how they distinguish certain meanings from others.

"For example, we found that while certain neurons preferentially activated when people heard words such as 'ran' or 'jumped,' which reflect actions, other neurons preferentially activated when hearing words that have emotional connotations, such as 'happy' or 'sad,'" said Williams.

"Moreover, when looking at all of the neurons together, we could start building a detailed picture of how word meanings are represented in the brain."

To comprehend language, though, it is not enough to only understand the meaning of words, but also to accurately follow their meanings within sentences. For example, most people can rapidly tell the correct meaning of words such as "sun" and "son" or "see" and "sea" when used in a sentence, even though the words sound exactly the same.

"We found that certain neurons in the brain are able to reliably distinguish between such words, and they continuously anticipate the most likely meaning of the words based on the sentence contexts in which they are heard," said Williams.

Lastly, and perhaps most excitingly, the researchers found that, by recording a relatively small number of brain neurons, they could reliably predict the meanings of words as they were heard in real-time during speech. That is, based on the activities of the neurons, the team could determine the general ideas and concepts experienced by an individual as they were being comprehended during speech.

"By being able to decode word meaning from the activities of small numbers of brain cells, it may be possible to predict, with a certain degree of granularity, what someone is listening to or thinking," said Williams.

"It could also potentially allow us to develop brain-machine interfaces in the future that can enable individuals with conditions such as motor paralysis or stroke to communicate more effectively."

More information: Mohsen Jamali et al, Semantic encoding during language comprehension at single-cell resolution, *Nature* (2024). DOI: 10.1038/s41586-024-07643-2

Provided by Massachusetts General Hospital

Our brains trick us into thinking consciousness can reside outside the body, research argues

Psychology professor Iris Berent says perceiving minds and bodies as separate has evolutionary roots. Credit: Matthew Modoono/Northeastern University© Provided by Medical Xpress

The origins of consciousness have been debated by philosophers for centuries. Each conscious person has a sense of "being me," which invariably gives rise to the question of where that sense originated—from within or outside the body, says Northeastern University psychology professor Iris Berent.

"How do human brains give rise to this experience? That's the big mystery, right?" she says.

Influential philosopher David Chalmers famously won a bet in 2023 for claiming consciousness exists beyond the merely physical, Berent says.

But she says the question of where consciousness exists is a false one—and she has a new paper that presents her position.

In an article published in the *Neuroscience of Consciousness*, she argues that the debate stems from the delusional—albeit natural—biases in the way humans think about the separation, or lack thereof, between body and mind.

"One of the biases is dualism, intuitive dualism—the fact that we perceive minds as separate from our bodies."

"The extent to which we look at consciousness and think that it is this really mysterious thing could very well arise from how we see it rather from what consciousness really is," Berent says.

"Consciousness isn't hard. Psychology is," she says.

Mary and the zombie

Berent points to an experiment in perception she conducted in her lab that used the well-known Mary and the zombie hypothetical exercise, but with a twist.

According to the experiment, when people are asked to think of a zombie twin of themselves, they describe a creature with their physical features but without their thoughts or feelings.

"They intuit that the mind, consciousness included, is really separate from the physical," Berent says.

In the other thought experiment, Mary is a neuroscientist who knows everything about color and how the brain perceives color, even though she lives in a black-and-white world.

When Mary sees a red rose for the first time, people participating in the experiment say she learns something outside the bounds of physical, scientific explanation.

Berent says she decided to challenge these conclusions with two additional questions.

"The first question is kind of a reality check question, which is do they think Mary's case is significant? Is it transformative? And everybody said, 'Sure, it's super transformative,'" Berent says.

"We also asked how likely is it that this experience will actually show up in her brain? If we scan her brain, will it light up? And it turns out that that's exactly what people said. It will significantly register in the brain."

"The point being, in the condition of the zombie people say, 'no,' (consciousness) is not physical," Berent says. "And in Mary's condition, people say it's physical."

"If people change their mind in this way, it can't possibly be that in reality consciousness has changed. It must be that there is something within the human psyche that colors how we see consciousness."

"For me, this means that we need to be really careful before we assume that there is any real mystery going on."

The evolutionary roots of dualism

Berent blames what she calls "delusional attitudes about bodies and minds" to "the same old psychological biases that I've been studying in my lab for years."

She calls the separation of mind and body dualism Previous research by Berent shows that autistic people are less dualistic than neurotypical people and that males are less dualistic than females.

Evolution is responsible for the fact people hold two different systems of perception in their mind, Berent says.

"Animals have an evolutionary advantage to be able to perceive objects, say, the bodies of their mothers," she says.

It's also important to be able to perceive objects that have agency as separate from other objects, Berent says. "You want to follow the mother and not a body that is inanimate" to receive nurturance and protection.

This type of dualism, she says, "primes us to think about people and their minds and bodies as separate from each other. That's one reason we think about consciousness as this ethereal thing separate from the body."

"The point is that our perception of consciousness changes depending on the situation. And if that's the case, there's no way that we can trust it to reflect what our consciousness really is. It must be that our brain plays tricks on us."

An intimate understanding of who we are

"Every psychology student that has ever come into my class asks if we're going to talk about consciousness," Berent says.

"This is considered to be super important. This is our intimate understanding of who we are."

Berent says the thought experiment outlined in her paper provides "the smoking gun" that intuitions about consciousness existing outside the body are manufactured by humans' dualistically inclined brains.

Consciousness likely comes down to electrochemical functions in the brain, she says. "It's hard for psychological reasons."

More information: Iris Berent, Consciousness isn't "hard"—it's human psychology that makes it so!, *Neuroscience of Consciousness* (2024). DOI: 10.1093/nc/niae016

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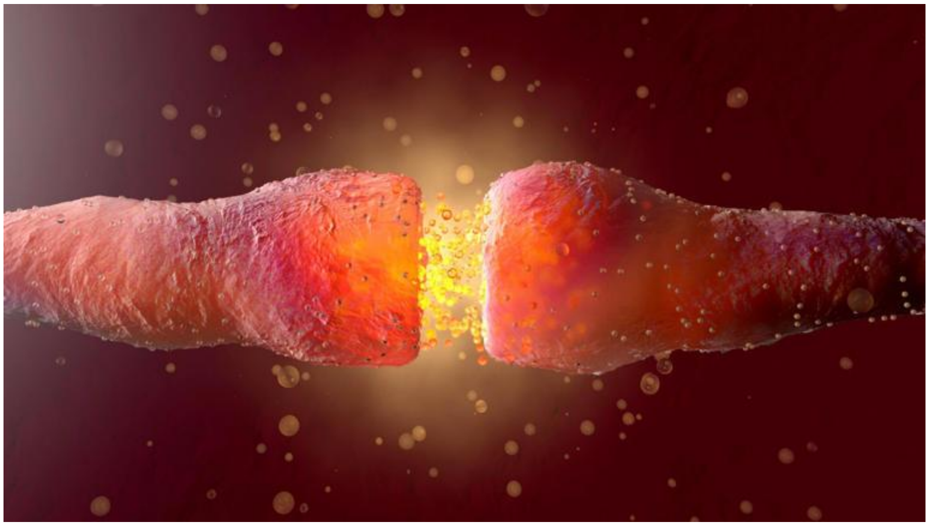
Provided by Northeastern University

Secret to lifelong memories sticking is molecular 'glue'



Scientists have discovered that a particular protein is responsible for guiding an enzyme needed to maintain long-term memory to the correct region of the brain. Specifically, this is to particular synapses, or connections between neurons, as illustrated above.© Westend61 via Getty Images

Some memories last a lifetime — and now, scientists have revealed a type of molecular "glue" that helps those memories stick around.

Memories form when collections of neurons in a region of the brain called the hippocampus activate in response to a particular experience. Each time you recall that experience, the same set of cells activates. When one neuron repeatedly activates another, the connection between those neurons strengthens.

Over time, this process in the hippocampus, along with related activity in other regions of the brain, solidifies a short-term memory into a long-term one.

To maintain these long-term memories, brain cells make proteins that help strengthen the connections, or synapses, between neurons. One critical protein is the enzyme PKMzeta, which is continually made by neurons. However, an outstanding question is how this enzyme "knows" to go to the right synapses to ensure that certain memories stay with us forever.

In a new study, scientists think they've found the answer: an unsung molecule called KIBRA glues the enzyme to strong synapses and also summons new PKMzeta to replace that enzyme when it degrades. The researchers published their findings Wednesday (June 26) in the journal Science Advances.

Related: The brain has a 'tell' for when it's recalling a false memory, study suggests

Previous research in humans suggested that different versions of the KIBRA molecule are associated with differences in memory performance, either better or worse. KIBRA was also already known to interact with the PKMzeta enzyme in the hippocampus of mice. So, the scientists behind the new study decided to delve further into that interaction.

In lab experiments, the team investigated whether blocking the interaction between KIBRA and PKMzeta influenced how well mice performed in long-term memory tests. These tests included seeing whether the mice could remember to avoid entering an area where they had previously been shocked with electricity.

Blocking the interaction between KIBRA and PKMzeta impaired the mice's long-term spatial memory — in other words, their ability to avoid the shock zone.

In a separate experiment, when the KIBRA-PKMzeta interaction was left undisturbed, the team found that even when PKMzeta degraded as expected, new complexes of KIBRA and PKMzeta formed in the hippocampus. This, in turn, helped maintain the mice's memory of the shock zone for a month.

Earlier work by the same team showed that if researchers increase the amount of PKMzeta in a rodent's brain, it appears to enhance weak long-term memories that have faded over time. This initially surprised the scientists, as the team expected PKMzeta to boost the strength of synapses at random, rather than specifically acting on those involved in long-term memory.

Instead, the new findings suggest that KIBRA acts like a "glue," sticking to these strong synapses and also guiding PKMzeta to them, which would explain this phenomenon, the team said.

The research is only in its infancy. However, eventually, it may be possible to someday use this knowledge to treat brain disorders that cause memory loss, such as Alzheimer's disease, said study co-senior author André Fenton, a professor of neural science at New

York University. Such treatments could work by using KIBRA to deliver PKMzeta or similar molecules to weakened synapses.

However, with neurodegenerative diseases such as Alzheimer's, the conditions damage and eventually kill off neurons in the brain. That means that this kind of therapy would theoretically only work for as long as there are still synapses left to enhance.

For now, more research is needed to understand how the interaction between PKMzeta and KIBRA actually translates into people's experiences of memory.

"We have quite a way to go to turn the description of these molecules into that experiential thing that we cherish — what we call memory, belief, intention and so forth," Fenton said.