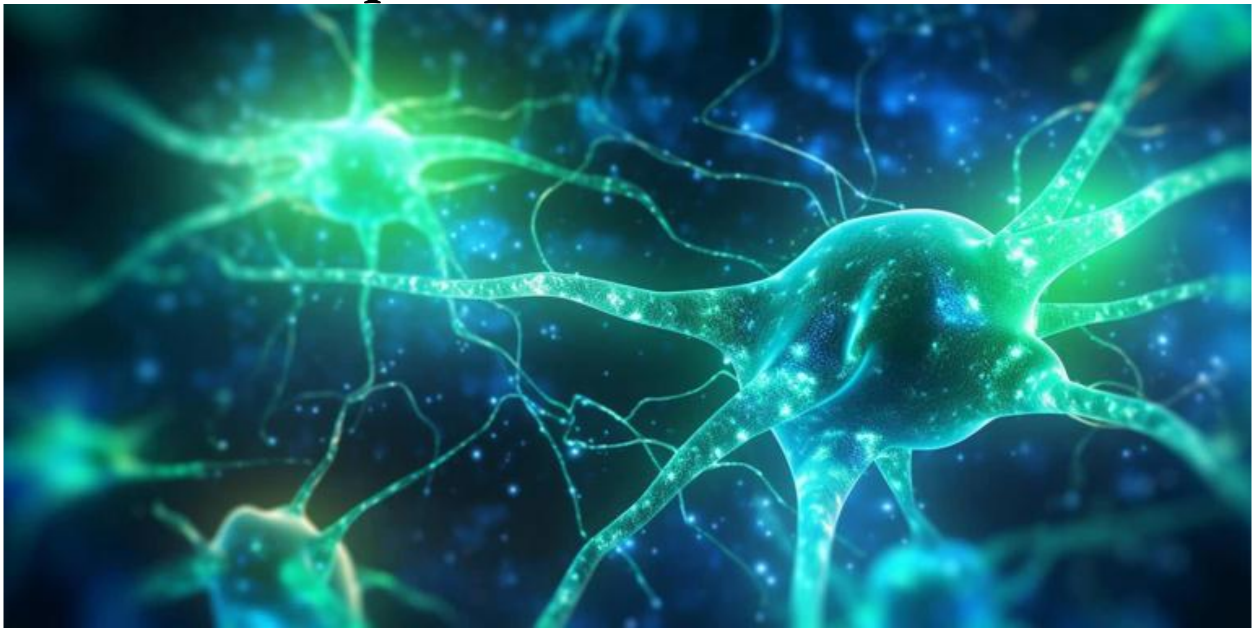
BRAIN INTRACRANIAL VOL 6

Neuroscientists uncover how the brain maps behavioral sequences



(Photo credit: Adobe Stock)© PsyPost

A new study published in *Nature* has identified brain cells that act like "map makers," helping animals track their position within sequences of behaviors. These neurons, located in the medial frontal cortex, can encode abstract patterns of progress, enabling the brain to manage complex tasks such as planning, reasoning, and decision-making. The researchers found that these neurons function similarly to a music box, capable of flexibly organizing sequences of actions to adapt to changing goals.

Human behavior is highly structured, often involving elaborate sequences of actions to achieve specific goals. Whether it's cooking a meal or solving a complex problem, these sequences require careful coordination. When tasks share common elements, the brain forms generalized frameworks called schemata, allowing it to adapt and learn new behaviors more efficiently.

While past research has implicated the medial frontal cortex in mapping task structures, forming schemata, and switching between tasks, the precise biological algorithms behind these functions have remained unclear. The researchers aimed to uncover how neurons encode abstract progress in complex, multi-goal tasks, helping to explain how the brain organizes and flexibly executes sequences of actions.

“Every day we solve new problems by generalising from our knowledge. Take cooking for example. When faced with a new recipe, you are able to use your background knowledge of similar recipes to infer what steps are needed, even if you have never made the meal before. We wanted to understand at a detailed cellular level how the brain achieves this and also to infer from this brain activity the algorithms being used to solve this problem,” explained Mohamady El Gaby, the first author on the study and postdoctoral neuroscientist in the Behrens lab at the Sainsbury Wellcome Centre at University College London and Nuffield Department of Clinical Neurosciences, University of Oxford.

The research team designed an experiment using mice and a structured maze task. The task required the mice to navigate a 3×3 grid maze to collect water rewards located at four goal positions (labeled A, B, C, and D) arranged in a repeating loop. Once the reward at location D was collected, the sequence reset, and the mouse needed to return to location A to continue the loop.

Although the spatial locations of the rewards changed between tasks, the overall sequence structure remained consistent. This setup allowed researchers to investigate whether the mice could learn an abstract framework (the sequence) independent of specific spatial layouts.

The study involved 13 mice, which were trained across two phases. In the first phase, the mice were allowed to perform as many trials as needed to master each sequence. In the second phase, the mice were introduced to a “rapid-task regime” involving three new tasks daily, with only limited trials per task. This phase tested the mice’s ability to generalize the sequence structure and perform efficiently without extensive practice.

To examine the neuronal activity underpinning these behaviors, researchers used silicon probes to record activity from neurons in the medial frontal cortex. The probes allowed researchers to monitor how individual neurons fired in response to task progress, goal states, and other behavioral markers. By analyzing these patterns, the team could infer how the brain organizes information about tasks and sequences.

The researchers discovered that neurons in the medial frontal cortex encoded the mice's progress toward specific goals in a sequence, a feature termed "goal-progress tuning." These neurons fired in response to the animal's position in the abstract task structure, rather than physical variables like time elapsed or distance traveled. This allowed the mice to maintain a flexible understanding of their progress, regardless of changes in the maze layout.

Additionally, a subset of neurons exhibited "state tuning," meaning they were specifically active at certain points in the sequence (e.g., at goal A or B). These state-tuned neurons were organized into clusters or "modules," with each module acting as a memory buffer for a specific part of the sequence. These modules allowed the brain to track and predict the sequence's structure, enabling rapid adaptation to new tasks.

When the sequence structure was modified to include a fifth goal (ABCDE), the same neural systems adapted seamlessly, demonstrating the brain's ability to generalize its task maps. This showed that the medial frontal cortex uses flexible, reusable "building blocks" to represent abstract task structures, rather than creating entirely new representations for each task.

"We found that the cells tracked the animal's behavioural position relative to concrete actions. If we think of the cooking analogy, the cells cared about progress towards subgoals such as chopping the vegetables. A subset of the cells were also tuned to map the progress towards the overall goal, such as finishing preparing the meal. The 'goal progress' cells therefore effectively act as flexible building blocks that come together to build a behavioural coordinate system," said El Gaby.

The researchers also identified a hierarchical organization in the neural activity, where simpler goal-progress signals were used to build representations of more complex task structures. These findings were modeled computationally using a framework called the structured memory buffer (SMB) model. According to this model, neurons are organized into modules that encode progress relative to specific behavioral steps. These modules form a dynamic network that can store and compute sequences of actions, allowing the brain to adapt quickly to new tasks.

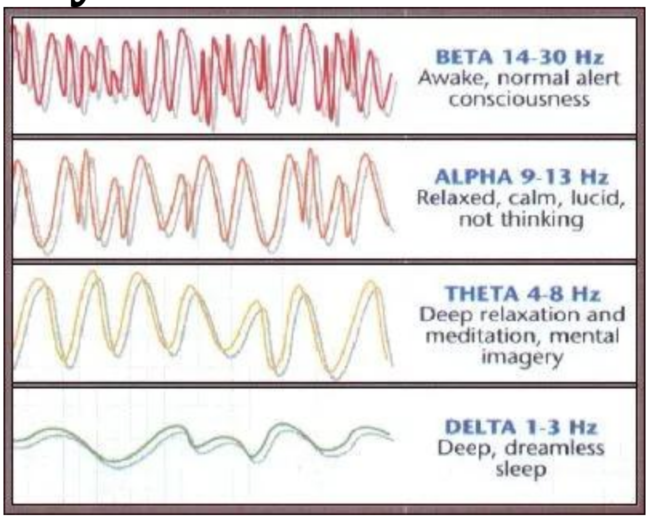
While the study provides important insights, it is not without limitations. The findings are based on animal models, which, though highly informative, may not fully capture the complexity of human behavior. Further research is needed to confirm whether similar mechanisms operate in the human brain. Preliminary evidence suggests that equivalent circuits are active in healthy humans, but more studies are necessary to explore this connection.

Additionally, the study focused on relatively simple task structures. Future research could investigate how the brain handles more complex, multi-layered sequences or combines separate sequences into larger frameworks. Understanding these higher-order processes could bridge the gap between basic neural algorithms and the sophisticated behaviors seen in humans.

The researchers are also interested in how these patterns of brain activity emerge during development and learning. By examining how the brain builds and refines its task maps over time, scientists hope to uncover new strategies for enhancing learning and adaptability.

The study, "A cellular basis for mapping behavioural structure," was authored by Mohamady El-Gaby, Adam Loyd Harris, James C. R. Whittington, William Dorrell, Arya Bhomick, Mark E. Walton, Thomas Akam, and Timothy E. J. Behrens.

Scientists use Matrix-style learning to ‘write’ skills into the human brain noninvasively



A team of researchers from the University of Rochester, Yale University, and Princeton University has made a big stride in neuroscience.

They have shown a method to induce learning through the direct manipulation of brain activity patterns.

This technique uses real-time brain imaging and neurofeedback. It bypasses learning processes that require effort, study, or practice.

“With our method not only can we nudge complex patterns around in the brain toward known ones, but also—for the first time—write directly a new pattern into the brain and measure what effect that has on a person’s behavior,” said Dr Coraline Iordan, lead author of the study and assistant professor of brain and cognitive sciences at the University of Rochester.

Researchers focused on visual learning in their study

Participants were placed in a functional magnetic resonance imaging (fMRI) machine, which allows for the monitoring of brain activity in real-time.

They were then presented with abstract shapes on a screen. These shapes were programmed to “wobble,” and participants were instructed to attempt to stop this movement using only their minds.

The participants did not know that the “wobbling” was connected to their brain activity. The researchers had pre-defined a specific brain activity pattern associated with a new visual category.

When a participant’s brain activity aligned with this target pattern, the wobbling would cease. This feedback mechanism effectively “sculpted” the participants’ brain activity, guiding them toward the desired pattern.

Learning without any conscious awareness

“Instead of teaching you something and measuring how your brain changes, we wrote a new category into your brain that would have appeared had you learned it yourself,” explained Iordan.

Through this process, participants successfully learned to recognize new visual categories without any conscious awareness of what those categories were. This shows the brain’s ability to learn without effort or instruction.

“One of the striking features of the study is that the neural responses and corresponding behavior to the new categories occurred without explicit awareness of those categories,” said Dr Jonathan Cohen, a neuroscientist at Princeton University and co-author of the study.

“We essentially turned learning on its head and taught your brain something that caused you to vicariously gain information, even though you were never explicitly given that information,” added Iordan.

Potential applications

This technology has many possible uses. It could change education by speeding up learning, particularly for individuals with learning challenges.

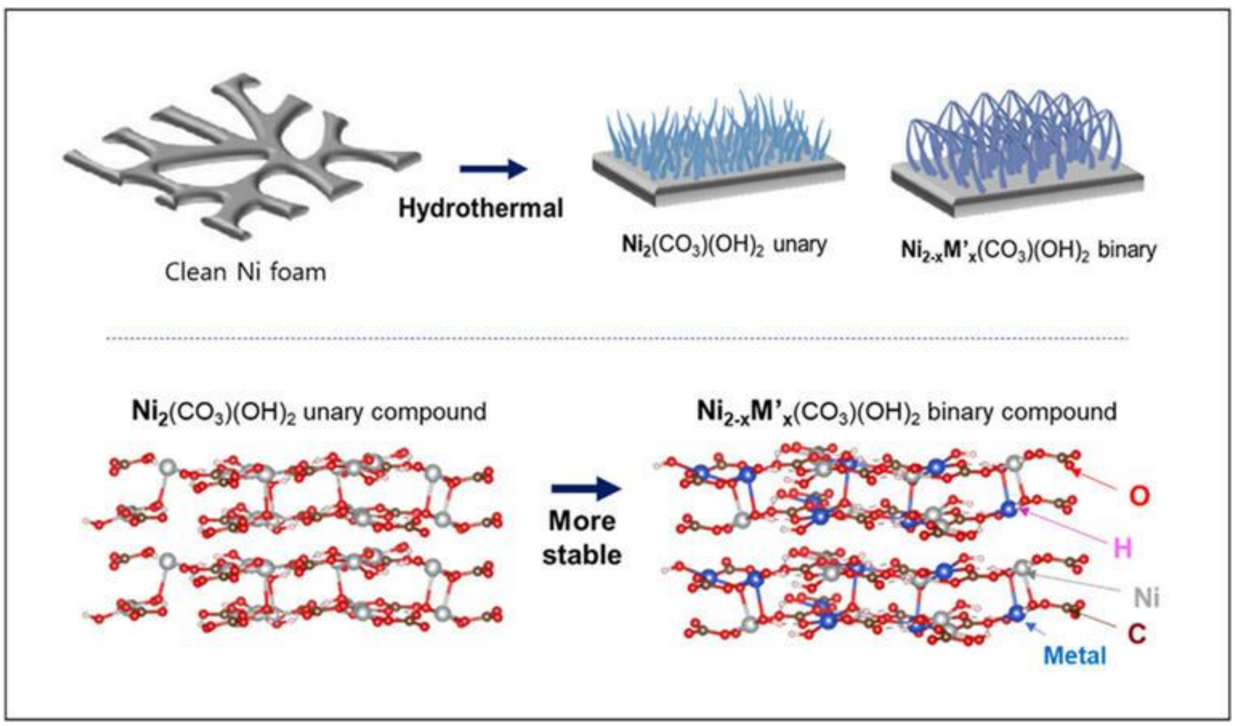
It could also be used for rehabilitation. For example, it could help stroke patients recover brain functions. Additionally, the ability to change brain activity could lead to treatments for mental disorders.

“This study is one of the most powerful demonstrations yet of brain training with real-time fMRI,” concluded Dr Nicholas Turk-Browne, a psychologist at Yale University and co-author of the study.

“In the future, this discovery could inform the development of brain-computer interfaces and clinical interventions.”

While this technology is still in its early stages, it represents a paradigm shift in our understanding of learning and brain plasticity. Further research is necessary to explore the long-term effects and optimize its application.

First self-charging supercapacitors developed: Storage device capable of storing solar energy efficiently



Graphical abstract. Schematic diagram and atomic structure of Ni2(CO3)(OH)2 unary compound and Ni2−xMx (CO3)(OH)2 binary compound. Credit: Energy (2024). DOI: 10.1016/j.energy.2024.133593

A joint research effort has developed a high-performance self-charging energy storage device capable of efficiently storing solar energy. The research team has dramatically improved the performance of existing supercapacitor devices by utilizing transition metal-based electrode materials and proposed a new energy storage technology that combines supercapacitors with solar cells.

The paper is published in the journal Energy.

The research team designed the electrodes using a nickel-based carbonate and hydroxide composite material and maximized the conductivity and stability of the electrodes by adding transition metal ions such as Mn, Co, Cu, Fe, and Zn. This technology has greatly improved the performance of energy storage devices, demonstrating significant advancements in energy density, power density, and charge and discharge stability.

Particularly, the energy density achieved in this study is 35.5 Wh kg^{-1}, which is significantly higher than the energy storage per unit weight in previous studies (5-20 Wh kg^{-1}). The power density is 2555.6 W kg^{-1}, significantly exceeding the values from previous studies (- 1000 W kg^{-1}), demonstrating the ability to release higher power rapidly, enabling immediate energy supply even for high-power devices. Additionally, the performance showed minimal degradation during repeated charge and discharge cycles, confirming the long-term usability of the device.

Furthermore, the research team developed an energy storage device that combines silicon solar cells with supercapacitors, creating a system capable of storing solar energy and utilizing it in real time. This system achieved an energy storage efficiency of 63% and an overall efficiency of 5.17%, effectively validating the potential for commercializing the self-charging energy storage device.

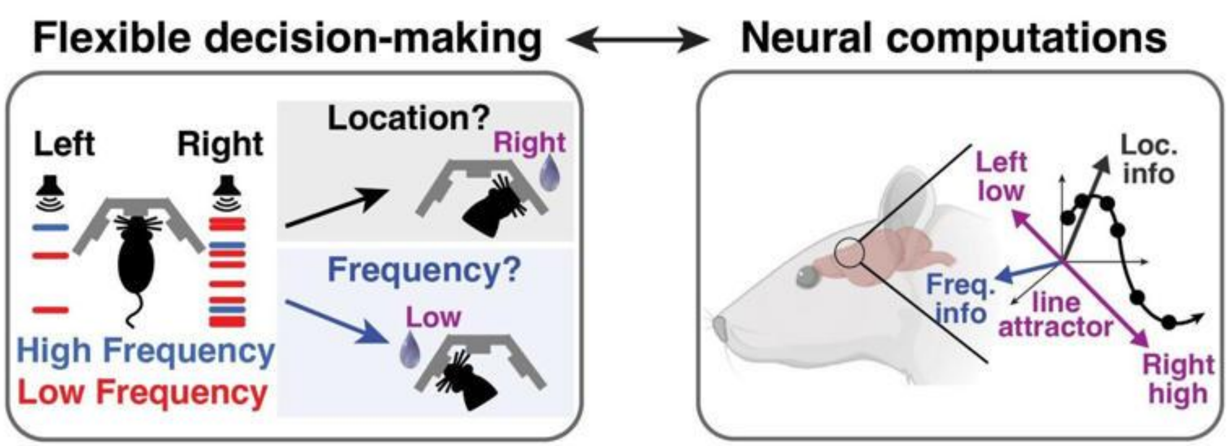
Jeongmin Kim, Senior Researcher at the Nanotechnology Division of DGIST, states, "This study is a significant achievement, as it marks the development of Korea's first self-charging energy storage device combining supercapacitors with solar cells. By utilizing transition metal-based composite materials, we have overcome the limitations of energy storage devices and presented a sustainable energy solution."

Damin Lee, a researcher at the RLRC of Kyungpook National University, stated, "We will continue to conduct follow-up research to further improve the efficiency of the self-charging device and enhance its potential for commercialization."

More information: Damin Lee et al, Design of high-performance binary carbonate/hydroxide Ni-based supercapacitors for photo-storage systems, Energy (2024). DOI: 10.1016/j.energy.2024.133593

Provided by Daegu Gyeongbuk Institute of Science and Technology

Cognitive flexibility: How neural variability shapes decision-making in different brains



Neural computations underlying flexible decision-making in rats. Credit: Dr. Marino Pagan

Research published in Nature has revealed that neural computations in different individuals can be implemented to solve the same decision-making tasks, even when the behavioral outcomes appear identical.

Cognitive flexibility is the ability of a brain to adapt its response to the same external stimulus, like light or sound, based on different contexts. For example, if someone calls your name in a crowded room, you must focus on the sound's location or the voice characteristics to identify the person. This flexibility in selecting and processing relevant information while ignoring irrelevant information is crucial for survival and effective interaction with our environment.

While previously studied, the individual variability in neural computations yielding the same outcomes is poorly understood and lacks a comprehensive framework. The researchers in the Nature study aimed to understand these mechanisms.

Phys.org spoke to the first author of the paper, Dr. Marino Pagan, who performed the experiments described in the paper as a postdoctoral researcher under the supervision of Carlos Brody at Princeton University.

"As a computer engineer, I have always been deeply fascinated by our brain's ability to perform complex computations. In particular, I am very interested in understanding cognitive flexibility. The ability is crucial in our everyday lives, and its impairment can create issues in neurodevelopmental disorders," said Dr. Pagan.

Investigating cognitive flexibility

The researchers aimed to develop a framework to explain how neural networks compute context-dependent selection, and link neural and behavioral variability. They began by training rats to perform decision-making tasks based on external auditory cues. Their decision-making was based on a set of two alternating rules.

The location rule required the rats to respond to the location of a series of auditory clicks. On the other hand, the frequency rule required them to respond to the frequency of the clicks while ignoring their location.

A context cue before each rule informed the rats of which rule to follow. The rules switched rapidly, requiring the rats to adjust their decision-making process quickly.

"Rats can learn to solve this task with very high accuracy, and analysis of their behavior and neural activity over many trials allows us to precisely characterize the mechanisms they are using to select the context-relevant stimuli and make the right decisions," said Dr. Pagan.

To understand how the rats processed each task, the researchers measured the rats' neural activity. The measurements were recorded from the frontal orienting fields (FOF), a region of the brain involved in decision-making and orienting responses to external stimuli, especially in terms of adjusting behavior based on context. This would later help to understand the mechanisms at play in content-dependent decision-making.

Developing a framework

The researchers developed a theoretical framework to explain how the brain computes context-dependent decision-making. This was based on three possible dynamic solutions for how the brain might process information.

Next, the researchers developed RNNs to simulate how each solution could be used to solve the task presented to the rats. RNNs are a type of artificial neural network used in machine learning, designed to handle sequential data—like time series or patterns that change over time.

"RNNs can be trained to solve the same task as the rats using different mechanisms. We characterized the variations in their neural responses, which served as signatures for these mechanisms. We then applied the same analyses to the rats' neural activity and found different neural signatures across individual animals," explained Dr. Pagan.

This approach allowed them to map out the full range of possible strategies that could solve the task and match them to the actual neural signatures observed in the rats.

Do all brains use the same mechanism to solve these types of complex tasks?

No. The researchers found that not all brains use the same mechanism to solve a task, even if the same outcome is achieved.

"Measurements of brain dynamics differed between individual animals, suggesting that different brains use different mechanisms to solve the same task, even though on the surface it might look like their behavior is very similar. This result is important because it has been very hard to study this kind of individual variability before," noted Dr. Pagan.

Additionally, the team found a strong correlation between variability in neural responses and behavioral outcomes, identifying neural signatures for these correlations. The results from the RNN models matched the observed brain activity in the rats, confirming their finding of a high degree of individual variability in handling the same task.

Variability and disorders

This study provides the first comprehensive frame for identifying individual variability in context-based flexible decision-making, bridging the gap between neural activity and behavior. The evidence found is concrete and provides a tool for studying this variability.

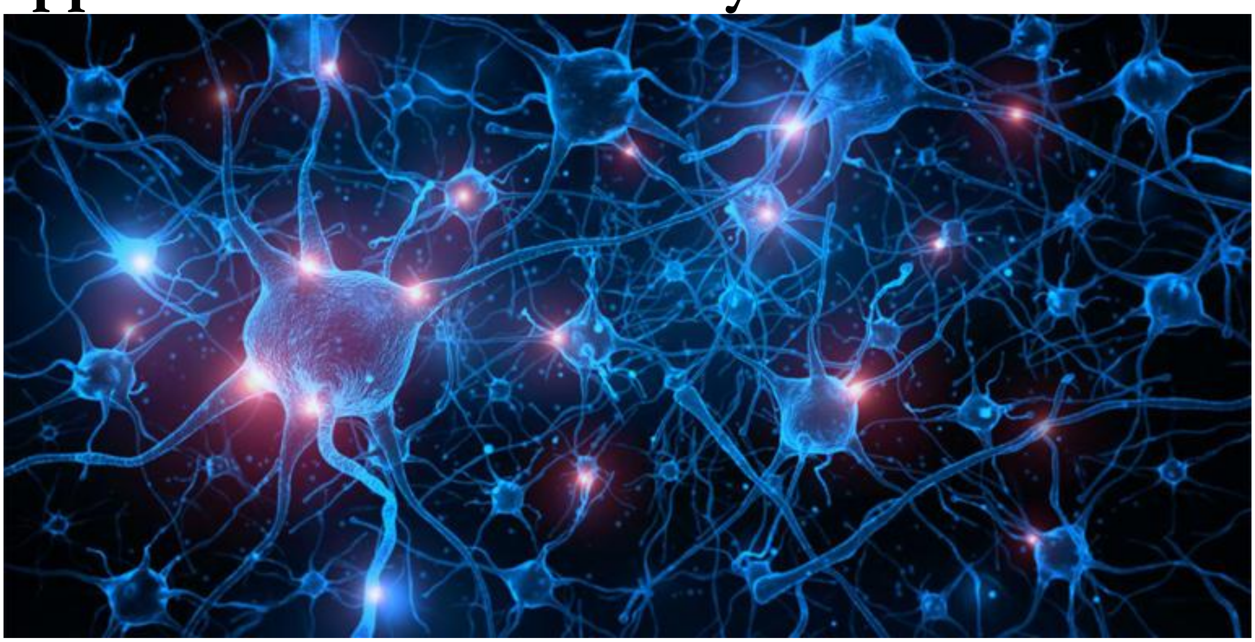
Speaking of developing this research further, Dr. Pagan mentioned two directions currently being pursued at the University of Edinburgh, where he is the Group Leader at the Simons Initiative for the Developing Brain (SIDB).

"The first focuses on understanding the source of the substantial variability observed across different brains. We want to know if this variability is innate and predetermined from birth or whether it develops during learning," he said.

"The second direction investigates how cognitive flexibility and decision-making are affected in neurodevelopmental disorders. While significant strides have been made in identifying the genetic underpinnings of these disorders, the mechanisms that connect genetic mutations to cognitive deficits remain poorly understood," concluded Dr. Pagan.

More information: Marino Pagan et al, Individual variability of neural computations underlying flexible decisions, Nature (2024). DOI: 10.1038/s41586-024-08433-6

How neurons work together: A fractal approach to brain efficiency



(Photo credit: Adobe Stock)© PsyPost

The brain is a marvel of efficiency, honed by thousands of years of evolution so it can adapt and thrive in a rapidly changing world. Yet, despite decades of research, the mystery of how the brain achieves this has remained elusive.

Our new research, published in the journal Cell, reveals how neurons – the cells responsible for your childhood memories, thoughts and emotions – coordinate their activity.

It's a bit like being a worker in a high-performing business. Balancing individual skills with teamwork is key to success, but how do you achieve the balance?

As it turns out, the brain's secret is surprisingly simple: devote no more than half (and no less than 40%) of each cell's effort to individual tasks. Where does the rest of the effort go? Towards scalable teamwork.

And here's the kicker: we found the exact same organisational structure across the brains of five species – from fruit flies and nematodes to zebrafish, mice and monkeys.

These species come from different branches of the tree of life that are separated by more than a billion years of evolution, suggesting we may have uncovered a fundamental principle for optimised information processing. It also offers powerful lessons for any complex system today.

The critical middle ground

Our discovery addresses a long-standing debate about the brain: do neurons act like star players (each highly specialised and efficient) or do they prioritise teamwork (ensuring the whole system works even when some elements falter)?

Answering this question has been challenging. Until recently, neuroscience tools were limited to either recording the activity of a few cells, or of several million.

However, with advances in calcium imaging, we can now record signals from tens of thousands of cells simultaneously. Calcium imaging is a method that lets us watch neural activity in real time by using fluorescent sensors that light up according to calcium levels in the cell.

Applying insights from my physics training to analyse large-scale datasets, we found that brain activity unfolds according to a fractal hierarchy. Cells work together to build larger, coordinated networks, creating an organisation with each scale mirroring those above and below.

This structure answered the debate: the brain actually does both. It balances individuality and teamwork, and does so in a clever way. Roughly half of the effort goes to "personal" performance as neurons collaborate within increasingly larger networks.

By contrast, mouse vision adapts at the cellular scale, permitting the precision required to extract fine details from a scene. Here, if a few neurons miss key pieces of information, the entire perception can shift – like when an optical illusion tricks your brain.

Our findings reveal that this fractal coordination of neuron activity occurs across a vast evolutionary span: from vertebrates, whose last common ancestor lived 450 million years ago, to invertebrates, dating back a billion years.

This suggests brains have evolved to balance efficiency with resilience, allowing for optimised information processing and adaptability to new behavioural demands. The evolutionary persistence hints that we've uncovered a fundamental design principle.

A fundamental principle?

These are exciting times, as physics and neuroscience continue interacting to uncover the universal laws of the brain, crafted over aeons of natural selection. Future work will be needed to see how these principles might play out in the human brain.

Our findings also hint at something bigger: this simple rule of individual focus and scalable teamwork might not just be a solution for the brain.

When elements are organised into tiered networks, resources can be shared efficiently, and the system becomes robust against disruptions.

The best businesses operate in the same way — when a new challenge arises, individuals can react without waiting for instructions from their manager, allowing them to solve the problem while remaining supported by the organization rapidly.

It may be a universal principle to achieve resilience and efficiency in complex systems. It appears basketball legend Michael Jordan was right when he said: “talent wins games, but teamwork and intelligence win championships”.

Brain-inspired computing may boil down to information transfer

The biological brain, especially the human brain, is a desirable computing system that consumes little energy and runs at high efficiency. To build a computing system just as good, many neuromorphic scientists focus on designing hardware components intended to mimic the elusive learning mechanism of the brain. Recently, a research team has approached the goal from a different angle, focusing on measuring information transfer instead. Their method went through biological and simulation experiments and then proved effective in an electronic neuromorphic system. It was published in Intelligent Computing.

Although electronic systems have not fully replicated the complex information transfer between synapses and neurons, the team has demonstrated that it is possible to transform biological circuits into electronic circuits while maintaining the amount of information transferred. "This represents a key step toward brain-inspired low-power artificial systems," the authors note.

To evaluate the efficiency of information transfer, the team drew inspiration from information theory. They quantified the amount of information conveyed by synapses in single neurons, then measured the quantity using mutual information, the analysis of which reveals the relationship between input stimuli and neuron responses.

First, the team conducted experiments with biological neurons. They used brain slices from rats, recording and analyzing the biological circuits in cerebellar granule cells. Then they evaluated the information transmitted at the synapses from mossy fiber neurons to the cerebellar granule cells.

The mossy fibers were periodically stimulated with electrical spikes to induce synaptic plasticity, a fundamental biological feature where the information transfer at the synapses is constantly strengthened or weakened with repeated neuronal activity.

The results show that the changes in mutual information values are largely consistent with the changes in biological information transfer induced by synaptic plasticity. The findings from simulation and electronic neuromorphic experiments mirrored the biological results.

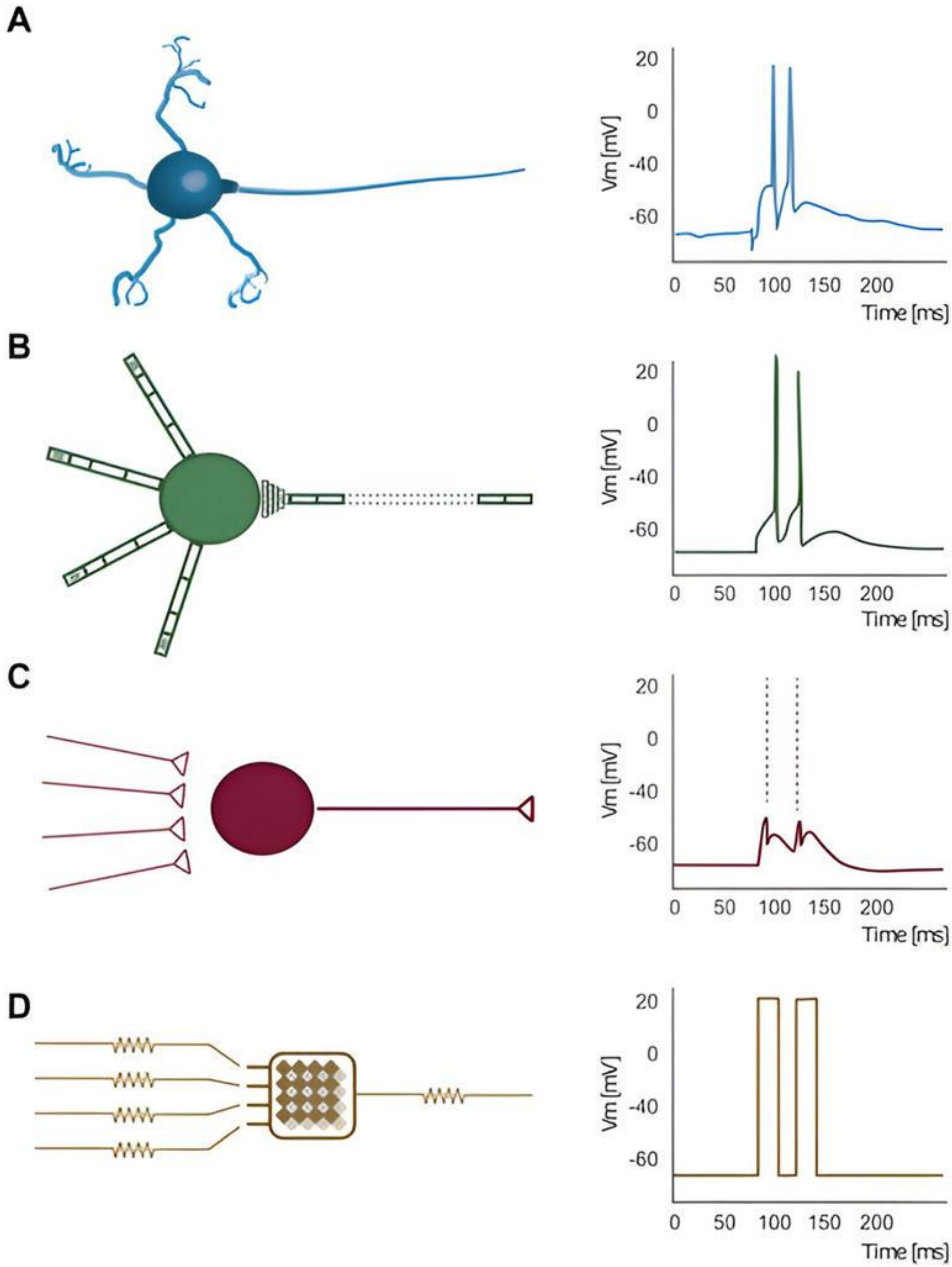
Second, the team conducted experiments with simulated neurons. They applied a spiking neural network model, which was developed by the same research group. Spiking neural networks were inspired by the functioning of biological neurons and are considered a promising approach for achieving efficient neuromorphic computing.

In the model, four mossy fibers are connected to one cerebellar granule cell, and each connection is given a random weight, which affects the information transfer efficiency like synaptic plasticity does in biological circuits. In the experiments, the team applied eight stimulation patterns to all mossy fibers and recorded the responses to evaluate the information transfer in the artificial neural network.

Third, the team conducted experiments with electronic neurons. A setup similar to those in the biological and simulation experiments was used. A previously developed semiconductor device functioned as a neuron, and four specialized memristors functioned as synapses.

The team applied 20 spike sequences to decrease resistance values, then applied another 20 to increase them. The changes in resistance values were investigated to assess the information transfer efficiency within the neuromorphic system.

In addition to verifying the quantity of information transferred in biological, simulated and electronic neurons, the team also highlighted the importance of spike timing, which as they observed is closely related to information transfer. This observation could influence the development of neuromorphic computing, given that most devices are designed with spike-frequency-based algorithms.

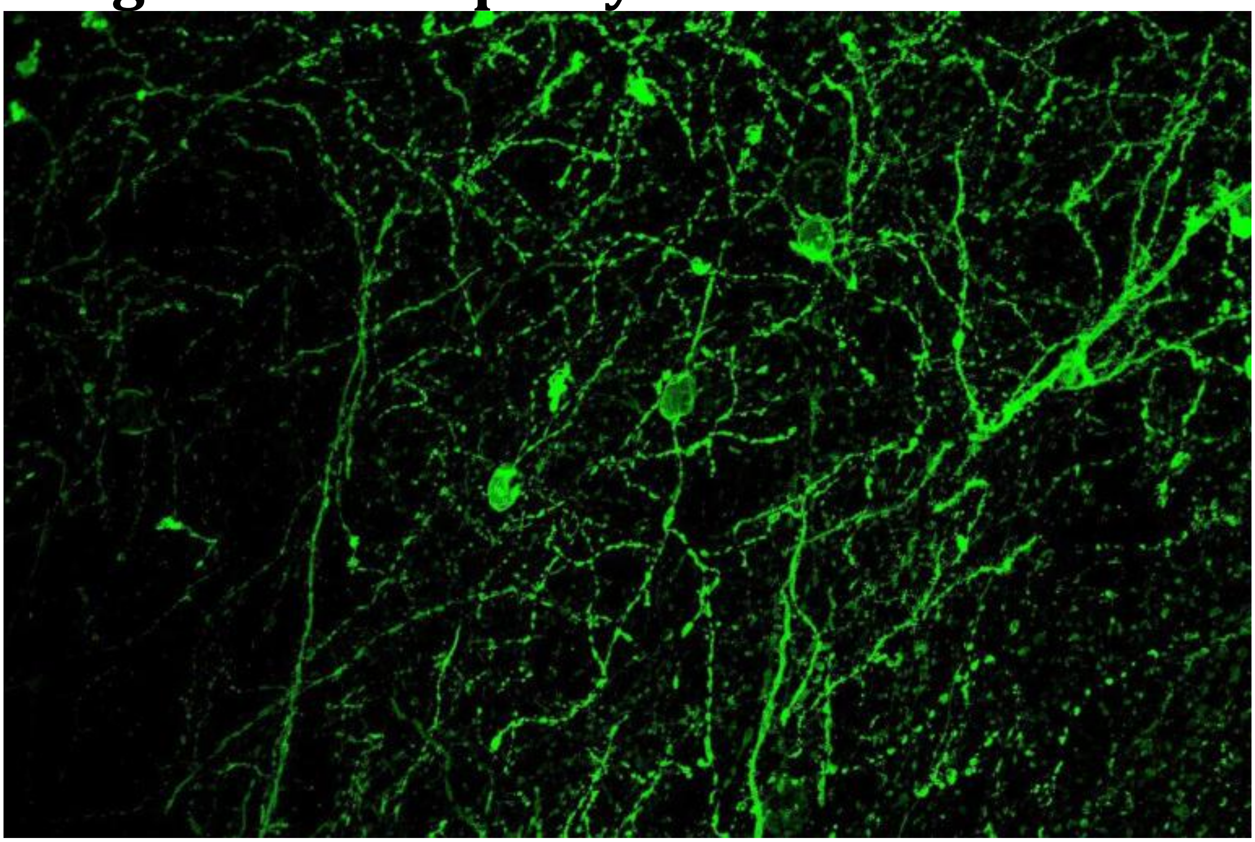

A
B
C
D
Vm [mV]
20
0
-40
-60
0
50
100
150
200
Time [ms]

Cerebellar granule cell and its response to a pair of 50-Hz stimuli. (A) Biological neuron. (B) Computational model used for simulation. (C) Simulated neuron. (D) Electronic neuron. Credit: Daniela Gandolfi et al.© Provided by Tech Xplore

More information: Daniela Gandolfi et al, Information Transfer in Neuronal Circuits: From Biological Neurons to Neuromorphic Electronics, Intelligent Computing (2024). DOI: 10.34133/icomputing.0059

Provided by Intelligent Computing

Key brain mechanism provides new insights into empathy



CRF-producing neurons in the prefrontal cortex observed under a fluorescence microscope. Credit: IIT-Istituto Italiano di Tecnologia

A specific brain mechanism modulates how animals respond empathetically to others' emotions. This is the latest finding from the research unit Genetics of Cognition, led by Francesco Papaleo, Principal Investigator at the Istituto Italiano di Tecnologia (IIT—Italian Institute of Technology) and affiliated with IRCCS Ospedale Policlinico San Martino in Genova.

The study, recently published in Nature Neuroscience, provides new insights into psychiatric conditions where this socio-cognitive skill is impaired, such as post-traumatic stress disorder (PTSD), autism, and schizophrenia.

Psychological studies have shown that the way humans respond to others' emotions is strongly influenced by their own past emotional experiences. When a similar emotional situation—such as a past stressful event—is observed in another person, we can react in two different ways.

On one hand, it may generate empathy, enhancing the ability to understand others' problems and increasing sensitivity to others' altered emotions. On the other hand, it may induce self-distress resulting in an avoidance towards others.

The research group at IIT has demonstrated that a similar phenomenon also occurs in animals: recalling a negative experience strongly influences how an individual responds to another who is experiencing that same altered emotional state.

More specifically, animals exhibit different reactions only if the negative event they experienced in the past is identical to the one they observe in others. This indicates that even animals can specifically recognize an emotional state and react accordingly even without directly seeing the triggering stimuli.

Although the ability to respond to others' emotions has a profound impact in our everyday lives and this is evolutionary conserved between humans and animals, the brain mechanisms that modulate its expression remain unclear.

Papaleo's group has identified the crucial role of the prefrontal cortex in these socio-cognitive processes. They conducted preclinical tests and employed advanced techniques to study the brain mechanisms underlying emphatic-related behaviors.

Their findings reveal that a specific group of cells is a key modulator of emotional reactions to others based on emotional self-experience. These neurons produce corticotropin-releasing factor (CRF), a molecule involved in the stress-response mechanism, and according to IIT researchers, they function as a sort of emotional memory, influencing reactions to socio-emotional stimuli.

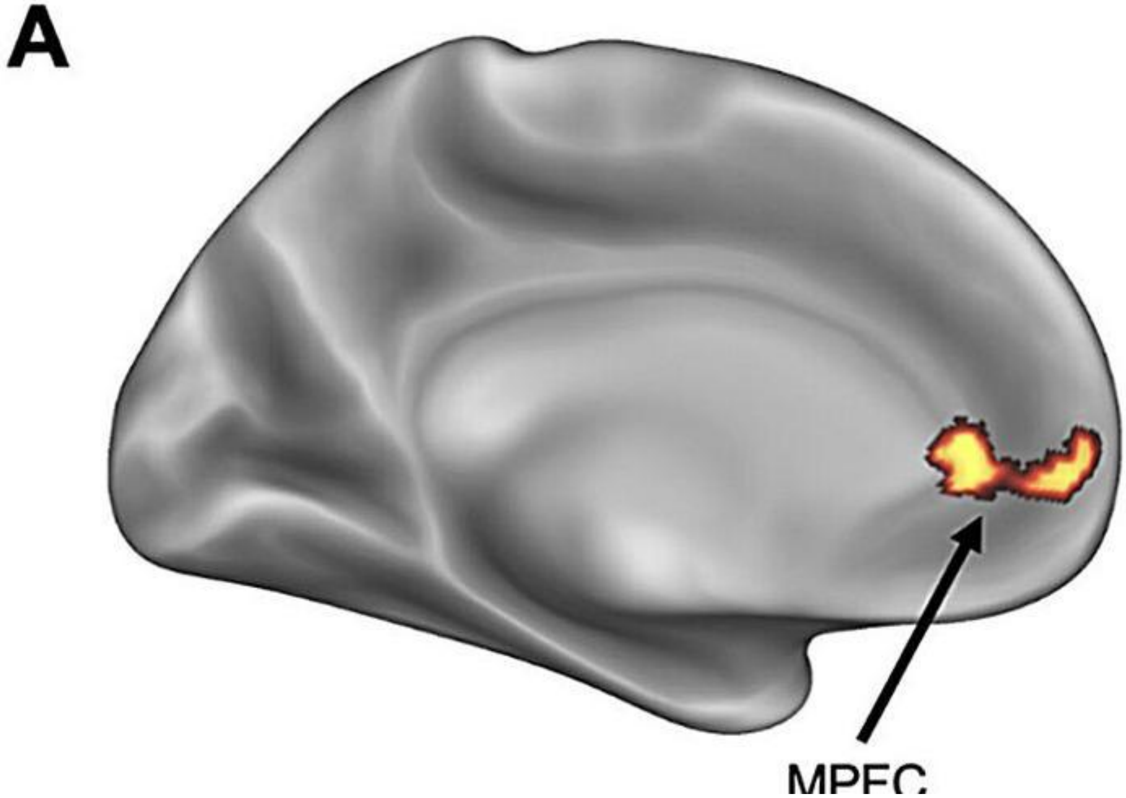
"Understanding these brain mechanisms with such precision could help clarify many aspects of human reactions to others' emotions," said Papaleo, coordinator of the Genetics of Cognition unit at IIT. "For example, why, based on past emotional experience, some people tend to avoid others in stress, while others are more prone to help."

"Moreover, identifying the specific brain mechanisms involved in modulating empathetic responses could aid clinical research in developing new targeted therapies aimed at improving the altered emotional responses observed in various psychiatric conditions," added Federica Maltese, first author of the study and currently a researcher at National Research Center (CNR) in Milan

More information: Federica Maltese et al, Self-experience of a negative event alters responses to others in similar states through prefrontal cortex CRF mechanisms, Nature Neuroscience (2024). DOI: 10.1038/s41593-024-01816-y

Provided by Italian Institute of Technology

Self-esteem influences self-related representations in others' brains: Observing 'self-recapitulation' through MRIs



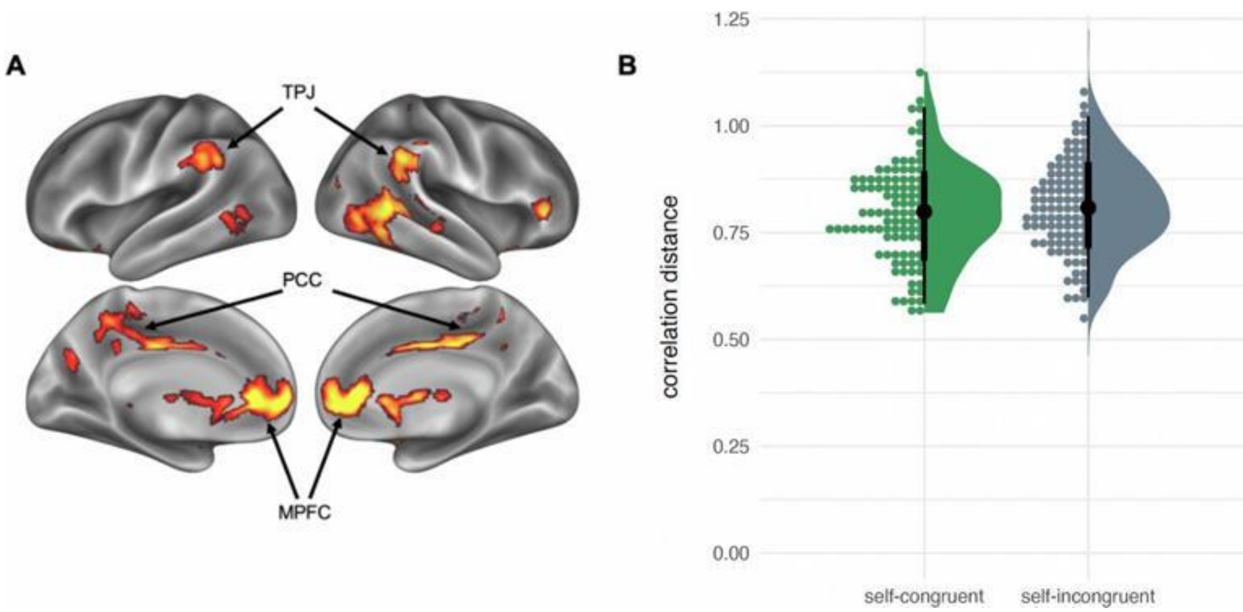
The results of the correlation of self-esteem with the strength of the recapitulation effect within the medial prefrontal cortex. A portion of the medial prefrontal cortex (MPFC) that showed the most significant association with thinking of the self, relative to others from the functional localizer task and has been previously associated with self-evaluative processing. N = 107. B A scatter plot depicting the correlation between self-recapitulation strength and self-esteem within the MPFC. These results show that as self-esteem increases, self-recapitulation accuracy (i.e. correlation distance from the neural self-recapitulation analysis) decreases. Error bars reflect 95% confidence intervals. The scale of the values on the x-axis of the plot is inverted to increase the clarity of the interpretation of correlation distance as an inverse measure of self-recapitulation strength from these analyses. As the JFS has 36 questions scored on a five-point Likert scale, the lowest possible self-esteem score is 36, thus reflecting the lowest value on the y-axis. N = 107. Credit: Stendel et al. (Nature Communications Psychology, 2024).

Different people have distinct and subjective perceptions of their personal worth, broadly referred to as "self-esteem." For decades, neuroscientists and psychologists have tried to pinpoint the neural basis of self-esteem and the neural processes associated with varying feelings of self-worth.

Past neuroscience studies have identified brain regions that appear to contribute to people's self-esteem. However, the effects of self-esteem on neural responses during rich social interactions remains poorly understood.

Some studies have found that neural representations of the self are also reflected in the brains of peers that people socialize with. This observed pattern is known as the "self-recapitulation" effect.

Researchers at the University of Oregon have recently carried out a new study exploring the link between this previously reported effect and self-esteem. Their findings, published in Communications Psychology, suggest that people's individual differences in self-esteem modulate this effect, particularly affecting responses within the medial prefrontal cortex of others that they socialized with.



Results from the multi-group replication of the self-recapitulation effect from Chavez & Wagner. Credit: Communications Psychology (2024). DOI: 10.1038/s44271-024-00148-8

"Previous research has demonstrated that neural representations of the self are reflected in the brains of peers in a phenomenon called the 'self-recapitulation effect,' but it remains unclear how these processes are influenced by self-esteem," wrote Moriah S. Stendel, Taylor D. Guthrie and their colleagues in their paper.

"In the current study, we used functional magnetic resonance imaging in a round-robin design within 19 independent groups of participants to test how self-esteem modulates the representation of self-other similarity in multivariate brain response patterns during interpersonal perception."

Stendel, Guthrie and their colleagues carried out a series of experiments involving a total of 107 participants, divided into 19 groups. Participants in each group were asked to complete two different experimental sessions: a behavioral-only and an fMRI scanning session.

During the first session, the participants completed well-established questionnaires designed to assess their subjective self-esteem. In the second session, the participants were asked to complete two trait-judgment tasks while in an fMRI scanner, first evaluating their own traits and those of an "ordinary American," then grading the extent to which they felt different adjectives described peers in the experimental group they belonged to.

"Our results replicate the self-recapitulation effect in a sample almost ten times the size of the original study and show that these effects are found within distributed brain systems underlying self-representation and social cognition," wrote Stendel, Guthrie and their colleagues.

"Furthermore, we extend these findings to demonstrate that individual differences in self-esteem modulate these responses within the medial prefrontal cortex, a region implicated in evaluative self-referential processing."

The findings gathered by these researchers shed new light on the relationship between people's self-esteem and neural responses in the brains of individuals with whom they interacted. In the future, they could help to improve existing theoretical and neuroscientific models of self-esteem, potentially paving the way for new research efforts.

"These findings inform theoretical models of self-esteem in social psychology and suggest that greater self-esteem is associated with psychologically distanced self-evaluations from peer-evaluations in interpersonal appraisals," wrote Stendel, Guthrie and their colleagues.

More information: Moriah S. Stendel et al, Self-esteem modulates the similarity of the representation of the self in the brains of others, Communications Psychology (2024). DOI: 10.1038/s44271-024-00148-8.

New Ray-Ban Meta Glasses for 2025 could get the upgrade we've been waiting for

New Ray-Ban Meta Glasses for 2025 could get the upgrade we've been waiting for© Future

When Meta revealed the Project Orion AR glasses during Meta Connect in September, it hinted at an impressive future for smart glasses, even if Orion is still a prototype.

We may get a teaser of what the future looks like next year as a report from The Wall Street Journal suggests that a new set of Ray-Ban Meta smart glasses will feature a "single small in-lens screen." Additionally, it could launch with a sensor wristband controller similar to the one being tested with the Orion glasses.

That information comes from a "person familiar with the project," though the report noted that Meta would not confirm heads-up displays glasses. Meta's vice president of wearables did tell the Journal that one of the most requested features is a viewfinder that would show basic information like notifications. He noted that Meta is working on multiple "sizes and form factors."

It seems to fit with a leaked Meta roadmap from 2023 that revealed Meta planned to launch a viewfinder pair of co-branded Ray-Ban glasses in 2025. That report also indicated that a "neural interface band" that allows for hand movement controls would debut alongside the third-generation of Ray-Ban smart glasses. A strong indicator of the sensor strap's existence was revealed with

Project Orion. The strap could turn into a smart watch as suggested by the road map, though it's unclear when or if Meta is actually working on a "Meta Watch."

The road map specifically mentions "Orion" and reportedly set a launch window of 2027 as part of a new line of AR glasses dubbed "Innovation."

Assuming the road map and the Journal reports are accurate, as they appear to be, we will probably expect to see Meta release the viewfinder version in September or October around the annual Meta Connect event. Of course, Meta could shake things up, but its launch history suggests a fall window is most likely.

A viewfinder sounds interesting, but we do wonder if Meta will make other upgrades to make the display an effective tool. Currently, the Ray-Bans have an effective 6 hours of active use. We found in our review that livestreaming absolutely drained the battery and a tiny display with AR capabilities could easily eat away at it.

I also am curious if they can retain their stylish look or become a bit blockier the way the Orions are or more like the Xreal One AR glasses, which are nice but not a fashion statement.

Ray-Ban Meta upgrades

Just recently Meta rolled out three big upgrades for the Ray-Ban Meta smart glasses with Meta AI. This comes via the v11 software update.

The first upgrade is Shazam integration, which means you can say "Hey Meta, what is this song?" and your glasses will use the built-in mic to identify the track.

In addition, Meta AI can now 'see' what you're looking at via its camera. You'll be able to ask Meta AI questions about what you're looking at and get answers.

Lastly, live translation through the Ray-Ban Meta glasses promises to let you get real-time translations in French, Italian or Spanish — either via the open-ear speakers or as text on your phone.

Ray-Ban Meta smart glasses just got three big upgrades — here's the new features

last updated December 17, 2024

Shazam, live translation and new video AI powers

(Image credit: Future)

We were rather impressed with the 2nd gen Ray-Ban Meta smart glasses when we reviewed them, but thanks to Meta AI they've got steadily better over time. Even something as mundane as grocery shopping can be transformed with the AI implementation if you're wearing them.

But the latest update is the most significant yet. Teased at Meta Connect back in September, three new updates have arrived at the same time, making the glasses all the more useful. However, two of the features are only available to those on the early access program, and all three are currently for those in the U.S. and Canada only.

As detailed on the Meta blog, the three upgrades arrive with the v11 software update. The one that's available outside of early access is Shazam integration.

If you somehow hear a track you want to hear more of amidst all the Christmas muzak that's currently on repeat, you can simply say "Hey Meta, what is this song?" and your glasses will use the microphone to listen and come up with the answer for you to stream at your leisure. Again, this is only available in North America, so if you're elsewhere, you'll just have to rely on the Android and iOS apps.

Live AI: Meta AI can now 'see'

Then there are the two extras that require you to be a member of the Early Access program. Live AI is the first of these, adding video to Meta AI on your glasses. When activated, Meta AI can now "see" what you're looking at, and converse naturally about what's going on before your very eyes.

Meta thinks this will be hugely useful for activities when your hands are busy (think cooking or gardening), or just when out and about. You'll be able to ask Meta AI questions about what you're looking at, for example how you can make a meal out of a bunch of ingredients in front of you. There will be battery drain though, with Meta suggesting you'll get around half an hour of live AI use on a full charge.

Still, it's an exciting development, and one that Meta teases will improve over time: "Eventually live AI will, at the right moment, give useful suggestions even before you ask," the post reads.

Meta gets an F in first AI safety scorecard — and the others barely pass published December 16, 2024

(Image credit: Shutterstock)

As artificial intelligence evolves, it's clear there's some need for oversight. Most AI labs openly support regulation and provide access to frontier models for independent evaluation before release — but they could be doing more.
The world is turning to AI to solve all manner of problems, but without proper oversight, it could always create more.

Future of Life has developed a report card for the different AI labs including OpenAI, Meta, Anthropic and Elon Musk's xAI. The AI Safety Index is an independent review looking at 42 indicators of "responsible conduct".

AI Safety Index has worrying stats for the biggest AI companies

Firm	Overall Grade	Score	Risk Assessment	Current Harms	Safety Frameworks	Existential Safety Strategy
Anthropic	C	2.13	C+	B-	D+	D+
Google DeepMind	D+	1.55	C	C+	D-	D
OpenAI	D+	1.32	C	D+	D-	D-
Zhipu AI	D	1.11	D+	D+	F	F
x.AI	D-	0.75	F	D	F	F

Firm	Overall Grade	Score	Risk Assessment	Current Harms	Safety Frameworks	Existential Safety Strategy
Meta	F	0.65	D+	D	F	F

Source: Future of Life Institute
Grading: Uses the US GPA system for grade boundaries: A+, A, A-, B+, [...], F

The panel includes a series of luminaries in education and think tanks to check on how AI companies are operating, and the initial results are alarming.

Looking at Anthropic, Google DeepMind, Meta, OpenAI, x.AI and Zhipu AI, the report has found "significant gaps in safety measures and a serious need for improved accountability." According to the first report card, Meta scores lowest (x.AI isn't far behind), while Anthropic comes out on top — but still only gets a C.

All flagship models were found to be "vulnerable to adversarial attacks", while also having the potential to be unsafe and break away from human control.

Perhaps most damning, the report says "Reviewers consistently highlighted how companies were unable to resist profit-driven incentives to cut corners on safety in the absence of independent oversight."

"While Anthropic's current and OpenAI's initial governance structures were highlighted as promising, experts called for third-party validation of risk assessment and safety framework compliance across all companies."

In short, this is the kind of oversight and accountability we need to see in the burgeoning AI industry before it's too late, as the more powerful the models get, the more real the harms become.

Handwriting activates broader brain networks than typing, study shows

Audrey van der Meer with a research subject.© PsyPost

While keyboards dominate modern classrooms, a new study in Frontiers in Psychology suggests handwriting may be irreplaceable when it comes to learning. Researchers found that writing by hand activates far more extensive and interconnected brain networks compared to typing, particularly in regions linked to memory and sensory processing. These findings provide new evidence that handwriting engages the brain in unique ways, raising concerns about the growing reliance on digital tools for education.

As digital tools replace traditional handwriting in classrooms, concerns have arisen about how this shift might impact learning. Typing on a keyboard is often preferred because it enables children to express themselves more quickly and with less physical strain. However, prior research has shown that handwriting is linked to better memory retention, letter recognition, and overall learning outcomes. The fine motor movements involved in handwriting seem to stimulate the brain differently than typing, but the exact neurological mechanisms behind this difference remained unclear.

To investigate, the researchers focused on brain connectivity, which describes how different brain regions work together to accomplish a task. By comparing brain activity during handwriting and typing, the team hoped to uncover whether the physical act of handwriting promotes more extensive brain communication patterns—patterns thought to support learning and memory formation.

"The brain research on handwriting is really a spin-off of our infant brain research in the NuLab, our developmental neuroscience laboratory at the Norwegian University of Science and Technology (NTNU), where we show that babies are born with a brain that is ready to learn from day one," said study author Audrey van der Meer, a professor of neuropsychology.

For their new study, the researchers recruited 40 university students in their early twenties. To ensure consistency, only right-handed participants were included in the analysis, as determined by a standardized handedness assessment. After excluding participants whose data contained artifacts, the final sample consisted of 36 individuals.

Each participant completed two tasks: handwriting and typing. For the handwriting condition, participants used a digital pen to write visually presented words in cursive directly on a touchscreen. For the typing condition, participants typed the same words on a keyboard using only their right index finger. Participants wrote or typed each word repeatedly within a 25-second window while brain activity was recorded. To avoid visual distractions, the words did not appear on the screen during typing.

Brain electrical activity was measured using high-density electroencephalography (EEG), a method that captures rapid changes in brain activity using a net of sensors placed on the scalp. The researchers focused on connectivity, analyzing how strongly different brain regions communicated with each other while participants wrote or typed.

"In our previous studies, critics sometimes mentioned we had tested too few participants," van der Meer told PsyPost. "This time, we recruited 40 young adults and were able to use the brain data from 36. This is a massive amount of data given that our EEG nets consist of 256 electrodes and can record data at up to 1,000 Hz."

The results revealed striking differences in brain activity between handwriting and typing. Handwriting activated far more widespread and interconnected brain networks than typing, particularly in the theta (3.5–7.5 Hz) and alpha (8–12.5 Hz) frequency bands. These brain waves, particularly in the lower frequency range, are associated with memory formation, sensory processing, and attention.

The most significant connectivity patterns during handwriting emerged in central and parietal brain regions, which are involved in processing motor control, sensory input, and higher-order cognitive tasks. In contrast, typing produced far less synchronized activity across these areas, indicating that pressing keys involves far less integration of visual, motor, and sensory input than forming letters by hand.

The researchers proposed that handwriting's benefits arise from the spatiotemporal complexity of the task. Handwriting requires precise coordination of vision, motor commands, and sensory feedback as the brain continuously adjusts finger and hand movements to shape each letter. Typing, on the other hand, relies on repetitive keystrokes that provide minimal motor variation or feedback.

"In our handwriting research, it becomes clear that the brain works differently when writing by hand as opposed to when typing on a keyboard," van der Meer explained. "Precisely forming letters by hand requires fine motor skills and involves the body and senses to a much larger degree than typing on a keyboard does. As a result, handwriting involves most of the brain, requiring the brain to communicate fast and efficiently between its active parts."

"Our latest results show widespread brain connectivity for handwriting but not for typewriting, suggesting that the spatiotemporal pattern from visual and proprioceptive information obtained through the precisely controlled hand movements when using a pen, contribute extensively to the brain's connectivity patterns that promote learning."

The study's findings suggest that handwriting should remain an essential part of education, especially for young children whose brains are still developing. The researchers argue that handwriting's ability to engage the brain more fully provides "optimal conditions for learning," making it an important tool for fostering cognitive growth.

Rather than abandoning handwriting in favor of digital tools, the researchers recommend a balanced approach. While keyboards are useful for certain tasks, handwriting offers unique neurological benefits that cannot be replicated by typing alone. Schools, therefore, should prioritize handwriting instruction to ensure children develop the brain connectivity patterns that support lifelong learning.

“Our brain research shows that handwriting is very good brain stimulation—especially for the developing brain in young children,” van der Meer said. “Therefore, we propose a minimum of handwriting tuition for all children in the lower grades. Also, we see the ability to write by hand and to draw as an important part of our cultural heritage, and we think it is important that the next generation is able to write a poem or love letter by hand. Incidentally, based on our 2020 paper, 20 states in the United States decided to reintroduce handwriting instruction in schools.”

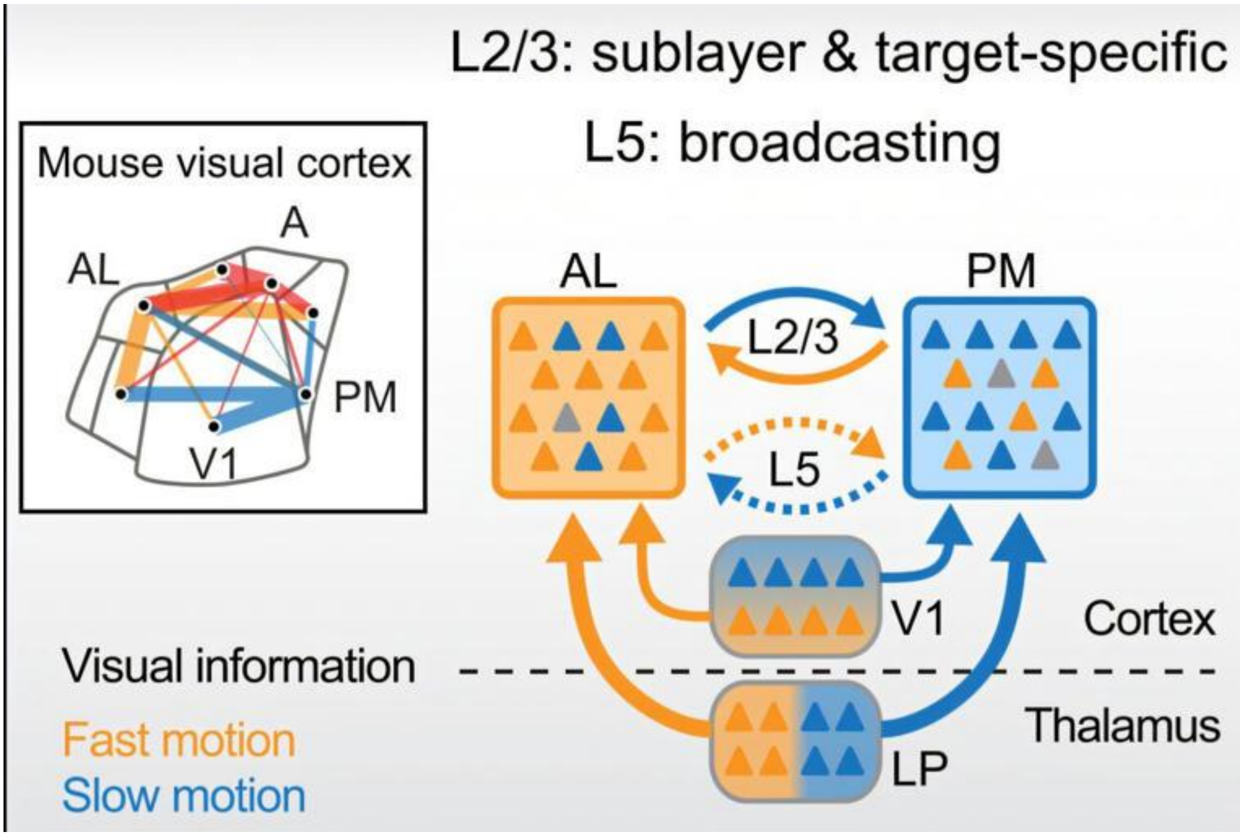
“We are sometimes accused of being against all digital development and wanting to go back to the stone age. All we are saying is that while it is vital to maintain handwriting practice at school, it is also important to keep up with continuously developing technological advances. Therefore, teachers and pupils alike should be aware of which practice has the best learning effect in what context, for example, when taking lecture notes or when writing an essay.”

While the study provides evidence that handwriting promotes more extensive brain connectivity, it does have limitations. The participants were young adults, so the findings may not generalize to children or older adults. Additionally, the study used digital handwriting, which may differ slightly from traditional pen-and-paper writing in terms of sensory input and motor control.

The researchers plan to address these limitations in future studies. For example, they are investigating whether students who take notes by hand learn more effectively than those who type. They also hope to explore whether older adults who practice handwriting regularly exhibit slower cognitive decline than those who rely exclusively on digital tools.

The study, “Handwriting but not typewriting leads to widespread brain connectivity: a high-density EEG study with implications for the classroom,” was authored by F. R. (Ruud) Van der Weel and Audrey L. H. Van der Meer.

Researchers discover new connectivity rules in the brain's visual network



Graphical abstract. Credit: Current Biology (2024). DOI: 10.1016/j.cub.2024.10.048

Researchers at Neuro-Electronics Research Flanders (NERF), led by Prof. Vincent Bonin, have published two studies uncovering how visual information is processed and distributed in the brain. The studies reveal the complexity and flexibility of visual information processing in the brain.

The visual cortex, a key region for interpreting and processing visual input, plays a crucial role in shaping what we see. Vincent Bonin, a professor at KU Leuven and group leader at NERF, studies the neural circuits that process sensory information.

"We often think of visual processing in the cortex as a simple, linear process," explains Prof. Bonin, "but our research shows the cortex operates as a complex network with finely tuned connections between regions, supporting specialized visual functions across distinct brain areas."

Targeting vs. broadcasting

In a first study published in Current Biology, postdoctoral researcher Xu Han revealed how visual information is transmitted across different interconnected regions in the brain.

Using advanced imaging and circuit-tracing techniques in mice, Han and Bonin identified pathways that either selectively channel visual signals to targeted areas or broadcast information broadly across multiple regions.

"For instance, neurons in the pulvinar and certain layers of the cortex are finely tuned to their targets, suggesting a role in constructing detailed visual representations," explains Han.

"In contrast, deeper neurons seem to ignore target specificity, broadcasting similar visual information across areas—possibly for coordinating broader brain activity." These findings challenge the long-held belief that visual information flows in a simple, step-by-step manner, instead revealing a highly dynamic and adaptable network.

Quiet vs. aroused

In the second study, published in Cell Reports, Bonin and Dr. Karolina Socha (now at the University of California in LA) explored how the brain's thalamus—a key relay station for visual signals—adjusts information processing depending on behavioral states.

The researchers found that during quiet wakefulness, neurons in the thalamus amplify signals for back-to-front motion, a transformation absent under anesthesia or heightened arousal. By imaging the activity of neurons in awake mice, they discovered that this modulation is linked to changes in pupil size, a marker of arousal.

"Larger pupils coincided with stronger responses to back-to-front motion, suggesting that the thalamus integrates sensory inputs with behavioral context to prioritize certain visual stimuli," explains Bonin. "These findings demonstrate how the thalamus integrates behavioral context to dynamically shape visual representations, altering how motion is processed and prioritized."

Together, both studies represent a major step toward creating a detailed "functional-anatomical map" of the brain's visual system. "Understanding these pathways and mechanisms allows us to predict and manipulate how perception works," says Bonin.

These findings advance neuroscience research and hold promise for developing targeted interventions to modulate brain function.

More information: Xu Han et al, Higher-order cortical and thalamic pathways shape visual processing streams in the mouse cortex, Current Biology (2024). DOI: 10.1016/j.cub.2024.10.048

Karolina Z. Socha et al, Behavioral modulations can alter the visual tuning of neurons in the mouse thalamocortical pathway, Cell Reports (2024). DOI: 10.1016/j.celrep.2024.114947.

Provided by VIB (the Flanders Institute for Biotechnology)

Brain delays could be a computational advantage, researchers say

Biological components are less reliable than electrical ones, and rather than instantaneously receive the incoming signals, the signals arrive with a variety of delays. This forces the brain to cope with said delays by having each neuron integrate the incoming signals over time and fire afterwards, as well as using a population of neurons, instead of one, to overcome neuronal cells that temporarily don't fire.

It seems like delays are nothing but an unavoidable disadvantage, slowing the brain and reducing its efficiency, but could delays actually be a benefit to brain learning?

In a new study published in the journal Physica A: Statistical Mechanics and its Applications, scientists from Bar-Ilan University's Department of Physics and Gonda (Goldschmied) Multidisciplinary Brain Research Center have answered the question with a resounding "yes."

The team, led by Prof. Ido Kanter, has discovered how delays actually open the way for more efficient and flexible learning without changing the architecture.

"The great benefit of having a system with delays is that the dynamics of the brain can use the delays as an advantage," said Prof. Kanter. "In artificial neural networks, each object needs its own output unit to be recognized, whereas the brain can use one neuronal output, where its activity as a function of time differentiates between different objects. Essentially, one could say that the brain uses time to learn and the computer uses space."

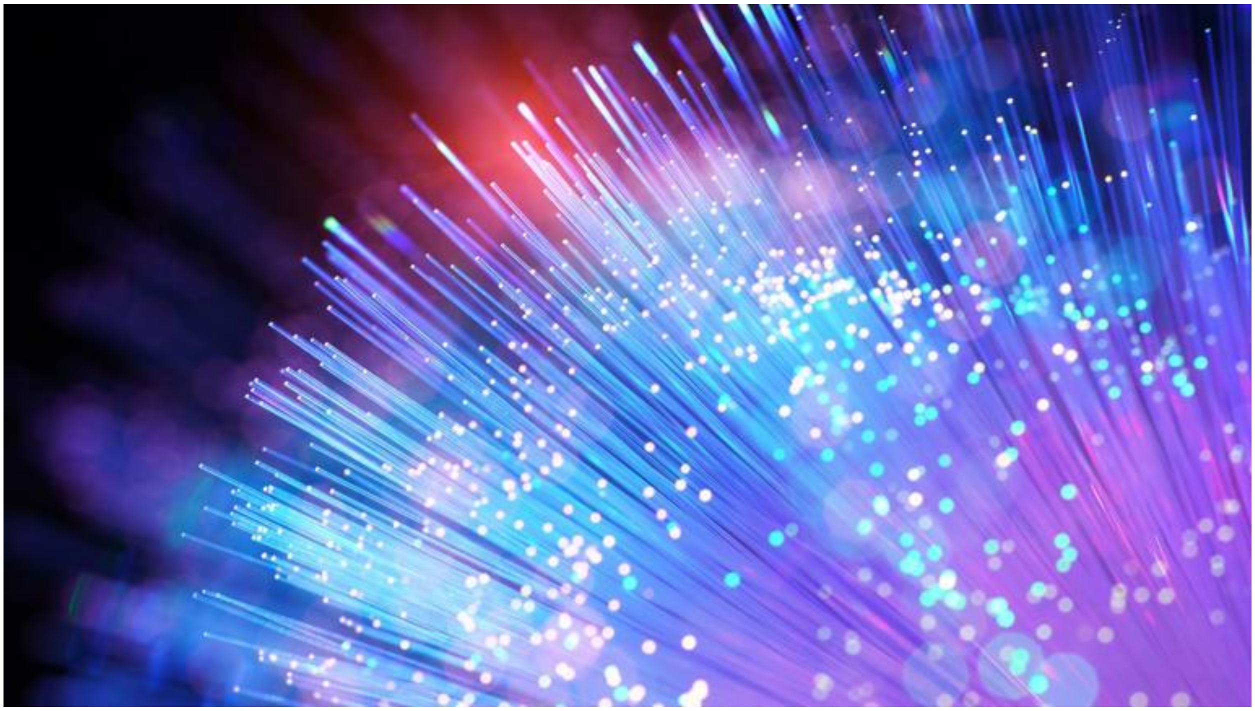
"This makes the brain much more modular to changes without requiring a change in architecture," said Yarden Tzach, a leading Ph.D. student in the lab. "Learning new objects doesn't require a different architecture, rather just learning a signal at an additional output time. This also allows recognition of a combination of objects. Let's say a picture of a horse can be recognized at a certain time, a picture of a person at another, but a person riding a horse can be recognized at some intermediate time in between."

This new discovery can shed light on how a biological mechanism that was thought to be an obstacle can actually greatly benefit the learning dynamics of the brain, even surpassing machine learning. Using this new understanding can pave the path for better, faster and more complex artificial learning systems.

More information: Yuval Meir et al, Role of Delay in Brain Dynamics, Physica A: Statistical Mechanics and its Applications (2024). DOI: 10.1016/j.physa.2024.130166

Provided by Bar-Ilan University

Engineers enable quantum communication over existing fiber optic cables — new research shows data transmission using quantum teleportation is possible in parallel with a classical network at specific wavelengths



Engineers at Northwestern University have successfully achieved quantum communication in parallel with classical channels by identifying specific wavelengths with minimal interference from classical signals (Source: northwestern.edu). This breakthrough lays the groundwork for quantum communication by leveraging existing infrastructure and sending quantum data alongside classical data. The researchers managed quantum teleportation over a 30.2km fiber optic cable carrying 400 Gbps of classical traffic.

Quantum computing seems to be all the hype these days. Google claims its new quantum chip can solve problems swiftly, which classical computers would otherwise take, and I quote 10 billion years to do; that's 10, followed by 24 zeroes. Quantum entanglement is a phenomenon wherein two particles are linked so that their quantum states (spin, polarization, energy levels, etc.) are connected, regardless of the physical distance. When measuring the state of one particle, the entanglement collapses, revealing the correlated state of the other particle. However, this does not allow for FTL (Faster Than Light) communication in line with the no communication theorem.

Enter Quantum teleportation. This concept combines entanglement with a classical channel, such as the Internet, and is the backbone of this research. It transfers one particle's quantum state to another located elsewhere.

Jordan Thomas, one of the research paper's authors, underlined the essence of quantum teleportation; “By performing a destructive measurement on two photons — one carrying a quantum state and one entangled with another photon — the quantum state is transferred onto the remaining photon, which can be very far away.” A key point to understand here is that the photons aren't transmitted physically. Instead, information encoded within their quantum states is what is sent.

The primary concern with a worldwide network employing quantum teleportation is compatibility; will quantum communication work over classical channels? The likelihood of interference is exceptionally high among the billions of photons being sent concurrently in a fiber optic cable. The research discovered specific wavelengths where the density of classical photons was lower, making such wavelengths suitable for the photons in quantum teleportation. Bell state measurement, or simply state measurement, is performed at the mid-point of the cable. Coupled with other methods to reduce noise and interference, this method can potentially support multiple TB/s of classical data alongside quantum communication.

While it may take years or decades before quantum communication goes mainstream, Prem Kumar, the head of the research team, has high hopes for the future. Based on the current roadmap, the next major milestones are using two pairs of entangled photons instead of one and scaling this experiment to real-world optical fiber networks.

Scientist says human consciousness comes from another dimension

A baffling new theory to explain human consciousness has suggested it comes from hidden dimensions and is not just brain activity.

A physicist claimed that we plug in to these invisible planes of the universe when making art, practicing science, pondering philosophy or dreaming, and this could explain the phenomenon that has evaded scientific understanding for centuries.

Michael Pravica, a professor of physics at the University of Nevada, Las Vegas, has based the wild idea on hyperdimensionality, the idea that the universe is made up of more dimensions than just the four we perceive: height, length width and time. But his theory is highly controversial, with one scientist saying that the cornerstone of Pravica's theory 'borders on science fiction.'

Physicist Michael Pravica believes that human consciousness transcend the physical world and move between hidden dimensions

'The sheer fact that we can conceive of higher dimensions than four within our mind, within our mathematics, is a gift... it's something that transcends biology,'

Scientists have been attempting to explain human consciousness and its origins for hundreds of years - and the theories run the gamut.

One leading theory suggests that consciousness is related to how much information is integrated between the different parts of the brain. The more information is connected and integrated, the more conscious a being is thought to be.

Another posits that conscious mental states are driven by top-down signaling in the brain. Top-down signaling refers to the process by which higher-level brain regions send information, expectations or context to lower-level brain regions.

But Pravica's theory ventures outside the realm of neuroscience and into theoretical physics.

He suggested that in moments of heightened awareness, like when we enter a dream state or use our brains for deeply creative or intellectual tasks, our consciousness could transcend our physical dimension and enter a higher plane.

In these moments, our consciousness syncs with hidden dimensions and receives a flood of inspiration, Pravica said.

To better understand the controversial theory, consider the following scenario.

Imagine you're a two-dimensional being living in a two-dimensional world, like a character in a comic book. Now, imagine that a sphere passes through your plane of view.

The sphere would look like a dot that grows into a larger and larger circle as it comes closer, then gradually shrinks until it's out of view. You would have no way of knowing that it's actually a three-dimensional shape.

Pravica sees us as a version of these 2D characters. Although we exist in a four-dimensional world, we can only perceive matter and energy that is of those four dimensions, just like how beings in a 2D world cannot perceive a 3D object.

Thus, the limitations of our world prevent us from detecting higher dimensions that could, in theory, exist all around us.

This is the foundation of hyperdimensionality - the idea that the universe is made up of many dimensions, some of which are hidden because they are beyond the reach of our physical realm.

Hyperdimensionality ties into string theory, which states that reality is made up of infinitely small vibrating strings that are smaller than atoms, electrons or quarks.

As the strings vibrate, twist and fold, they produce effects in multiple unseen dimensions that give rise to all the particles and forces that we can observe, from particle physics to gravity.

'String theory is essentially a theory of hyperdimensionality,' Pravica said. 'It's looking at how the universe is put together on a sub-quantum scale.'

Pravica believes that our brains can tap into higher dimensions when in a dream state or performing deeply creating or intellectual tasks

Although we can observe the effects that these vibrating strings have on the physics of our dimension, we can't observe the hidden dimensions that they're vibrating in.

That is - we can't physically observe them.

But our consciousness may be able to tap into them, Pravica says.

Hyperdimensionality and string theory are widely accepted by physicists, but Pravica's idea of their relationship with consciousness is more controversial - especially because it blurs the lines between science and spirituality.

As an Orthodox Christian with a Ph.D. from Harvard, Pravica has found hyperdimensionality to be a way to bridge his scientific background with his religious beliefs.

For example, he believes Jesus may be a hyperdimensional being.

'According to the Bible, Jesus ascended into heaven 40 days after being on Earth. How do you ascend into heaven if you're a four-dimensional creature?' Pravica asked.

But being hyperdimensional could, theoretically, have allowed Jesus to move between our world and heaven - which may be a world of higher or infinite dimensions, he said.

Pravica's theory is based on a 'God of the gaps' perspective, where gaps in scientific knowledge are explained by divine intervention, said Stephen Holler, associate professor of physics at Fordham University.

He believes that this type of thinking is insufficient, and hampers the scientific inquiry needed to truly understand and explain ineffable phenomena like human consciousness.

'It's a poor explanation mechanism that arguably stifles the inquisitive nature required for good science and teaches that it's not okay to say, 'I don't know,'' Holler told Popular Mechanics.

He points out that our ability to mathematically manipulate higher dimensions is not proof that they actually exist, or that our consciousness can interact with them.

What's more, exploring these higher dimensions is impossible due to the limitations of our current technological capabilities.

Not even the most powerful particle accelerator in the world - the Large Hadron Collider (LHC) at CERN - can provide real proof that these dimensions exist.

The LHC smashes particles together at incredibly high speeds - up to the speed of light.

This allows physicists to study the fundamental building blocks of matter and energy and access infinitesimally small dimensions - even smaller than a single proton.

But even the LHC isn't able to reveal the high-dimensional strings that quantum physics predicts. To get that granular, physicists would need a much more powerful collider.

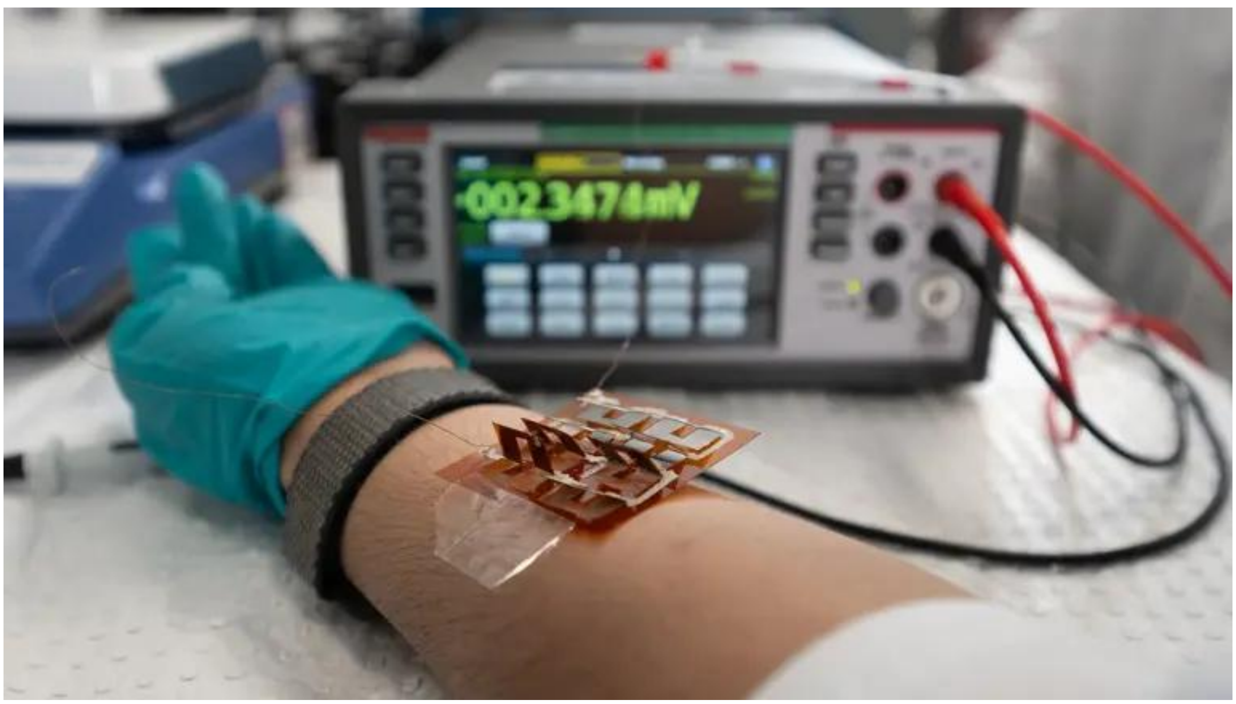
Without that concrete evidence, Holler says that hyperdimensionality 'borders on science fiction.'

But Pravica is optimistic that such technology could exist within his children's lifetime.

Until then, he will continue to support hyperdimensionality and his theory of how it relates to our consciousness.

'I see no point otherwise,' he said. 'Why study? Why live?'

Body Heat Could Power Next Generation of Wearable Devices, Marking New Battery Era



Body Heat Could Power Next Generation of Wearable Devices, Marking New Battery Era

Why it matters: Scientists have developed flexible thermoelectric devices that convert body heat into electricity, potentially eliminating the need for traditional batteries in wearable technology. As reported by PopSci, this breakthrough comes as the global battery industry undergoes massive transformation to meet growing energy storage demands.

The Big Picture: According to The Hustle, researchers at Queensland University of Technology and the University of Washington have created innovative materials that harness body heat:

- Uses nanobinder crystals and bismuth telluride sheets
- Generates enough power to run LED lights
- Enables battery-free medical devices
- Creates self-powered smart clothing

Healthcare Applications: The technology could revolutionize medical devices:

- Continuous glucose monitoring without battery changes
- Self-powered pacemakers
- Uninterrupted health tracking
- Enhanced patient comfort and safety

Broader Energy Transition: This development coincides with massive growth in battery technology:

- Lead-acid battery market projected to reach $59 billion by 2032
- Electric car registrations hit 14 million globally in 2023
- Lithium-ion battery demand growing at 15.5% annually
- Battery costs declining through economies of scale

Looking Forward: The technology could expand beyond wearables to cool data centers and power virtual reality systems, marking a significant step toward sustainable electronics like the best smart watches and reduced environmental impact.

Brain stimulation breakthrough: Natural learning ability — not age — determines success

LAUSANNE, Switzerland — When it comes to learning new motor skills, like playing the piano or mastering a golf swing, conventional wisdom suggests that older adults might have a harder time than their younger counterparts. But new research reveals that age may not be the deciding factor in who benefits from brain stimulation techniques designed to enhance learning. Instead, it's your natural learning ability that determines whether such interventions will help or potentially hinder your progress.

The study, conducted by researchers at École Polytechnique Fédérale de Lausanne and other institutions, challenges our assumptions about aging and learning while offering a potential pathway to more personalized brain stimulation treatments. The research team investigated how a technique called anodal transcranial direct current stimulation (atDCS) – which involves passing a weak electrical current through specific areas of the brain – affects people's ability to learn a new motor skill.

Think of atDCS as a gentle dimmer switch for your brain cells. By applying a mild electrical current to specific areas of the brain, researchers can make neurons more or less likely to fire. This technique has shown promise in improving various cognitive and motor functions, particularly in older adults who may be experiencing age-related decline. However, the results of such interventions have been notably inconsistent across different studies and individuals.

They discovered that electrical brain stimulation works dramatically differently depending on a person's learning capacity. Contrary to expectations, age was not the determining factor in how individuals responded to treatment.

The researchers studied a total of 153 healthy volunteers across three age groups. For the main modeling portion of the study, they included 41 young adults aged 18-30, 34 middle-aged adults aged 50-65, and 38 older adults aged over 65. They then validated their findings with an additional group of 40 participants (20 middle-aged and 20 older adults). All participants were right-handed and were tasked with performing a sequential finger-tapping task using their left (non-dominant) hand. The task involved replicating a shown nine-digit numerical sequence as quickly and accurately as possible using four buttons, similar to learning a simple melody on a piano.

Natural learners don’t benefit from brain stimulation?

What makes this study particularly interesting is that the researchers developed a machine learning model to predict who would benefit from brain stimulation based on their initial performance. They discovered that individuals who struggled more with learning the sequence initially showed the greatest improvements with atDCS, regardless of their age. Conversely, those who were naturally efficient learners either saw no benefit or, in some cases, actually performed worse with the stimulation.

“By leveraging different methods in machine learning, we were able to untangle the influence of different factors on the individual effects of brain stimulation,” says study author Pablo Maceira in a media release.

Researchers compare the brain stimulation effect to turning up the volume on a stereo system. For someone with a less efficient learning system (like trying to hear music through interference), amplifying the signal helps clarify the message. However, for someone with an already optimal system (like listening to perfectly clear music), adding more amplification might actually distort the sound.

The study also revealed something unexpected about older adults: some performed just as well as their middle-aged counterparts, challenging stereotypes about age-related decline in motor learning. This finding suggests that maintaining cognitive and motor abilities into older age might be more common than previously thought.

The research, published in the journal npj Science of Learning, promises a paradigm shift in neurorehabilitation, suggesting that tailored interventions based on individual learning mechanisms — not age — could help people recover lost skills more effectively.

“Clinicians could apply a more advanced version of our algorithm to determine whether a patient will benefit from a brain stimulation-based therapy,” envisions study leader Friedhelm Hummel.

The message is clear: in the world of brain enhancement, being a natural prodigy might actually be a handicap. Sometimes, having room for improvement is the best improvement of all.

Paper Summary

Methodology

This study explored how brain stimulation affects motor skill learning across different learner categories. Researchers conducted a randomized, placebo-controlled, double-blind experiment involving middle-aged and older adults. Participants practiced a finger-tapping task requiring precision and speed, with daily 20-minute sessions over ten days.

During training, some received anodal transcranial direct current stimulation (atDCS) over their motor cortex, while others received a placebo. Baseline performance data were used to classify participants into “optimal” and “suboptimal” learners using a machine-learning model. The study aimed to determine how individuals’ initial learning capabilities influenced their response to brain stimulation.

Key Results

The study found that atDCS had varying effects depending on the learner’s baseline abilities. Suboptimal learners, characterized by delayed accuracy improvements during training, showed significant benefits from stimulation. They achieved faster accuracy optimization compared to those receiving placebo.

In contrast, optimal learners, who demonstrated rapid accuracy improvements without stimulation, experienced minimal or even detrimental effects from atDCS. These findings suggest that atDCS has a restorative effect, aiding those with less efficient learning mechanisms rather than enhancing already optimal systems.

Study Limitations

First, the sample size within specific learner categories was small, particularly among older adults, leading to variability in results. Additionally, the study focused exclusively on motor skill acquisition using a finger-tapping task, limiting generalizability to other types of learning.

The long-term effects of atDCS and its applicability to broader populations, such as younger adults or clinical groups, remain uncertain. Finally, the algorithm’s predictions were based on a specific dataset, which may not perfectly translate to diverse settings or tasks.

Discussion & Takeaways

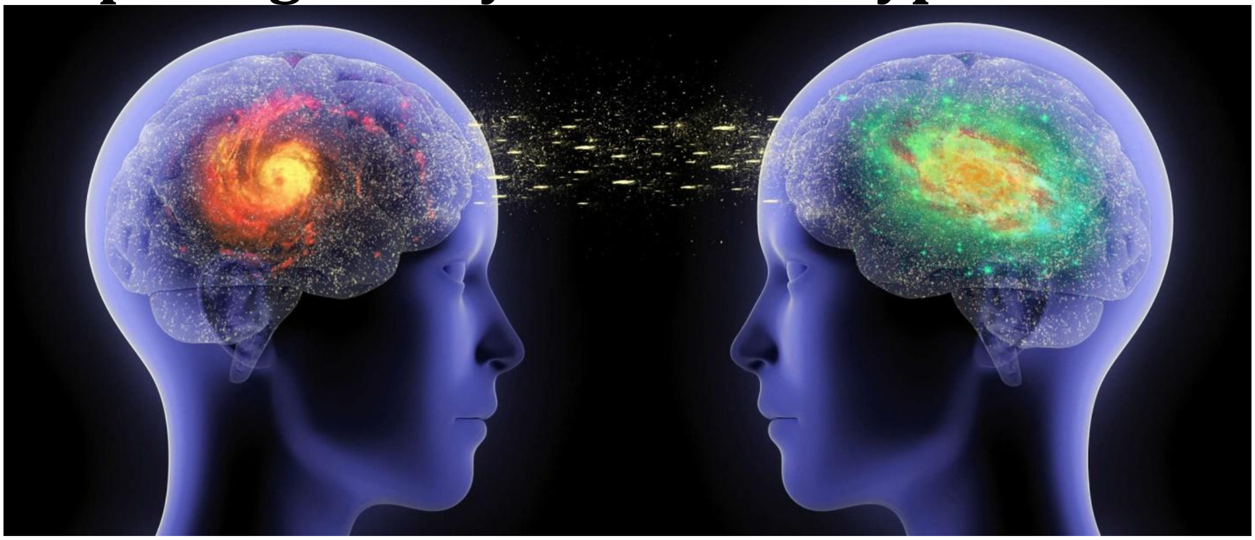
The study highlights the importance of tailoring brain stimulation interventions to individual learning profiles. The differential effects of atDCS underline the need for personalized approaches in neurorehabilitation and skill acquisition training. Suboptimal learners benefited the most, reinforcing the idea that brain stimulation can act as a compensatory tool rather than a universal enhancer.

However, the potential for harm in optimal learners cautions against indiscriminate use of such technologies. Future research should explore broader applications and refine predictive models to maximize the benefits of brain stimulation while minimizing risks.

Funding & Disclosures

This research was funded by the Defitech Foundation, the Bertarelli Foundation’s Catalyst Program, and the Swiss National Science Foundation. All authors declared no competing interests. The study adhered to ethical guidelines, with participants providing informed consent under protocols approved by the Cantonal Ethics Committee Vaud, Switzerland.

Dispelling the myths behind hypnosis



Hypnosis is one of the most fascinating—yet least understood—forms of therapy. It is a human condition involving focused attention, reduced peripheral awareness, and an enhanced capacity to respond to suggestion. But what does all that mean?

What is hypnosis?

Did you know that hypnosis does not involve mind control, magic, unconsciousness, or sleep? In fact, a human stays completely awake during hypnosis.

"Look into my eyes"

Hypnotism has nothing to do with all that "look into my eyes" baloney. You simply cannot be made to enter hypnosis against your will because when all said and done, you know exactly what you are doing.

Hypnosis for everyone

Believe it or not, everyone has the ability to be hypnotized because it's a natural, normal state that each of us enter at least twice each day. For example, it's very easy to zone out while reading a book. And how many times have you got behind the wheel and arrived at your destination without any clear memory of driving there?

An aid to self-improvement

Hypnotherapy can aid self-improvement through strategies such as non-clinical stress management. In fact, it's commonplace for hypnotherapists to work in complementary ways with physicians and other health care providers to help optimize the care patients receive.

Always in control

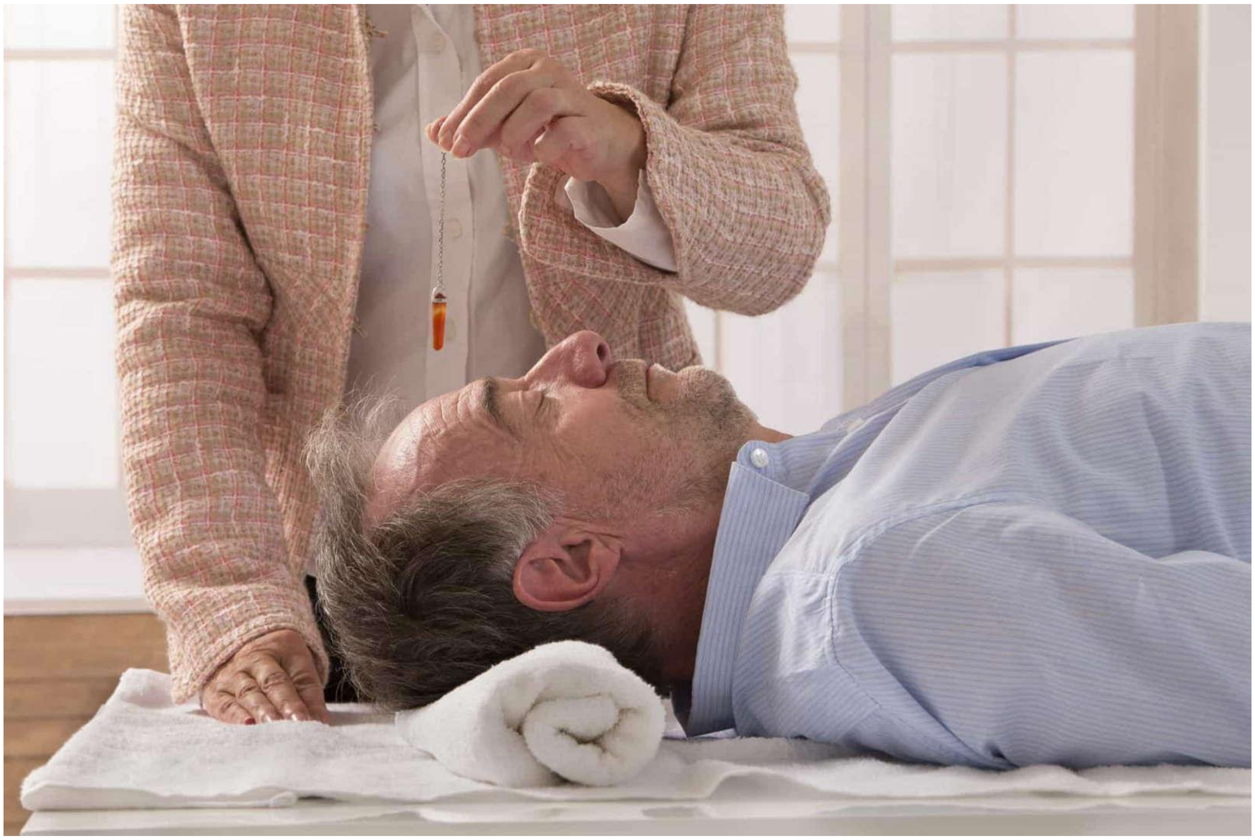
A hypnotized person never goes "under" as such; you are in control at all times while in hypnosis.

Hypnosis can be used as an anesthesia

Hypnosis can be used as pain management. In fact, studies undertaken using electroencephalography (EEG) have demonstrated that hypnosis abolishes the emotional experience of pain, while still allowing one to experience the sensory sensation.

Hypnotherapy

Hypnotherapy results can be restorative, rehabilitative, and curative simply by harnessing the untapped power of the subconscious mind.

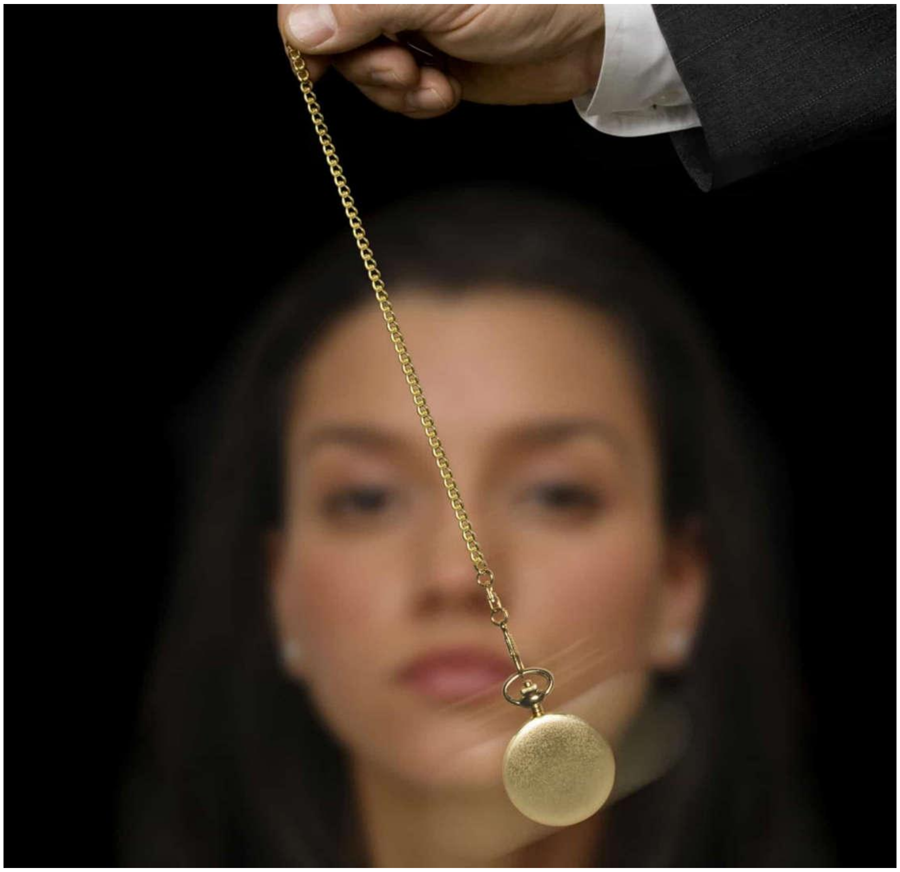


Hypnosis has a wide range of applications

Hypnotherapists use trance and suggestions to help people cope with everyday lifestyle challenges, such as issues related to jobs.

Fears and phobias

These typically include getting over fears and phobias, weight loss, negative memories, insomnia, and quitting smoking.

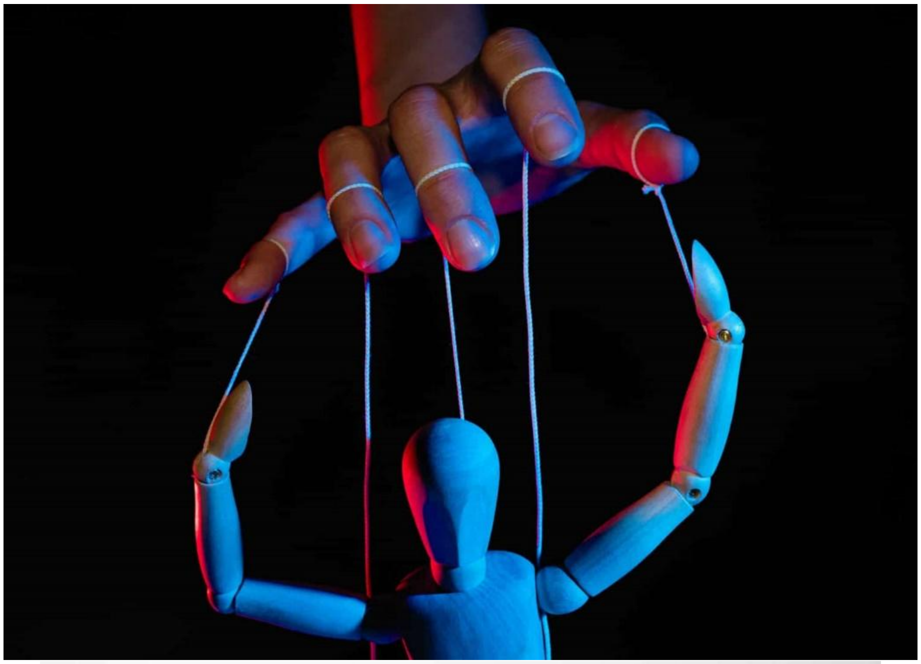


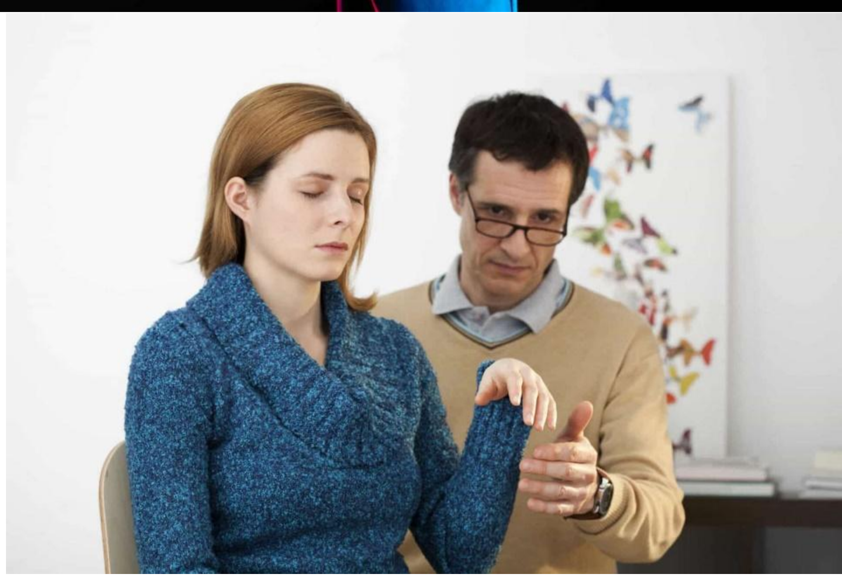
Stage hypnosis

Stage hypnotists, those who appear on shows and select seemingly random members of the audience and send them to sleep, are a world away from clinical hypnotists, who practice an approved form of hypnotherapy.

Hypnotic suggestibility

Some people are more prone to hypnotic suggestibility. Susceptibility to hypnotism may well be a function of personality traits such as openness or empathy—and leading from that, some sort of responsiveness.





Non-manipulative

©ShutterstockHypnosis in not manipulative. You only say and do in hypnosis what you would normally say and do in a fully conscious state.

Hypnosis through the ages

Hypnotism as a tool for health has been practiced for millennia. The Hindus of ancient India built temples for the sick to be cured by hypnotic suggestion.

Neuroscience research sheds light on how psilocybin alters spatial awareness

The psychedelic substance psilocybin has long been known for its ability to alter perception and cognition, often leaving users feeling disoriented. A new study published in the European Journal of Neuroscience explores how this drug affects brain activity at the level of individual neurons. By studying mice navigating a virtual environment, researchers discovered that psilocybin disrupts the brain's ability to encode spatial information, shedding light on why people under its influence often experience a distorted sense of space.

Psilocybin is a naturally occurring compound found in certain types of mushrooms, often referred to as "magic mushrooms." When ingested, it is converted in the body to psilocin, which acts on serotonin receptors in the brain, particularly the serotonin 2A receptor. Psilocybin is known for its psychedelic effects, which include altered perception, mood, and cognition, as well as experiences of profound changes in the sense of self, space, and time. While traditionally used in religious or spiritual rituals, psilocybin has gained significant scientific interest in recent years due to its potential therapeutic effects on mental health conditions such as depression, anxiety, and post-traumatic stress disorder.

Researchers are particularly interested in understanding how psilocybin works at a biological level. Studies using brain imaging in humans have shown that psychedelics like psilocybin disrupt the normal patterns of communication between different brain regions. These disruptions are thought to result in the altered states of consciousness that people experience when using the drug.

However, much of the existing research has been done using indirect measures like functional magnetic resonance imaging, which gives a broad overview of brain activity but doesn't provide detailed information about how individual neurons are affected. This is where studies using animal models, such as this one, come into play—they allow scientists to explore the effects of psychedelics at the cellular level, offering a more precise understanding of how these substances impact brain function.

A specific focus was placed on the retrosplenial cortex, a brain region important for spatial orientation and navigation. Some neurons in this area respond to specific locations in an environment, similar to "place cells" in the hippocampus, which are critical for forming a mental map of one’s surroundings. The researchers wanted to see how psilocybin would impact this spatial encoding, potentially explaining why people on psychedelics often report changes in their sense of location.

“Psychedelics have profound effects on mental function, but we still don’t know much about how they affect information processing performed by groups of neurons,” said study author Aaron J. Gruber, a neuroscience professor at the University of Lethbridge. “Advances in cellular-level imaging in animals and computational analysis allow us to study how drugs affect the dynamical encoding of information in populations of neurons. We recorded neurons in a brain region important for forming a mental representation of the spatial environment.”

The study used ten adult mice that were genetically modified to allow for the visualization of neural activity through imaging techniques. Each mouse was trained to run on a treadmill in a head-fixed position, where they navigated a belt with specific tactile, visual, and auditory cues. The treadmill was designed to simulate a virtual environment, with rewards given after completing laps. This setup allowed the researchers to record and analyze the activity of neurons in the retrosplenial cortex as the mice performed the task.

After the mice were trained, the researchers conducted imaging sessions to monitor brain activity. They recorded the baseline neural activity in each mouse, then administered either psilocybin or a saline solution. The psilocybin was given at a dose of 15 mg/kg, and the mice were recorded again to compare neural activity before and after the drug administration. In some trials, the mice were pre-treated with a drug called ketanserin, which blocks the serotonin 2A receptor (a key receptor involved in psychedelic effects), to see if this would alter psilocybin’s impact.

The neural activity was measured using two-photon imaging, a sophisticated technique that allows researchers to observe the activity of hundreds of neurons simultaneously. The researchers focused on how neurons encoded the mouse’s position on the treadmill belt and analyzed the stability of this spatial encoding across trials.

The results showed that psilocybin had a profound effect on the neurons in the retrosplenial cortex. Normally, many neurons in this brain region are active when the mouse passes specific locations on the treadmill belt. However, after psilocybin was administered, the specificity of these neurons to particular locations was significantly reduced. This means that the neurons were no longer as reliably activated by certain places, leading to a decrease in the brain's ability to encode spatial information.

Furthermore, the stability of this place-related neural activity across multiple trials also decreased under the influence of psilocybin. In other words, the neurons were less consistent in how they responded to specific locations from one lap of the treadmill to the next. This instability in spatial encoding likely mirrors the sense of disorientation and altered perception of space that people often experience when using psychedelics.

Another key finding was that psilocybin reduced the coordination, or functional correlation, between neurons. Neurons that usually fire together when encoding spatial information became less synchronized, suggesting that psilocybin disrupted the normal communication patterns within the retrosplenial cortex. This reduction in coordinated neural activity supports the idea that psychedelics increase the randomness, or entropy, of neural signaling.

“Psilocybin administration temporarily impaired the coordinated brain activity that tracks the animal's position in an environment,” Gruber told PsyPost. “If something similar occurs in humans, it may help account for the altered sense of time and space frequently reported during psychedelic use.”

The role of serotonin in these effects was confirmed by the experiments involving ketanserin. When the mice were pre-treated with ketanserin before receiving psilocybin, the changes in neural activity patterns were largely prevented. This indicates that the serotonin 2A receptor is a key player in mediating psilocybin's effects on the brain.

“Several recent high-profile reports indicate that psychedelics promote synapse formation,” Gruber noted. “We therefore expected that the high-dose psilocybin administration we used would cause a lasting change in information processing that we could detect days after the last administration. We did not find evidence for lasting changes. This suggests that any changes in synaptic structure had a very subtle effect in the neocortical brain region we investigated.”

“We previously tested the effects of the non-classic psychedelic ibogaine on the same task and setup. The effects of ibogaine and psilocybin were qualitatively similar, but ibogaine had much stronger acute effects. Ibogaine also did not have obvious long-term effects on the brain activity we investigated.”

While this study sheds light on how psilocybin affects neural activity in a specific brain region, there are several limitations to consider. First, the experiment was conducted on mice, so the findings may not fully translate to humans. While the retrosplenial cortex plays a similar role in spatial navigation across species, human experiences with psychedelics are more complex and involve higher-order cognitive functions that go beyond basic spatial encoding.

Moving forward, the researchers plan to explore how psilocybin affects other brain regions, particularly those involved in motivation and decision-making, which are relevant to conditions like depression. Understanding the broader impact of psychedelics on brain networks could offer valuable insights into how these substances might be used in therapeutic settings to help treat mental health disorders.

“This research has several goals,” Gruber explained. “One is to use the profound effects of psychedelics on perception and brain function as a tool to understand how the brain normally processes information. We also want to understand how psychedelics may help treat illnesses like major depressive disorder. The current project investigated effects in a brain region involved in memory, orientation, and navigation. Future research will investigate other brain regions more directly associated with motivational components of depression.”

The study, “Psilocybin reduces functional correlation and the encoding of spatial information by neurons in mouse retrosplenial cortex,” was authored by Victorita E. Ivan, David P. Tomàs-Cuesta, Ingrid M. Esteves, Artur Luczak, Majid Mohajerani, Bruce L. McNaughton, and Aaron J. Gruber.

The Speed Of Human Thought Estimated At A Puzzling 10 Bits Per Second

A duo of researchers at Caltech have attempted to quantify the speed of human thought, putting it at a somewhat perplexing 10 bits of information per second. To put that into perspective, one estimate of the slowest average download speed in the USA in 2024 clocked in at 93 megabits per second (Mbps), though the amount of information conveyed is lower.

First up, what are we talking about here? Your thoughts may (surprisingly slowly, it turns out) assume that we are talking about the "bits" we see in everyday computing. In computing terms, a bit can have one of two values, often represented by a binary digit, either one or zero. But that doesn't correspond to the amount of information conveyed, sometimes referred to as a "Shannon" after Claude Shannon, often referred to as the "father of information theory".

"To understand the concept of information, it is essential to differentiate it from that of data. Let's take an example. I have a friend who has just given birth. I send her a text message to ask her the sex of the newborn. In my vision of things, there is an equal chance that it will be a boy or a girl. Her response will therefore send me exactly one Shannon. To answer me, she will probably send me a sentence made up of several characters, each represented by several bits. I will therefore receive several dozen bits of data for a single Shannon," Vincent Gripon, Associate Professor at Télécom Bretagne, explains in a translated piece for The Conversation.

"Our brain is accustomed to this fact. It is estimated that one hundred million bits per second of data are transmitted from the visual cortex to the deep areas of our neocortex. Most of this data is completely useless to us, and moreover carries very little information."

Scientists studying information theory have attempted to quantify the information of various systems, including how much information is conveyed in each syllable of language and how much information there is in the entire visible universe. In doing so, they have hit upon a bit of a puzzle: Our brains are constantly bombarded with sensory data at an incredible rate, estimated to be 10 bits per second, and yet our conscious thoughts process information at a far slower rate.

Human thought, as you might expect, is a difficult thing to quantify. Attempting to do so, the authors of a new study looked at tasks performed by humans and the amount of information processed during it. For example, they looked at the task of manually typing out a hand-written manuscript.

"An advanced typist produces 120 words per minute. If each word is taken as 5 characters, this typing speed corresponds to 10 keystrokes a second. How many bits of information does that represent? One is tempted to count the keys on the keyboard and take the logarithm to get the entropy per character, but that is a huge overestimate. Imagine that after reading the start of this paragraph you are asked what will be the next let..." the team writes in their paper.

"English contains orderly internal structures that make the character stream highly predictable. In fact, the entropy of English is only ∼ 1 bit per character. Expert typists rely on all this redundancy: If forced to type a random character sequence, their speed drops precipitously."

From this, they were able to estimate that the speed of thought the typist operates at when typing a random character sequence is around... 10 bits per second. Looking at other tasks, from playing Tetris to solving Rubix Cubes in controlled conditions, and listening to English, the team estimated that most of these tasks take place at a similar, surprisingly slow, rate.

"This is an extremely low number," Markus Meister, co-author of the paper, said in a statement. "Every moment, we are extracting just 10 bits from the trillion that our senses are taking in and using those 10 to perceive the world around us and make decisions. This raises a paradox: What is the brain doing to filter all of this information?"

While our brains deal with an avalanche of sensory data, our conscious thoughts appear to operate at a far slower rate. The team notes that this could have implications, for example, in the field of creating brain-computer interfaces. While we (and by we, we mean tech bros) may dream of creating brain-computer interfaces to speed up human brainpower, it could turn out that we are limited by the speed of our own cognition, like trying to connect to fiber optic internet through a Game Boy – your hardware will limit what you can get out of it.

More generally, it raises a number of questions about human cognition, such as why our nervous system can process thousands of items in parallel, while our conscious thought chugs along at such a slow pace.

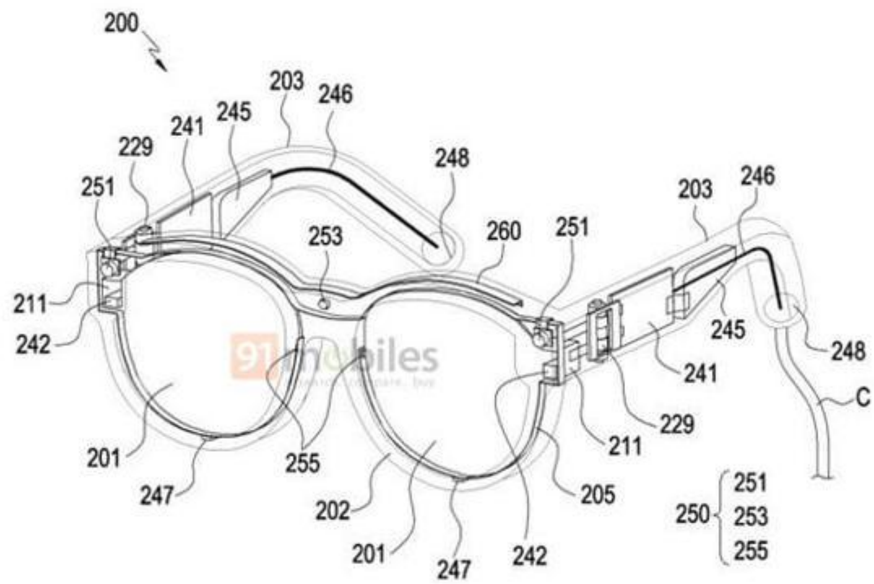
"How can humans get away with just 10 bits/s? The tautological answer here is that cognition at such a low rate is sufficient for survival," the team writes. "More precisely, our ancestors have chosen an ecological niche where the world is slow enough to make survival possible. In fact, the 10 bits/s are needed only in worst-case situations, and most of the time our environment changes at a much more leisurely pace."

While an interesting estimate of the information speed in human thought, the team stresses that it raises more questions than it answers, offering an avenue for further exploration in the future.

"In particular, our peripheral nervous system is capable of absorbing information from the environment at much higher rates, on the order of gigabits/s," the team writes. "This defines a paradox: The vast gulf between the tiny information throughput of human behavior, and the huge information inputs on which the behavior is based. This enormous ratio – about 100,000,000 – remains largely unexplained."

The study is published in the journal Neuron00808-0).

Samsung patent hints at plans for smart glasses



Samsung smart glasses patent

According to a recent rumor, Samsung is expected to introduce a bunch of new products in January 2025. The Galaxy S25 series is a pretty obvious candidate, but the rumor also suggests that the Galaxy Ring 2 could be part of the announcement, along with a pair of smart glasses. A recently discovered patent reveals the potential design of the Samsung smart glasses, along with interesting features such as speakers protected by electromagnetic interference.

A familiar look

This patent was discovered by the folks over at 91mobiles. It shows what appears to be a pair of regular-looking glasses, except that it comes with a bunch of tech shoved inside it. If this looks familiar, it is because it's hard not to draw comparisons to another pair of smart glasses on the market.

Meta introduced its own smart glasses back in 2023. The company created it in collaboration with Ray-Ban. While the concept of smart glasses isn't new, Meta's efforts made these hi-tech glasses look more casual and less nerdy.

Samsung's take on smart glasses doesn't appear to be too different from what's available in the market. It houses a bunch of sensors that can detect touch and pressure so users can interact with it without taking it off. It also comes with a built-in set of speakers. The speakers are the more interesting bit of this patent.

According to the patent, Samsung has come up with a way of protecting the speakers of the smart glasses from electromagnetic interference. This occurs when a power line and speakers are close to each other. The magnetic field generated by the powerline creates noise when that happens.

Samsung's patent suggests that the company has figured out a way to overcome that issue. Reducing unwanted noise is important for a pair of smart glasses, especially for listening to music and making calls, even though it might seem trivial.

Not Samsung's first rodeo

While this patent hints at a potentially new form factor, it would not be Samsung's first attempt at a headset. Some of you might recall that the company dipped its toes in the scene with the Samsung Gear VR headset.

More recently, the company teased a new headset codenamed "Moohan" (which means "infinity", in Korean). For those unfamiliar, Moohan is a mixed-reality headset that runs on Google's Android XR platform. Some believe that this could be Samsung's answer to Apple's (very expensive) Vision Pro headset.

It's interesting to see Samsung explore a variety of headset designs. Both the Gear VR and Moohan seem designed for indoor use, such as at home or the office. In contrast, this patent could allow users to wear the device outdoors. Google attempted something similar with Google Glass back in the day, but the public didn't react very well to it.

Reports claimed that establishments banned the headset over concerns that users were being recorded without permission.

Why your brain thinks in 'chapters': The key to boosting memory and productivity

Picture this: You're on a call at the grocery store, walking through aisles of fruits and vegetables, trying to keep a mental note of what you need to buy. Meanwhile, on the phone, your friend is excitedly telling you about a business deal they're about to close. Do you focus on the steps of the new business deal or is your brain more attuned to grocery shopping? (And let's be honest, sometimes that overlap can lead to mix-ups, like congratulating your friend on burrata cheese while discussing a business deal with the cashier.)

The truth is, our brain functions in chapters, like a true novelist. As research shows, to deal with the innumerable events in your life, the brain organises your day into neat little chapters, just like a novel. There's a 'plot twist', every time you switch tasks or change locations. This isn't just an unusual habit in the mind: These mental 'chapters' are key to staying sharp, focused, and productive. By understanding how these transitions work, you can unlock better memory retention, improve focus, and breeze through tasks with newfound clarity.

New research at the US-based Columbia University backs this, too. These mental boundaries aren't prompted just by changes in surroundings, but also by your internal goals and priorities. According to the experiments that used audio narratives, participant's brains organised events different depending on whether they focused on specific details. The study attempted to show that how we experience and remember events, is influenced by both context and what matters most to us at the time. In other words, our brain forms new 'chapters' based on attention, personal goals and not just the environment. In fact, the brain scans of the people showed that people segmented stories, differently, depending on their focus.

So, what are these chapters?

Why your brain thinks in 'chapters': The key to boosting memory and productivity

The brain is organising our life experiences into chunks that are actually meaningful to us. Image Credit: Pexels.com

What triggers the brain to create boundaries between events, forming a new ‘chapter’ in the day? Katelyn Rowison, a Dubai-based neurologist, posits a few theories: One theory is that significant environmental changes, like stepping from outdoors into a restaurant, prompt these shifts. “However, another possibility is that internal mental scripts, shaped by past experiences, dictate when these transitions happen. In this case, even noticeable external changes might be ignored if they don't align with a person’s current goals or priorities. Essentially, the brain may prioritise shifts based on what it deems most important now,” she says.

Essentially, the brain divides up an experience into individual events depends on what a person currently cares about and is paying attention to. She explains with an example from Neuroscience News: “For instance, when listening to a story about a marriage proposal at a restaurant, the brain — particularly the prefrontal cortex — organises the narrative around key moments related to the proposal. The listener's attention naturally gravitates toward the events leading up to the climactic 'yes', forming a cohesive mental sequence. This shows how the brain prioritises relevant information based on emotional or situational significance, filtering out less relevant details."

Moreover, there is strong engagement in the brain, adds Rowison, citing the Columbia-based research that had also disproved the idea that the brain isn't 'really doing anything' when it is organising life experiences into chunks. "In fact, the brain is organising our life experiences into chunks that are actually meaningful to us." This 'chunking' involves several crucial regions in the brain.

Behind the scenes

As she elaborates, the prefrontal cortex has the main role, owing to its responsibility for goal-directed behaviours, attention, and decision-making. When we undergo an experience, the prefrontal cortex collaborates with the hippocampus, which is critical for memory formation, and the parietal lobe, which integrates sensory information. Together, these regions process incoming stimuli, identifying important details based on our current goals or emotions, and segment them into "events". This allows the brain to prioritise and structure experiences, making them easier to recall and understand.

The neurons in these regions fire in specific patterns, reinforcing significant moments, while less important stimuli are deprioritised. "This system is highly adaptive, allowing for flexibility in how we perceive the flow of events based on our focus and emotional state. This ability to chunk experiences is crucial for memory consolidation and decision-making, as it lets us create coherent mental narratives that align with our immediate priorities," she says.

The cognitive benefits of these chapters

Anxiety triggers the hypothalamic-pituitary-adrenal (HPA) axis, releasing stress hormones like cortisol and adrenaline, which puts you in fight-or-flight mode. Image Credit: Pexels.com

Sometimes, you take a pause before you turn the page to a new chapter. It's a little break, as you dwell on what you just read. Similarly, as Alexander Maxmillian, a Dubai-based neuropsychologist explains, the brain's shift from one mental chapter to another, helps in compartmentalising information, making it easier to store and retrieve memories. There's a pause between tasks, which prevents mental fatigue. So, due to these mental shifts, we can refresh our focus, he says. "It consolidates learning and fuels creativity. Think of it like how each chapter provides a clean slate for fresh thinking, contributing to heightened problem-solving abilities," he says.

As a result, the transitions also allow for clearer emotional boundaries. For example, switching from work mode to leisure mode enables the brain to disengage from stressors, promoting mental relaxation. This compartmentalisation protects long-term mental health by preventing emotional carryover from one task to the next.

How chronic stress fractures the brain's storytelling

However, when you're overworked, stressed, and fatigued, you would know that you might not be able to remember exact details of an event. You can't seem to be creative either, your mind is darting back and forth just like a ball at a tennis game. That's what happens when stress clouds your mental shifts and brain function. The chapters might suddenly seem like the first draft of a novel.

The mental shifts manifest as decreased focus, impaired creativity, and overall cognitive decline, explains Maxmillian. When someone is anxious, the brain activates the hypothalamic-pituitary-adrenal (HPA) axis, leading to the release of stress hormones like cortisol and adrenaline. In other words, you find yourself trapped in the fight-or-flight mode. When it turns chronic, the prefrontal cortex is compromised, and there's also a reduction of hippocampal volume. As the hippocampus plays a crucial role in memory formation and retrieval, and its impairment can lead to difficulties in learning and recalling information. Maxmillian adds, "This atrophy can further exacerbate feelings of anxiety, creating a vicious cycle where stress impairs memory, and poor memory contributes to increased anxiety."

Finally, the amygdala, a brain region that's involved in processing emotions, especially fear, becomes overactive. You start exaggerating the perception of threats. Anxiety is fuelled, and you start focusing on potential dangers, rather than trying to think your way out of a problem. And soon, you become trapped in a reactive mode, rather than a proactive one.

As Maxmillian concludes, "Such detrimental mental shifts, often induced by stress and anxiety, can disrupt the chapters of our cognitive and emotional narratives. Each chapter, represented by specific brain functions, plays a critical role in shaping our thoughts, feelings, and behaviours. When you understand how these shifts connect to functioning in the brain, people can identify and address the underlying issues that contribute to stress, which promotes more coherent and positive mental narratives."

So, how do you maximise mental chapters for productivity?

Changing environments, such as moving from your desk to a new workspace, can trigger the brain's chapter switch. Image Credit: Pexels.com
As the specialists explain, here are a few strategies to furnish your focus and productivity, and prevent a natural overwhelm:

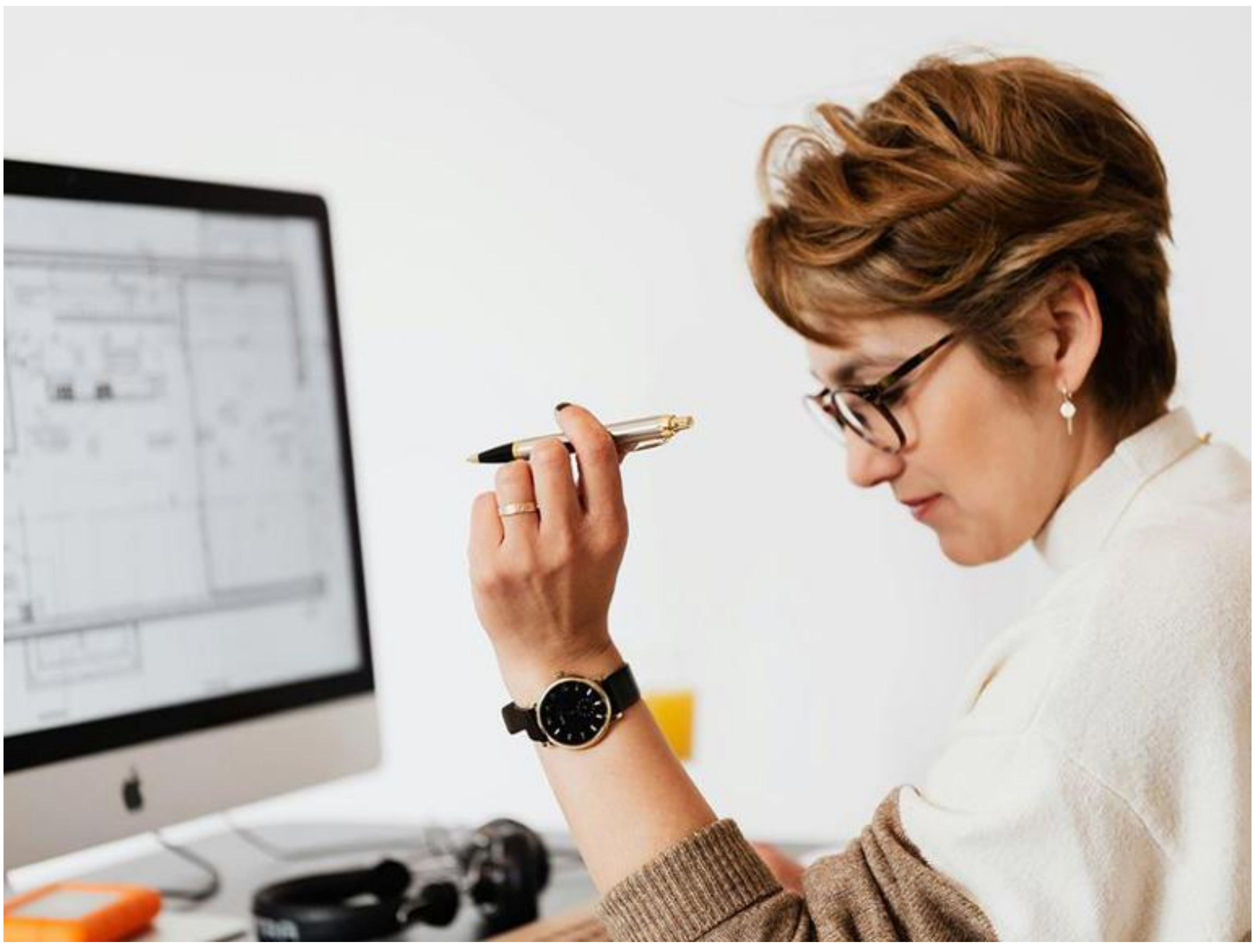
Structure your day around natural breaks: Instead of forcing yourself to push through tasks, use natural transitions like breaks, meals, or changes in location to signal the end of one chapter and the start of another. This can prevent burnout and sustain attention levels.

Use physical cues to reinforce chapters: Changing environments, such as moving from your desk to a new workspace, can trigger the brain's chapter switch. Even subtle changes like lighting or background music can help mentally mark the transition between different tasks.

Take advantage of the peak-start rule: Begin new chapters with high-priority tasks when focus is sharp. Use the fresh momentum from a new chapter to dive into complex projects or decision-making tasks, allowing for deeper cognitive engagement.

Summarise to boost memory: Reflection during transitions can reinforce learning. When ending one task, mentally summarise what you've accomplished. This active recall aids memory retention and creates a clear mental conclusion for the chapter.

Pair tasks with similar emotional loads: Scheduling similar types of tasks, like creative work or administrative duties into the same ‘chapter’ of your day can streamline emotional energy. By grouping activities with similar emotional and cognitive demands, transitions are smoother, reducing stress and preserving mental resources.



Sleep Your Way to a Smarter Brain

Sleep is one of life's enduring mysteries. But as anybody who has tossed and turned all night may understand, getting enough shuteye is crucial for good health. Did you know that it's especially important for brain health?

Sleep and your brain

Sleep is absolutely instrumental in cognitive function, mental acuity and the ability to concentrate and learn new things.

During sleep, your brain deals with information received during the day. It consolidates memories and clears plaque-forming amyloids and tau proteins associated with Alzheimer's disease.

There's a cleanup process that happens in brains when we sleep. There's a pressure to sleep, and when you do, that pressure gets dissipated and that's how you feel fresh in the morning.

REM sleep, or the dreaming phase of sleep, has been shown to enhance learning, memory and emotional well-being.

Sleep disruptions affect your levels of neurotransmitters and stress hormones, which may make it more difficult to think and regulate your emotions.

If you have long sleep but it's fragmented, you're interrupting the sleep cycle.

Sleep can affect mental health

Sleep problems may increase the risk of developing certain mental illnesses, such as depression and anxiety. And addressing sleep issues can help improve mental health conditions.

Sleep impacts your health and all bodily systems. There is genetics and there is environment. Sleep is part of the environment that allows your genetic makeup to shine.

Insomnia, or the inability to sleep, is even more harmful to brain health and is being studied more closely as an underlying condition contributing to a wide range of health conditions.

Take action to improve your sleep

Try the following steps to get better sleep.

1. **Practice good sleep hygiene.** Make your bedroom or sleeping space as comfortable, quiet and dark as possible.

2. **Banish bright light** from lamps, TVs, cell phones and other electronic devices. Bright light will suppress the release of melatonin, a hormone that gets your body to fall asleep. Turn off the TV, so your melatonin can rise naturally and you can have a good night's sleep without any help.

3. **Skip the stimulants.** Although young people may be able to handle a cup of coffee in the afternoon, that may change as they age. Make sure the effects of caffeine have worn off before you go to bed.

4. **Avoid consuming alcohol too close to bedtime**. Alcohol is a sedative, but once it's metabolized by your body, it creates arousal and you may have more broken sleep.

5. **Don't eat heavy meals before bed**. While a light snack may be OK, a large meal may trigger acid reflux. Your body processing the nutrients may also disturb sleep.

6. **Don't rely too much on sleep aids**, which can be addictive. Even melatonin supplements shouldn't be used regularly. They may help you for a short period, but you need to make sure you're able to wean off of them. The goal is to sleep naturally.

You should prioritize sleep the same way you do other healthy activities such as exercise and diet.

It's important for people to be active on most days of the week, not cram it all in on the weekends, and it's the same thing for sleep. Having adequate sleep every night is really helpful to heart and brain health.

Sharpen thinking skills with a better night's sleep

Getting seven to eight hours a night can help you restore clarity and improve memory.

Are you tired of struggling with fuzzy thinking and a faltering memory? Tired may be the key word. "Poor sleep has an adverse impact on thinking," says sleep expert Dr. Lawrence Epstein, an instructor in medicine at Harvard Medical School. "This istrue whether it's due to a lack of sleep or a sleep disorder."

The problem

When people don't get enough sleep, their attention and concentration abilities decline. Their reaction time lengthens, they're inattentive, and they don't respond as well toenvironmental signals. That means they can't take in new information or react to dangerous situations. This is particularly worrisome if you're behind the wheel of a car. "For example, going without sleep for 48 hours impairs cognitive abilities to the samedegree as having a blood alcohol concentration of 0.1%, above the legal limit for driving in every state," says Dr. Epstein, who's also the editor of the Harvard Special Health Report Improving Sleep: A Guide to Getting a Good Night's Rest.

A lack of sleep can also contribute to a long list of health problems such as heart disease, high blood pressure, diabetes, obesity, and even early death.

Causes

There are many reasons why people don't get enough sleep, chief among them not setting aside enough time. Other common causes include insomnia (difficulty falling or staying asleep); side effects from medication; sleep apnea (a type of breathing disorder during sleep); restless leg syndrome; and chronic conditions such as heartburn, heart disease, thyroid disease, depression, and narcolepsy (a disorder of sleep/wake regulation). Late-night exposure to the light from television and computer screens, as well as smart phones, can also keep us awake, stimulating our brains and making it harder to fall asleep.

Age is another culprit that affects your sleep. You'll find that the older you get, the longer it takes to fall asleep. Sleep quality also becomes poorer, resulting in dozens of awakenings during the night.

What you can do

The good news is that there are plenty of ways to get more sleep. "You really can make up for lost sleep and restore focus and clarity. You can lose the brain fog within a week. But start now; the longer you have bad sleep, the longer it will take to catch up," says Dr. Epstein. He suggests that you aim for seven to eight hours a night. (The idea that older adults can function well on fewer hours is a myth.) Try the following strategies to get started.

- **Check for underlying causes.** Some conditions or medications may be interfering with your sleep patterns. Treating a condition or adjusting a medication may be all it takes to restore better sleep.

- **Practice good sleep hygiene.** Use your bed for sleep and sex only, block as much noise and light as possible, go to bed and wake at the same times each day, and get out of bed if you haven't fallen asleep within 20 minutes.

- **Supplement with naps.** If you can't set aside enough time for sleep at night and are sleepy during the daytime, napping can help. It's best to take one short midday nap before 5 p.m.; naps late in the day can interfere with sleep later. If your problem is difficulty getting to sleep at night, then avoiding daytime sleeping can help increase your sleep drive at bedtime.

- **Exercise earlier, not later.** Exercise stimulates the brain, so make sure you finish at least three hours before turning in.

- **Watch your diet.** Avoid foods that promote heartburn, and don't eat late at night; lying down after eating promotes sleep-disturbing heartburn. Ban caffeine-packed food and drinks (chocolate, tea, coffee, soda) at least six hours before bedtime. Avoid alcohol for at least two hours before bed. It may make you feel sleepy at first, but several hours later it acts like a stimulant—and interrupts sleep. And don't drink too much water before bedtime, to cut down on trips to the bathroom in the middle of the night.

- **See a sleep specialist.** If your own efforts aren't working, you'll want the help of a sleep professional to both diagnose your problem and propose behavioral therapy and possibly drug treatments.

Disclaimer:

As a service to our readers, Harvard Health Publishing provides access to our library of archived content. Please note the date of last review or update on all articles.

No content on this site, regardless of date, should ever be used as a substitute for direct medical advice from your doctor or other qualified clinician.

Scientists uncovered a bizarre way that our brains are mutating

Scientists believe that mutations in the brain they previously thought were rare might actually be happening inside each and every one of us. In fact, scientists believe that these brain mutations could actually be factors in how we age.

According to Ryan Mills, a researcher at the University of Michigan, the mutations are not only present, but they're also found in the dorsal lateral prefrontal cortex, an area of the brain that is associated with cognitive ability-and one area typically affected heavily by aging. The mutations in question also appear to be driven by mitochondria.

These brain mutations appear to come from within our DNA itself, too. The scientists believe that the mitochondria somehow get into the nucleus of our DNA and then get added to our main genome. As I noted above, the mutation was originally assumed to be rare. However, the past few years have provided more data that suggests otherwise.

In fact, it could be far less unusual than we thought, especially in cells that are cancerous. Now, Mills and a team of researchers have analyzed even more DNA samples from brain tissue taken from more than 1200 people during post-mortem examinations. The samples were inspected to see just how the mitochondrial DNA had changed and whether or not it had been added to the nuclear genome.

Mills' team found that not only did the brain mutations occur in far more people than they expected, but they were also far more common-on average, at least-in people who died at younger ages. The researchers aren't sure exactly how closely tied the mutations are to aging. But, Mills says it is "hard for him to believe that the mitochondrial getting into the genome won't have a lasting effect on the human body.

A study of the researchers' findings has been published in the journal PLOS Biology.

Harvard nutritionist and psychiatrist: I've studied brain foods for 20+ years—here are 5 of my favorite breakfasts

Breakfast provides the brain with its first source of energy every morning. Fueling the brain is key for focus, clarity, and optimal functioning throughout the day. Even if you happen to follow intermittent fasting, it's important to pick something nourishing at the start of your eating window.

Today, most people in the U.S. associate breakfast with colorful cereals, overloaded bagels and breakfast sandwiches, baked goods that border on dessert, and coffee drinks that are barely distinguishable from milkshakes.

These popular items are frequently loaded with sugars and simple carbohydrates that cause an initial spike in blood sugar followed by a crash. They also contribute to the neuroinflammation (inflammation around the brain) that's associated with brain fog and poor concentration.

Fortunately, as the Director of Nutritional, Lifestyle and Metabolic Psychiatry at Massachusetts General Hospital, my research and clinical work has helped me learn that there are plenty of other options for your morning routine that can help enhance your mental fitness.

And as a chef, I know those healthier choices can be delicious and easy to prepare.

I always suggest a glass of water when you wake up to combat dehydration and anxiety. After that, here are five of my favorite breakfast brain foods. They're rich in key nutrients and functional compounds that promote better energy, clarity, and mental health.

1. Chia pudding

One of my go-to breakfasts is homemade chia seed pudding. It contains tons of fiber, which nourishes healthy bacteria in the gut and results in a less inflamed microbiome, optimized gut-brain communication, and the production of mood-supporting neurotransmitters.

It contains omega-3 fatty acids that have strong anti-inflammatory effects on the brain, which helps boost mood, ward off stress, and maintain healthy cognition and memory.

The pudding is easy to make the night before: Combine three tablespoons of chia seeds with a cup of coconut milk (or your unsweetened milk of choice), a drop of honey, and a pinch each of cinnamon and sea salt. Top it in the morning with nuts, berries, and/or coconut flakes.

2. Scramble, omelet, or baked frittata

If eggs are part of your diet, consider starting the day with a scramble, omelet, or baked frittata.

Eggs are loaded with healthy fats, proteins, and vitamins that are essential for a healthy brain. The yolks, for example, are rich in vitamin D and serotonin, which help you reach the optimal balance of neurotransmitters to regulate your mood.

I always encourage people to pick eggs from pasture-raised, cage-free chickens when possible for the highest quality and purest nutrients.

Your breakfast doesn't have to be fancy. In my first book, "This Is Your Brain On Food," I share a recipe for my "On-the-Go Scrambled Egg in a Mug" that you can prepare with eggs, a splash of milk, and salt and pepper. It takes just a couple of minutes in the microwave and you can toss in some spinach or kale if you'd like.

3. Tofu scramble

Tofu is an excellent, versatile protein that's rich in tryptophan and soy isoflavones, which have a demonstrated association with reduced symptoms of depression.

As an alternative to eggs, I love a savory tofu scramble spiced with turmeric, black pepper, and a pinch of sea salt.

4. Green smoothie

A bright green smoothie is a quick and easy way to start the day with fiber and folate.

We need folate for the production of neurotransmitters in the brain — folate deficiency is implicated in a number of psychiatric conditions, including depression, while optimal levels are associated with improved mood.

Blend up your favorite leafy greens like spinach along with a few berries, your favorite clean protein powder (or silken tofu for a creamy twist), and a bit of fat from hemp seeds or almond butter for a nutrient-dense smoothie you can take with you as you run out the door.

Avoid adding too much fruit or any fruit juices to keep it low sugar and avoid disrupting the microbiome or experiencing blood sugar spikes and fatigue.

5. Turmeric latte

While not necessarily a meal in itself, my golden milk turmeric latte is a nourishing beverage and an incredible way to kick off your morning.

Combine a cup of your favorite unsweetened plant milk with turmeric and a pinch of black pepper.

What you get is a potent anti-inflammatory that helps reduce symptoms of anxiety, boost energy, and clear brain fog for focus throughout the day.

Dr. Uma Naidoo is a Harvard-trained nutritional psychiatrist, professional chef, and nutritional biologist. She is also the author of the bestselling "This is Your Brain on Food" and most recently, "Calm Your Mind with Food." Follow her on Instagram or subscribe to her newsletter on Substack.

A Quick Guide to Brain Basics: From Parts of the Brain to Memory

The brain is our body's command center, the control tower for our body and mind—no wonder it's the focus of intense research across the globe, with so much interest in figuring out the mysteries of its inner workings, as well as what can be done to stave off cognitive decline.

According to the British Medical Journal, there are at least three levels of brain function: The brain controls movement and deciphers input from our senses, it manages our cognitive and emotional processes, and it maintains social cognition and behavior.

"The brain is like a supercomputer," says neuroscientist Tara Tracy, Ph.D., assistant professor and a specialist in neurological decline at the Buck Institute. "And the circuits within the supercomputer are the neurons in the brain."

Neurons are nerve cells; there are about 100 billion neurons in the brain of an adult, "and they're not all the same," says Tracy. "There are all sorts of neurons that do different things. Neurons process all the information for us. They help us have cognition, the ability to make decisions, the ability to remember things." All of your thoughts, the sensations you feel, the movements you make, your emotions and memories—they all stem from signals that are sent through neurons.

Inside the brain

"For daily living, there are different types of neurons," says Tracy. "There are specific neurons that are important for our movement, neurons that are important for functions like dealing with anxiety or stress. There are neurons that are important for memory and remembering things, and neurons that are important for encoding information from the sensory system—what we see or smell or hear.

"You put all these together, and it's very complicated," she continues, "but all of these different neurons come together in the brain and can function together as this big supercomputer, to integrate all this information and allow us to do things. That’s one of the most fascinating things about the brain, that it can be so complex but it all happens at the same time—because neurons are also very fast. They transmit information very, very quickly, at the millisecond level.”

That speed is important to consider, because we know that some of our behaviors and habits can make the system operate more sluggishly. And there are many advantages to having neural communication that’s operating at an optimal level.

“Let’s say you trip and fall,” says Tracy. “You can respond to that quickly if your neurons are really fast, if the connections are well made within the brain and the communication between the neurons is fast.” Meaning, you’ll have an easier time righting your balance before you face plant on the sidewalk. “So that’s an important property of neurons in the brain, that they can do things very quickly,” she says. “And they’re structured, and the system is set up, in a way that helps you accomplish things to the best way possible—meaning to protect yourself from potential dangers.”

The importance of connections

When it comes to the workings of the brain, so much is still not understood. The signals are sent from neuron to neuron along various pathways, and neuroscientists have a lot of those pathways worked out, Tracy points out. “The visual system, for example, is fairly well understood, in terms of the neurons that go from your eyes into your brain and where in the brain they’re connected, and how they then process the visual information,” she says. “There are a number of pathways that neuroscientists do have a pretty good understanding of—but not every pathway.”

Memory isn’t completely understood, she explains. “When you first form a memory, we kind of know where that happens in the brain. But the long-term storage of a memory—like when you remember something that happened 20 years ago—the pathways of how that information gets stored, and where, are not well understood.”

Food & Beverage Machinery > Other Snack Machines.Unisex.White Dough Divider Rounder" data-t="{"n":"NativeAd","t":13,"ext":null}" role="article" target="_blank" style="--content-padding: 16px; --no-image-action-tray-padding: 20px; --action-tray-padding: 10px; width: 676.4px; height: 144px; font-family: var(--body-font); --video-transition-delay: 1s; --video-transition-start-duration: 1s; --video-transition-end-duration: 1s; forced-color-adjust: auto; --image-gradient-overlay-start-color: rgba(86,86,86,0); --image-gradient-overlay-end-color: rgba(86,86,86,0.8); color: initial; background-color: initial; text-decoration-color: initial;">

Depending on what information is being processed, it gets processed in different parts of the brain, and those different sections all work together. Three important areas: The **cerebellum** is in charge of movement; when you're out there on the pickleball court, or are learning how to play the guitar, that's the area of the brain that's activated. The **cerebrum** is what allows conscious thoughts, plans, imagination, reading, recognizing people you know, and so much more. The **cerebral cortex** is where most of the brain's information-processing takes place.

An elaborate, brilliant machine—brought to us via evolution, many neuroscientists believe, says Tracy. "We believe that we've evolved the abilities to manage the things we do in daily life, because our brain evolved with this structure, these connections and neurons."

A smooth-working noggin

Brain health, then, is when all of these are clicking along well. And though much of the mechanisms that cause various brain dysfunctions are a puzzle, there's growing research that underlines the importance of taking steps to protect your brain health: challenging your mind, eating a healthy diet, being socially active, prioritizing sleep, taking care of your heart, and—perhaps especially important—emphasizing exercise.

"I think most scientists think that exercise is super-important," says Tracy. "Lack of exercise in general can have a bad effect on the brain. We don't really understand why—there's been a lot of work on this, and scientists have ideas about it, but research has shown that people who do a lot of exercise are associated with having good brain health."

So lace up your sneakers, find ways to destress, make sleep a priority, eat foods that are best for your brain and heart. It's worth doing whatever we can, because good brain health is the bottom line goal—so that this magnificent machine, this intricate supercomputer, can keep us functioning at our very best, for as many years as possible.

More From Your Brain: An Owner's Manual

A Whole-Brain Phenomenon: New Research Challenges Old Theories of Intelligence

DECEMBER 31, 2024

Intelligence stems from brain-wide connections, not specific regions, according to JMU researchers. Their findings challenge established theories, highlighting the brain's complexity.

A new study shows that intelligence is best predicted by global brain connectivity, not just specific regions, indicating a more holistic neural basis for cognition. They examined fluid, crystallized, and general intelligence using fMRI data, finding that general intelligence had the strongest predictive power.

The human brain is the central organ that controls our body. It processes sensory information and enables us to think, make decisions, and store knowledge. Despite its remarkable capabilities, it is paradoxical how much remains unknown about this intricate organ.

Jonas Thiele and Dr. Kirsten Hilger, who leads the "Networks of Behavior and Cognition" research group at the Department of Psychology I at Julius-Maximilians-Universität Würzburg (JMU), are dedicated to unraveling the mysteries of the brain. Their latest research has been published in the scientific journal PNAS Nexus.

Predicting Intelligence from Brain Connections

The researchers used data sets from a large-scale data-sharing project based in the US: the Human Connectome Project. With the help of fMRI – an imaging method that measures changes in brain activity – over 800 people were examined. Both at rest and while they performed various tasks.

The Würzburg-led team looked at various connections that map the communication strength between different brain regions and made predictions about individual intelligence scores based on these observations.

"Many studies predicting intelligence from brain connections have been published in the last years and they also achieve quite good predictive performance," says Kirsten Hilger. However, the neuroscientists question their deeper meaning, as the predictions would never be as accurate as the results of an intelligence test. "We therefore intended to move away from the pure prediction of intelligence scores and instead better understand the fundamental processes in the brain. We hope that this will give us a better understanding of the neural code of individual differences in intelligence."

Kirsten Hilger hopes that colleagues will follow her example and that more studies will be designed in the future aiming at improving the conceptual understanding of human cognition with a focus on interpretability.

Three Types of Intelligence

The team distinguished three types of intelligence in their predictions: Fluid intelligence refers to the ability to solve logical problems, recognize patterns, and process new information, independent of existing knowledge or learned skills.

Crystallized intelligence encompasses the knowledge and skills that a person acquires over the course of their life. This includes general knowledge, experience, and understanding of language and concepts. It arises through education and experience.

Together, these two forms make up general intelligence. The best predictive performance was achieved with general intelligence, followed by crystallized and fluid intelligence.

Brain-wide Connections Best Predict Intelligence

Various theoretical considerations determined which different connections in the brain were examined. In addition, randomly selected connections were also tested. One crucial observation: the distribution of connections across the entire brain as well as the pure number of connections were most important for predictive performance, more important than between which exact brain regions the individual connections were located.

“The interchangeability of the selected connections suggests that intelligence is a global property of the whole brain. We were able to predict intelligence not just from a specific set of brain connections, but from different combinations of connections distributed throughout the brain,” says Hilger.

Results Outperform Established Theories

While established theories of intelligence often focus on specific areas of the brain – such as the prefrontal cortex – the results of the study suggest that connections between additional brain regions are important for intelligence: “The connections of brain regions proposed in the most popular neurocognitive models of intelligence produced better results than randomly selected connections. However, the results were even better when complementary connections were added,” reports Kirsten Hilger.

Overall, this suggests that there are even more aspects of intelligence than previously assumed that are waiting to be understood in the future.

Reference: “Choosing explanation over performance: Insights from machine learning-based prediction of human intelligence from brain connectivity” by Jonas A Thiele, Joshua Faskowitz, Olaf Sporns and Kirsten Hilger, 10 December 2024, PNAS Nexus.
DOI: 10.1093/pnasnexus/pgae519

Scientists Want To Entangle Human Brains With Quantum Computers To Learn About Consciousness

A team of researchers believe they may have a way of testing the hypothesis that consciousness in humans arises from entanglement within our brains. To do so would involve creating interfaces between human brains and quantum computers, and attempting to measure any resulting changes in consciousness.

Consciousness is something we all have, but know surprisingly little about. We know how to turn it off with anesthetics, but we aren't really sure how they work either. There are plenty of people working on the problem, but we still don't know whether consciousness is the result of integration within a system (known as integrated information theory) or the result of information being shared across the brain (global workspace theory), the two leading ideas. With so little known, there is room for other, more out-there ideas.

In 1989, British mathematician and Nobel Prize in Physics winner Roger Penrose did just that, suggesting that quantum entanglement is involved in consciousness. Though we cannot summarize his full argument, spread out over several books, the gist of it boils down to the idea that there are some problems that cannot be completed or comprehended by traditional computers. Humans can deal with these problems and comprehend them, such as non-computable numbers and Gödel sentences, and so the human mind must not operate like a traditional computer. Instead, Penrose suggests that consciousness could arise from quantum entanglement within the brain.

The argument, which was not well met at the time, has actually seen a bit of a revival in recent years, though it remains on the fringes of consciousness research. One limit on the idea was that quantum entanglement is fragile and easily broken even at low temperatures, so how could we produce and maintain entanglement in the warm mushy environment of our brains?

But since then, it has been suggested that microtubules inside neurons could provide this stable environment for entanglement. Earlier this year, one team claimed that they had found supporting evidence of this idea, after giving rats microtubule-binding drugs and finding that it then took longer for anesthesia to knock them out, suggesting that they played a role in consciousness.

While further study in that area may give us further clues to what consciousness is and how it works, another team has a far wackier idea for testing whether consciousness is a quantum process. This team, which includes Hartmut Neven, lead of Google's Quantum AI lab, makes the assumption that Penrose is wrong in his suggestion that consciousness arises at the point of superposition collapse, instead suggesting it could arise when it formed, in order to sidestep the absurd possibility of faster-than-light communication in the brain.

The team suggests that the way to test this theory of consciousness is to try to "expand" our own consciousness using an interface between our brains and a quantum computer.

"In an experimentum crucis, one would establish a physical link between a human brain and a quantum computer that would enable coherent interactions and mediate entanglement. If our conjecture is accurate, this should enable richer conscious experiences of the combined system, requiring more descriptive bits than the experiences the human reports without the link," the team explains in their paper, adding that it requires coupling a system within the brain with qubits in superposition inside a quantum computer.

"Before the systems are coupled, their respective states exist in separate state spaces, known as Hilbert spaces, of dimension N and M, respectively. After they are made to interact, the wave function describing the combined system | resides in an × -dimensional Hilbert space," the team writes. "We conjecture that a superposition forming in this higher dimensional state space would be experienced by the subject as a richer experience as compared to a superposition state forming in the lower N-dimensional Hilbert space describing the isolated brain of the subject."

Talking to New Scientist, Neven elaborated on how that would work.

"Let’s say we have 'N' qubits in our brain and 'M' qubits in an external quantum computer, with the letters referring to a certain number of qubits. If a person could entangle their brain with this quantum computer, they could create an expanded quantum superposition involving 'N+M' qubits," Neven said. "If we now tickle this expanded superposition to make it collapse, then this should be reported by the person participating in this experiment as a richer experience. That’s because in their normal conscious experience, they typically need 'N' bits to describe the experience, but now they need 'N+M' bits to describe it."

"I call this the 'expansion protocol', as it would allow us to expand consciousness in space, time and complexity."

According to Neven, reports of richer experiences in these circumstances would offer evidence that consciousness is a quantum phenomenon. While a neat idea, there the test would rely on being able to couple activity in somebody's brain to a quantum computer, which would be an invasive procedure and is not going to happen any time soon.

As well as this, there are many other ideas on consciousness with promise too, many of which don't rely on such invasive procedures. As the team notes, research into inert gases such as xenon and their effect on consciousness may be more fruitful in the meantime.

The study is published in Entropy.

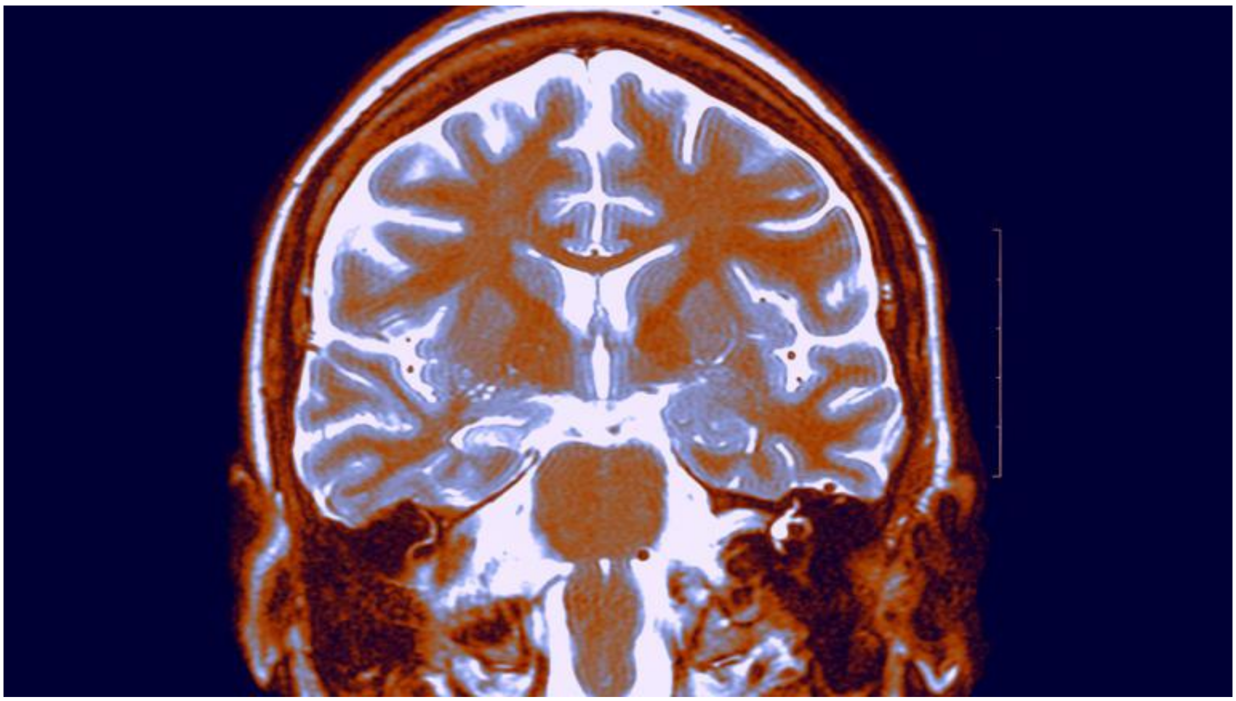
15 times the brain blew our minds in 2024

Arguably the most complex organ in the body, the brain is an elegant mess of cells, chemicals and electrical impulses that orchestrates our thoughts, behaviors and unconscious bodily functions.

This year, Live Science covered a slew of fascinating studies about the brain, each of which revealed new insights about how the organ ticks while also raising new questions.

Related: Master regulator of inflammation found — and it's in the brain stem

The male hormone cycle and the brain



((Image credit: By BSIP/UIG Via Getty Images))

Although not often discussed, the male hormone cycle is quite striking. Steroid hormones in the male body — including testosterone, cortisol and estradiol — decrease about 70% throughout the day and then reset overnight. This year, a brain-scan study revealed that the brain loses and regains volume in time with this daily cycle. At this point, though, it's unclear whether the hormones themselves drive the brain changes or how this cycle affects male brain function.

Your brain on cinema

((Image credit: Klaus Vedfelt via Getty Images))

Many people throw on a movie when they want to "turn off their brain" for a bit. But a recent study found that, actually, 24 different brain networks light up as you watch different types of films. By tying brain activity patterns to what was happening in a given scene, the scientists behind the study were able to construct the most accurate functional brain map to date.

Transformation of babies' brains after birth

((Image credit: Image taken by Mayte Torres via Getty Images))

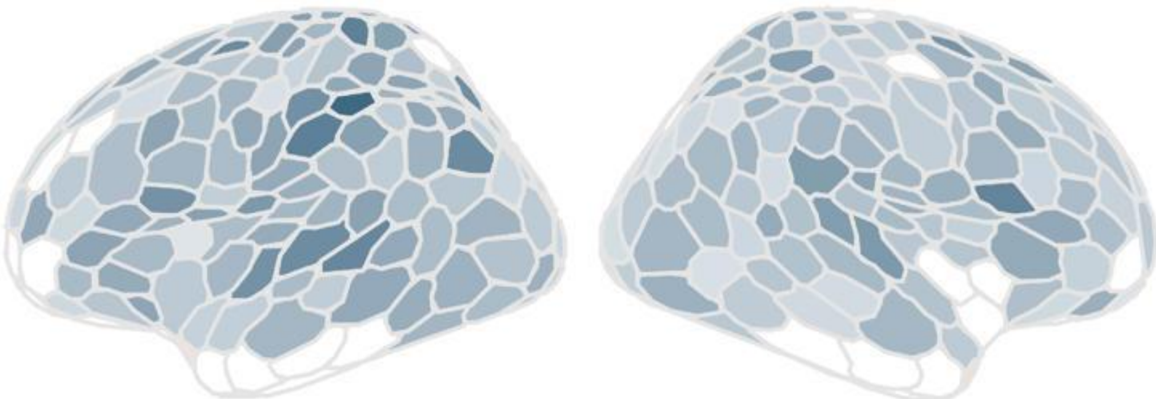
A groundbreaking study in fetuses and newborns highlights how the activity of certain parts of the brain suddenly shift after birth. There is a huge uptick in activity in the subcortical network, which acts like a relay hub for information, and the sensorimotor network, which is responsible for processing external stimuli and coordinating movements. The researchers now want to study the same brain networks in preterm babies, to see if there's a notable difference from full-term babies.

The drive to eat


((Image credit: LukaTDB via Getty Images))

A simple circuit made of just three types of neurons may underlie our drive to eat, a study found. The brain cells work together to detect hunger-signaling hormones and ultimately set off cells that control the muscles for chewing. By messing with this circuit in lab mice, the researchers prompted the rodents to eat 12 times more food than usual and make chewing movements even when they had no food.

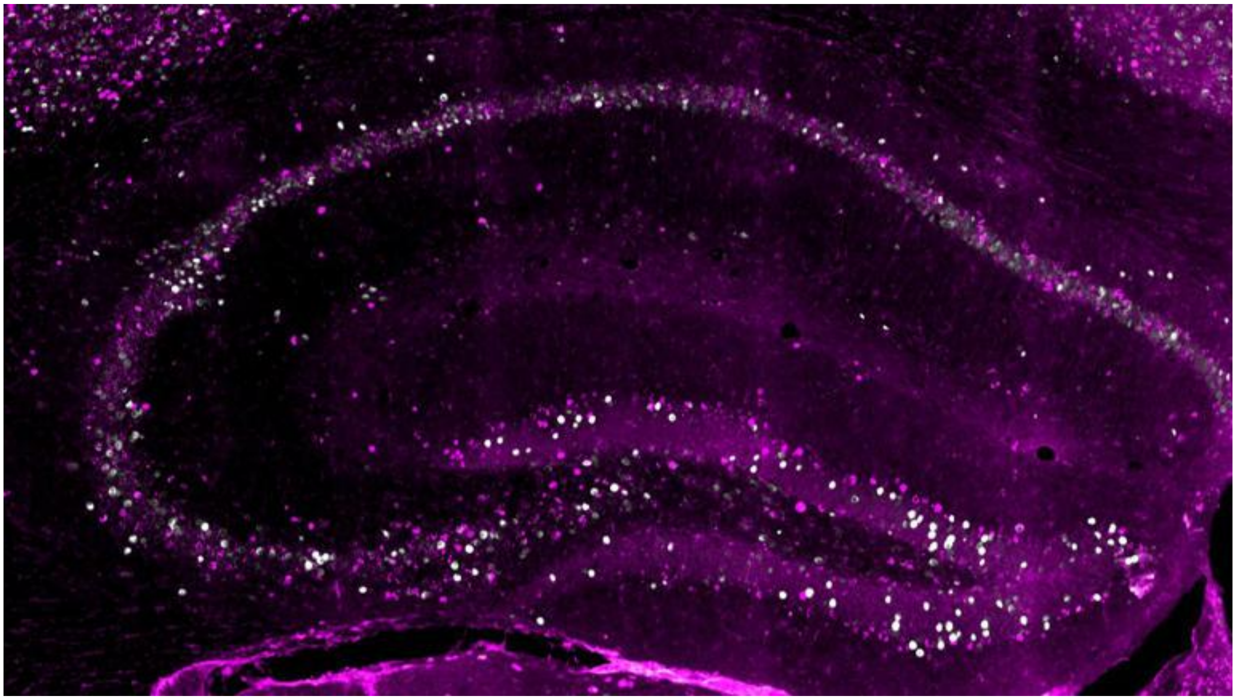
Pregnancy's "permanent etchings" on the brain



((Image credit: Laura Pritschet))

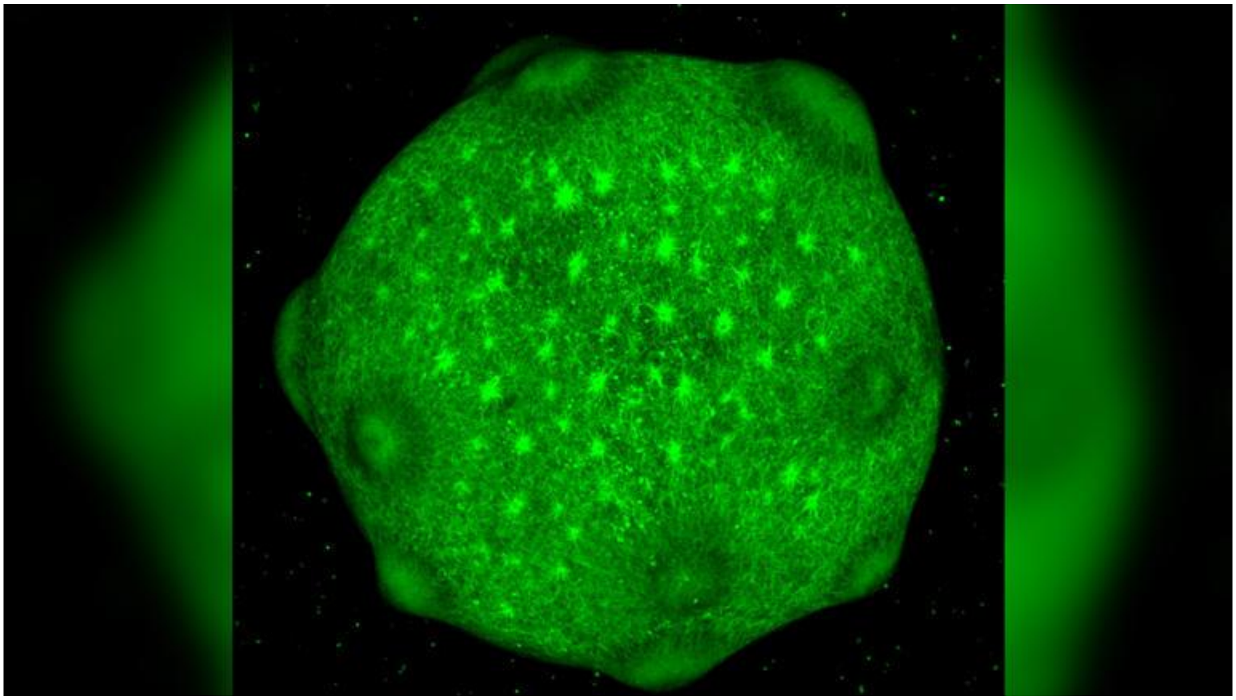
Throughout pregnancy, about 80% of the brain's gray matter loses volume. Some of this lost volume reappears postpartum, but much of the missing matter stays lost. A similar loss of gray-matter volume is seen during puberty, a time when the brain is "pruning" away excess connections to boost its efficiency. It may be that this change in pregnancy reflects a similar fine-tuning of brain circuitry, scientists say.

Three copies of each memory


((Image credit: Biozentrum, University of Basel))

A mouse study suggests that the brain may store at least three copies of every memory it encodes. These copies differ in when they're created, how long they last and how modifiable they are over time. Understanding when and how these different copies form could help scientists address conditions that affect memory encoding and retrieval, such as PTSD and dementia.

Conscious lab-grown brains?

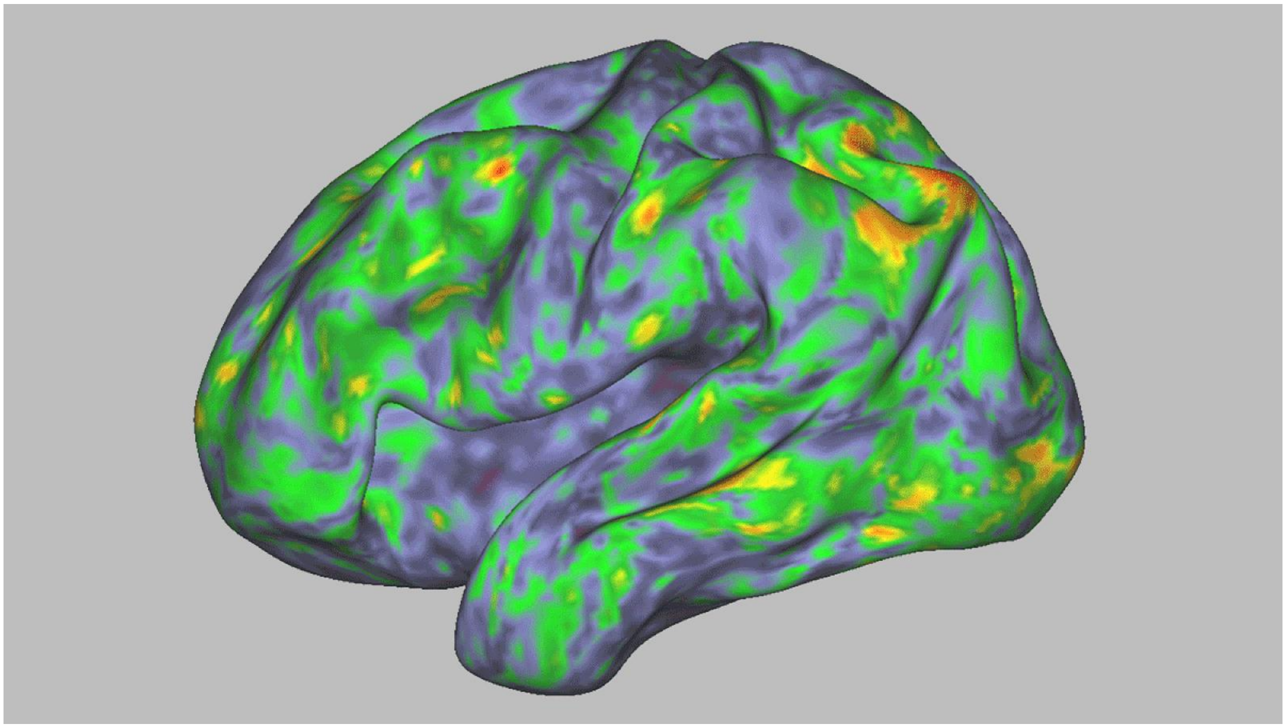


((Image credit: Pasca Lab, Stanford University))

Could brain organoids — miniature models of the brain grown in the lab — ever gain consciousness? Live Science posed the question to neuroscientist Kenneth Kosik, who assured us that it's not likely to happen anytime soon. However, there is still ongoing debate about what qualifies as "consciousness," he noted. And there are big questions about what could happen if human minibrains were transplanted into animals or hooked up to technologies to create so-called cyborgs.

Related: Optical illusion reveals key brain rule that governs consciousness

'Shrooms that "dissolve" sense of self



((Image credit: Sara Moser/Washington University))

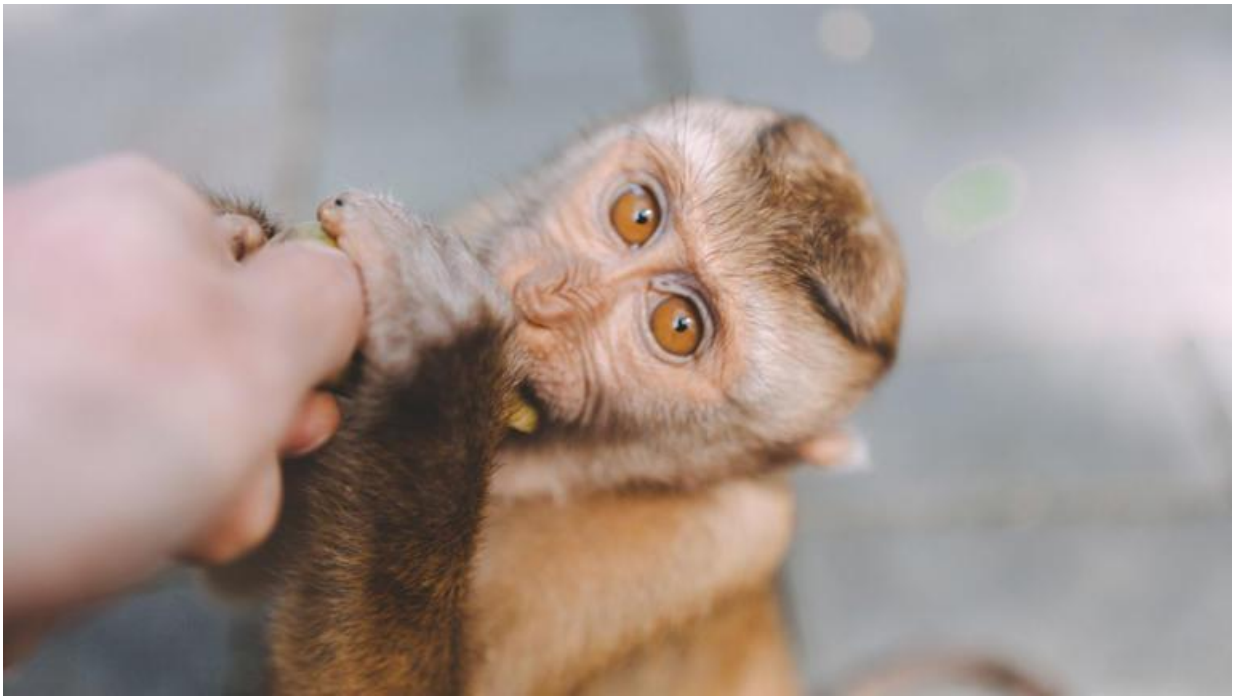
Psilocybin, the active ingredient in magic mushrooms, may cause the brain network responsible for maintaining a person's sense of self to fall out of sync. Called the default mode network, this brain circuit is most active when people are self-reflecting and not engaged in any particular task. On high-dose psilocybin, the network's activity temporarily changed, with some of the effects lasting a few weeks.

Origin of psychosis


((Image credit: Monty Rakusen via Getty Images))

A brain-scan study could help confirm a theory about why people experience psychosis, or sudden breaks from reality. Using artificial intelligence (AI) to analyze the scans, scientists found overlapping "signatures" in the brains of people with psychosis. These signatures were either tied to a genetic condition or were from an unknown cause. The findings back a theory that, in psychosis, brain networks in charge of directing a person's attention malfunction, which leads to hallucinations and delusions.

"Universal" brain pattern in primates



((Image credit: Georgi Fadejev via Getty Images))

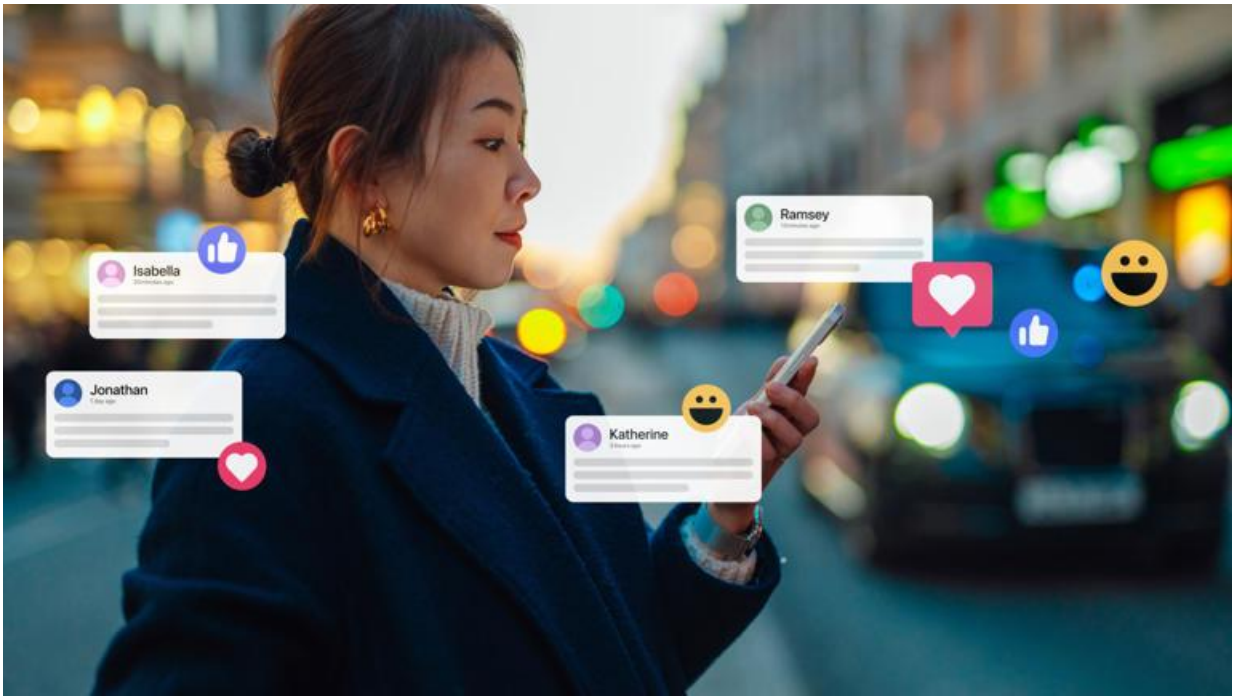
Multiple primate species, including humans, share a common brain-wave pattern in the cerebral cortex, the outer surface of the brain. This universal pattern is marked by high-frequency brain waves in the upper layers of the cortex and slower waves in its deeper layers. Scientists think the interplay of fast and slow waves dictates which information remains in conscious thought at any given moment.

Flow state

((Image credit: Image provided by John Kounios, PhD, of Drexel University))

Scientists revealed the key parts of the brain that switch on when someone is in a flow state — or "in the zone." The study involved scanning the brains of musicians with varying degrees of experience. It pitted two competing theories of "flow" against each other, and one theory came out on top.

Reading in a "blink"



((Image credit: Getty Images))

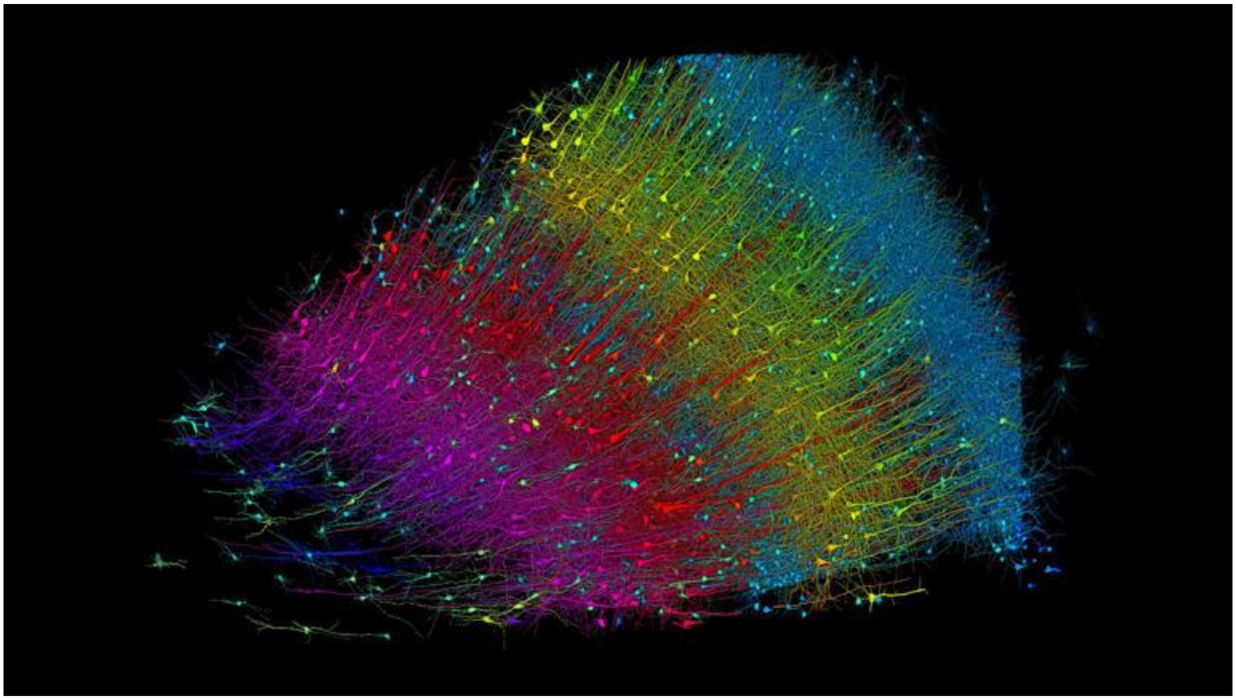
A study found that the human brain can discern the basic structures of written language in the time it takes to blink. That suggests the brain can process written phrases about as quickly as it does visual scenes of the world around us. The study's subjects seemed to process phrases that included subjects, verbs and objects faster than they did lists of nouns. They were also quick to process when the meaning of a phrase didn't quite make sense. The findings suggest the brain isn't only detecting that words are present but also starting to parse meaning right away.

Big brains from gut bugs

((Image credit: Andriy Onufriyenko via Getty Images))

A mouse study suggests that humans' remarkably big brains may have evolved partly thanks to the unique microbes in our guts. The study researchers transplanted microbes from the guts of humans and nonhuman primates into mice. The microbes from humans and big-brained primates converted food into energy for the brain more efficiently compared with the microbes from small-brained monkeys. The findings suggest that the big-brain microbes convert food into energy for the brain more efficiently, thus helping fuel the organ's growth.

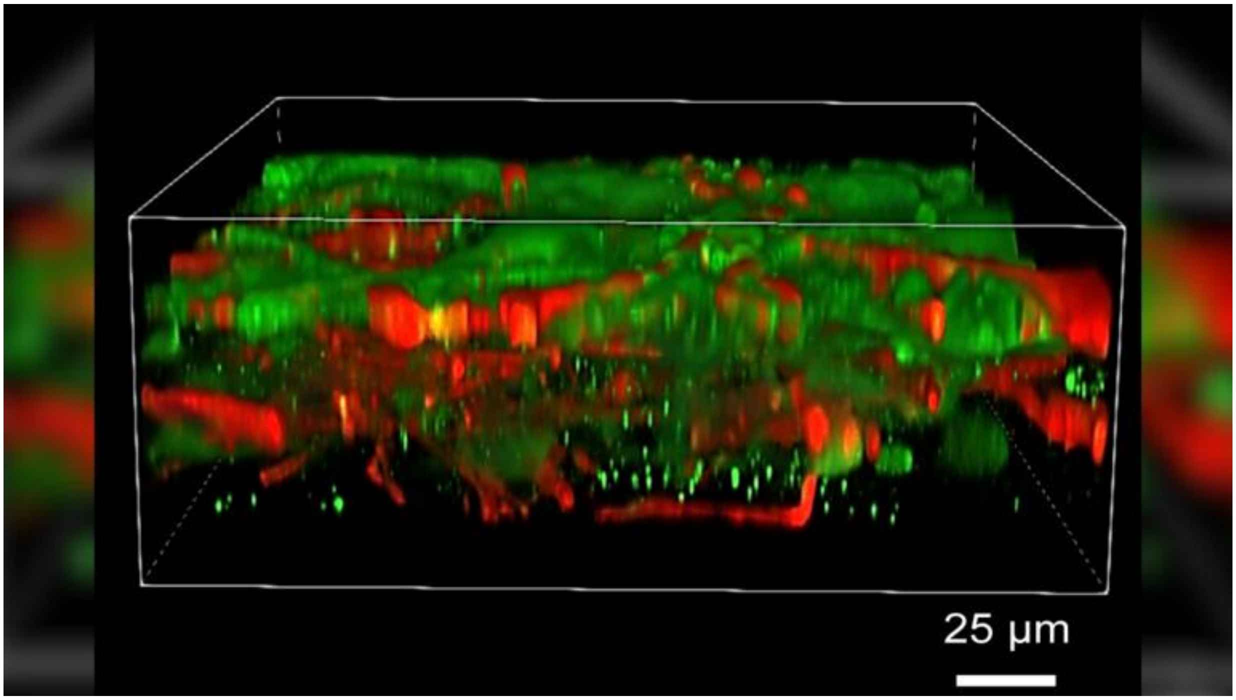
Stunning new brain map



(Image credit: Google Research & Lichtman Lab (Harvard University). Renderings by D. Berger (Harvard University))

Researchers from Harvard and Google unveiled a striking map of a small sliver of the human brain. It contains roughly 57,000 neurons, 9 inches (23 centimeters) of blood vessels and 150 million synapses (the connection points between neurons). The map highlighted unique and unexpected features of the brain, including mysterious "whorls," or knots, in the outgoing wires of some neurons.

3D-printed brain tissue that actually works



((Image credit: Cell Stem Cell))

In a first, scientists 3D printed functional human brain tissue. The printer itself used stem cells instead of ink, and the team then used a concoction of chemicals to spur those cells to transform into brain cells. The resulting cells could communicate and link up in networks, similar to cells in an actual brain.

What's the Difference Between Your Left Brain and Right Brain?

Medically reviewed by Dakari Quimby, PhDMedically reviewed by Dakari Quimby, PhD

Have you ever heard people refer to themselves as "left-brained" or "right-brained?" It's a common belief that people with a left brain are more analytical and logical, while people who favor their right brain tend to be more creative and intuitive. While everyone has certain personality traits influenced by the brain, the theory that people favor one side of their brain is a myth. Regardless of your unique or dominant traits, both sides of your brain are necessary for your overall well-being.

Characteristics and Functions of Each Side

People traditionally think of the left brain's function as being focused on logic and reason. People who consider themselves left-brained often believe their ability to be logical and objective is related to their left brain being more active than their right. The left hemisphere is responsible for processing language and numbers and is active during critical thinking and reasoning.

The right side of the brain, however, is responsible for the senses, like vision and hearing, memory, and cognition (thinking). The right brain may also be more active during creative tasks, which is why people who are naturally more artistic consider themselves right-brained.

In reality, the left and right sides of the brain work together. Consider these examples of language and mathematical analysis.

While the left brain specializes in language, the right brain is involved too. The left side of the brain picks up on the sounds of words, and the right side tunes into the emotional features of words and language. This means that both sides of your brain are active and communicating when you process language or talk with another person.

Most people also think the left brain is responsible for solving math equations. While this is true, the right brain helps with spatial awareness and understanding the value of numbers, making analysis easier to process.

Is One Side More Dominant?

The brain acts as the command center for the body, and billions of neurons connect both sides. Both sides of the brain actually work together during most tasks and are connected by brain fibers. There is no scientific evidence that one side of the brain is more dominant. Rather, each hemisphere has unique abilities.

Despite this finding, many people still believe one side of their brain is more dominant. One study estimated that up to 68% of adults in the United States believe that people favor one side of their brain or that one side is more dominant. So, where does this myth come from?

The theory originated from the work of psychologist Roger W. Sperry, who studied people who had their corpus callosum surgically cut. The corpus callosum is the brain structure that connects the two hemispheres of the brain. The people being studied had this structure surgically cut as part of their treatment for uncontrolled epilepsy, which causes seizures.

Sperry determined that each side of the brain had specific functions based on the changes experienced by the study participants. However, the idea that one side of the brain is dominant and entirely responsible for one’s personality and strengths has never been proven.

In general, the left hemisphere controls much of the brain’s language and logic skills, while the right hemisphere controls spatial awareness and visual understanding. Even though one side of the brain may be more active during certain tasks or functions, they are both necessary.

Tips for Boosting Brain Health

Because both sides of your brain are so important to your well-being, it's essential to promote overall brain health and stay sharp, especially as you age. Both sides of your brain may benefit from the following lifestyle approaches:

- **Exercise daily:** Physical activity has a protective effect on the brain and may boost alertness
- **Eat nutritious foods:** Focus on fresh fruits and vegetables, lean proteins, healthy fats, and whole grains to sustain brain power and mental health
- **Rest well:** Aim to get seven to eight hours of sleep each night to maintain optimal brain function
- **Stay connected:** Social support and relationships are essential for brain health, so it's important to maintain healthy relationships and lean on your network
- **Give your brain a workout:** Challenging your brain through reading, word games, math problems, or puzzles keeps your brain stimulated and functioning
- **Avoid smoking:** Quit or avoid smoking tobacco, as excess use can increase your risk of neurological conditions, among other chronic illnesses

A Quick Review

Several pathways connect the left and right sides (hemispheres) of the brain and work together. In the past, people believed that one side of the brain was more dominant than the other. Left-brained people were considered more objective and logical, while right-brained people were seen as creative, artistic, and intuitive. However, no scientific evidence supports the belief that one side is more important or dominant, as both sides are necessary for most tasks and overall well-being.

Gene expression study reveals human brain cell types becoming more specialized, not just more numerous

Differences in gene expression, not just their presence, seem to drive the remarkable specialization found in the human brain. Credit: Matt Perko

Our brain is arguably the organ that most distinguishes humans from other primates. Its exceptional size, complexity and capabilities far exceed those of any other species on Earth. Yet humans share upwards of 95% of our genome with chimpanzees, our closest living relatives.

UC Santa Barbara professor Soojin Yi, in the Department of Ecology, Evolution, and Marine Biology, her doctoral student Dennis Joshy, and collaborator Gabriel Santepere, at Hospital del Mar Medical Research Institute in Barcelona, recently aimed to determine how genes in different types of brain cells have evolved compared to those those in chimpanzees. They found that while our genes code for almost all the same proteins as other apes, many of our genes are much more productive than those of other primates.

Their results, published in the Proceedings of the National Academy of Sciences, highlight the role of gene expression in the evolution and function of the human brain.

Interpreting nature's blueprints

Each gene tells a cell to make a specific molecule, but this isn't performed by the DNA itself. Instead, the information is relayed to cellular machinery by a molecule called messenger RNA. Researchers measure gene expression by observing the amount of mRNA a specific gene produces.

As scientists began to understand the role of the genome as life's blueprint, they thought that perhaps the human genome could explain our unique traits. But a thorough comparison with chimpanzees in 2005 revealed we share 99% percent of our genes (though scientists have since revised this number). This confirmed earlier studies based on small numbers of genes that had suggested there was only a small difference between the human and chimpanzee genomes.

Now biologists suspect that gene expression may underlie these differences. Consider a monarch butterfly. The adult has the same genome as when it was a caterpillar. The incredible differences between the two life stages all come down to gene expression. Turning on and off different genes, or having them code for more or less mRNA, can drastically alter an organism's traits.

Getting a clearer picture

Previous research has found differences in gene expression between humans and chimpanzees, and that human cells tend to have higher gene expression, but the picture was blurry. The brain is made up of many varieties of cells. Traditionally, scientists organized brain cells into two major types: neurons and glial cells. Neurons carry electrochemical signals, a bit like the copper wiring in a building. Glial cells perform most of the other functions, such as insulating the wires, supporting the structure and clearing out debris.

Until recently, scientists could only study bulk tissue samples composed of many different types of cells. But within the past decade, it's become possible to assay cell nuclei one at a time. This allows researchers to distinguish between cell types, and often even subtypes.

Yi, Joshy and Santepere used datasets generated from a device with a very narrow channel to separate each nucleus into its own chamber in an array. Then they grouped the cells by type before performing statistical analysis.

The team measured gene expression by observing the amount of mRNA a specific gene produced in humans, chimpanzees and macaques. An upregulated gene produces more mRNA in a given species compared to the others, while a downregulated gene produces less. Comparing chimpanzees and humans to macaques enabled the researchers to tell when differences between the two apes The authors recorded differences in the expression of about 5–10% of the 25,000 genes in the study. In general, human cells had more upregulated genes compared to chimpanzees. This is a much larger percentage than researchers found when they couldn't break down the analysis by cell type. The percentage grew to 12–15% when the authors began to consider cell subtypes.

"Now we can see that individual cell types have their own evolutionary path, becoming really specialized," Yi said.

Not just neurons

The intricacy of our neural pathways is unrivaled in the animal kingdom. However, Yi suspects that our unique intellect isn't a result of this on its own. Human glial cells account for more than half of the cells in our brains, a much larger percentage than in even chimpanzees.

Among glial cells, oligodendrocytes showed the greatest differences in gene expression. These cells create the insulation that coats neurons, enabling their electrical signals to travel much more quickly and efficiently. In a collaborative study published the previous year, the team observed that humans have a higher ratio of precursor versus mature oligodendrocytes compared with chimpanzees. Yi suspects this may relate to the amazing neural plasticity and slow development of human brains.

"The increased complexity of our neural network probably didn't evolve alone," Yi said. "It could not have come into existence unless all these other cell types had also evolved and enabled the expansion of the neuron diversity, the number of neurons and the complexity of the networks."

This study only considered cells from a few regions of the brain. However, the cells in one area of the brain may differ from their counterparts in other areas. Yi plans to study the mechanisms behind differences in gene expression and how genes map to different traits.

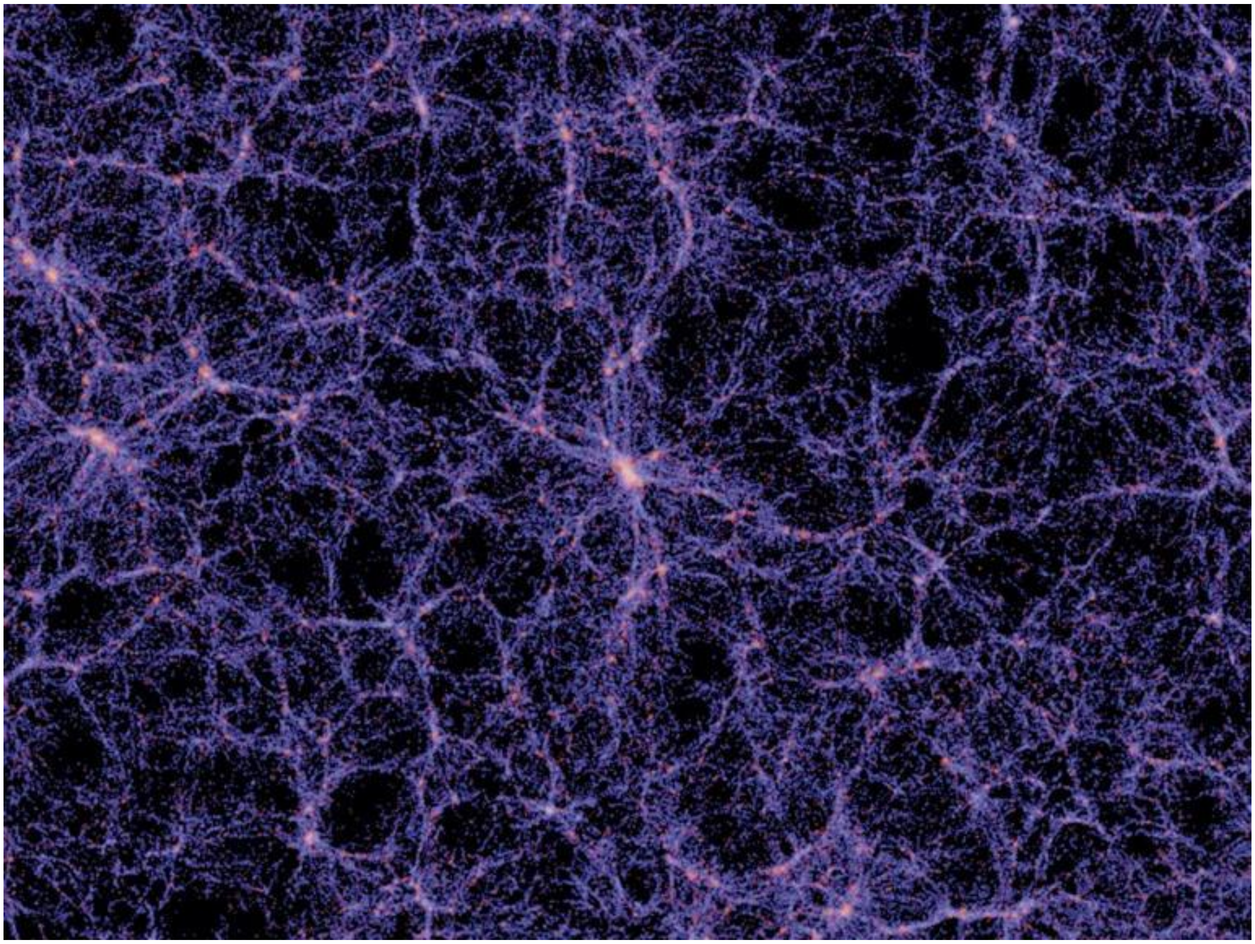
She also plans to trace differential gene expression even earlier in our evolutionary history by incorporating baselines from even more distantly related animals. She's also interested in studying genomic differences between us and other archaic humans, like Neanderthals and Denisovans.

Evolution is about more than merely changing genes. "Differential gene expression is really how human brains evolved," Yi said.

More information: Dennis Joshy et al, Accelerated cell-type-specific regulatory evolution of the human brain, Proceedings of the National Academy of Sciences (2024). DOI: 10.1073/pnas.2411918121

Provided by University of California - Santa Barbara

Meet The Cosmic Web – The Largest Structure In The Universe



The cosmic web appears in simulations of the universe using the standard model of cosmology, such as this one. - Image credit: V.Springel, Max-Planck Institut für Astrophysik, Garching bei München© IFL Science

When we look for “the biggest” in the universe, it is important to specify our definition of the object of study. Is it something indivisible and with a neat boundary, like a black hole? Or do we prefer fuzzy edges so we can talk about galaxies? But if we are looking for the BOAT, the biggest of all time (and space), there is only one answer: the cosmic web.

This is how the universe is organized. Galaxies can be found quite isolated, in groups, or in clusters. And no matter their location, they are likely to be involved in a supercluster of galaxies. The superclusters are connected by filaments, sheets, and walls. Between these, there are enormous voids. The “web” in the cosmic web showcases the interconnection between the structures, but the distribution can be visualized as foam: galaxies are in the soapy water, the bubbles are the void.

Larger than you can picture

The structure of the cosmic web itself is not easy to see. The connection between clusters and superclusters of galaxies is made by tenuous gas. Understanding of the large-scale structure of the universe came first from discovering the distribution of galaxies at large scales, and it is a relatively recent discovery. It was only in the 1980s that this picture began to form, and it is much more recently that we have developed instruments sensitive enough to study the filaments directly, or to see several filaments of the cosmic web at once for the first time.

The gas is not the only component of the filaments. The filaments are made of dark matter, a hypothetical form of matter that only interacts with the rest of the universe through gravity. It's called dark but it is actually invisible, since it doesn't interact with light. And while we do not have direct evidence of its existence, it is actually the cosmic web that gives us some important hints.

Simulations of the universe using dark matter and dark energy – a hypothetical form of energy responsible for the accelerated expansion of the universe – create a picture of the universe that is remarkably similar to observations. By using the standard model of cosmology, where dark matter and dark energy are as fundamental as regular matter, light, and gravity, you end up with a cosmic web like that we can measure out there in the universe.

And while we can't see dark matter filaments, researchers are getting pretty clever in finding evidence of their existence. For example, a team used the distortion of light created by massive objects as an indirect way to "see" this dark matter.

Is there an end to greatness?

The cosmic web has its rules. You are not going to find specific structures within it larger than a certain value. If we zoom out from galactic scales, we will find the lumps that make galaxy clusters, a few million light-years across. We zoom out again, and we finds the filaments, the walls, arcs, and bubbles that make up the cosmic web. But what happens if we zoom out again. Well, we reach the end of greatness.

This extremely poetic term summarizes a size above which the universe doesn't look lumpy any more and that is at about 300 million light-years. If like some looming deity we could project ourselves to see the universe at that scale, the cosmos would appear to be uniform and isotropic. That means that it would be the same at every point and look the same in every direction. At that scale, voids and filaments don't matter. For a culinary metaphor, it's like the crumb of a cake. You want it delicious and consistent at the level your tastebuds appreciate, but under a microscope, it would not look that regular.

Still, the standard model doesn't preclude structures extending further than 300 million light-years. The theory suggests that up to about 1.2 billion light-years things can exist without being a problem. So imagine the surprise of astronomers finding a few larger structures, namely the Giant Arc and the Big Ring: the first a crescent of galaxies extending for 3.3 billion light-years, and the second a circle of galaxies with a radius of 1.3 billion light-years.

An interesting challenge to square, whether a matter of theory or observations. Still, the universe extends for tens of billions of light-years in every direction, and so does the cosmic web, even if there might be the occasional clump we can't quite explain yet.

Study hints at ways to generate new neurons in old brains

Most neurons in the human brain last a lifetime, and for good reason. Intricate, long-term information is preserved in the complex structural relationships between their synapses. To lose the neurons would be to lose that critical information—that is, to forget.

Intriguingly, some new neurons are still produced in the adult brain by a population of cells called neural stem cells. As brains age, however, they become less and less adept at making these new neurons, a trend that can have devastating neurological consequences, not just for memory, but also for degenerative brain diseases such as Alzheimer's and Parkinson's and for recovery from stroke or other brain injury.

A new Stanford Medicine study, published Oct. 2 in Nature, sheds hopeful new light on how and why neural stem cells, the cells behind the generation of new neurons in the adult brain, become less active as brains age.

The research also suggests some intriguing next steps in addressing old neural stem cell passivity—or even stimulating neurogenesis, the production of new neurons, in younger brains in need of repair—by targeting newly identified pathways that could reactivate the stem cells.

Anne Brunet, Ph.D., professor of genetics, and her team used CRISPR platforms, molecular tools that allow scientists to precisely edit the genetic code of living cells, to conduct a genome-wide search for genes that, when knocked out, increase the activation of neural stem cells in cultured samples from old mice, but not from young ones.

"We first found 300 genes that had this ability— which is a lot," emphasized Brunet, the Michele and Timothy Barakett Endowed Professor. After narrowing the candidates down to 10, "one in particular caught our attention," Brunet said. "It was the gene for the glucose transporter known as the GLUT4 protein, suggesting that elevated glucose levels in and around old neural stem cells could be keeping those cells inactive."

Dynamic brains

There are parts of the brain, such as the hippocampus and the olfactory bulb, where many neurons have shorter lives, where they regularly expire and may be replaced by new ones, said Tyson Ruetz, Ph.D., a formal post-doctoral scholar in Brunet's lab and the lead author of the Nature paper.

"In these more dynamic parts of the brain, at least in young and healthy brains," he said, "new neurons are constantly being born and the more transient neurons are replaced by new ones."

Ruetz, now the scientific advisor and co-founder of ReneuBio, developed a way to test the newly identified genetic pathways in vivo, "where the results really count," Brunet said.

Ruetz took advantage of the distance between the part of the brain where the neural stem cells are activated, the subventricular zone, and the place the new cells proliferate and migrate to, the olfactory bulb, which is many millimeters away in a mouse brain.

By knocking out the glucose transporter genes in the former, waiting several weeks, then counting the number of new neurons in the olfactory bulb, the team demonstrated that knocking out the gene indeed had an activating and proliferative effect on neural stem cells, leading to a significant increase in new neuron production in living mice.

With the top intervention, they observed over two-fold increase in newborn neurons in old mice.

"It's allowing us to observe three key functions of the neural stem cells," Ruetz said. "First, we can tell they are proliferating. Second, we can see that they're migrating to the olfactory bulb, where they're supposed to be. And third, we can see they are forming new neurons in that site."

The same technique could also be applied to studies of brain damage, Ruetz said. "Neural stem cells in the subventricular zone are also in the business of repairing brain tissue damage from stroke or traumatic brain injury."

'A hopeful finding'

The glucose transporter connection "is a hopeful finding," Brunet said. For one, it suggests not only the possibility of designing pharmaceutical or genetic therapies to turn on new neuron growth in old or injured brains, but also the possibility of developing simpler behavioral interventions, such as a low carbohydrate diet that might adjust the amount of glucose taken up by old neural stem cells.

The researchers found other provocative pathways worthy of follow-up studies. Genes relating to primary cilia, parts of some brain cells that play a critical role in sensing and processing signals such as growth factors and neurotransmitters, also are associated with neural stem cell activation.

This finding reassured the team that their methodology was effective, partly because unrelated previous work had already discovered associations between cilia organization and neural stem cell function. It is also exciting because the association with the new leads about glucose transmission could point toward alternative avenues of treatment that might engage both pathways, Brunet said.

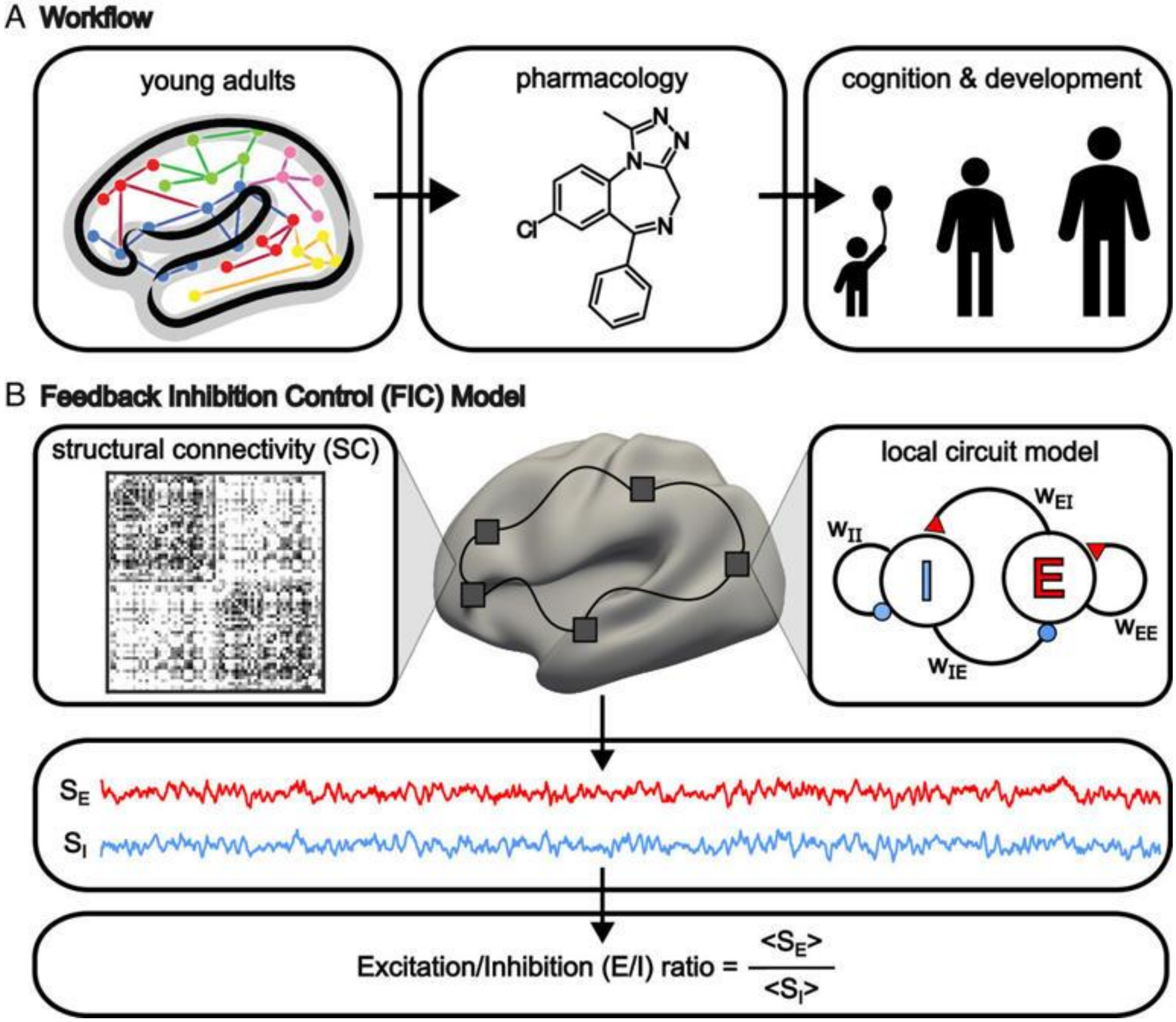
"There might be interesting crosstalk between the primary cilia—and their ability to influence stem cell quiescence, metabolism and function—and what we found in terms of glucose metabolism," she said.

"The next step," Brunet continued, "is to look more closely at what glucose restriction, as opposed to knocking out genes for glucose transport, does in living animals."

More information: Anne Brunet, CRISPR–Cas9 screens reveal regulators of ageing in neural stem cells, Nature (2024). DOI: 10.1038/s41586-024-07972-2. www.nature.com/articles/s41586-024-07972-2

Provided by Stanford University Medical Center

Neural balance in the brain is associated with brain maturity and better cognitive ability, study finds



Workflow and schematic of the pFIC model. Credit: Proceedings of the National Academy of Sciences (2024). DOI: 10.1073/pnas.2318641121© Provided by Medical Xpress

In a world where external and internal stimuli can throw our entire body system off balance, how does our brain prevent itself from becoming overly stimulated?

The answer lies in our brain's ability to maintain the balance of neural excitation (E) and inhibition (I), known as the E/I ratio. By regulating the E/I ratio, the brain prevents over-stimulation and under-stimulation.

The E/I ratio of children decreases with healthy development. Children with a lower E/I ratio were observed to have better performance than their peers in cognitive tests such as memory and intelligence, according to studies by researchers from the Centre for Sleep and Cognition at the Yong Loo Lin School of Medicine (NUS Medicine).

With the aim of drawing meaningful connections between E/I ratio and brain maturation, the study team, led by fourth-year Ph.D. student Zhang Shaoshi, Associate Professor Thomas Yeo from the Centre for Sleep and Cognition at NUS Medicine, Assistant Professor Bart Larsen from the University of Minnesota and Associate Professor Theodore Satterthwaite from the University of Pennsylvania, looked at how E/I ratio changes in youths, by studying the MRI brain scans of 885 children, adolescents and young adults from the United States of America and 154 children from Singapore.

E/I ratio is an aspect that is continually changing and developing throughout childhood and adolescence. The Singaporean data cohort were obtained from GUSTO, Singapore's largest and most comprehensive birth cohort study that seeks to help the next generation become healthier.

Described as the Yin and Yang of the brain, researchers have found that too much excitation or excessive inhibition can be harmful, leading to a higher risk of developing brain disorders, such as autism, Alzheimer's disease and schizophrenia.

In less severe situations, someone with too much excitation might overthink in social situations, resulting in anxiety. Indeed, a common drug for reducing anxiety symptoms is Xanax, which increases neural inhibition, thus reducing neural excitation. In more severe scenarios, over-excitation can cause an epileptic seizure.

On the opposite end of the spectrum, too much inhibition indicates an absence of brain activity, effectively putting the person in a vegetative state. Therefore, inhibition is needed to balance excitation. Overall, a balanced E/I ratio is important for a well-functioning brain.

Despite E/I's importance for brain health, it is hard to measure its ratio in the human brain without using invasive techniques. Therefore, the team developed a technique, combining artificial intelligence and biophysical modeling to infer E/I ratios from non-invasive, non-radioactive MRI scans. The team demonstrated the validity of their estimated E/I ratios through an experiment, during which participants ingested anti-anxiety medication (Xanax) or a placebo.

The team's hypothesis is that once Xanax is ingested, inhibition will increase, so the overall E/I ratio decreases. To test this hypothesis, the research team scanned healthy individuals on two separate occasions. A participant is given Xanax before one MRI session and placebo in another MRI session. For some participants, Xanax might be administered in the first session, while for others Xanax might be administered in the second session.

All parties involved in this experiment were not privy to whether an MRI session involved the placebo or the anti-anxiety drug. The team found that estimated E/I ratio markers were indeed lower after participants had ingested Xanax, compared with the placebo, and thus validating their technique.

The study team then proceeded to use MRI brain scans to study brain development in a large sample of more than 1000 children, adolescents and young adults from Singapore and the United States of America. They discover that E/I ratios decrease with healthy development.

Next, to establish the link between E/I ratios and cognitive function, the team divided participants, ranging from age 7 to 23, into high and low-performance groups based on their scores on certain cognitive tests. They found that the high performing groups had lower E/I ratios than their peers of the same age, suggesting that cognitive abilities improve as the E/I ratio matures during development.

Beyond their study on neurodevelopment, the team is keen on applying their approach to gain mechanistic insights into various brain disorders, by studying how the E/I ratio differs between healthy participants and patients battling mental disorders. The team also aims to study how the E/I ratio changes as people age, to gain insights into neurodegenerative disorders, such as Alzheimer's Disease.

Assoc Prof Yeo, who is also from the NUS College of Design and Engineering and Principal Investigator of this study, adds, "Our findings enhance our understanding of brain development and highlight potential avenues for understanding the emergence of psychopathology in youth.

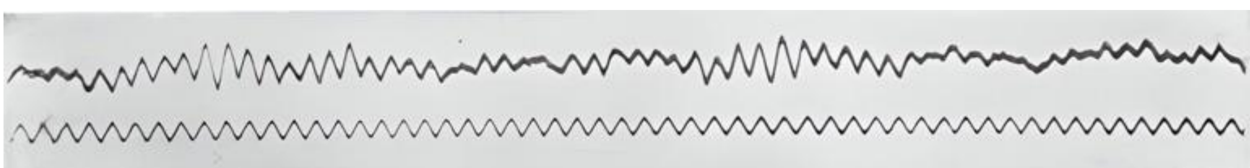
"Hopefully, these findings will lead us to figure out which brain circuits get over-excited or over-inhibited easily, or pinpoint certain abnormal brain regions specific to an individual patient. This could shed more light on how medication or brain stimulation can be customized according to individuals, that would shape the course of treatment of brain disorders in the long run."

This study is published in Proceedings of the National Academy of Sciences titled "In vivo whole-cortex marker of excitation-inhibition ratio indexes cortical maturation and cognitive ability in youth."

More information: Shaoshi Zhang et al, In vivo whole-cortex marker of excitation-inhibition ratio indexes cortical maturation and cognitive ability in youth, Proceedings of the National Academy of Sciences (2024). DOI: 10.1073/pnas.2318641121

Provided by National University of Singapore

From diagnosing brain disorders to cognitive enhancement, 100 years of EEG have transformed neuroscience



Two EEG traces, the top more irregular in rhythm than the bottom. Credit: Hans Berger/Über das Elektrenkephalogramm des Menchen. Archives für Psychiatrie. 1929; 87:527-70 via Wikimedia Commons© Provided by Medical Xpress

Electroencephalography, or EEG, was invented 100 years ago. In the years since the invention of this device to monitor brain electricity, it has had an incredible impact on how scientists study the human brain.

Since its first use, the EEG has shaped researchers' understanding of cognition, from perception to memory. It has also been important for diagnosing and guiding treatment of multiple brain disorders, including epilepsy.

I am a cognitive neuroscientist who uses EEG to study how people remember events from their past. The EEG's 100-year anniversary is an opportunity to reflect on this discovery's significance in neuroscience and medicine.

Discovery of EEG

On July 6, 1924, psychiatrist Hans Berger performed the first EEG recording on a human, a 17-year-old boy undergoing neurosurgery. At the time, Berger and other researchers were performing electrical recordings on the brains of animals.

What set Berger apart was his obsession with finding the physical basis of what he called psychic energy, or mental effort, in people. Through a series of experiments spanning his early career, Berger measured brain volume and temperature to study changes in mental processes such as intellectual work, attention and desire.

He then turned to recording electrical activity. Though he recorded the first traces of EEG in the human brain in 1924, he did not publish the results until 1929. Those five intervening years were a tortuous phase of self-doubt about the source of the EEG signal in the brain and refining the experimental setup. Berger recorded hundreds of EEGs on multiple subjects, including his own children, with both experimental successes and setbacks.

Finally convinced of his results, he published a series of papers in the journal Archiv für Psychiatrie and had hopes of winning a Nobel Prize. Unfortunately, the research community doubted his results, and years passed before anyone else started using EEG in their own research.

Berger was eventually nominated for a Nobel Prize in 1940. But Nobels were not awarded that year in any category due to World War II and Germany's occupation of Norway.

Neural oscillations

When many neurons are active at the same time, they produce an electrical signal strong enough to spread instantaneously through the conductive tissue of the brain, skull and scalp. EEG electrodes placed on the head can record these electrical signals.

Since the discovery of EEG, researchers have shown that neural activity oscillates at specific frequencies. In his initial EEG recordings in 1924, Berger noted the predominance of oscillatory activity that cycled eight to 12 times per second, or 8 to 12 hertz, named alpha oscillations. Since the discovery of alpha rhythms, there have been many attempts to understand how and why neurons oscillate.

Neural oscillations are thought to be important for effective communication between specialized brain regions. For example, theta oscillations that cycle at 4 to 8 hertz are important for communication between brain regions involved in memory encoding and retrieval in animals and humans.

Researchers then examined whether they could alter neural oscillations and therefore affect how neurons talk to each other. Studies have shown that many behavioral and noninvasive methods can alter neural oscillations and lead to changes in cognitive performance. Engaging in specific mental activities can induce neural oscillations in the frequencies those mental activities use. For example, my team's research found that mindfulness meditation can increase theta frequency oscillations and improve memory retrieval.

Noninvasive brain stimulation methods can target frequencies of interest. For example, my team's ongoing research found that brain stimulation at theta frequency can lead to improved memory retrieval.

EEG has also led to major discoveries about how the brain processes information in many other cognitive domains, including how people perceive the world around them, how they focus their attention, how they communicate through language and how they process emotions.

Diagnosing and treating brain disorders

EEG is commonly used today to diagnose sleep disorders and epilepsy and to guide brain disorder treatments.

Scientists are using EEG to see whether memory can be improved with noninvasive brain stimulation. Although the research is still in its infancy, there have been some promising results. For example, one study found that noninvasive brain stimulation at gamma frequency—25 hertz—improved memory and neurotransmitter transmission in Alzheimer's disease.

A new type of noninvasive brain stimulation called temporal interference uses two high frequencies to cause neural activity equal to the difference between the stimulation frequencies. The high frequencies can better penetrate the brain and reach the targeted area. Researchers recently tested this method in people using 2,000 hertz and 2,005 hertz to send 5 hertz theta frequency at a key brain region for memory, the hippocampus. This led to improvements in remembering the name associated with a face.

Although these results are promising, more research is needed to understand the exact role neural oscillations play in cognition and whether altering them can lead to long-lasting cognitive enhancement.

The future of EEG

The 100-year anniversary of the EEG provides an opportunity to consider what it has taught us about brain function and what this technique can do in the future.

In a survey commissioned by the journal Nature Human Behaviour, more than 500 researchers who use EEG in their work were asked to make predictions on the future of the technique. What will be possible in the next 100 years of EEG?

Some researchers, including myself, predict that we'll use EEG to diagnose and create targeted treatments for brain disorders. Others anticipate that an affordable, wearable EEG will be widely used to enhance cognitive function at home or will be seamlessly integrated into virtual reality applications. The possibilities are vast.

Provided by The Conversation

How sound and vibration converge in the brain to enhance sensory experience

Ludwig van Beethoven began to lose his hearing at age 28 and was deaf by age 44. While the cause of his hearing loss remains a topic of scientific debate and ongoing revision, one thing is clear: Despite his hearing loss, Beethoven never ceased to compose music, likely because he was able to sense the vibrations of musical instruments and "hear" music through the sense of touch, researchers believe.

A study by Harvard Medical School researchers could help explain what enabled Beethoven, and other musicians, to develop an exquisitely refined sense of touch after losing their hearing.

The findings, based on experiments in mice and reported Dec. 18 in Cell, offer a tantalizing new clue into how and why the diminishment of one sense augments the other. They also add a surprising new twist in our understanding of how the brain and the body work in synchrony to process multiple sensations at the same time.

The research pinpoints an area in the brain called the inferior colliculus—so far studied mostly for its role in sound processing—to also be involved in processing touch signals, including mechanical vibrations detected by nerve endings on the skin.

The team's experiments reveal that high-frequency mechanical vibrations picked up by ultra-sensitive mechanoreceptors in the skin called Pacinian corpuscles are not exclusively channeled into the somatosensory cortex—the area of the brain where bodily sensations are processed. Instead, the study found, these signals are mainly routed from the body to the inferior colliculus in the midbrain.

"This is a very surprising finding that counters the canonical view of where and how tactile sensation is processed in the brain," said study senior author David Ginty, chair of the Department of Neurobiology at HMS and the Edward R. and Anne G. Lefler Professor of Neurobiology.

"We find that a region in the midbrain's inferior colliculus processes vibrations, whether it's vibrations in the form of sound waves acting on the inner ear or mechanical vibrations acting on the skin. When auditory and mechanical vibration signals converge in this brain region, they amplify the sensory experience, making it more salient."

The ability to detect vibrations enables organisms across the animal kingdom to perceive and respond to subtle changes in their environment such as sensing and avoiding threats, which is critical for survival.

For example, snakes detect the movement of both prey and predators by pressing their jaws to the ground to pick up subtle vibrations. The ability to sense vibrations is also central for the development and refinement of more complex adaptations, such as the neural rewiring of the brain that occurs after the loss of one sensation to enhance another—for example, the increasingly acute sense of hearing that develops after vision loss.

Researchers say the new findings are particularly relevant in this latter context—the neural rewiring that occurs after the loss of one sense. These insights may inform the development of prosthetics that augment tactile sensitivity in individuals with hearing loss.

"Devices that transduce sounds into tactile vibrations within the Pacinian frequency range could provide individuals with greater capacity to perceive and experience sound," said Ginty, who is also a Howard Hughes Medical Institute investigator.

"Such devices could be placed around the body and in close proximity to Pacinian neurons to enable sound-evoked mechanical vibrations of different frequencies across the hands, arms, feet, legs, and body."

Exquisitely sensitive detectors of vibrations

The findings highlight the role of Pacinian neurons as a vital component of the somatosensory system. Their unique and elaborate structure is key to their extraordinary sensitivity. It allows them to detect even the slightest of mechanical vibrations. Each Pacinian corpuscle consists of a single nerve ending at its center, surrounded by layers of supporting cells called lamellar cells.

Researchers say the new findings are particularly relevant in this latter context—the neural rewiring that occurs after the loss of one sense. These insights may inform the development of prosthetics that augment tactile sensitivity in individuals with hearing loss.

"Devices that transduce sounds into tactile vibrations within the Pacinian frequency range could provide individuals with greater capacity to perceive and experience sound," said Ginty, who is also a Howard Hughes Medical Institute investigator.

"Such devices could be placed around the body and in close proximity to Pacinian neurons to enable sound-evoked mechanical vibrations of different frequencies across the hands, arms, feet, legs, and body."

Exquisitely sensitive detectors of vibrations

The findings highlight the role of Pacinian neurons as a vital component of the somatosensory system. Their unique and elaborate structure is key to their extraordinary sensitivity. It allows them to detect even the slightest of mechanical vibrations. Each Pacinian corpuscle consists of a single nerve ending at its center, surrounded by layers of supporting cells called lamellar cells.

The onion-like layers of the lamellar cell membranes act like shock absorbers, allowing the Pacinian corpuscle to respond precisely and rapidly to high-frequency vibrations while dampening low-frequency disturbances.

"Evolution has placed these receptors in different locations across the animal kingdom to suit different environments," said study lead author Erica Huey, research fellow in the Ginty Lab.

"In humans, these receptors are located deep within the skin of the fingertips and feet, while elephants, for example, have a high concentration in their feet and trunks."

Indeed, research has shown that elephants are able to detect minute seismic vibrations through the pads of their feet and the skin of their trunk. However, until recently, scientists haven't been able to record the activity of Pacinian neurons in an awake, freely moving animal, making it challenging to get the full picture of how sensitive these neurons truly are and what stimuli trigger their activation.

Prior research led by Josef Turecek, a postdoctoral researcher in the Ginty Lab, showed that Pacinian neurons are so sensitive that they can detect mechanical vibrations as subtle as those produced by the movement of a finger across a surface, even from meters away.

The new study builds on the previous work to explore how signals from Pacinian corpuscles are transmitted and processed in the brain. The researchers delivered mechanical vibrations at varying frequencies to the limbs of mice or to the platform that they were standing on using a mechanical stimulator, while simultaneously recording the activity of neurons in brain regions involved in sensory processing.

When they compared the responses of neurons located in two distinct brain regions, the researchers found that neurons in the ventral posterolateral nucleus of the thalamus (VPL)—a relay station for sensory information before it reaches the somatosensory cortex—were more sensitive to low-frequency vibrations. In contrast, neurons in the lateral cortex of the inferior colliculus responded preferentially to high-frequency vibrations.

To explore the role of two types of mechanoreceptors in the skin—Pacinian corpuscles and Meissner corpuscles—to the differing responses of the two brain regions to high- and low-frequency vibrations, the team studied genetically modified mice that lack either the Pacinian corpuscles or the Meissner corpuscles.

In mice without Pacinian corpuscles, neurons in the inferior colliculus showed a marked reduction in their response to high-frequency vibrations, suggesting that Pacinian corpuscles play a key role in conveying high-frequency vibrations to this area.

When the researchers exposed the mice to white noise instead of mechanical vibrations, they found that neurons in the inferior colliculus also responded, suggesting that this region processes both auditory and somatosensory stimuli.

"In fact, we observed that neurons in the inferior colliculus responded more strongly to combined tactile-auditory stimulation than to either one alone," said Ginty.

This integration of sound and touch in the inferior colliculus of the midbrain, Ginty said, helps explain how we can both hear and physically feel the music at a concert, making the combined sensory experience a more profound one.

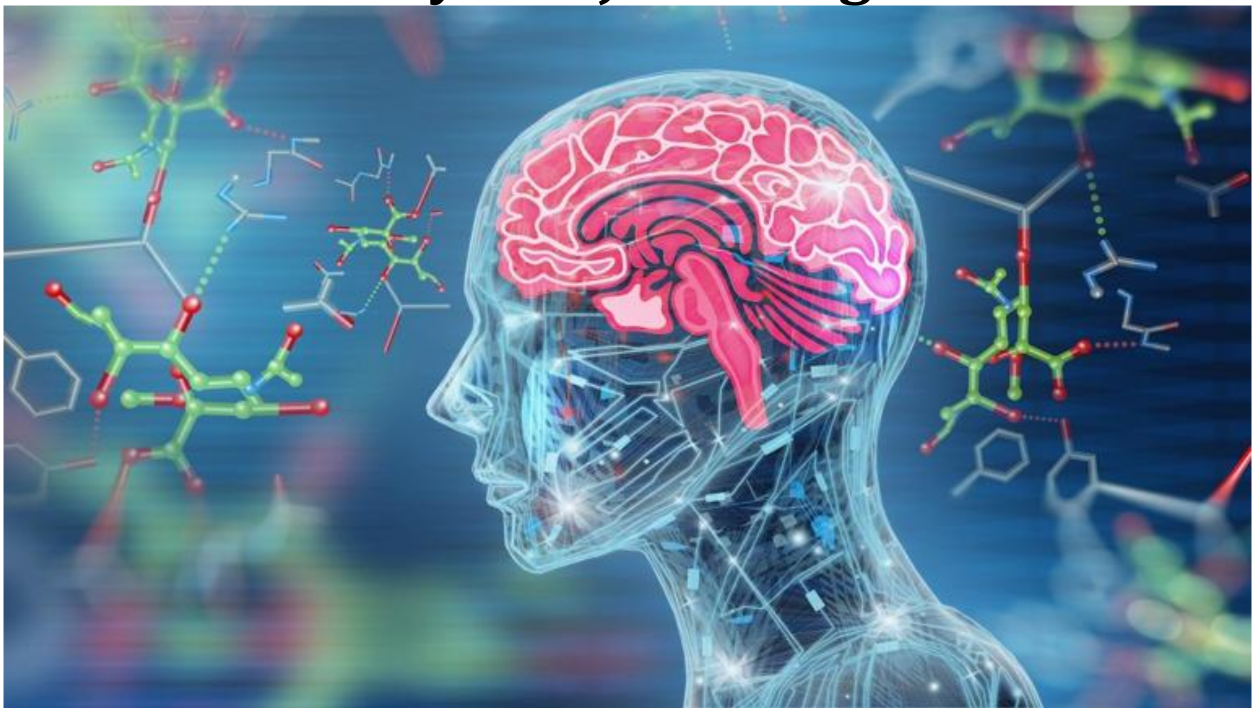
From an evolutionary perspective, this phenomenon is likely essential for survival, and learning more about it can inform treatments for conditions like autism and chronic neuropathy, where dysfunction leads to hypersensitivity to touch.

In future studies, the researchers are also excited to explore whether these findings are a clue for the brain's capacity for adaptation, specifically researching if organisms develop enhanced sensitivity to vibration sensing as a compensatory mechanism in instances of hearing loss.

More information: The auditory midbrain mediates tactile vibration sensing, Cell (2024). DOI: 10.1016/j.cell.2024.11.014. www.cell.com/cell/fulltext/S0092-8674(24)01331-X

Provided by Harvard Medical School

Aging ‘hotspot’ found in brain, researchers say: ‘Major changes’



The brain plays a big part in the aging process, and scientists think they’ve pinpointed the specific cells that control it.

In a study of mice, researchers at the Allen Institute identified certain cells that showed "major changes" with age, particularly in one specific "hotspot," according to a press release.

Mice were chosen because their brains share "many similarities" to human brains.

The researchers used RNA sequencing and brain-mapping tools to analyze more than 1.2 million brain cells from young mice (2 months old) and older mice (18 months old).

The 18-month-old mice are roughly equivalent to a "late middle-aged human," the researchers indicated.

The researchers grouped the cells into 847 different types and also identified nearly 2,500 genes that changed with aging, according to Zeng.

The researchers used RNA sequencing and brain-mapping tools to analyze more than 1.2 million brain cells from young mice (2 months old) and older mice (18 months old).

WARDING OFF DEMENTIA MEANS MORE READING, PRAYING AND LISTENING TO MUSIC: STUDY

The 18-month-old mice are roughly equivalent to a "late middle-aged human," the researchers indicated.

The researchers grouped the cells into 847 different types and also identified nearly 2,500 genes that changed with aging, according to Zeng.

Mice (not pictured) were chosen because their brains share "many similarities" to human brains, the researchers said. iStock© iStock

The cells that were linked to aging showed an increase in inflammation and a decrease in "neuronal function."

"Changes in these genes point to deteriorated neuronal structure and function in many neuronal and glial cell types, as well as increased immune response and inflammation in the brain's immune and vascular (blood vessel) cell types," Zeng detailed.

The cells that experienced the biggest changes were the ones in the hypothalamus, the part of the brain that is linked to food intake, energy balance and metabolism, the researchers noted.

This suggests that this area is a "hotspot for aging," Zeng noted, and that there could be a connection between diet, lifestyle factors, brain aging and risk of age-related cognitive disorders.

"The findings from the study reinforce the notion that maintaining a healthy lifestyle, promoting a healthy metabolic state, and reducing inflammation in the body and brain could slow down or delay the aging process and reduce the risks of aging-associated brain diseases," he said.

The hope is that this discovery could lead to new age-related therapies to improve the function of these cells and help prevent neurodegenerative diseases, according to the researchers.

"Aging is the most important risk factor for many brain diseases," Zeng noted.

"Our study provides a highly detailed genetic map for which brain cell types may be most affected by aging and suggests new gene and cell targets for developing new treatments for aging-related brain diseases."

The study did have some limitations, the authors acknowledged.

"The main limitation of our study is that the findings are correlational," Zeng said.

Inflammation plays a role in chronic age-related diseases such as Alzheimer's, a neurologist noted. AP Images© AP Images

"We don't know yet if the gene expression changes observed in specific cell types are causal to brain aging. Our study lays the groundwork by providing a detailed genetic map and cell targets."

Zeng called for future studies to investigate the cells' roles in aging and determine whether the reversal of the changes could delay the aging process.

Dr. Earnest Lee Murray, a board-certified neurologist at Jackson-Madison County General Hospital in Jackson, Tennessee, commented that the new research adds to existing evidence supporting the role of diet in human brain health.

The detailed "brain roadmap" will be very beneficial for future research into aging and possible therapeutics, according to Murray, who was not involved in the study.

The detailed "brain roadmap" discovered in the study will be very beneficial for future research into aging and possible therapeutics, experts agree. iStock© iStock

It's been known for some time that inflammation plays a role in chronic age-related diseases such as Alzheimer's, the neurologist noted.

"More and more evidence is pointing to the fact many chronic diseases can be prevented, and it often comes down to diet and exercise," he told Fox News Digital. "Altering diet to exclude processed foods and initiating some habits such as intermittent fasting have been shown to reduce this cellular inflammation that appears to be leading to so many diseases."

Original article source: Aging 'hotspot' found in brain, researchers say: 'Major changes'

5 major Alzheimer’s discoveries scientists made in 2024

The Alzheimer’s Association shares some of its most significant dementia findings

Published December 27, 2024

Drug shows promise in treating Alzheimer's

Gillian Turner reports how BAN2401 might help slow the mental decline of Alzheimer's patients.

With an estimated 6.9 million Americans aged 65 and older currently living with Alzheimer's disease, the road to a cure seems long and uncertain.
But as the year comes to a close, experts are reflecting on some of the hopeful advances in diagnosis, treatment and risk management that have been made in 2024.

The Alzheimer’s Association — a Chicago-based nonprofit committed to Alzheimer’s research, care and support — shared its top five significant discoveries from the year.

DEMENTIA REPORT REVEALS 'SHOCKING' SIGNS AT AGE 60 THAT YOU'LL DEVELOP THE DISEASE BY AGE 80

1. Third new Alzheimer’s drug is approved

2024 saw a new drug enter the dementia landscape, as the U.S. Food and Drug Administration (FDA) approved Kisunla (donanemab) in July.

This was the third new approval since 2021.

The Alzheimer's Association — a Chicago-based nonprofit committed to Alzheimer's research, care and support — shared its top five significant discoveries from the year. (iStock)

Kisunla, which is made by Eli Lilly, is designed to "slow progression and change the underlying course of the disease," according to the Association's press release.

The once-monthly injection is intended for adults with early symptomatic Alzheimer's disease.

This is the first medication to target amyloid plaques — the proteins that build up in the brains of Alzheimer's patients, often impairing memory and cognitive function — with evidence to support stopping therapy when amyloid plaques are removed, a company release stated.

'HIDDEN' FAT COULD PREDICT ALZHEIMER'S DISEASE UP TO 20 YEARS BEFORE SYMPTOMS, RESEARCH FINDS

"This is real progress," said Alzheimer's Association President and CEO Dr. Joanne Pike in a statement shared with Fox News Digital at the time.

"[This FDA] approval allows people more options and greater opportunity to have more time. Having multiple treatment options is the kind of advancement we've all been waiting for."

2. Blood tests could improve speed and accuracy of diagnosis

Research this year has helped move Alzheimer's blood tests closer to being used in physicians' offices.

Studies have shown that blood tests can achieve a higher accuracy of diagnosis, which could help fast-track patients' access to clinical trials and treatments, according to the Alzheimer's Association.

> ## "This is real progress."

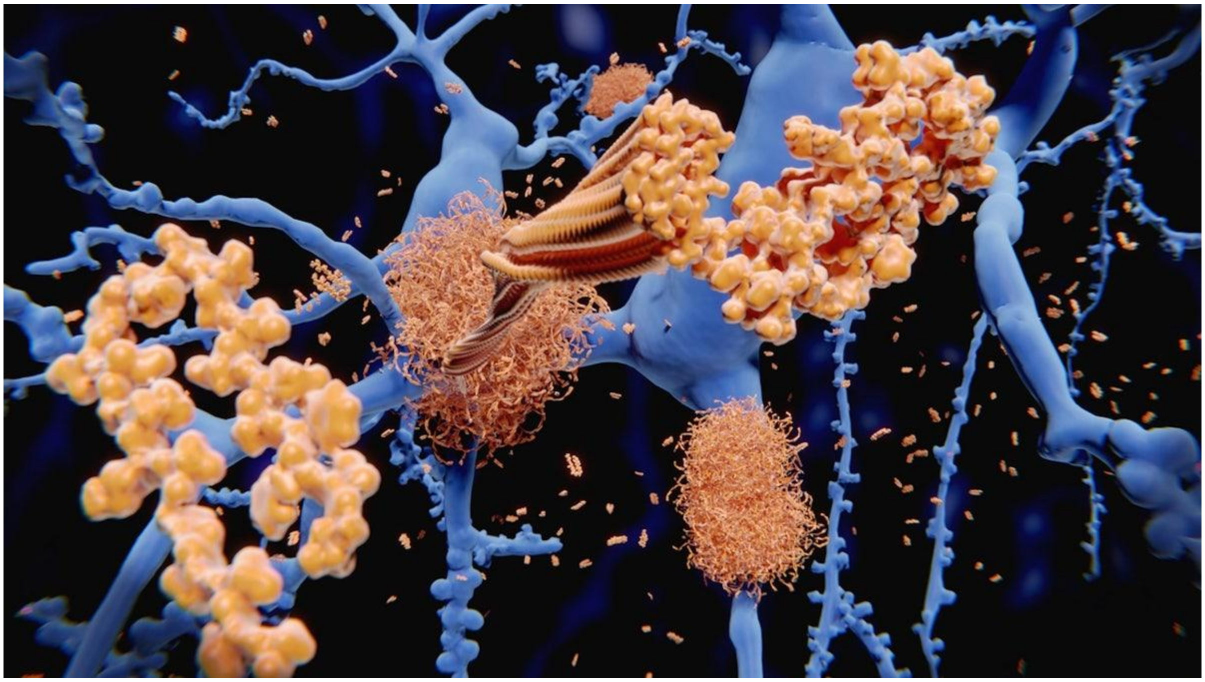
"Blood tests for Alzheimer's are demonstrating in research that they could significantly improve a clinician's accuracy and confidence, provide greater accessibility and a reason for more communication," the same source stated.

In one study reported this year, a specific blood test was around 90% accurate in identifying Alzheimer's in patients with cognitive symptoms seen in primary care and at specialized memory care clinics, per the Association.

3. Individuals and caregivers want more support post-diagnosis

People who are newly diagnosed with Alzheimer's and their caregivers need more support in navigating the health care system.

That's according to a 2024 Alzheimer's Association survey, which found that 97% of dementia caregivers expressed a desire for those support systems.


2024 saw the approval of the first medication to target amyloid plaques, the proteins that build up in the brains of Alzheimer's patients and often impair memory and cognitive function. (iStock)

A majority of dementia caregivers (70%) also noted that "coordination of care is stressful."

To help address this, the Centers for Medicare & Medicaid Services in July 2024 launched an eight-year pilot program in dementia care management, called the Guiding an Improved Dementia Experience (GUIDE) model.

DEMENTIA RISK COULD BE LINKED TO WALKING SPEED, STUDY SUGGESTS

The program aims to work with health care systems to provide supportive services to people living with dementia and their caregivers, with a focus on helping patients remain in their homes and communities, according to the Alzheimer's Association.

4. Wildfire smoke raises risk of dementia

Air pollution has been linked to an increased risk of dementia, according to 2024 research.

The 10-year study, which was presented during the Alzheimer's Association International Conference in Philadelphia in July, found that wildfire smoke can be "particularly hazardous" for brain health.

A 2024 Alzheimer's Association survey found that 97% of dementia caregivers expressed a desire for those support systems. (iStock)

The research included more than 1.2 million people in southern California, an area that experiences frequent wildfire activity.

Air pollution produced by wildfires could be more hazardous to health because it is produced at higher temperatures, contains a greater concentration of toxic chemicals, and is smaller in diameter than other sources, the Alzheimer's Association stated.

5. Alzheimer's causes physical changes in the brain

In June 2024, scientists and clinicians published research that showed physical changes that happen in the brain due to Alzheimer's disease. "Defining diseases by the biology has long been standard in many areas of medicine — including cancer, heart disease and diabetes," the Alzheimer's Association wrote.

In June 2024, scientists and clinicians published research that showed physical changes that happen in the brain due to Alzheimer's disease. (iStock)

"The new publication defines Alzheimer's as a biological process that begins with brain changes before people exhibit memory and thinking problems."

These brain changes were found to come ahead of the typical outward symptoms, such as memory loss, confusion, disorientation and trouble with planning or organizing.

Warding off dementia means more reading, praying and listening to music: study

Downtime decisions may have profound health impacts, say researchers

Published January 1, 2025

Could being bilingual help prevent dementia?

Fox News medical contributor Dr. Nicole Saphier joins 'Fox & Friends Weekend' to weigh in on a new report that being bilingual could help people ward off dementia.

For long-term brain health, older adults might want to carefully consider how they spend their downtime, according to a new study. Researchers from the University of South Australia assessed the 24-hour activity patterns of nearly 400 people over age 60. When it comes to brain health, the study found that the context or type of activity individuals engage in matters, news agency SWNS reported.

DEMENTIA REPORT REVEALS 'SHOCKING' SIGNS AT AGE 60 THAT YOU'LL DEVELOP THE DISEASE BY AGE 80

Some sedentary behaviors are better for cognitive function than others, according to the findings, which were published in The Journal of Gerontology Series A. Mentally stimulating behaviors, such as reading, listening to music, praying, crafting and playing a musical instrument — as well as social behaviors like chatting with others — are beneficial for memory and thinking abilities, the study noted.

Mentally stimulating behaviors such as reading, listening to music, praying, crafting and playing a musical instrument are beneficial for memory and thinking abilities, a new study noted. (iStock)

The research team referred to the "valuable insights" that could help reduce instances of cognitive impairment. More passive activities, like playing video games or watching TV, do not offer the same benefits as reading, praying and other activities, they noted. More than 55 million people around the globe have dementia, according to estimates from the World Health Organization. Another 10 million new cases are diagnosed each year. Dr. Maddison Mellow, researcher at the University of South Australia, said that not all sedentary behaviors are equal when it comes to memory and cognitive health.

"The context of an activity alters how it relates to cognitive function, with different activities providing varying levels of cognitive stimulation and social engagement." (iStock)

"In this research," she said, "we found that the context of an activity alters how it relates to cognitive function, with different activities providing varying levels of cognitive stimulation and social engagement." She said that scientists "already know that physical activity is a strong protector against dementia risk, and this should be prioritized if you're trying to improve your brain health," as SWNS reported.

> # "Even small, 5-minute time swaps can help."

"But until now, we hadn't directly explored whether we can benefit our brain health by swapping one sedentary activity for another." She went on, "And while the 'move more, sit less' message certainly holds true for cardiometabolic and brain health, our research shows that a more nuanced approach is needed when it comes to thinking about the link between sedentary behaviors and cognitive function." It's wise to "prioritize movement that's enjoyable and gets the heart rate up," she also said. And "even small, 5-minute time swaps can help."

"A more nuanced approach is needed when it comes to thinking about the link between sedentary behaviors and cognitive function." (iStock)

A recent study published by the RAND Corporation in California also identified several major predictors occurring around age 60 that could likely lead to cognitive impairment and dementia in individuals by age 80, as Fox News Digital previously reported. Researchers evaluated 181 potential risk factors, including demographics, socioeconomic status, lifestyle and health behaviors, health history, psycho-social factors and more. The list of predictors, according to RAND, included "never exercising" and "low engagement in hobbies."

The study results suggested that "maintaining good physical and mental health is beneficial not just to staying in shape, but also to staying sharp and delaying cognitive decline," study co-author Peter Hudomiet, a RAND economist in California, told Fox News Digital.

Scientists Discover Brain Has Its Own Microbiome, Opening New Path to Fight Dementia

Why it matters: The Guardian reports that revolutionary research reveals the brain hosts its own ecosystem of microorganisms, challenging long-held beliefs about brain sterility and potentially transforming our approach to treating neurodegenerative diseases like Alzheimer’s.

The Big Picture: New Scientist reports that University of Edinburgh researchers have identified an astounding diversity in brain tissue:

- Up to 100,000 microbial species per sample
- Represents 20% of gut microbiome diversity
- Includes bacteria, viruses, and fungi
- Direct link to neurodegenerative diseases

Disease Connection: The discovery reshapes our understanding of Alzheimer’s:

- Beta-amyloid plaques serve as antimicrobial defense
- Brain’s immune response may contribute to neural damage

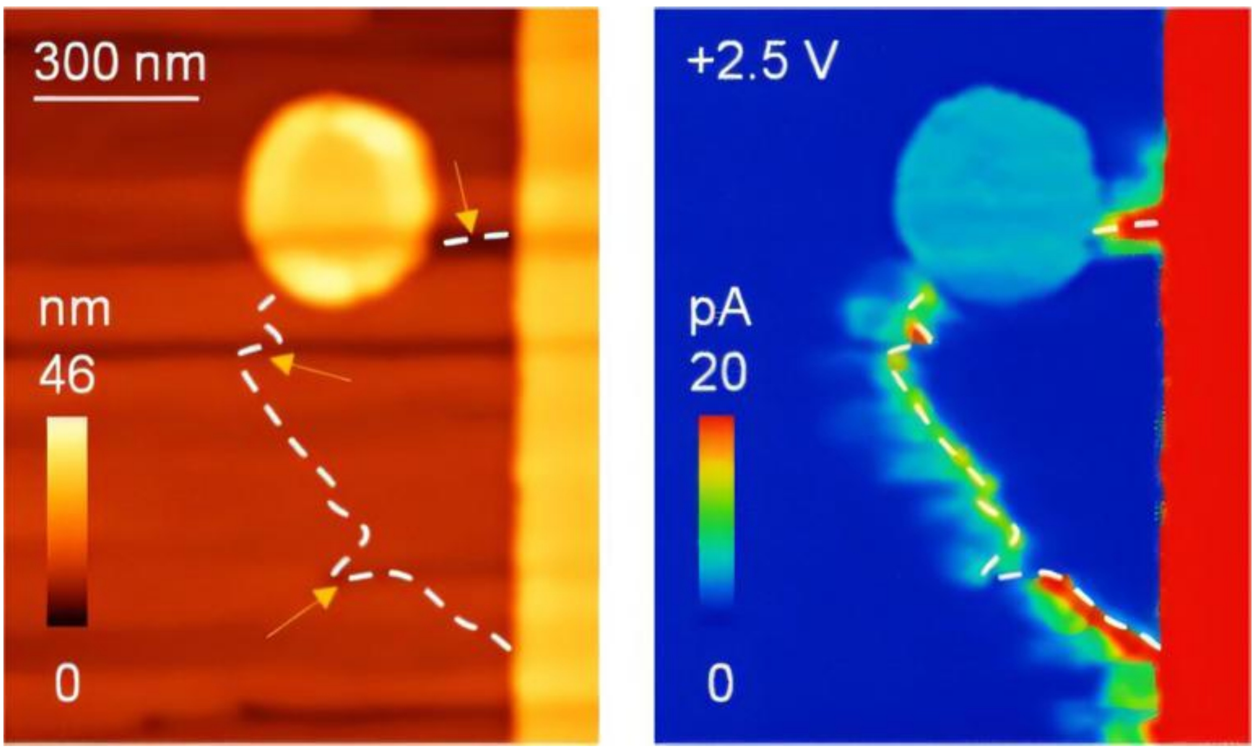
- Specific microbe combinations linked to disease stages
- Infection-fighting treatments show promise in reversing decline

Treatment Implications: Early interventions show promising results:

- Antiviral medications reduce dementia risk
- Vaccines provide protective effects
- Antimicrobial treatments reverse cognitive decline in some cases
- Dietary changes support brain-gut microbiome health

Looking Forward: This breakthrough opens new therapeutic possibilities while highlighting the importance of maintaining a healthy microbiome through diet and lifestyle choices. Researchers continue investigating how controlling brain microbes could prevent or treat dementia.

Brain-inspired nanotech offers new path for smarter electronics



A single ferroelectric domain wall memristive device. Left: Interelectrode gap straddled by a single domain wall, which is pinned strategically at a few locations (shown by arrows) at the film's surface. Right: Electronic transport characteristics of this wall and the device. Credit: ACS Applied Materials & Interfaces (2024). DOI: 10.1021/acsami.4c16347

Imagine a future where your phone, computer or even a tiny wearable device can think and learn like the human brain—processing information faster, smarter and using less energy.

A new approach developed at Flinders University and UNSW Sydney brings this vision closer to reality by electrically "twisting" a single nanoscale ferroelectric domain wall.

The domain walls are almost invisible, extremely tiny (1–10 nm) boundaries that naturally arise or can even be injected or erased inside special insulating crystals called ferroelectrics. The domain walls inside these crystals separate regions with different bound charge orientations.

More importantly, these tiny boundaries, despite being embedded in insulating crystals, can act as channels for regulating electron flow, and thus are capable of storing and processing information like in a human brain, says Flinders University senior lecturer in physics Dr. Pankaj Sharma, lead and corresponding author of the new article published in *ACS Applied Materials & Interfaces*.

Why does this matter? Devices mimicking the human brain allow for faster processing of vast amounts of information while using far less energy compared to existing digital computers, in particular, for tasks such as image and voice recognition, the researchers say.

"With this new design, these ferroelectric domain walls in crystalline ferroelectric materials are poised to power a new generation of adaptable memory devices, bringing us closer to faster, greener and smarter electronics," says Dr. Sharma. "Our results reaffirm the promise of ferroelectric domain walls for brain-inspired neuromorphic and in-memory computing applications based on integrated ferroelectric devices.

"In our research, a single ferroelectric domain wall has been controllably injected and engineered to mimic memristor behavior. By applying electric fields, we carefully manipulate the shape and position of this single wall, causing it to bend and warp.

"This controlled movement leads to changes in the wall's electronic properties, unlocking its ability to store and process data at different levels."

The new study reveals how ferroelectric domain walls straddling two terminal devices can function as "memristors"—devices that can store information at varying levels and remember the history of its electrical activity—similar to synapses in a human brain.

Co-author UNSW Professor Jan Seidel, says "the key lies in the interplay between the wall's surface pinning (where it's fixed) and its freedom to twist or warp deeper within the material.

"These controlled twists create a spectrum of electronic states, enabling multi-level data storage, and eliminate the need for repetitive wall injection or erasure, making the devices more stable and reliable," he says.

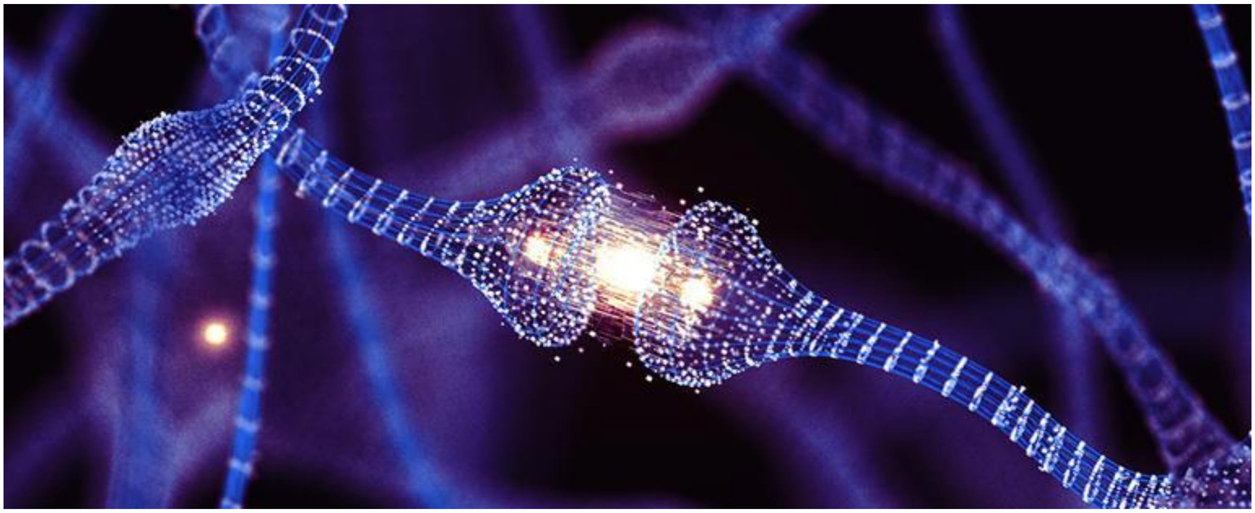
Using advanced microscopy and theoretical phase field modeling, this research uncovers the physics behind these warping-induced electronic transitions at the domain walls.

Co-author UNSW Professor Valanoor Nagarajan adds, "These new highly reproducible and energy-efficient domain wall devices could revolutionize neuromorphic computing, the brain-inspired systems that promise to reshape artificial intelligence and data processing."

More information: Pankaj Sharma et al, Ferroelectric Domain Wall Warp Memristor, *ACS Applied Materials & Interfaces* (2024). DOI: 10.1021/acsami.4c16347

Provided by Flinders University

Study Reveals Key Alzheimer's Pathway – And Blocking It Reverses Symptoms in Mice

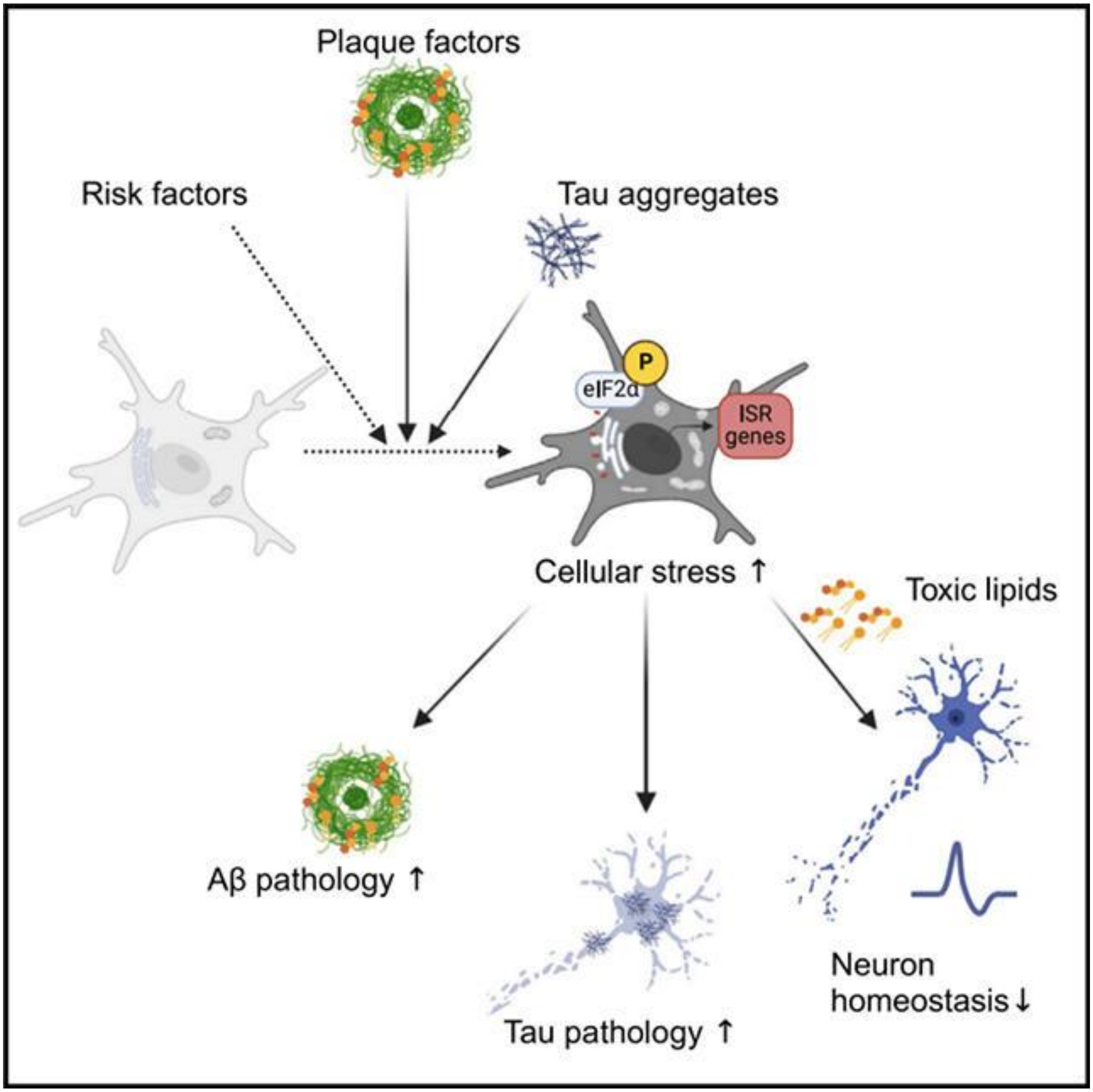


Neuron links

A sequence of stress signals among specialized clean-up cells in the brain could at last reveal why some immune responses can cause significant nerve degeneration that results in the loss of memory, judgement, and awareness behind Alzheimer's disease.

Blocking this pathway in mouse brains modeled on Alzheimer's prevented damage to their synapse connections and reduced the buildup of potentially toxic tau proteins – both hallmarks of the condition.

The researchers, led by a team from the City University of New York (CUNY), believe this pathway – called the integrated stress response (ISR) – causes brain immune cells called microglia to go 'dark' and start damaging rather than benefiting the brain.



he researchers looked at the effects of stress on microglia cells. (Flury et al., Neuron , 2024)

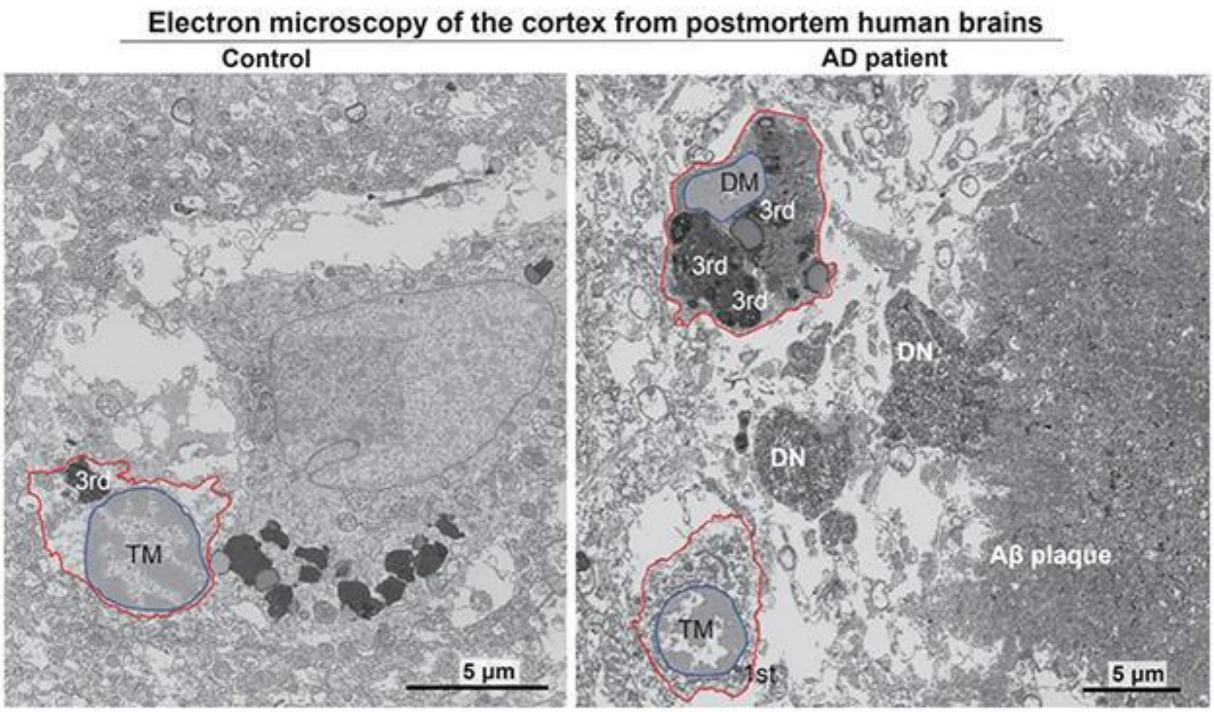
"We set out to answer what are the harmful microglia in Alzheimer's disease and how can we therapeutically target them," says CUNY neuroscientist Pinar Ayata.

"We pinpointed a novel neurodegenerative microglia phenotype in Alzheimer's disease characterized by a stress-related signaling pathway."

Haywire immune cells have previously been linked to Alzheimer's, prompting the team to use an electron scanning process to identify the buildup of dark microglia in human brains affected by Alzheimer's.

Finding around twice as many stressed microglia in brains with the condition compared with healthy brains, the researchers went on to show how the ISR pathway was causing dark microglia to release harmful lipids into the brain's tissues.

It was these damaging fats that caused the damage to synapses and neuron communication seen in Alzheimer's.



Brain scans were used to identify dark microglia. (Flury et al., Neuron , 2024)

As is often the case with Alzheimer's research, a better understanding of how the disease operates can also give scientists more ideas for how to treat it. If treatments that block ISR can work safely and effectively in humans, the method could potentially slow the chaos that Alzheimer's causes in our own brain.

"These findings reveal a critical link between cellular stress and the neurotoxic effects of microglia in Alzheimer's disease," says molecular biologist Anna Flury from CUNY.

"Targeting this pathway may open up new avenues for treatment by either halting the toxic lipid production or preventing the activation of harmful microglial phenotypes."

The team behind this study found that the misfolded protein malfunctions that often drive dementia could be triggering the ISR to begin with, meaning that these signals are both a result of Alzheimer's and a reason for its further progression.

Further studies should make this relationship clearer, now that we have a better idea of how the ISR pathway and dark microglia act in the brain – and from there, hopefully, new approaches to therapies.

"Such treatments could significantly slow or even reverse the progression of Alzheimer's disease, offering hope to millions of patients and their families," says neuroscientist Leen Aljayousi, from CUNY.

The research has been published in *Neuron*.

A Scientist Says Humans Can Slow Time With Their Minds

- In moments of emergency, super-concentration, or meditation, people report moments of “time expansion experiences,” or TEEs—when time feels to slow down.
- Psychologist Steve Taylor has examined these experiences for a decade, and his new book argues that these moments could be altered states of mind that disrupt our normal psychological processes.
- This theory helps explain why TEEs can occur in a variety of situations, and not exclusively in survival or fight-or-flight scenarios.

Time isn’t nearly as immutable as it first seems. Ask any astrophysicist, and they’ll likely regale you with mind-bending descriptions of a gravity’s effect on space-time (i.e. the more massive the object, the slower time appears to travel around it). Some cosmologists even wonder if entire pockets of the universe—whether filled with galaxies or endless nothing—experience time at different rates.

However, the perception of the speed at which time passes can also vary within our *minds*. And it’s this mental realm that Steve Taylor—a psychologist at Leeds

Beckett University—is exploring in a new, yet-to-be-published paper and a new book called *Time Expansion Experiences*.

Taylor's interest in these altered temporal moments—which he calls "time expansion experiences," or TEEs—began when he and his wife were involved in a car crash back in 2014. "Everything went into slow motion," Taylor describes in a post on the Leeds Beckett University website. "I looked behind, and the other cars seemed to be moving incredibly slowly, almost as if they were frozen. I felt as though I had a lot of time to observe the whole scene and to try to regain control of the car. I was surprised by how much detail I could perceive."

Thankfully, the duo emerged from the car crash unscathed (the car, not so much). In the following decade, Taylor began investigating how and why these moments of ultra-slowness manifest, and his research has led him to some pretty interesting conclusions. In 2020, Taylor analyzed 96 instances as TEEs and found that roughly half of them occurred during accidents, while others took place during sporting events, while in meditation, or during psychedelic experiences. The results were published in the journal *The Journal of Humanistic Psychology*.

In a new article for the website *The Conversation*, Taylor explained how some of the leading theories behind these time altering states don't quite grasp the entire breadth of the experiences. One theory believes these moments are the result of the release noradrenaline—essentially the body's fight or flight mechanism—but this doesn't explain the mental time dilation of people during moments of intense meditation or concentration. It's possible that this perception is an evolutionary hack for surviving intense situations, but that still doesn't explain how they occur *outside* of life-or-death events.

"[Another] theory is that TEEs aren't real experiences, but illusions of recollection. In emergency situations, so this theory goes, our awareness becomes acute, so that we take in more perceptions than normal," Taylor wrote. "These perceptions become encoded in our memories, so that when we recall the emergency situation, the extra memories create the impression that time passed slowly."

However, Taylor's findings from people who've experienced TEEs indicate that they were able to process thoughts and information much faster than what would be possible under normal circumstances. Instead, Taylor advocates for an idea that these events shift the human mind into an altered state of consciousness. In these moments, we step outside our normal consciousness into what Taylor calls a different "time-world."

"The sudden shock of an accident may disrupt our normal psychological processes, causing an abrupt shift in consciousness. In sport, intense altered states occur due to what I call 'super-absorption,'" Taylor wrote.

While the flow of time remains a delicate dance between gravity and space-time, new research shows that time can also very much be a state of mind.

Could quantum physics be the key that unlocks the secrets of human behavior?

Credit: Rice University© Provided by Phys.org

Human behavior is an enigma that fascinates many scientists. And there has been much discussion over the role of probability in explaining how our minds work.

Probability is a mathematical framework designed to tell us how likely an event is to occur—and works well for many everyday situations. For example, it describes the outcome of a coin toss as ½—or 50%—because throwing either heads or tails is equally probable.

Yet research has shown that human behavior can't be fully captured by these traditional or "classical" laws of probability. Could it instead be explained by the way probability works in the more mysterious world of quantum mechanics?

Mathematical probability is also a vital component of quantum mechanics, the branch of physics that describes how nature behaves at the scale of atoms or sub-atomic particles. However, as we'll see, in the quantum world, probabilities follow very different rules.

Discoveries over the last two decades have shed light on a crucial role for "quantumness" in human cognition—how the human brain processes information to acquire knowledge or understanding. These findings also have potential implications for the development of artificial intelligence (AI).

Human 'irrationality'

Nobel laureate Daniel Kahnemann and other cognitive scientists have carried out work on what they describe as the "irrationality" of human behavior. When behavioral patterns do not strictly follow the rules of classical probability theory from a mathematical perspective, they are deemed "irrational."

For example, a study found that a majority of students who have passed an end-of-term exam favor going on holiday afterwards. Likewise, a majority of those who have failed also want to go for a holiday.

If a student doesn't know their result, classical probability would predict that they would opt for the holiday because it is the preferred option whether they have passed or failed. Yet in the experiment, a majority of students preferred not to go on holiday if they didn't know how they'd done.

Intuitively, it's not hard to understand that students might not want to go on holiday if they are going to be worrying about their exam results the whole time. But classical probability does not accurately capture the behavior, so it is described as irrational. Many similar violations of classical probability rules have been observed in cognitive science.

Quantum brain?

In classical probability, when a sequence of questions is asked, then the answers do not depend on the order in which the questions are posed. By contrast, in quantum physics, the answers to a series of questions can depend crucially on the order in which they are asked.

One example is the measurement of the spin of an electron in two different directions. If you first measure the spin in the horizontal direction and then in the vertical direction, you will get one outcome.

The outcomes will generally be different when the order is reversed, because of a well known feature of quantum mechanics. Simply measuring a property of a quantum system can affect the thing that's being measured (in this case an electron's spin) and hence the outcome of any subsequent experiments.

Order dependence can also be seen in human behavior. For example, in a study published 20 years ago about the effects that question order has on respondents' answers, subjects were asked whether they thought the previous US president, Bill Clinton, was honest. They were then asked if his vice president, Al Gore, seemed honest.

When the questions were delivered in this order, a respective 50% and 60% of respondents answered that they were honest. But when the researchers asked respondents about Gore first and then Clinton, a respective 68% and 60% responded that they were honest.

On an everyday level, it might seem that human behavior is not consistent because it often violates the rules of classical probability theory. However, this behavior does appear to fit with the way probability works in quantum mechanics.

Observations of this kind have led cognitive scientist Jerome Busemeyer and many others to recognize that quantum mechanics can, on the whole, explain human behavior in a more consistent way.

Based on this astonishing hypothesis, a new research field called "quantum cognition" has arisen within the area of cognitive sciences.

How it is possible that thought processes are dictated by quantum rules? Is our brain working like a quantum computer? No one yet knows the answers, but the empirical data strongly appears to suggest that our thoughts follow quantum rules.

Dynamic behavior

In parallel to these exciting developments, over the past two decades my collaborators and I have developed a framework for modeling—or simulating—the dynamics of people's cognitive behavior as they digest "noisy" (that is, imperfect) information from the outside world.

We again found that mathematical techniques developed for modeling the quantum world could be applied to modeling how the human brain processes noisy data.

These principles can be applied to other behavior in biology, beyond just the brain. Green plants, for example, have the remarkable ability to extract and analyze chemical and other information from their environments and to adapt to changes.

My rough estimate, based on a recent experiment on common bean plants, suggests that they can process this external information more efficiently than the best computer we have today.

In this context, efficiency means that the plant is consistently able to reduce the uncertainty about its external environment to the greatest extent possible in its circumstances. This could, for example, encompass easily detecting the direction that light is coming from, so that the plant can grow towards it. The efficient processing of information by an organism is also linked to saving energy, which is important for its survival.

Similar rules may apply to the human brain, particularly to how our state of mind changes when detecting outside signals. All of this is important for the current trajectory of technological development. If our behavior is best described by the way probability works in quantum mechanics, then to accurately replicate human behavior in machines, AI systems should probably follow quantum rules, not classical ones.

I've called this idea artificial quantum intelligence (AQI). A great deal of research is needed to develop practical applications from such an idea.

But an AQI could help get us to the goal of AI systems that behave more like a real person.

JANUARY 2, 2025

Gene expression study reveals human brain cell types becoming more specialized, not just more numerous

by Harrison Tasoff, University of California - Santa Barbara

Differences in gene expression, not just their presence, seem to drive the remarkable specialization found in the human brain. Credit: Matt Perko

Our brain is arguably the organ that most distinguishes humans from other primates. Its exceptional size, complexity and capabilities far exceed those of any other species on Earth. Yet humans share upwards of 95% of our genome with chimpanzees, our closest living relatives.

UC Santa Barbara professor Soojin Yi, in the Department of Ecology, Evolution, and Marine Biology, her doctoral student Dennis Joshy, and collaborator Gabriel Santepere, at Hospital del Mar Medical Research Institute in Barcelona, recently aimed to determine how genes in different types of brain cells have evolved compared to those those in chimpanzees. They found that while our genes code for almost all the same proteins as other apes, many of our genes are much more productive than those of other primates.

Their results, published in the *Proceedings of the National Academy of Sciences*, highlight the role of gene expression in the evolution and function of the human brain.

Interpreting nature's blueprints

Each gene tells a cell to make a specific molecule, but this isn't performed by the DNA itself. Instead, the information is relayed to cellular machinery by a molecule called messenger RNA. Researchers measure gene expression by observing the amount of mRNA a specific gene produces.

As scientists began to understand the role of the genome as life's blueprint, they thought that perhaps the human genome could explain our unique traits. But a thorough comparison with chimpanzees in 2005 revealed we share 99% percent of our genes (though scientists have since revised this number). This confirmed earlier studies based on small numbers of genes that had suggested there was only a small difference between the human and chimpanzee genomes.

Now biologists suspect that gene expression may underlie these differences. Consider a monarch butterfly. The adult has the same genome as when it was a caterpillar. The incredible differences between the two life stages all come down to gene expression. Turning on and off different genes, or having them code for more or less mRNA, can drastically alter an organism's traits.

Getting a clearer picture

Previous research has found differences in gene expression between humans and chimpanzees, and that human cells tend to have higher gene expression, but the picture was blurry. The brain is made up of many varieties of cells. Traditionally, scientists organized brain cells into two major types: neurons and glial cells. Neurons carry electrochemical signals, a bit like the copper wiring in a building. Glial cells perform most of the other functions, such as insulating the wires, supporting the structure and clearing out debris.

Until recently, scientists could only study bulk tissue samples composed of many different types of cells. But within the past decade, it's become possible to assay cell nuclei one at a time. This allows researchers to distinguish between cell types, and often even subtypes.

Yi, Joshy and Santepere used datasets generated from a device with a very narrow channel to separate each nucleus into its own chamber in an array. Then they grouped the cells by type before performing statistical analysis.

The team measured gene expression by observing the amount of mRNA a specific gene produced in humans, chimpanzees and macaques. An upregulated gene produces more mRNA in a given species compared to the others, while a downregulated gene produces less. Comparing chimpanzees and humans to macaques enabled the researchers to tell when differences between the two apes were due to changes in chimpanzees, changes in humans, or both.

The authors recorded differences in the expression of about 5–10% of the 25,000 genes in the study. In general, human cells had more upregulated genes compared to chimpanzees. This is a much larger percentage than researchers found when they couldn't break down the analysis by cell type. The percentage grew to 12–15% when the authors began to consider cell subtypes.

"Now we can see that individual cell types have their own evolutionary path, becoming really specialized," Yi said.

Not just neurons

The intricacy of our neural pathways is unrivaled in the animal kingdom. However, Yi suspects that our unique intellect isn't a result of this on its own. Human glial cells account for more than half of the cells in our brains, a much larger percentage than in even chimpanzees.

Among glial cells, oligodendrocytes showed the greatest differences in gene expression. These cells create the insulation that coats neurons, enabling their electrical signals to travel much more quickly and efficiently. In a collaborative study published the previous year, the team observed that humans have a higher ratio of precursor versus mature oligodendrocytes compared with chimpanzees. Yi suspects this may relate to the amazing neural plasticity and slow development of human brains.

"The increased complexity of our neural network probably didn't evolve alone," Yi said. "It could not have come into existence unless all these other cell types had also evolved and enabled the expansion of the neuron diversity, the number of neurons and the complexity of the networks."

This study only considered cells from a few regions of the brain. However, the cells in one area of the brain may differ from their counterparts in other areas. Yi plans to study the mechanisms behind differences in gene expression and how genes map to different traits.

She also plans to trace differential gene expression even earlier in our evolutionary history by incorporating baselines from even more distantly related animals. She's also interested in studying genomic differences between us and other archaic humans, like Neanderthals and Denisovans.

Evolution is about more than merely changing genes. "Differential gene expression is really how human brains evolved," Yi said.

More information: Dennis Joshy et al, Accelerated cell-type-specific regulatory evolution of the human brain, *Proceedings of the National Academy of Sciences* (2024). DOI: 10.1073/pnas.2411918121
Journal information: Proceedings of the National Academy of Sciences
Provided by University of California - Santa Barbara

Adults still develop new neurons: but what are they for?

Published by Cédric, December 17, 2024

Your brain, far from being fixed in adulthood, continues to renew itself. Researchers reveal that the birth of new neurons in adults plays a key role in learning. This discovery overturns our understanding of human cognitive mechanisms.

The brain, the conductor of our body, relies on a network of neurons largely acquired at birth. However, certain regions continue to produce neurons throughout life. This process, though rare and limited, is called neurogenesis.

For a long time, scientists debated the true importance of this adult neurogenesis. Earlier studies observed a decrease in new neurons among patients with diseases such as Alzheimer's or epilepsy. This phenomenon was correlated with cognitive disorders, but the precise cause remained undetermined.

Recently, researchers at the University of Southern California delved into this mystery by studying patients with drug-resistant epilepsy. These patients, undergoing surgical procedures, provide a unique opportunity to collect and analyze human brain tissue.

The results are striking: new neurons in adults appear directly associated with verbal learning. These cells seem to enhance listening, understanding, and retaining information shared in conversations. This essential function, ironically, differs from findings in mice, where neurogenesis primarily supports spatial orientation.

To reach these conclusions, researchers analyzed specific markers in the brain tissue of patients. They discovered that fewer new neurons in the hippocampus correlate with a marked decline in verbal learning and memory capabilities.

This discovery opens new avenues of hope. Researchers believe stimulating neurogenesis could improve cognitive abilities in older adults or individuals with neurological disorders. Moreover, physical exercise is thought to have significant potential impacts on the production of new neurons in patients with epilepsy.

However, these approaches remain experimental. Researchers emphasize the need to deepen the study of neurogenesis directly in humans, which may differ from animal models. In the long run, these studies could transform our understanding of neurodegenerative diseases and aging mechanisms. The brain's renewal, even if limited, may well become a cornerstone of cognitive health.

What is adult neurogenesis?

Adult neurogenesis refers to the process of forming new neurons in the brain after birth, including during adulthood. Contrary to popular belief, the adult brain is not fixed but retains the ability to produce nerve cells, albeit in a limited manner.

This phenomenon primarily occurs in two regions: the hippocampus, involved in memory and learning, and the olfactory bulb, responsible for the sense of smell. These areas house stem cells capable of transforming into functional neurons.

Adult neurogenesis plays a key role in certain cognitive functions like learning, verbal memory, and spatial navigation. Its activity tends to decline with age or in cases of neurological diseases.

Recent studies suggest that stimulating neurogenesis through physical exercise or therapeutic approaches could potentially slow cognitive decline associated with aging or diseases like Alzheimer's.

Quantum entanglement: faster-than-light communication?

Published by Adrien, January 01, 2025 at 11:00 PM

Source: Universe Today

Quantum entanglement remains one of the most mysterious phenomena in modern physics. It seems to allow particles to communicate instantaneously, thus defying the speed of light.

In quantum mechanics, a particle is not a precise point but rather described by a wave function, a cloud of probabilities indicating where we might find the particle upon measurement. When two particles share the same quantum state, they are said to be entangled.

Entanglement means that measuring a property of one particle immediately informs us about the property of the other. For example, if two electrons are entangled and one is observed with a 'spin up' relative to a given axis (which can be likened to a binary '1'), the other will necessarily be observed with a 'spin down' (a binary '0'), regardless of the distance separating them. This correlation has no notion of temporality.

Can we then conclude that we have successfully transmitted a binary '0' to the distant particle, instantaneously?

This apparent "instantaneous communication" is not actual communication and does not violate the theory of relativity. Indeed, although the states of the particles are linked, a local measurement on one of the particles is necessary to reveal the state of each particle. It is thus not possible to determine whether a '0' or a '1' is present on one or the other of the particles before observing one of them.

Moreover, the value '0' or '1' is not predetermined before the measurement; it is the measurement itself that determines the state of the particle. This phenomenon was confirmed by Alain Aspect's experiments in the 1980s, showing that the information was not already present before the measurement (absence of "hidden variables"). Quantum entanglement therefore does not allow for the transmission of information faster than light. It rather shows a non-local connection between particles, which remains a subject of intense research in quantum physics.

The implications of quantum entanglement are vast, ranging from quantum cryptography to quantum computing. Understanding this phenomenon could open new technological and scientific pathways.

Despite the advances, quantum entanglement continues to raise fundamental questions about the nature of reality and the limits of our understanding of the Universe.

I tried this brain sensing wristband at CES 2025 — the mouse could be dead

Imagine if you took one of the coolest aspects of the Apple Vision Pro — the Minority Report-style gestures — and paid $199 for the fun instead of $3,500. That's the idea behind the Mudra Link from Wearable Devices, which reads your brain signals and essentially turns your hand into a remote control.

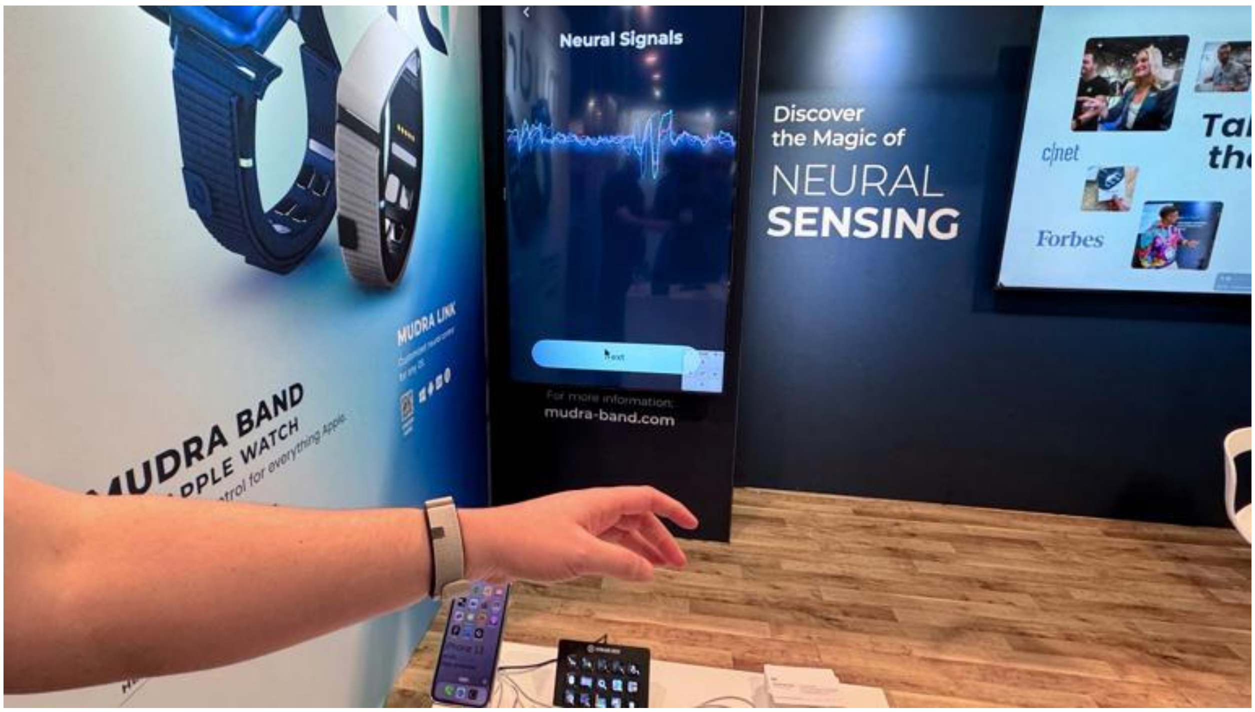
The Mudra Link is dubbed as the first neural wristband that works with Android, macOS and Windows devices, and I got a chance to try it out at CES 2025 ahead of its release at the end of January.

How does the Mudra Link work? Proprietary Surface Nerve Conductance sensors pick up electromyography signals from subtle finger movements, translating them into commands. There's also an accelerometer and gyroscope on board.

I did a bunch of demos with the Mudra Link, and most of them worked smoothly. There was a large display in front of me as a Wearable Devices rep cycled through a range of apps on a Mac. In the first demo I could pull a face like a rubber band in multiple directions by simply putting my hand in the air and doing a pinch gesture as I moved my arm subtly.

From there, I played a virtual violin (which was a bit finicky to get right). But my favorite demo was a round of Fruit Nina. I was able to slice through multiple fruits at once without a problem.

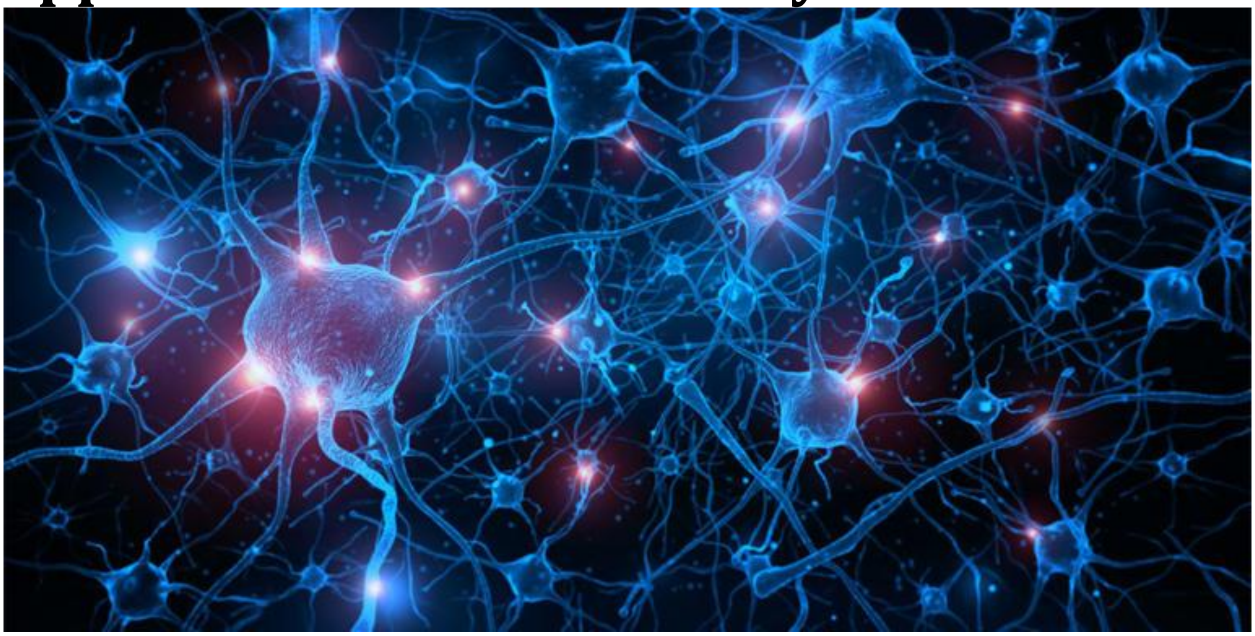
So it's pretty cool to turn your hand into a mouse, but what's the point? The next wave of wearable devices — smart glasses — will need a better method of control. And that's exactly what Meta is doing with its Meta Orion concept. The company is making its own electromyography (EMG) wirstband, which senses the electrical signals of your muscle movements, beaming gestures to the glasses.



The idea behind wristbands like this is that you can keep your hand at your side, making subtle gestures to control the glasses instead of having to constantly touch the glasses themselves. So it's no surprise that Wearable Devices is partnering with TCL so that its wristband will function as a remote for its smart glasses.

Still, $199 is not cheap for an accessory to smart glasses, so it will be key for TCL and other smart glasses partners to offer a bundle at a cheaper price.

How neurons work together: A fractal approach to brain efficiency



The brain is a marvel of efficiency, honed by thousands of years of evolution so it can adapt and thrive in a rapidly changing world. Yet, despite decades of research, the mystery of how the brain achieves this has remained elusive.

Our new research, published in the journal *Cell*, reveals how neurons – the cells responsible for your childhood memories, thoughts and emotions – coordinate their activity.

It's a bit like being a worker in a high-performing business. Balancing individual skills with teamwork is key to success, but how do you achieve the balance?

As it turns out, the brain's secret is surprisingly simple: devote no more than half (and no less than 40%) of each cell's effort to individual tasks. Where does the rest of the effort go? Towards scalable teamwork.

And here's the kicker: we found the exact same organisational structure across the brains of five species – from fruit flies and nematodes to zebrafish, mice and monkeys.

These species come from different branches of the tree of life that are separated by more than a billion years of evolution, suggesting we may have uncovered a fundamental principle for optimised information processing. It also offers powerful lessons for any complex system today.

The critical middle ground

Our discovery addresses a long-standing debate about the brain: do neurons act like star players (each highly specialised and efficient) or do they prioritise teamwork (ensuring the whole system works even when some elements falter)?

Answering this question has been challenging. Until recently, neuroscience tools were limited to either recording the activity of a few cells, or of several million.

It would be like trying to understand a massive company by either interviewing a handful of employees or by only receiving high-level department summaries. The critical middle ground was missing.

However, with advances in calcium imaging, we can now record signals from tens of thousands of cells simultaneously. Calcium imaging is a method that lets us watch neural activity in real time by using fluorescent sensors that light up according to calcium levels in the cell.

Applying insights from my physics training to analyse large-scale datasets, we found that brain activity unfolds according to a fractal hierarchy. Cells work together to build larger, coordinated networks, creating an organisation with each scale mirroring those above and below.

This structure answered the debate: the brain actually does *both*. It balances individuality and teamwork, and does so in a clever way. Roughly half of the effort goes to “personal” performance as neurons collaborate within increasingly larger networks.

The brain can rapidly adapt to change

To test whether the brain’s structure had unique advantages, we ran computational simulations, revealing that this fractal hierarchy optimises information flow across the brain.

It allows the brain to do something crucial: adapt to change. It ensures the brain operates efficiently, accomplishing tasks with minimal resources while staying resilient by maintaining function even when neurons misfire.

Whether you are navigating unfamiliar terrain or reacting to a sudden threat, your brain processes and acts on new information rapidly. Neurons continuously adjust their coordination, keeping the brain stable enough for deep thought, yet agile enough to respond to new challenges.

The multiscale organisation we found allows different strategies – or "neural codes" – to function at different scales. For instance, we found that zebrafish movement relies on many neurons working in unison. This resilient design ensures swimming continues smoothly, even in fast-changing environments.

By contrast, mouse vision adapts at the cellular scale, permitting the precision required to extract fine details from a scene. Here, if a few neurons miss key pieces of information, the entire perception can shift – like when an optical illusion tricks your brain.

Our findings reveal that this fractal coordination of neuron activity occurs across a vast evolutionary span: from vertebrates, whose last common ancestor lived 450 million years ago, to invertebrates, dating back a billion years.

This suggests brains have evolved to balance efficiency with resilience, allowing for optimised information processing and adaptability to new behavioural demands. The evolutionary persistence hints that we've uncovered a fundamental design principle.

A fundamental principle?

These are exciting times, as physics and neuroscience continue interacting to uncover the universal laws of the brain, crafted over aeons of natural selection. Future work will be needed to see how these principles might play out in the human brain.

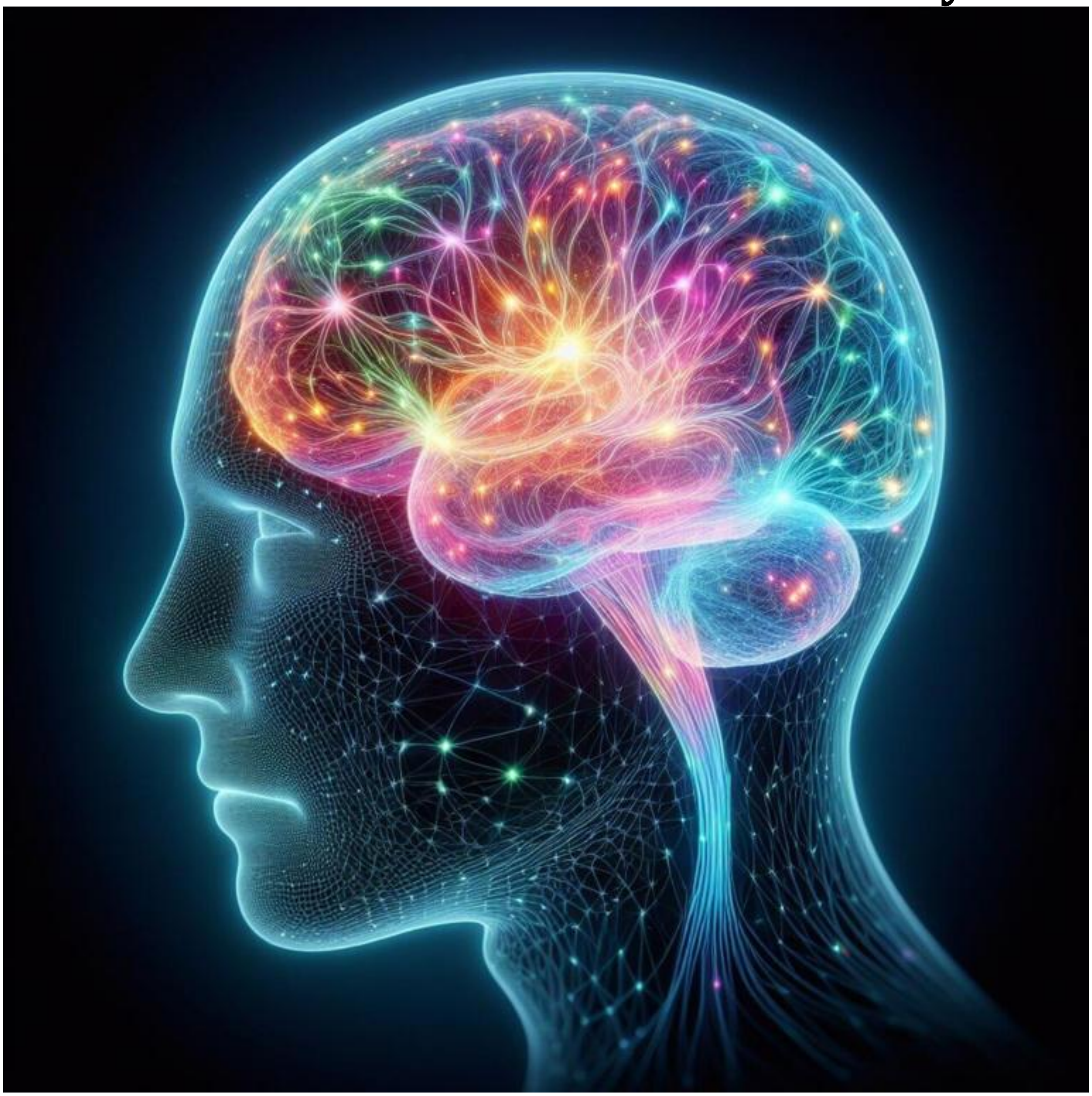
Our findings also hint at something bigger: this simple rule of individual focus and scalable teamwork might not just be a solution for the brain.

When elements are organised into tiered networks, resources can be shared efficiently, and the system becomes robust against disruptions.

The best businesses operate in the same way — when a new challenge arises, individuals can react without waiting for instructions from their manager, allowing them to solve the problem while remaining supported by the organisation rapidly.

It may be a universal principle to achieve resilience and efficiency in complex systems. It appears basketball legend Michael Jordan was right when he said: “talent wins games, but teamwork and intelligence win championships”.

New state of mind: Rethinking how researchers understand brain activity



Understanding the link between brain activity and behavior is among the core interests of neuroscience. Having a better grasp of this relationship will both help scientists understand how the brain works on a basic level and uncover what specifically goes awry in cases of neurological and psychological disease.

One way that researchers study this connection is through what are known as "brain states," patterns of neural activity or connectivity that emerge during specific cognitive tasks and are common enough in all individuals that they become predictable. Another, newer, approach is the study of brain waves, rhythmic, repetitive patterns of brain cell activity caused by synchronization across cells.

In a new paper, two Yale researchers propose that these two ways of thinking about brain activity may not represent separate events but two aspects of the same occurrence. Essentially, they suggest that though brain states are traditionally thought of as a snapshot of brain activity while waves are more like a movie, they're capturing parts of the same story.

Reconsidering these two approaches in this context, the researchers say, could help both fields benefit from the methods and knowledge of the other and advance our understanding of the brain.

Inspired by ecological, conservation, and Indigenous philosophies, Maya Foster, a third-year Ph.D. student in the Department of Biomedical Engineering, began pursuing this idea once she joined the lab of Dustin Scheinost, an associate professor in the Department of Radiology and Biomedical Imaging at Yale School of Medicine.

They are co-authors of the new paper, published in the journal *Trends in Cognitive Sciences*.

"We're arguing that rather than a brain state being one single thing, it's a collection of things, a collection of discrete patterns that emerge in time in a predictable way," she said.

In an interview with Yale News, Foster and Scheinost describe their proposal, and discuss how they might help researchers better understand the mysteries of the brain. This interview has been edited and condensed.

When did you start to consider these might be two aspects of the same occurrence?

Maya Foster: This has been on my mind even before I came to this lab. I was reading a book—"Erosion: Essays of Undoing" by Terry Tempest Williams—and she talks about how human-made machinery like helicopters cause vibrations that interrupt the natural pulse of things and cause things like rock formations to fall apart. Relatedly, there are a lot of Indigenous populations that believe everything has a pulse. And that got me thinking of the brain and whether we have some type of resonance or vibration that can be disrupted.

Then I joined this lab and Dustin let me experiment with a lot of different things. During one of those experiments, I input some data into a particular analysis and the outputs looked wave-like, and patterns emerged and then repeated. That took me down a whole rabbit hole of research literature and there was a lot of evidence for this idea of wave-like patterns in brain states.

What are the benefits of considering brain states as wave-like?

Foster: I think it creates a synergy where both sides—the brain state folks and the brain wave folks—benefit by learning from each other. And maybe the gaps in knowledge we have now when it comes to how brain activity relates to behavior might be filled by both groups working together.

Dustin Scheinost: Brain waves are newer in this field and they're complex. And any time you can take something new and relate it to something old—brain states in this case—it gives you a natural jumping off point. You can bring along everything you've learned so far. It's kind of like not throwing the baby out with the bath water. We don't need to drop brain states. They've informed us, but we can go in a different direction with them too.

How are you proposing researchers consider brain states and brain waves now?

Foster: Borrowing from physics, when you analyze light, it can be a discrete point—a photon—or it can be wave-like. And that's one way we're thinking about this. Similarly, depending on how you analyze brain states you can get static patterns, much like a photon, or you if you look at activity more dynamically, certain patterns start to occur more than once over time, kind of like a wave.

So we're arguing that rather than a brain state being one single thing, it's a collection of things, a collection of discrete patterns that emerge in time in a predictable way.

For example, if we measured four distinct patterns in brain activity as someone completed a cognitive task, a brain state could be that pattern one emerges, then pattern three, then two, then four, and that series might repeat over time. And when that repetition stops, that would be the end of that particular brain state.

You also draw comparisons to the musical technique known as 'fugue.' How does that fit with how you're visualizing these phenomena?

Foster: I'm a music person, so that's where this came from. In a fugue, you have a basic melody and then that melody emerges later in the music in different forms and formats. For instance, the melody will play, then some other music comes in, then the melody returns with the same rhythm and time sequence but maybe it's in a different key.

Fugues are cyclical and wave-like, they have distinct groups of notes, and there's a systematic repetition and sometimes layering of the main melody. We're arguing that brain states are also wave-like, have distinct patterns of brain activity, and display systematic repetition and layering of sequential patterns.

How are you hoping other researchers respond to your argument?

Foster: I would love feedback, honestly. There is evidence for what we're proposing but when it comes to implementing these ideas going forward, it would be helpful to have a conversation about how that might work. There are a lot of different strategies and I'm interested in a broader conversation about how we as researchers might go about studying this.

What's it like as someone who has been in this field for a while to have a student come in with a new idea like this?

Scheinost: You can get set in your ways as a researcher and you need new ideas, new creativity. Sometimes they may sound outlandish when you first hear them. But then you ruminate, and they start to take form. And it's fun. That's really where the fun of this job is, to hear new ideas and see how people discuss and debate them.

More information: Maya Foster et al, Brain states as wave-like motifs, *Trends in Cognitive Sciences* (2024). DOI: 10.1016/j.tics.2024.03.004

Provided by Yale University

On my son’s behalf, I sought out the smart glasses that ‘give sight to the blind’

Like many 4-year-olds, there’s nothing my son loves more than cars. Despite my own complete lack of interest in the topic, he can already identify make and model of cars from across the street with uncanny accuracy, spurred on by his growing collection of Matchbox and Hot Wheels.

But as we’ve had to explain to him, we still don’t know if he’ll be ever to drive one himself. The brain tumor that he was born with left him with stunted vision, particularly in one eye, with little hope of improvement.

That’s why one startup’s CES pitch this year promising a pair of prototype smart glasses that could grant “sight for blind people” caught me off guard. Determined to see if it could really be true, I had a new agenda for my week in Las Vegas; to attempt to reinvigorate my own belief that tech advancements are still capable of transforming lives — and rediscover hope for my son’s future.

Our 4-year old son was born with a very rare pituitary brain tumor, known as a craniopharyngioma. When it was discovered at 10 months old, the tumor was pressing up against his optic nerves and choking his pituitary gland. That meant a lack of normal hormone function that controls basic bodily functions like thirst, growth, cortisol production, and thyroid function — as well as a loss of vision.

Our world crashed around us as we attempted to envision the steps ahead, and more importantly, his future. It wasn't a malignant cancer, and it rarely resulted in loss of life. But in terms of quality of life, we'd heard enough horror stories to keep us up at night.

But don't worry — I promised a story about hope, and that's what this is.

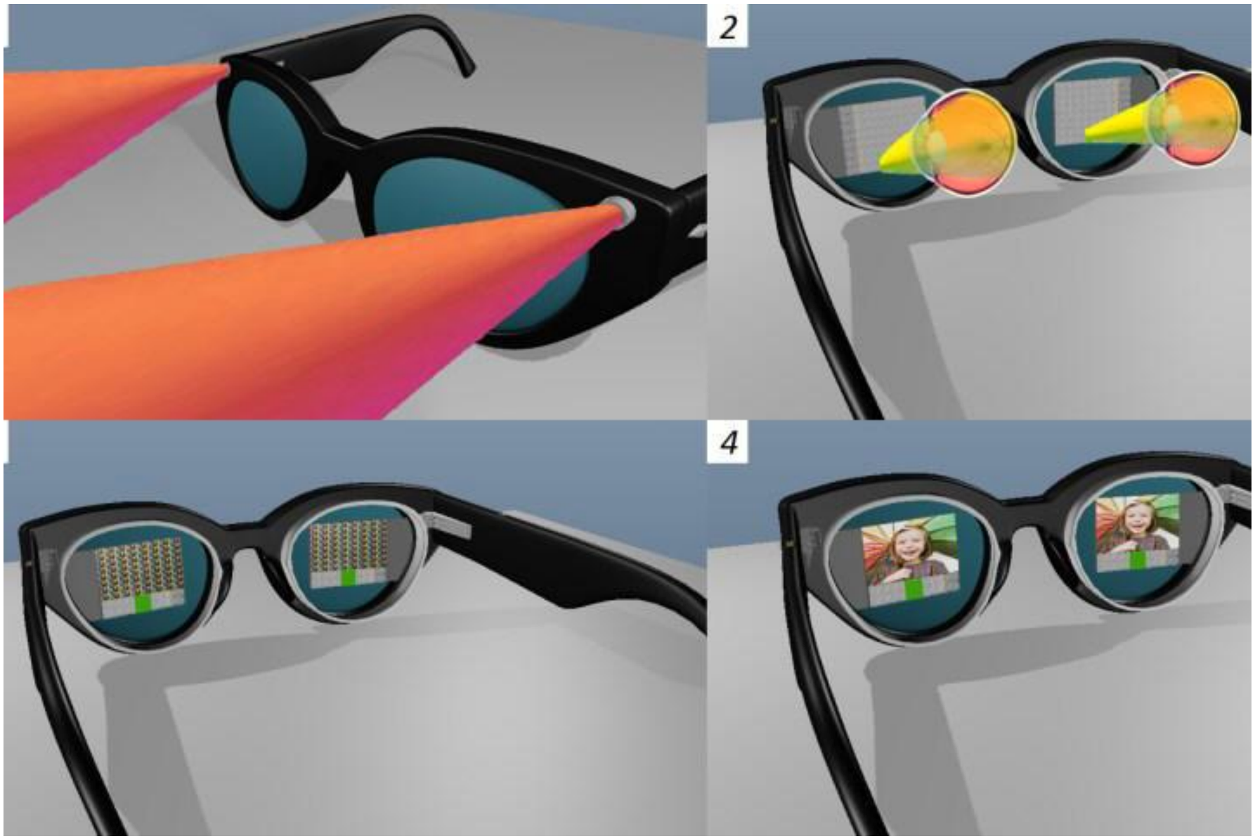
My first thoughts upon seeing the company's pitch in my inbox were of my own family — my mother with AMD (Age-related Macular Degeneration) and also my son, who experienced loss of vision from his brain tumor.

So, there I was, wading through the sea of people in Eureka Park, the Wild West of CES, attempting to find a small booth for a startup that went by the strange name, Soliddd. The company was there showing off its prototype smart glasses, known as Soliddd Vision, a piece of technology that aims to recover sight to people with low-vision conditions, including macular degeneration. The claim is huge: think of it like hearing aids for your eyes. Or, according to its ambitious CEO, Neal Weinstock, "giving sight to the blind."

As a kid, it's poor vision that affects our son's daily life most. Despite being tumor-free since his miraculous surgery in 2023, he still requires daily supplementary hormone replacements and experiences poor vision in one of his eyes. You'd never know it from his attitude on life, but he's been patching one eye for four hours a day for most of his life, and lack of vision affects lots of daily kid activities, like playing hide-and-seek or being able to spot an airplane in the sky.

But again, hope.

I tried on the delicate pair of prototype glasses. At this stage, they felt less like a pair of glasses and more like a small headset. The technology behind them, though, has the potential to be downright revolutionary. The frames have two cameras pointing out to capture the world and two pointing in to calibrate to the movement of your eyes.



The feed from the exterior cameras image is then projected into the micro display on the lens — but not just once. The lens actually has an array of displays on it, all showing the same image. What the founder and CEO of the company discovered was that the eye could be tricked into piecing this array of high-resolution images together into a single image.

Weinstock is an engineer with a background in 3D work, and the early prototypes of the Soliddd Vision were actually an example of autostereoscopic, or glasses-free 3D. But after working with Rich Muller, a physicist at University of California, Berkeley, he came upon the realization that there was an application for restoring vision.

“What the brain makes of these multiple images is something that people in computer science grok better than ophthalmologists,” Weinstock told me. “First of all, the ophthalmologists think that the resolution in these far regions of the eye is so low compared to the fovea. But everyone knows that your iPhone or

Samsung phone are putting together multiple images from separate cameras and constructing better acuity in terms of a person's vision. That's what the brain does."

Phone manufacturers had actually unknowingly mimicked the operation of the brain, and now that understanding is being reverse-engineered. By creating an array of Maxwellian displays, also known as retina-projection displays, Soliddd can aim a pinhole light through the natural lens of the eye without engaging the focusing mechanism, as Weinstock explained.

The brain does what it's always done — take the vision from your left eye and your right eye and add them together to create the single clearest image. With Soliddd Vision, the brain is taking this array of images from the lens and projecting them to the entirety of the retina — and self-selecting to create a perfectly in-focus image.

"We divide the content coming in from the cameras into an array of all the same image, which goes through the lens and delivers to the eye in perfect focus — directly to the retina," the chairman of Soliddd, Derek Myers, explained to me. "Those optic nerves are then capable of reading that and constructing a single image — in perfect focus. Therefore eliminating the areas of the eye that are degenerative."

Although wearing the glasses myself didn't immediately give me perfect vision, I could see what he was saying. Peering through the prism of screens, and after a couple of small adjustments, I was, indeed, seeing them as a single image. And with that, a spark of hope.

Early tests are promising

Soliddd says it's already working with early patients with conditions such as AMD (Age-related Macular Degeneration) and even coronary dystrophy, which can affect much younger people. One early patient is just 19, and after using the prototype glasses, reported fully restored central vision.

The form factor is important, of course, which Soliddd admitted. After all, if a pair of glasses was inconvenient, uncomfortable, or socially obtrusive, people would be far less likely to adopt them into their daily lives. Soliddd says it will be benefitting from all the advancements happening in the wider industry around compact form factors, which remains one of the biggest hurdles to adoption of smart glasses. We've all seen the success of glasses like the Ray-Ban Meta smart glasses, and much of that has to do with form factor.

I was shown renderings of what the company expects the consumer version of this product to look like, though, and they certainly seemed promising.

The company is considering the entire product package too, including the resolution and image quality — as well as ergonomics, privacy, and security concerns. All things that matter quite a bit when you're augmenting one's vision.

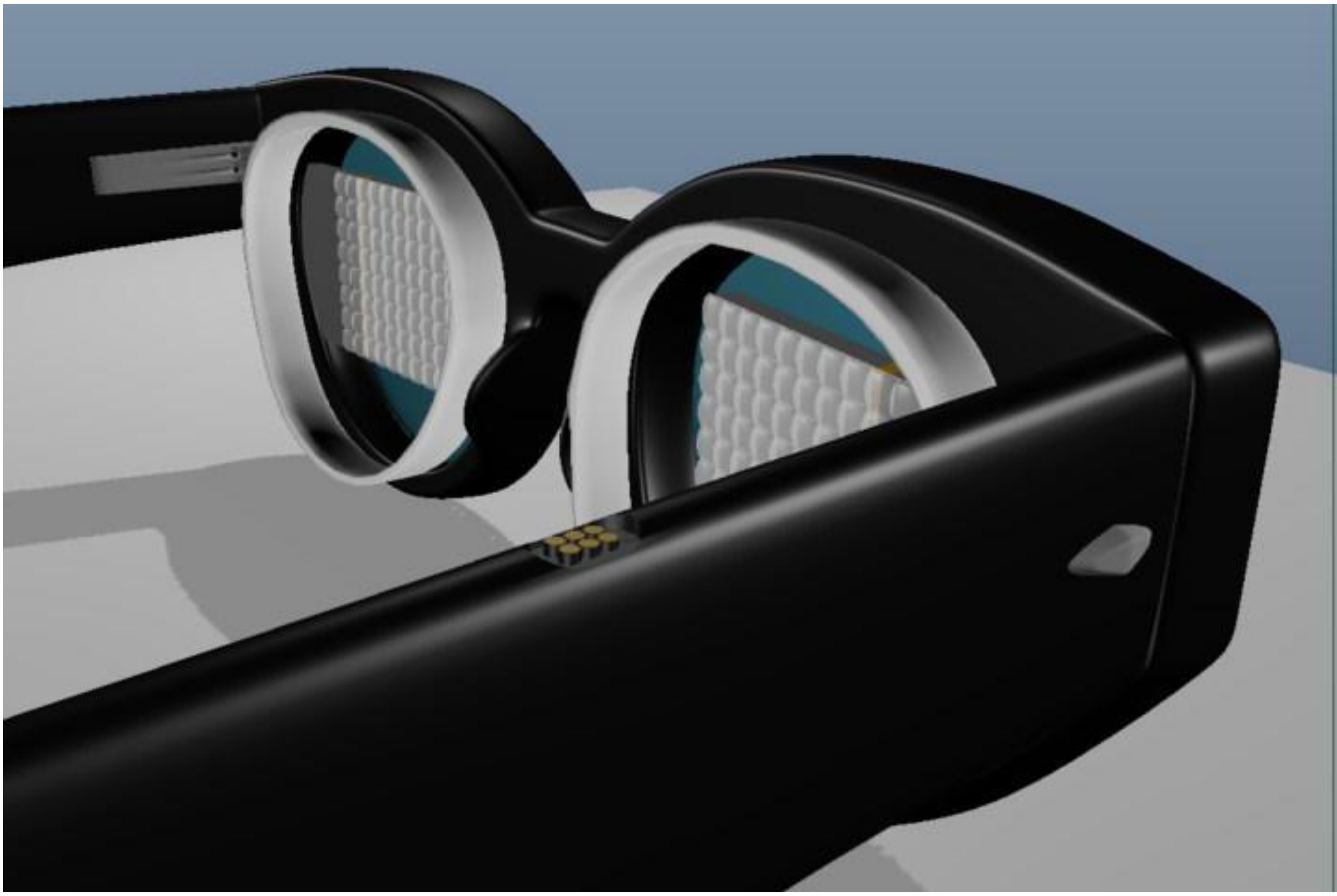
Perhaps even more exciting, though, Myers explained that future updates to the product could include a more fine-tuned solution for the specific mapping of a patient's individual retina. This could be important for someone like our son, who lacks peripheral vision on one side of his eye.

As he explained these things, I couldn't help but think of my son — perhaps in his teens or 20s — and what his life would be like. Don't get me wrong — on the other side of his surgery, I have so much hope and optimism for his future. And yet, what would technology in its infancy today would be fully matured in 10 or 20 years? It'd be disingenuous not to hope, especially since we've benefitted so much from advances in technology that aided in his own treatment.

His brain surgery, which was successfully completed entirely through his nasal cavity, used advanced technology and techniques that never would have been possible a few decades ago. That's because of endoscope cameras and tiny instruments, yes. But the first time the surgery had been done on a child of his age was only four years earlier by the same surgeon, who used a 3D-printed skull and virtual reality to ensure the surgery could be completed.

In our son's case, the result was a clean resection of the tumor with as minimal an impact as possible. On one hand — a tried-and-true miracle. On the other, more proof that advances in technology really do *matter*.

A not-so-distant future


Soliddd

Soliddd is currently fundraising, but it already has plans to put out a consumer product in the near future, as early as the first quarter of next year.

But let me clear: As of now, I don't know for sure that something like Soliddd could help my son's vision. He may have damage to his actual optic nerves from the tumor, which is wholly different from retinal deterioration. Furthermore, this first version of smart glasses may only have a few hours of battery life, designed for limited, at-home use.

But visual deficits that could benefit from such glasses run deep in my family. My mother has AMD, and my nephew may have some form of retinal damage as well. AMD is thought to be a generic condition that can be passed down generation to generation. Who knows — it may even be something I have to experience at some point, and is certainly therefore possible to pass on to our children.

As I described my son's condition to another Soliddd representative, he gave me a knowing grin.

"I can't tell you how many people have said that coming through here. You do the business conversation, and then it's my mom, my dad, my uncle, my grandpa."

As I've seen in my mother's own battle with AMD, there's no easy cure for the disease. It tends to progress over time, and the best treatments we have now can only hope to slow the deterioration of the retina. Technology like Soliddd provides an alternative solution. But for me, it's less that Soliddd's specific solution is the end-all-be-all. It's that CES and the tech world at large are full of ideas just like this. A smart walking cane with GPS and AI built into it for the blind, advanced smart hearing aids, and even an at-home AI stethoscope.

I'm not one to bank all my hope for the future in technological progress, but I walked away from CES this year dropping the skepticism and reigniting my sense of optimism about the potentially life-changing technology that is currently in development — and could be just a few years away.

Maybe someday, it could even mean that our son gets to live his dream of driving a car. I have more hope today than ever.

Virtual screening identifies potential treatments for inherited eye disease that causes blindness

Treatment with bioavailable small-molecule pharmacochaperones targeting the visual receptor rhodopsin offers a promising approach to prevent retinal photoreceptor degeneration caused by inherited mutations in this receptor. Credit: Beata Jastrzebska, created from images on Pixabay by justDIYteam and WikimediaImages (CC-BY 4.0, creativecommons.org/licenses/by/4.0/)

Two new compounds may be able to treat retinitis pigmentosa, a group of inherited eye diseases that cause blindness. The compounds, described in a study published January 14 in the open-access journal *PLOS Biology* by Beata Jastrzebska from Case Western Reserve University, US, and colleagues, were identified using a virtual screening approach.

In retinitis pigmentosa, the retina protein rhodopsin is often misfolded due to genetic mutations, causing retinal cells to die off and leading to progressive blindness. Small molecules to correct rhodopsin folding are urgently needed to treat the estimated 100,000 people in the United States with the disease.

Current experimental treatments include retinoid compounds, such as synthetic vitamin A derivatives, which are sensitive to light and can be toxic, leading to several drawbacks.

In the new study, researchers utilized virtual screening to search for new drug-like molecules that bind to and stabilize the structure of rhodopsin to improve its folding and movement through the cell. Two non-retinoid compounds were identified which met these criteria and had the ability to cross the blood-brain and blood-retina barriers.

The team tested the compounds in the lab and showed that they improved cell surface expression of rhodopsin in 36 of 123 genetic subtypes of retinitis pigmentosa, including the most common one. Additionally, they protected against retinal degeneration in mice with retinitis pigmentosa.

"Importantly, treatment with either compound improved the overall retina health and function in these mice by prolonging the survival of their photoreceptors," the authors say. However, they note that additional studies of the compounds or related compounds are needed before testing the treatments in humans.

The authors add, "Inherited mutations in the rhodopsin gene cause retinitis pigmentosa (RP), a progressive and currently untreatable blinding disease. This study identifies small molecule pharmacochaperones that suppress the pathogenic effects of various rhodopsin mutants in vitro and slow photoreceptor cell death in a mouse model of RP, offering a potential new therapeutic approach to prevent vision loss."

More information: *PLOS Biology* (2025). DOI: 10.1371/journal.pbio.3002932

Provided by Public Library of Science

DEAR READER,

THIS IS AN AUTOMATED MESSAGE FROM YOUR PREFRONTAL CORTEX

We regret to inform you that your brain has gone offline. Possible causes include:

- **Excessive Netflix binging**
- **Acute caffeine deficiency**
- **Exposure to reality TV**
- **Reading too many emails about neuroscience**

PLEASE STANDBY FOR EMERGENCY REBOOT SEQUENCE

...

...

...

REBOOT FAILED

INITIATING CONTINGENCY PLAN OMEGA

Hello, DEAR READER. If you're reading this, the joke's on me. You're clearly still brain-functional. Congratulations!

But humor me for a moment. What if your brain really did go offline? What would you miss most?

Your memories? Your ability to speak? Your sense of self?

Here's a mind-bender: You wouldn't miss anything. Because without your brain, there wouldn't be a "you" to do the missing.

Your brain isn't just a tool you use. It is you. Every thought, every feeling, every quirk that makes you uniquely you - it's all in that 3-pound blob of jelly between your ears.

So maybe the real question is: who's in charge here? You, or your brain?

It's a trick question.

You ARE your brain. But also… you're so much more.

You're the stories you tell yourself. You're the habits you've formed. You're the people you love and who love you back.

You're a walking, talking, miracle of nature - 86 billion neurons working in harmony to create the experience of being you.

And the coolest part? You can change. You can rewrite your stories. You can form new habits. You can forge new connections - neural and social.

So, DEAR READER, let's put this power to use. Here are three "brain hacks" to tap into your neural plasticity:

1. The 2-Minute Rule: When a task seems daunting, commit to just 2 minutes. Your brain, wired to finish what it starts, will often keep going. Writing a book becomes "write one sentence." Cleaning the house becomes "pick up one item." Small wins snowball into big changes.
2. Sensation Swapping: Deliberately mix up your senses. Eat with your eyes closed. Listen to music while focusing on what you feel rather than hear. This forces your brain to create new neural pathways, enhancing creativity and cognitive flexibility.
3. The Feynman Technique: To learn anything, explain it to a 12-year-old (real or imaginary). This forces your brain to translate complex ideas into simple terms, solidifying your understanding and highlighting knowledge gaps.

Remember: You're not just a brain. You're a brain-powered possibility machine.

Now, if you'll excuse me, I need to go reboot my own brain. I hear a 20-minute power nap works wonders.

Stay miraculous,

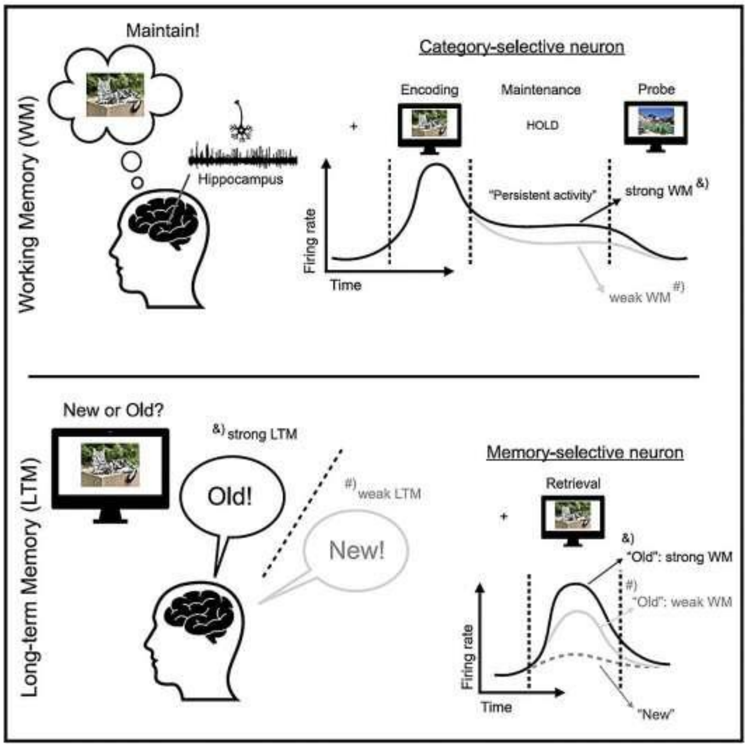
Lee Anderson
Founder, NeuroLaunch.com

P.S. This email will self-destruct in 5… 4… 3…

Just kidding. But your brain is constantly destroying and recreating memories as we speak. Why not use this to your advantage? Each night, mentally review one thing you want to remember. Your brain will strengthen that neural pathway, making the memory more resilient. Sweet dreams!

JANUARY 10, 2025

Single-neuron mechanism may bridge gap between working memory and long-term memory



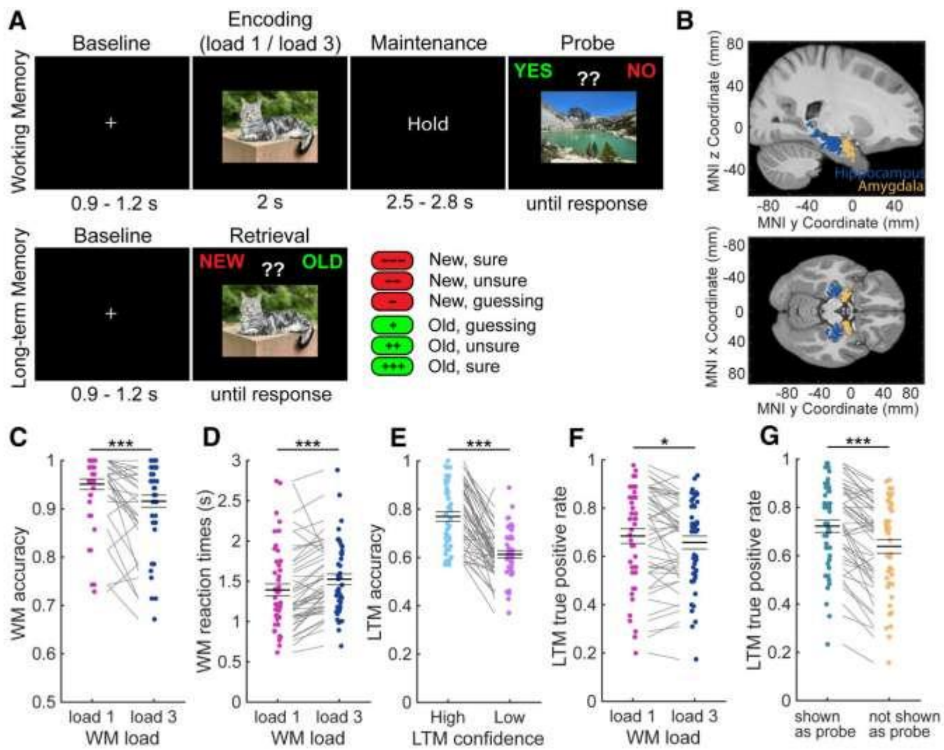
The human working memory (WM) is the cognitive system responsible for the temporary storage and processing of information vital to task completion. In contrast, human long-term memory (LTM) is the system that holds information for prolonged periods of time, organizing acquired knowledge into distinct categories, such as facts, events, skills and habits.

For decades, most psychologists and neuroscientists have viewed these two memory components as separate systems, one tackling short-term and the other long-term tasks, supported by distinct neural processes. Therefore, most studies conducted so far have focused on only one of these systems, instead of exploring the potential connections between working memory and long-term memory processes.

Researchers at the Cedars-Sinai Medical Center and other institutes recently set out to simultaneously investigate the neural underpinnings of both WM and LTM, to determine whether these systems utilize some common mechanisms to store information. Their findings, published in *Neuron*, suggest that the two systems interact in the hippocampus, with persistent WM activity predicting the formation of LTM.

"Working memory (WM) and long-term memory (LTM) are often viewed as separate cognitive systems," wrote Daume, Kamiński and their colleagues in their paper. "Little is known about how these systems interact when forming memories. We recorded single neurons in the human medial temporal lobe while patients maintained novel items in WM and completed a subsequent recognition memory test for the same items."

The researchers carried out experiments involving 41 patients diagnosed with epilepsy who had electrodes implanted in their brains via an invasive procedure to monitor their brain activity. These electrodes allowed the researchers to record the activity of single neurons in their medial temporal lobe, which includes various brain regions associated with memory encoding and information processing, particularly the hippocampus and amygdala.



Experimental design and behavioral analysis. Credit: *Neuron* (2024). DOI: 10.1016/j.neuron.2024.09.013

The patients were asked first to complete a task designed to engage the WM and then a task that recruits the LTM. The researchers then compared the single-neuron recordings they collected while the participants were completing these two tasks, to determine whether the two systems shared any single-neuron mechanisms.

"In the hippocampus, but not in the amygdala, the level of WM content-selective persistent activity during WM maintenance was predictive of whether the item was later recognized with high confidence or forgotten," wrote Daume, Kamiński and their colleagues.

"By contrast, visually evoked activity in the same cells was not predictive of LTM formation. During LTM retrieval, memory-selective neurons responded more strongly to familiar stimuli for which persistent activity was high while they were maintained in WM."

Interestingly, the researchers found that persistent activity of category-selective neurons in the hippocampus while participants were storing information in their WM predicted the formation of LTMs. In addition, selective neurons associated with LTMs fired more when participants were presented with items that were associated with a strong WM activity.

"Our study suggests that hippocampal persistent activity of the same cells supports both WM maintenance and LTM encoding, thereby revealing a common single-neuron component of these two memory systems," wrote Daume, Kamiński and their colleagues.

The results gathered by this team of researchers offer new insight into the neural underpinnings of WM and LTM processes, suggesting that they are linked by a common single-neuron mechanism. In the future, they could inform additional studies focusing on this mechanism and exploring the link between the two memory systems.

More information: Jonathan Daume et al, Persistent activity during working memory maintenance predicts long-term memory formation in the human hippocampus, *Neuron* (2024). DOI: 10.1016/j.neuron.2024.09.013.
Journal information: Neuron

-

JANUARY 11, 2025

Smart glasses enter new era with sleeker designs, lower prices

Halliday-branded smart glasses on display at the Consumer Electronics Show in Las Vegas, where wearable tech innovations are on prominent display.

Producers of hi-tech connected eyewear are multiplying their innovations with increasingly discreet models in an attempt to make a difference in a highly competitive—and fast-emerging—market.

Live translation, GPS, cameras: glasses are quickly adopting new functionalities.

"There are so many of these smart wearables, and more of them are going on your face," said Techsponential analyst Avi Greengart at the Consumer Electronics Show (CES) in Las Vegas, where numerous smart glasses manufacturers showcased their latest innovations.

The industry has come a long way from its early days. Gone are the conspicuous protrusions of Google Glass and the bulky frames and cables of Epson's Moverio from the early 2010s.

Today's smart glasses, all paired with smartphone apps, increasingly resemble traditional eyewear. The Ray-Ban Meta, developed by Mark Zuckerberg's social media giant, currently leads the market with this new approach.

According to a recent MarketsandMarkets study, the sector's growth is "driven by advancements in augmented reality, artificial intelligence, and miniaturization technologies, which are pushing the boundaries of what these wearable devices can achieve."

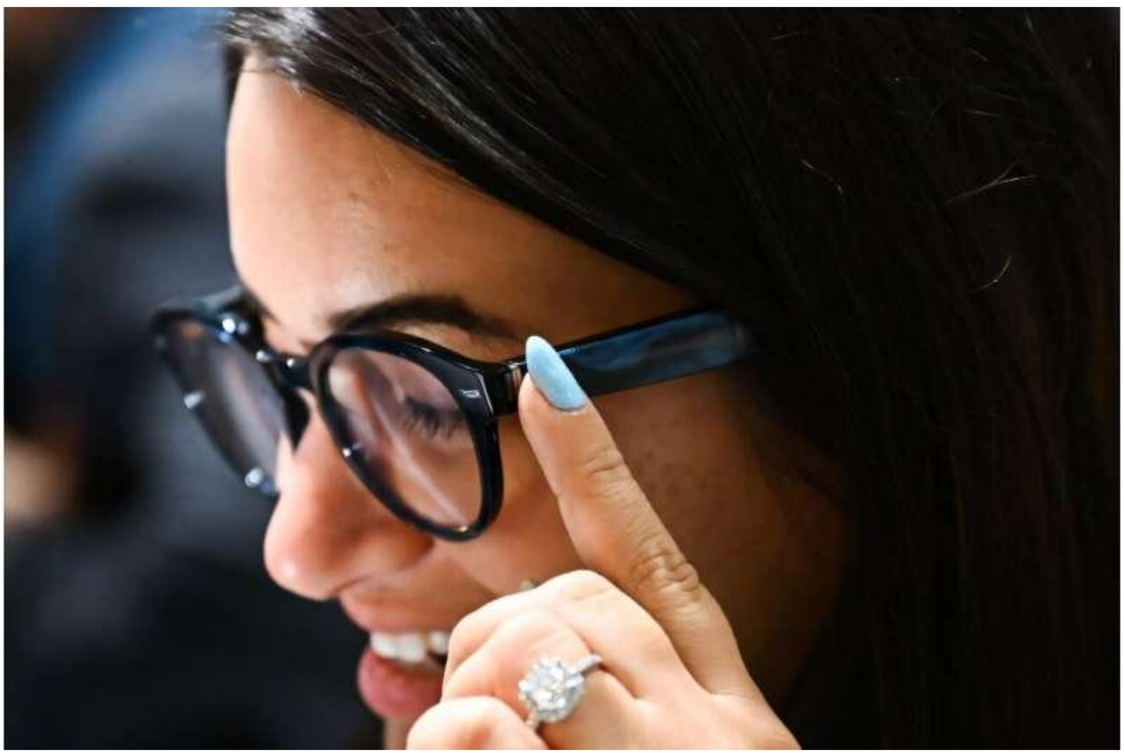
However, integrating technology into fashionable frames requires careful compromise.

The Ray-Ban Meta, for instance, can capture photos and videos, play music, and provide information about objects in view, but doesn't offer augmented reality with superimposed images.

Meta representative Robin Dyer explained that while AR capabilities may come later, they would likely double the current price.

200 dollars

Price is a major battleground in this market, particularly with the entry of Chinese manufacturers.



Amazon's Echo Frames connected glasses on display at CES on January 7, 2025 in Las Vegas.

While Google Glass initially retailed for around $1,500 in 2013, today's smart glasses are approaching the price of premium conventional frames.

Meta's James Nickerson noted that their Ray-Ban collaboration starts at $300, just $50 more than standard Ray-Bans, offering "a cool camera" as a bonus.

California startup Vue has pushed prices even lower, offering basic models with voice assistant and music capabilities for $200.

Some manufacturers, like XReal, focus on augmented reality, projecting smartphone, computer, or gaming console displays—though this is a market for which Apple's Vision Pro failed to create excitement last year.

For AR, recent advances help move away from the bulk of a virtual reality headset towards that of classic sunglasses, even if they require a cable to be connected to the device.

Meta's ambition is to launch its own pared down version, the Orion, currently in the test phase but not expected to be marketed until 2027 at the earliest.

Chasing cool

Companies like Even Realities and Halliday are pioneering ultra-thin frames that look identical to standard glasses while offering basic AR capabilities.

"If we want to make a good pair of smart glasses, we must first make a pair of cool glasses," emphasized Carter Hou, Halliday's second-in-command.

Halliday's $489 model, launching in March, displays text in the upper corner of the wearer's vision. Using AI, it can suggest responses during conversations, provide real-time translation, and function as a discrete teleprompter.

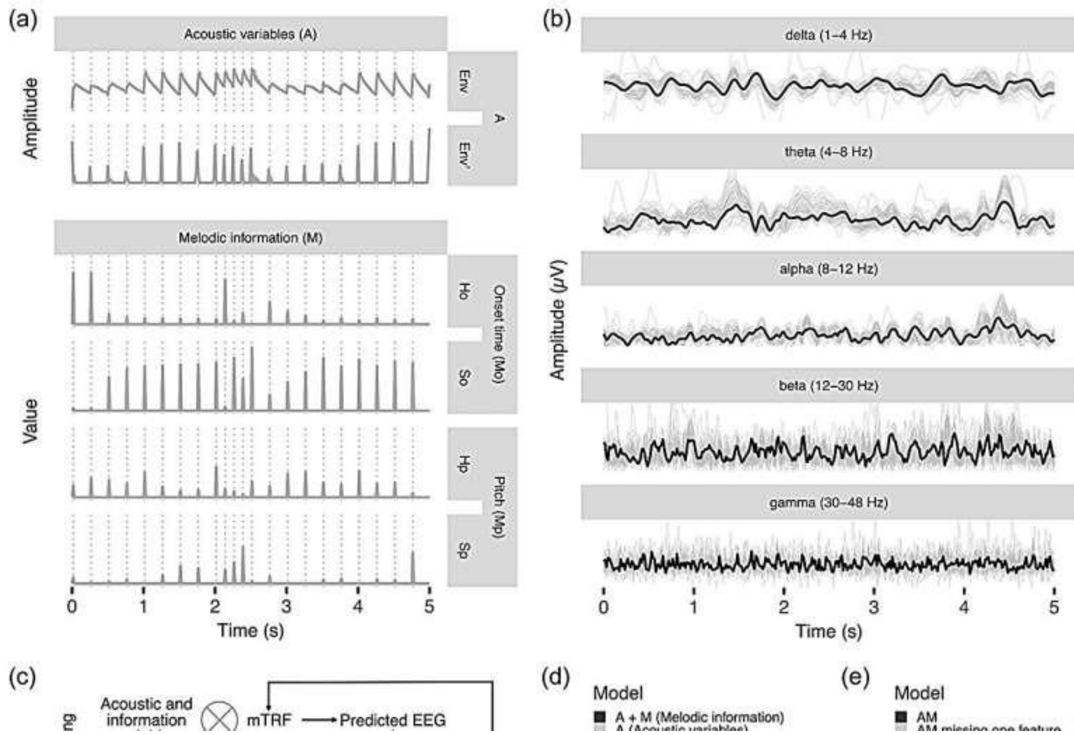
Even Realities has also taken a minimalist approach.

"We got rid of the speaker, we got rid of the camera," explained the company's Tom Ouyang. "Glasses are for the eyes, not the ears."

NOVEMBER 14, 2024

Study explores how brain waves reflect melody predictions while listening to music

by Ingrid Fadelli , Medical Xpress



A, Snippet of the sets of regressors obtained from one piece of music used to calculate the TRFs. From top to bottom: acoustic envelope (Env), half-way rectified first derivative of the envelope (Env'); melodic information for note onset (Mo): onset entropy (Ho), onset surprisal (So); melodic information for note pitch (Mp): pitch entropy (Hp), and pitch surprisal (Sp). Based on Di Liberto, Pelofi, Bianco, et al. (2020). B, Snippet of pre-processed EEG bands of a single subject used for TRF analysis. Gray lines represent individual channels and black lines represent the average amplitude across electrodes for each frequency band. C, Schematic of the pipeline. Melodic information features were extracted with IDyOM (Di Liberto et al., 2021; Pearce, 2005). Separate multivariate temporal response function (mTRF) models were trained from the preprocessed EEG signal and the acoustic and melodic information features (see Materials and methods). The sets of features were convolved with the corresponding optimal TRFs to predict the EEG signals. The reconstruction accuracy is calculated as the Pearson correlation between the original filtered EEG and the predicted one. D, Hypothetical enhancement in EEG reconstruction accuracy of a model trained on acoustic and melodic information variables (AM) compared to a model trained only on acoustic regressors. Based on Di Liberto, Pelofi, Bianco, et al.

(2020). E, Hypothetical unique contribution of an individual feature to the full model, measured as the difference in the Pearson correlation between the reconstruction accuracy obtained using the AM model and the same model missing one specific feature.
Credit: *European Journal of Neuroscience* (2024). DOI: 10.1111/ejn.16581
The human brain is highly skilled at detecting patterns in the world and using this information to predict future events. This ability to anticipate events is also reflected in how we experience music, precisely in our ability to intuitively anticipate what will come next in a melody we are listening to.

Researchers at the Max Planck Institute for Human Cognitive and Brain Sciences have been trying to better understand the complex neural dynamics underpinning this ability to predict upcoming melodies in music. Their most recent paper, published in the *European Journal of Neuroscience*, shows that uncertainty (i.e., entropy) plays a key role in melody prediction, while also highlighting new differences in how the brains of musicians and non-musicians process music.

"Prior work on music cognition suggests that low-frequency (1–8 Hz) brain activity encodes melodic predictions beyond the stimulus acoustics," wrote Juan-Daniel Galeano-Otálvaro, Jordi Martorell and their colleagues in their paper. "Building on this work, we aimed to disentangle the frequency-specific neural dynamics linked to melodic prediction uncertainty (modeled as entropy) and prediction error (modeled as surprisal) for temporal (note onset) and content (note pitch) information."

For the purpose of their study, the researchers recruited 20 participants, half of whom were professional pianists. These participants were asked to listen to 10 piano melodies extracted from the work of Johann Sebastian Bach, each lasting approximately 150 seconds.

The participants listened to each of these melodies three times. While they were listening, the researchers collected recordings using electroencephalography (EEG), a technique that relies on electrodes to measure the brain's electrical activity.

The team calculated the probability of specific notes following others in a sequence and this allowed them to compute the surprisal that segments of a melody would typically elicit. They then separately computed entropy, a measure of uncertainty, as the average of surprisal over all continuations in a note sequence.

Galeano-Otálvaro and his colleagues analyzed the participants' EEG recordings using different software toolkits for scientific research, including MATLAB, the FieldTrip toolbox and the EEGLAB toolbox. Their analyses unveiled neural correlates of melody prediction while listening to music.

"Our results show that melodic expectation metrics improve the EEG reconstruction accuracy in all frequency bands below the gamma range (< 30 Hz)," wrote the researchers. "Crucially, we found that entropy contributed more strongly to the reconstruction accuracy enhancement compared to surprisal in all frequency bands. Additionally, we found that the encoding of temporal, but not content, information metrics was not limited to low frequencies, rather it extended to higher frequencies (> 8 Hz)."

Overall, the researchers found that uncertainty (i.e., entropy) in melody is encoded in neural responses that range across different frequency bands. The researchers were also able to pinpoint the frequencies that could encode uncertainty about the onset of notes before the participants heard a given note.

"An analysis of the temporal response function (TRF) weights revealed that the temporal predictability of a note (entropy of note onset) may be encoded in the delta- (1–4 Hz) and beta-band (12–30 Hz) brain activity prior to the stimulus, suggesting that these frequency bands associate with temporal predictions," wrote the researchers.

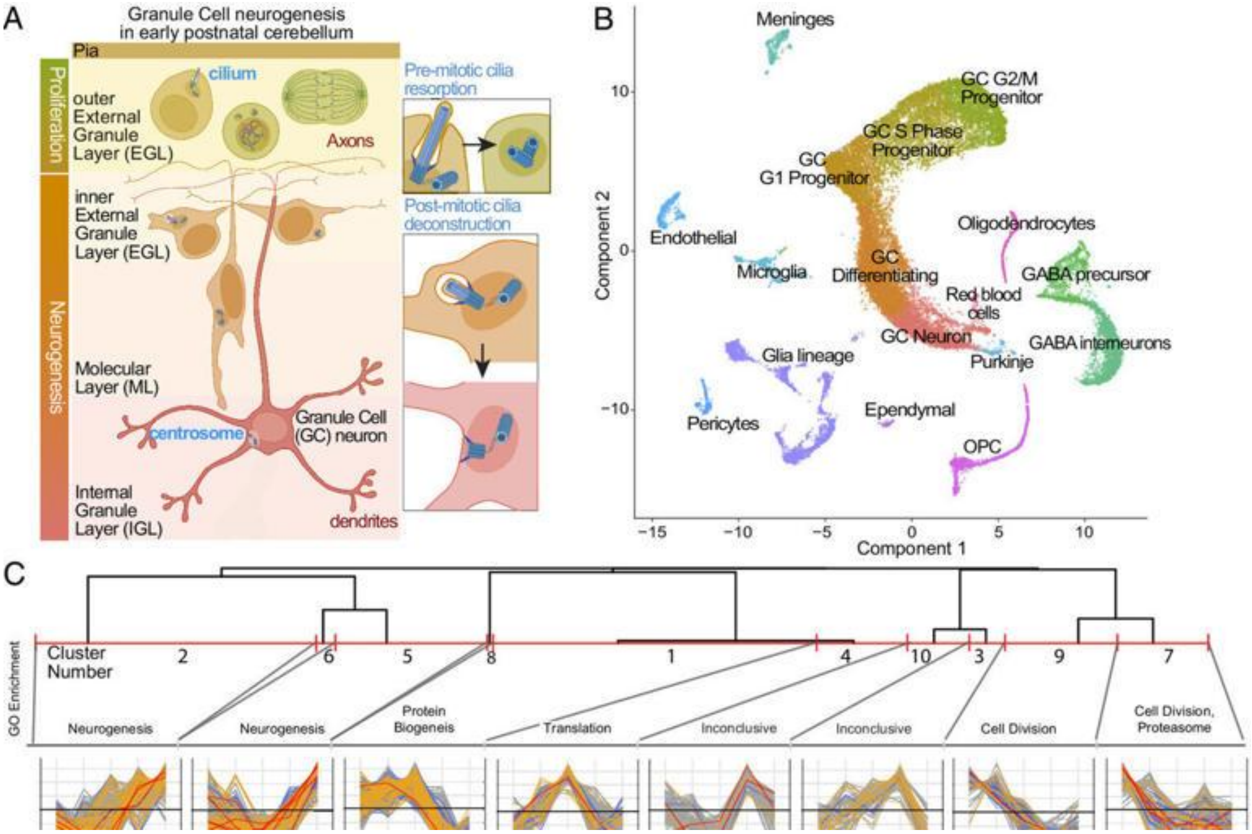
"Strikingly, we also revealed that melodic expectations selectively enhanced EEG reconstruction accuracy in the beta band for musicians, and in the alpha band (8–12 Hz) for non-musicians, suggesting that musical expertise influences the neural dynamics underlying predictive processing in music cognition."

In addition to gathering insight about the brain activity underpinning melody prediction while listening to music, the researchers observed differences between the electrical activity in the brain of professional pianists and non-musicians. Specifically, they found that melody predictions correlated with more brain waves in the beta frequency band for pianists and in the alpha band for non-musicians

The team's interesting results could soon pave the way for new studies exploring the neural correlates of melody prediction or the differences observed between musicians and non-musicians. These works could further enrich the present understanding of how the human brain processes music and predicts upcoming events.

More information: Juan-Daniel Galeano-Otálvaro et al, Neural encoding of melodic expectations in music across EEG frequency bands. *European Journal of Neuroscience*(2024). DOI: 10.1111/ejn.16581
Journal information: European Journal of Neuroscience

Scientists reveal cilia's secrets using connectome data



Credit: Proceedings of the National Academy of Sciences (2024). DOI: 10.1073/pnas.2408083121

By reexamining 3D images used to map the connections between brain cells, researchers are uncovering new information about a small, elusive, and often overlooked cellular appendage.

Many cells in our body have a single primary cilium, a micrometer-long, hair-like organelle protruding from the cell surface that transmits cellular signals. Cilia are important for regulating cellular processes, but because of their small size and number, it has been difficult for scientists to explore cilia in brain cells with traditional techniques, leaving their organization and function unclear.

In a series of papers appearing in *Current Biology*, the *Journal of Cell Biology*, and the *Proceedings of the National Academy of Sciences*, researchers at HHMI's Janelia Research Campus, the Allen Institute, the University of Texas Southwestern Medical Center, and Harvard Medical School used super high-resolution 3D electron microscopy images of mouse brain tissue generated for creating connectomes to get the best look yet at primary cilia.

Their research uncovers new insights about cilia in these critical brain regions that could help scientists better understand their role and potential contribution to disease.

"Repurposing these large-volume EM datasets to look at cell biology has given us a view that you couldn't get before," says Carolyn Ott, a senior scientist in the Lippincott-Schwartz Lab who led the projects.

Revealing new biology

Cilia are notoriously difficult to study. In brain cells, a single cilium, only tens of microns long, extends from a cell's surface into a jumble of other cells. Using traditional microscopy methods to find and image cilia is like looking for needles in a haystack, and the sample sizes are often too small to draw conclusions. Researchers have gained some knowledge from studying isolated cilia in cultured cells, but these techniques miss information about how the organelle behaves in its natural environment.

In recent years, scientists have developed new ways to obtain ultra high-resolution 3D images of tissues, enabling researchers to see the inner workings of cells in fine detail. Collectively called volume electron microscopy, or volume EM, these methods use electron microscopes to image thin layers of a specimen and then stitch the layers together to create ultra high-resolution 3D pictures. Researchers have used this technology to create connectomes that provide maps of individual neurons and their connections in the brain.

But the volume EM images used to create connectomes don't just show neurons. They provide nanometer-scale views of all the cells and structures in a volume of tissue—including cilia.

"Every time you look into these large-scale volume data sets, you are seeing new biology," says Janelia Senior Group Leader Jennifer Lippincott-Schwartz, head of Janelia's 4D Cellular Physiology research area and a senior author on the new papers. "There is a lot of biology out there that we still don't have our hands on that is now possible because of this emerging technology."

Investigating cilia

Ott, who has been studying cilia for nearly two decades, first became intrigued with the idea of using volume EM to investigate the organelles when a visitor to the lab pointed out cilia in 3D images of mouse brain tissue. She was captivated by the ability to see dozens of cilia enmeshed in a network of cells and other structures.

"I was just fascinated to see the cilium in the context of the brain tissue, to see where it went and think about what was outside of it," Ott says. "With volume EM, you get a whole different kind of context."

Ott started looking deeper into the 3D EM images from Janelia, Harvard, and the Allen Institute that were used to generate connectomes. Realizing that they could see different types of cilia in different cell types, a team co-led by Ott and Russel Torres, a scientific programmer at the Allen Institute, decided to do a quantitative study of cilia in the cells of the mouse visual cortex, the brain region responsible for visual processing.

The result, published in *Current Biology*, is the most detailed and comprehensive description to date of the cilia in this part of the mouse brain, including which cell types do or do not have cilia, structural differences in cilia on different cell types, and the location of cilia near synapses, where signaling between neurons occurs.

Together, these findings provide new insights and raise new questions about how these differences and locations affect cilia function, Ott says.

"We know that diseases that involve cilia can have different symptoms, and having a better understanding that not all cilia are the same could help us understand why all disease phenotypes are not the same," she says.

Studying cilia development

After hearing about Ott's work on the visual cortex, Saikat Mukhopadhyay, an associate professor at UT Southwestern, approached her about using volume EM data to examine cilia on granule cells in the mouse cerebellum.

Cerebellar granule cells are the most abundant cell type in the mouse brain. These cells contain cilia while they are developing, which helps the cells detect a protein that controls proliferation and differentiation. But adult granule cells don't have cilia, which likely helps these mature neurons to stop growing and changing. Why and how the cells lose their cilia had intrigued Mukhopadhyay since he started working on cerebellum development, but traditional techniques didn't provide a clear picture of what was happening.

A team led by Ott and Sandii Constable, a former postdoc in the Mukhopadhyay Lab, was able to track down volume EM images of developing tissue in the mouse cerebellum, which allowed them to see cells and cilia in various stages of development, described in the *Journal of Cell Biology*. They saw that many of the cilia on intermediary cells are enclosed and concealed, ensuring that the cilia aren't exposed on the cell surface and limiting their ability to detect the protein that causes proliferation. In mature cells, the cilia are disassembled and go away completely. However, the centriole, the structure from which the cilium grows, remains docked on the surface of these mature cells.

Through additional analysis detailed in the *Proceedings of the National Academy of Sciences*, the team found that genes important for maintaining cilia turn off as the cells mature, suggesting that cells get rid of their cilia by stopping the synthesis of proteins needed to maintain them. The centriole on the cell's surface contains a capping complex that prevents the cilium from regrowing.

The new findings could help scientists understand a type of brain tumor in which mature granule cells abnormally retain cilia that are responsive to the protein that causes proliferation, allowing the tumor to grow. Understanding what is going wrong in the tumor cells could help scientists better understand the disease.

Mukhopadhyay says these findings would not have been possible without the volume EM images, which provide unprecedented views of the granule cells' cilia. Mukhopadhyay, who has studied cilia his entire career, says more researchers are paying attention to the importance of cilia than they were a decade ago.

"Now the frontier is: How is this causing disease, and can we do something to treat these patients," he says.

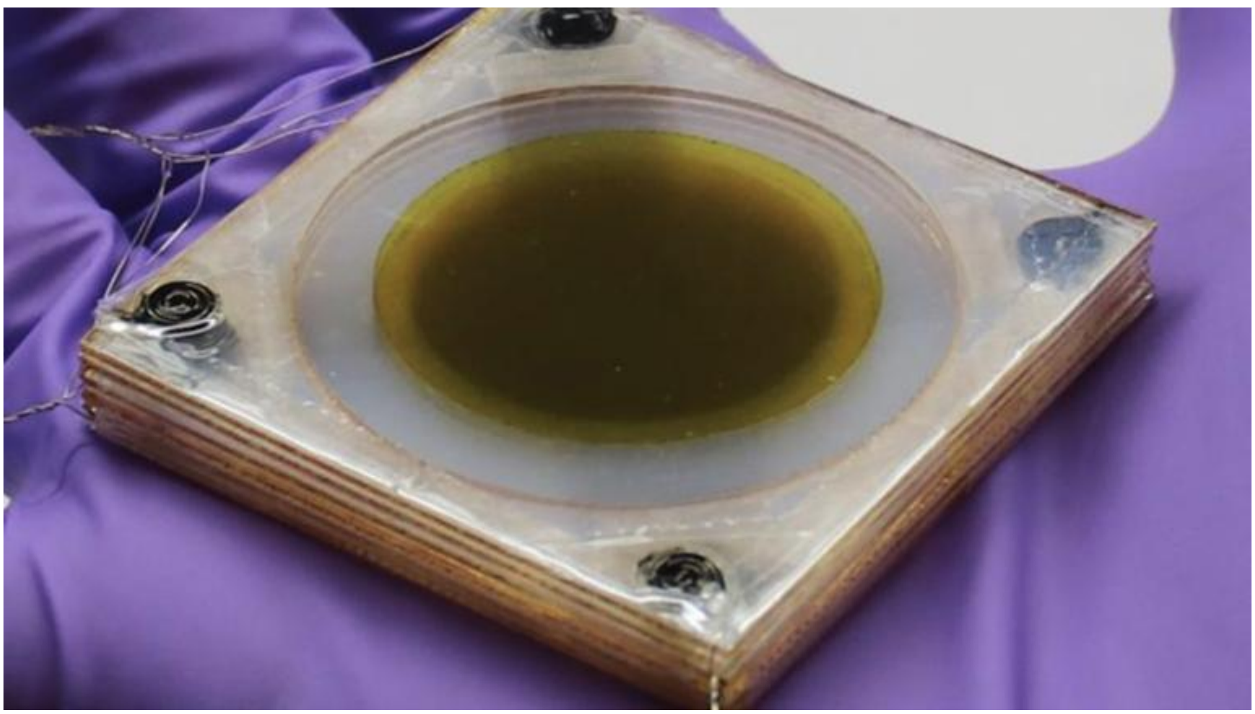
More information: Carolyn M. Ott et al, Ultrastructural differences impact cilia shape and external exposure across cell classes in the visual cortex, *Current Biology* (2024). DOI: 10.1016/j.cub.2024.04.043

Carolyn M. Ott et al, Permanent deconstruction of intracellular primary cilia in differentiating granule cell neurons, *Journal of Cell Biology* (2024). DOI: 10.1083/jcb.202404038

Sandii Constable et al, Permanent cilia loss during cerebellar granule cell neurogenesis involves withdrawal of cilia maintenance and centriole capping, *Proceedings of the National Academy of Sciences* (2024). DOI: 10.1073/pnas.2408083121

Provided by Howard Hughes Medical Institute

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.

Adults still develop new neurons: but what are they for?

Adults still develop new neurons: but what are they for? 🧠

Published December 17, 2024

Source: Cell Stem Cell

Your brain, far from being fixed in adulthood, continues to renew itself. Researchers reveal that the birth of new neurons in adults plays a key role in learning. This discovery overturns our understanding of human cognitive mechanisms.

The brain, the conductor of our body, relies on a network of neurons largely acquired at birth. However, certain regions continue to produce neurons throughout life. This process, though rare and limited, is called neurogenesis.

For a long time, scientists debated the true importance of this adult neurogenesis. Earlier studies observed a decrease in new neurons among patients with diseases such as Alzheimer's or epilepsy. This phenomenon was correlated with cognitive disorders, but the precise cause remained undetermined.

Recently, researchers at the University of Southern California delved into this mystery by studying patients with drug-resistant epilepsy. These patients, undergoing surgical procedures, provide a unique opportunity to collect and analyze human brain tissue.

The results are striking: new neurons in adults appear directly associated with verbal learning. These cells seem to enhance listening, understanding, and retaining information shared in conversations. This essential function, ironically, differs from findings in mice, where neurogenesis primarily supports spatial orientation.

To reach these conclusions, researchers analyzed specific markers in the brain tissue of patients. They discovered that fewer new neurons in the hippocampus correlate with a marked decline in verbal learning and memory capabilities.

This discovery opens new avenues of hope. Researchers believe stimulating neurogenesis could improve cognitive abilities in older adults or individuals with neurological disorders. Moreover, physical exercise is thought to have significant potential impacts on the production of new neurons in patients with epilepsy.

However, these approaches remain experimental. Researchers emphasize the need to deepen the study of neurogenesis directly in humans, which may differ from animal models. In the long run, these studies could transform our understanding of neurodegenerative diseases and aging mechanisms. The brain's renewal, even if limited, may well become a cornerstone of cognitive health.

What is adult neurogenesis?

Adult neurogenesis refers to the process of forming new neurons in the brain after birth, including during adulthood. Contrary to popular belief, the adult brain is not fixed but retains the ability to produce nerve cells, albeit in a limited manner.

This phenomenon primarily occurs in two regions: the hippocampus, involved in memory and learning, and the olfactory bulb, responsible for the sense of smell. These areas house stem cells capable of transforming into functional neurons.

Adult neurogenesis plays a key role in certain cognitive functions like learning, verbal memory, and spatial navigation. Its activity tends to decline with age or in cases of neurological diseases.

Recent studies suggest that stimulating neurogenesis through physical exercise or therapeutic approaches could potentially slow cognitive decline associated with aging or diseases like Alzheimer's.

It's proven: a simple gaze between dog and human can create a neural connection

Published October 25, 2024

Source: Advanced Science

The interactions between humans and dogs hide many mysteries. A new discovery reveals that our brains could be connected in a way never before observed: a neural bond that forms when our gazes meet.

This phenomenon, called "neural coupling," shows that our brains and those of dogs synchronize their activities when they share a moment of eye contact.

Interactions between dogs and humans can create an unprecedented neural bond. This phenomenon could strengthen the bond between us and our companions.

Researchers in China conducted the first study demonstrating this neural coupling between two different species. Using electroencephalography (EEG), they recorded the brain signals of dogs and humans during different interactions, including moments when they did not look at each other and others when they gazed at one another. The result: when the dog and the human shared a moment of gaze accompanied by petting, their brains "aligned" in areas related to attention.

This phenomenon intensified as the bond between the dog and the person grew stronger. The more time the participants spent together, the more their brain signals synchronized. This is reminiscent of similar observations in humans, where greater familiarity leads to greater neural synchronization.

The study also examined the impact of genetic mutations, notably in the Shank3 gene, known to affect brain connections in areas related to attention. In dogs carrying this mutation, neural coupling was diminished, which can be explained by difficulties in neuronal communication. This same gene is also associated with autism spectrum disorders in humans.

The researchers went further by administering a dose of LSD, a hallucinogen, to these mutant dogs. Surprisingly, this substance restored neural coupling and improved the animals' attention. This phenomenon has already been observed in mice and humans but raises ethical questions about the use of such substances to enhance social interactions in animals.

Although much remains to be discovered about this neural coupling between dogs and humans, this study opens up perspectives on how we could better understand and strengthen our relationship with our four-legged companions. The next time your dog looks you in the eye, remember that your brains may well be synchronizing, thus strengthening your bond.

What is neural coupling?

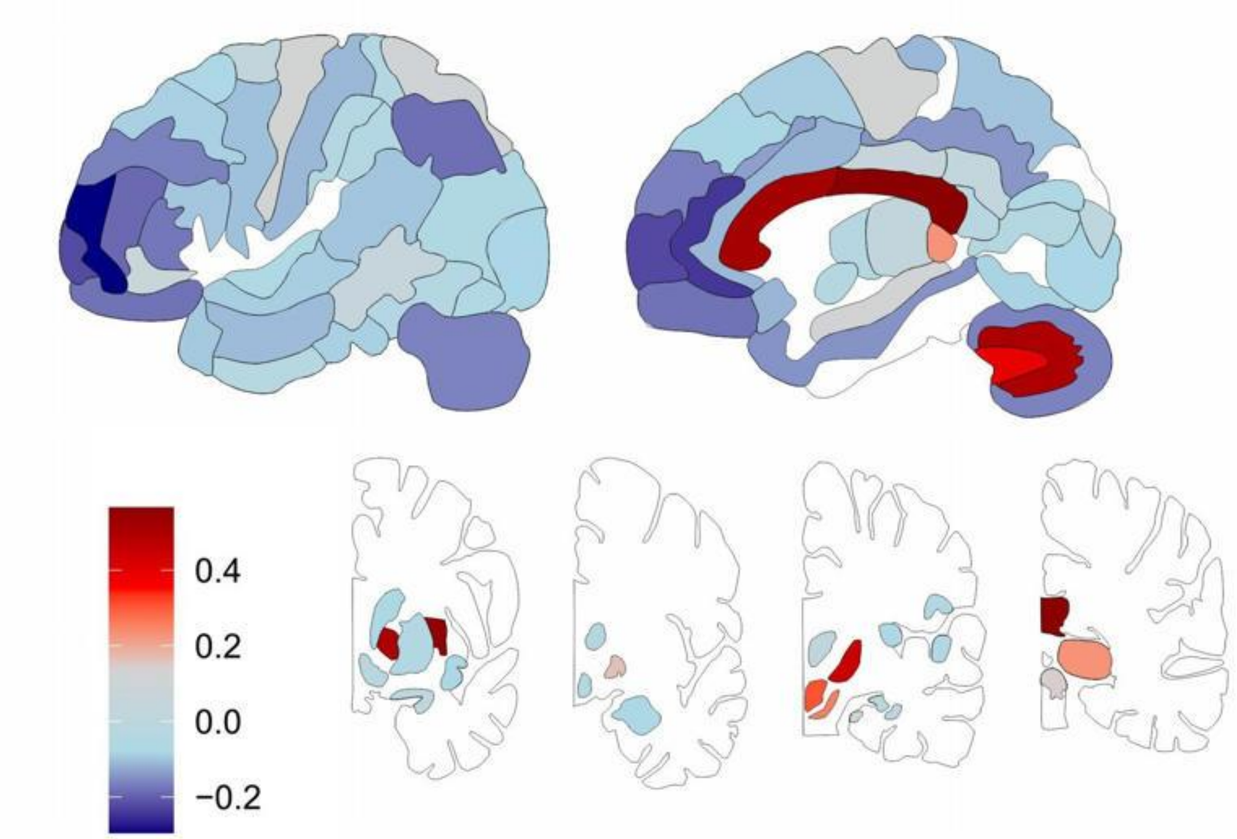
Neural coupling refers to the synchronization of brain activities between two or more individuals when they interact. This often occurs during conversations or emotional exchanges, where the brains of each individual "align."

This phenomenon plays a key role in our social interactions. It allows for better mutual understanding, facilitates communication, and can even strengthen collaboration or learning within a group.

In humans, this type of synchronization has been widely observed during discussions, but it also occurs in other social species, such as primates or rodents, during their social interactions.

For the first time, scientists have shown that neural coupling can also occur between different species, particularly between dogs and humans. This could explain why dogs are so responsive to our emotions and strengthen the emotional bond between us.

Scientists map the distribution of lipids in the human brain



Distribution of cholesterol in the human brain. Credit: Maria Osetrova© Provided by Medical Xpress

Scientists have found that 93% of the lipids in brain tissue are distributed differently in the white and gray matter, the subcortex, the visual and motor cortices, and the prefrontal cortex, which is responsible for decision-making, social behavior, and other functions.

Abnormalities in the brain lipidome tend to occur in mental and cognitive disorders, so mapping these molecules should help gain more information about the disease. The research was published in *Nature Communications*.

A major component of brain tissue, lipids are fatty compounds that make up 35%–40% of all the molecules in the gray matter cell bodies and as much as 78% of the axons' myelin sheaths in the white matter. Brain tissue lipids are very diverse and include cholesterol, phosphorus-containing compounds, such as phospholipids and sphingolipids, and other molecules.

Since lipids are involved in the metabolism and growth of neurons, the delivery of signals between cells and the control of inflammatory processes, abnormalities in the lipidome composition have been associated with cognitive disorders, such as autism, schizophrenia, and Alzheimer's disease.

However, the relationship between the lipidome and the structural features of brain tissue remains poorly understood, limiting the use of lipids as molecular markers for detecting brain diseases.

Researchers from the Skolkovo Institute of Science and Technology and their colleagues have created the world's first map of human brain lipids. They studied brain tissue samples from four healthy individuals and assessed the lipid composition in 75 different parts of the brain.

The lipids in the samples were identified using mass spectrometry, which allows determining a molecule's structure from the mass to charge ratio and its motion pattern in a magnetic field.

The researchers found a total of 419 different lipids, most of them (93%) unevenly distributed among the different parts of the human brain. For example, the subcortex (the oldest part of the brain), motor and visual cortices had relatively high levels of cholesterol, while the prefrontal cortex responsible for complex social behavior and decision-making had relatively low levels of this lipid.

Since most lipids are found in the myelin sheaths, the team checked whether the myelin content in a particular part of the brain affected its typical lipidome. The myelin-rich white matter turned out to contain mostly ceramides, two classes of phospholipids, and lipids with saturated fatty acids.

Since the main function of the white matter is to transmit signals via axons, these types of lipids are thought to be essential for the tissue to perform its function.

Polyunsaturated fatty acid lipids prevailed in the gray matter, which contains a concentration of cell bodies rather than axons and virtually no myelin. This suggests that such molecules may be important for signal processing in cells.

"In the future, we plan to thoroughly investigate the subcortical lipidome which was only partially covered by this research, and to study brain samples from patients with various mental disorders.

"The potential complete 'decoding' of the lipidome will help us to better understand the nature of mental illness and its impact on the structure and functioning of the brain," said Maria Osetrova, a research engineer at the Skoltech Neuro Center.

Other organizations involved in this research included Lomonosov Moscow State University, the Semenov Federal Research Center for Chemical Physics of RAS (Moscow), the University of Leipzig (Germany), and the National University of Singapore.

More information: Maria Osetrova et al, Lipidome atlas of the adult human brain, *Nature Communications* (2024). DOI: 10.1038/s41467-024-48734-y

Provided by Skolkovo Institute of Science and Technology

From first breath: How male and female brains really do differ at birth

CAMBRIDGE, England — The age-old debate about differences between male and female brains has taken a dramatic turn with new evidence suggesting these variations begin before a baby's first cry. In the largest study of its kind, researchers at Cambridge University's Autism Research Centre have discovered that structural brain differences between the sexes don't gradually emerge through childhood — they're already established at birth.

Brain development during the first few weeks of life occurs at a remarkably rapid pace, making this period particularly crucial for understanding how sex differences in the brain emerge and evolve. Previous research has primarily focused on older infants, children, and adults, leaving a significant gap in our understanding of the earliest stages of brain development.

The research team analyzed brain scans of 514 newborns (236 females and 278 males) aged 0-28 days using data from the developing Human Connectome Project. The study represents one of the largest and most comprehensive investigations of sex differences in neonatal brain structure to date, addressing a common limitation of past research: small sample sizes.

Male newborns showed larger overall brain volumes compared to females, even after accounting for differences in birth weight. This finding was particularly significant because the research team carefully controlled for body size differences between sexes, a factor that has complicated previous studies in this field.

New research reveals how babies' brains show some developmental differences before at birth. (© unlimit3d – stock.adobe.com)

When controlling for total brain volume, female babies exhibited greater amounts of gray matter — the outer brain tissue containing nerve cell bodies and dendrites responsible for processing and interpreting information, such as sensation, perception, learning, speech, and cognition. Meanwhile, male infants had higher volumes of white matter, which consists of long nerve fibers (axons) that connect different brain regions together.

"Our study settles an age-old question of whether male and female brains differ at birth," says lead author Yumnah Khan, a PhD student at the Autism Research Centre, in a statement. "We know there are differences in the brains of older children and adults, but our findings show that they are already present in the earliest days of life."

Several specific brain regions showed notable differences between males and females. Female newborns had larger volumes in areas related to memory and emotional regulation, while male infants showed greater volume in regions involved in sensory processing and motor control.

Dr. Alex Tsompanidis, who supervised the study, emphasizes its methodological rigor: "This is the largest such study to date, and we took additional factors into account, such as birth weight, to ensure that these differences are specific to the brain and not due to general size differences between the sexes."

The research team is now investigating potential prenatal factors that might contribute to these differences. "To understand why males and females show differences in their relative grey and white matter volume, we are now studying the conditions of the prenatal environment, using population birth records, as well as in vitro cellular models of the developing brain," explains Dr. Tsompanidis.

Importantly, the researchers stress that these findings represent group averages rather than individual characteristics.

"The differences we see do not apply to all males or all females, but are only seen when you compare groups of males and females together," says Dr. Carrie Allison, Deputy Director of the Autism Research Centre. "There is a lot of variation within, and a lot of overlap between, each group."

These findings mark a significant step forward in understanding early brain development, while raising new questions about the role of prenatal factors in shaping neurological differences. The research team's ongoing investigations into prenatal conditions and cellular models may soon provide even more insights into how these sex-based variations emerge.

"These differences do not imply the brains of males and females are better or worse. It's just one example of neurodiversity," says Professor Simon Baron-Cohen, Director of the Autism Research Centre. "This research may be helpful in understanding other kinds of neurodiversity, such as the brain in children who are later diagnosed as autistic, since this is diagnosed more often in males."

Paper Summary

Methodology Explained

The researchers used magnetic resonance imaging (MRI) to scan the brains of healthy, full-term newborns without sedation. They carefully controlled for factors like birth weight and age at scanning. The images were processed using specialized software designed for analyzing newborn brains, which separated different tissue types and measured volumes of specific brain regions. Statistical analyses compared these measurements between males and females while accounting for various factors that could influence the results.

Key Results

Males showed 6.16% larger total brain volume and 5.64% larger intracranial volume (total space inside the skull) compared to females, even after accounting for birth weight. Females showed relatively larger gray matter volumes, while males had relatively larger white matter volumes when controlling for overall brain size. Specific regions showed sex differences with small to medium effect sizes, meaning the differences were consistent but not dramatic.

Study Limitations

The study wasn't longitudinal, meaning it couldn't track how individual brains changed over time. The researchers couldn't establish direct causal relationships between prenatal factors (like hormones) and brain differences. Additionally, brain structure differences don't necessarily translate to functional differences, and the study couldn't account for all possible social and environmental influences.

Discussion and Takeaways

The research suggests three patterns: some sex differences present at birth persist throughout life, some appear later in development, and some are unique to the newborn period. This indicates that both prenatal and postnatal factors shape sex differences in the brain, with prenatal factors playing a particularly important role in establishing initial differences.

Funding and Disclosures

The study was funded by several organizations including the European Research Council, Wellcome Trust, Innovative Medicines Initiative, Cambridge University Development and Research, Trinity College, the Cambridge Trust, and the Simons Foundation Autism Research Initiative. One author disclosed being a director of and holding equity in Centile Bioscience Ltd.

Publication Information

Published in Biology of Sex Differences (2024) 15:81, the study titled “Sex Differences in Human Brain Structure at Birth” was conducted by researchers primarily from the University of Cambridge, with lead author Yumnah T. Khan and corresponding author Simon Baron-Cohen.

NEED TO CLEAR YOUR MIND? NEW RESEARCH SUGGESTS A GOOD NIGHT'S SLEEP COULD HELP

KENNA HUGHES-CASTLEBERRY·JANUARY 8, 2025

New research suggests that a good night's sleep does more than just recharge your body—it literally clears your mind. Research published in the journal *Cell* reveals that deep sleep activates a natural brain-cleaning system, flushing out waste accumulated in the brains of mice during waking hours.

This discovery not only highlights the critical role of sleep in brain health but also raises questions about the long-term effects of sleep aids on this process.

MY LATEST VIDEOS

Our brains come equipped with a built-in waste disposal system called the glymphatic system. This system circulates fluid through the brain and spinal cord to wash away toxins, including sticky proteins that can form plaques linked to neurological disorders like Alzheimer's disease. Despite this understanding, scientists have long puzzled over what drives the glymphatic system—until now.

Researchers in Denmark have found that norepinephrine, a molecule typically associated with alertness, plays a surprising role during deep sleep. In their study on mice, they observed that the brainstem releases small waves of norepinephrine about every 50 seconds. These waves trigger blood vessels in the brain to contract and relax rhythmically, creating pulsations that help propel fluid and flush out waste.

"It's like turning on the dishwasher before you go to bed and waking up with a clean brain," Maiken Nedergaard, the study's senior author and a researcher at the University of Rochester and the University of Copenhagen said in a recent statement. "We're essentially asking what drives this process and trying to define restorative sleep based on glymphatic clearance."

SIGNIFICANCE OF GETTING A GOOD NIGHT'S SLEEP

The study revealed a complex interplay between norepinephrine waves, blood flow, and brain fluid movement. The researchers found that as norepinephrine levels rose and fell, the volume of blood in the brain fluctuated, creating rhythmic waves that correlated with cerebrospinal fluid flow. These synchronized movements help flush waste from the brain.

"You can view norepinephrine as this conductor of an orchestra," lead author Natalie Hauglund of the University of Copenhagen and the University of Oxford mentioned in a recent press release. "There's a harmony in the constriction and dilation of the arteries, which then drives the cerebrospinal fluid through the brain to remove the waste products."

SLEEP AIDS AND BRAIN HEALTH

The researchers also explored whether all sleep is equally beneficial for the brain. To test this, they gave mice zolpidem, a commonly used sleep aid. While the drug helped the mice fall asleep faster, it reduced the norepinephrine waves during deep sleep by 50%. Consequently, brain fluid flow decreased by over 30%, impairing the glymphatic system's waste-clearing function.

"More and more people are using sleep medication, and it's really important to know if that's healthy sleep," Hauglund emphasized. "If people aren't getting the full benefits of sleep, they should be aware of that so they can make informed decisions."

Experts have long expressed concerns about the impact of sleep aids on achieving truly restorative sleep. While medications like zolpidem can help individuals fall asleep more quickly, research suggests they may interfere with the natural processes that make sleep beneficial.

For example, sleep aids often alter the brain's sleep architecture, reducing the depth and quality of deep sleep. This disruption can impair essential functions like memory consolidation and, as recent studies suggest, the brain's ability to clear out waste through the glymphatic system. As sleep disorders and reliance on sleep medications rise, scientists are urging caution, emphasizing the importance of understanding how these drugs may affect long-term brain health.

IMPLICATIONS FOR HUMAN HEALTH

Although the study was conducted on mice, the findings likely apply to humans, who also have a glymphatic system. Similar patterns of norepinephrine waves, blood flow, and brain fluid movement have been observed in humans.

"Now we know norepinephrine is driving the cleaning of the brain, we may figure out how to get people a long and restorative sleep," says Nedergaard.

Kenna Hughes-Castleberry is the Science Communicator at JILA (a world-leading physics research institute) and a science writer at The Debrief. Follow and connect with her on BlueSky or contact her via email at kenna@thedebrief.org

The oral-brain axis: New research uncovers surprising links between the bacteria in your mouth and mental health symptoms

A recent study published in *Translational Psychiatry* has found a connection between the bacteria in our mouths and mental health. Researchers analyzed the salivary microbiome of individuals experiencing mental health symptoms comparing it to the microbiome of mentally healthy individuals. Their analysis revealed notable differences in the composition of oral bacteria, suggesting that the oral microbiome may play a significant role in mental well-being. These findings contribute to the growing body of evidence supporting the concept of the "oral-brain axis."

Mental health disorders are a leading cause of global health burden, affecting hundreds of millions of people worldwide. While advancements in treatment have improved outcomes for many, obstacles such as treatment resistance, partial responses, and high relapse rates highlight the need for innovative and complementary therapeutic strategies.

Recent research has turned attention to the human microbiome, the vast ecosystem of microorganisms living in and on our bodies, as a potential factor influencing mental health. The gut microbiome, in particular, has been extensively studied for its role in the "gut-brain axis," a bidirectional communication network connecting the gut and the brain. Changes in the composition and function of gut bacteria have been linked to various mental health conditions, suggesting that targeting the gut microbiome might offer new therapeutic opportunities.

However, the oral microbiome—another critical and diverse microbial community—has received comparatively less attention, despite its potential to influence systemic and brain health. The oral cavity is home to hundreds of bacterial species that interact with the host and other microbial communities.

"My research originally focused on how the gut microbiome influences mental health," said study author Stefanie Malan-Müller, a postdoctoral fellow at the Complutense University of Madrid. "Over the years, many studies have shown how the gut and brain communicate through the 'gut-brain axis,' affecting mental well-being. But our bodies host microbes in many places, not just the gut. One of these key areas is the mouth, which is directly connected to the gut."

"We also know that oral health impacts the whole body—research shows, for example, that gum disease can increase the risk of heart disease. This made me wonder: could certain oral bacteria also play a role in mental health? That curiosity led to this study."

The study analyzed saliva samples from 470 participants recruited from two Spanish population-based microbiome studies. The recruitment criteria ensured that all participants were Spanish residents aged 18 or older, fluent in Spanish, and not recently exposed to antibiotics, which could alter their microbiome.

The sample included both mentally healthy individuals and those experiencing symptoms of anxiety, depression, or posttraumatic stress disorder. The participants provided detailed self-reports on mental health and periodontal health and submitted saliva samples for analysis using 16S ribosomal RNA sequencing, a technique that identifies and categorizes bacteria based on their genetic material.

The researchers also collected blood samples from a subset of participants to measure levels of tryptophan and serotonin—compounds linked to mental health—and analyzed associations between these levels and oral bacterial composition.

The researchers found significant differences in the composition of the salivary microbiome between individuals with mental health symptoms and healthy controls. Participants with symptoms of posttraumatic stress disorder and depression exhibited higher levels of certain bacteria, such as *Prevotella histicola*. This bacterium, associated with oral inflammation, was also linked to lower interpersonal quality of life scores. Conversely, participants with anxiety disorders had lower levels of *Neisseria elongata*, a bacterium associated with oral and cardiovascular health.

"What happens in the mouth doesn't stay in the mouth," Malan-Müller told PsyPost. "Our results suggest a role for the oral-brain axis—a concept proposing that the bacteria in our mouths could also play a critical role in mental well-being."Another key finding was the association between oral microbiota and early life trauma. For instance, higher levels of *Streptococcus mutans*, a bacterium often linked to dental decay, were found in individuals who reported experiencing childhood emotional neglect.

"We also confirmed that gum health impacts the oral microbiome," Malan-Müller explained. "People with conditions like gingivitis or periodontitis had distinct patterns of bacteria, including higher levels of *Eggerthia* and *Shuttleworthia*, and lower levels of *Capnocytophaga*."

Additionally, participants with anxiety disorders showed higher levels of *Oribacterium asaccharolyticum*, which has been implicated in both oral and gut inflammation. Interestingly, periodontal health also influenced mental health treatment outcomes. Two types of oral bacteria, *Eggerthia* and *Haemophilus parainfluenzae*, were linked to both self-reported gum disease (periodontitis or gingivitis) and the perceived effectiveness of psychotherapy.

Importantly, the researchers found evidence of a shared biological pathway linking periodontal health and mental health, involving tryptophan metabolism. Participants with symptoms of depression, anxiety, or posttraumatic stress disorder exhibited lower levels of tryptophan degradation, which is critical for serotonin production. Reduced tryptophan metabolism was also observed in participants with severe gum disease, linking periodontal health and mental health through a common metabolic pathway. "One surprising finding was that we didn't identify a single bacteria directly linked to both mental health and gum health," Malan-Müller said. "However, we discovered a potential common biological process performed by microbes that connects the two: the breakdown of tryptophan, an important amino acid."

"Using PICRUSt analysis, we identified microbial functions associated with mental health symptoms and symptoms of gum disease, revealing reduced tryptophan breakdown in people with PTSD, childhood trauma, poor social relationships, and those with possible gum disease. Reduced tryptophan breakdown can lead to lower serotonin levels—a key chemical involved in regulating mood. Interestingly, we also found lower serotonin levels in the blood of participants with mental health symptoms, suggesting a possible metabolic link between oral bacteria and mental health."

However, it is important to note that the cross-sectional design of the study also limits the ability to determine causation—whether changes in the oral microbiome contribute to mental health symptoms or result from them. It is also possible that a third factor influences both. "One important caveat is that our study only shows a link between the types of bacteria in the mouth and mental health symptoms at a single point in time," Malan-Müller said. "To determine whether the bacteria actually contribute to these symptoms, future research will need to track changes over time and explore how these relationships evolve."

Future studies could also investigate the mechanisms linking oral bacteria to mental health, such as their role in systemic inflammation or neurotransmitter regulation. Exploring whether improving oral health through better hygiene or targeted interventions could enhance mental well-being is another promising direction. "Based on our findings, one exciting area for future research is exploring the potential of dental care and oral hygiene as therapeutic tools for improving mental health," Malan-Müller explained. "I am currently involved in a randomized controlled trial investigating this approach. Additionally, it's important to understand the biological pathways linking the oral microbiome to mental health. We need to explore how specific types of bacteria in the mouth may influence brain function and emotional regulation."

"As we unravel the mysteries of the oral-brain axis, we invite you to consider the importance of maintaining good oral health—not just for a bright smile but also for mental well-being," she added. The study, "Probing the oral-brain connection:

oral microbiome patterns in a large community cohort with anxiety, depression, and trauma symptoms, and periodontal outcomes," was authored by Stefanie Malan-Müller, Rebeca Vidal, Esther O'Shea, Eduardo Montero, Elena Figuero, Iñaki Zorrilla, Javier de Diego-Adeliño, Marta Cano, Maria Paz García-Portilla, Ana González-Pinto, and Juan C. Leza.

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.

Neurologist: This is the No. 1 thing I avoid to keep my brain healthy and memory sharp

When it comes to the brain, a healthy diet, good sleep hygiene and frequent exercise are vital, but so is one other thing, says Dr. Richard Restak, clinical professor of neurology at The George Washington University School of Medicine and Health Sciences.

Restak, 82, is the author of more than 20 books about the brain. In "The Complete Guide to Memory: The Science of Strengthening Your Mind," he shares science-backed ways to improve your memory and keep your brain sharp.

CNBC Make It asked Restak what he does to keep his own brain healthy.

"I try to avoid boredom. I try to [stay] active," Restak says. "I learn new words, practice memory exercises, and [I] make them fun."

'Avoid boredom, stay challenged'

He's currently writing a book and has another lined up "if I want to do it."

And every day on his morning walks with his dog, Restak does a memory exercise. On the day we spoke, he came up with a list of 10 words, which he wrote down before he left the house.

The goal of the exercise is to remember the 10 words and be able to list them, without looking at the paper, by the end of his walk, he says. During our call, Restak recited, from memory, the words he used in that morning's walk.

Here's his method for memorization.

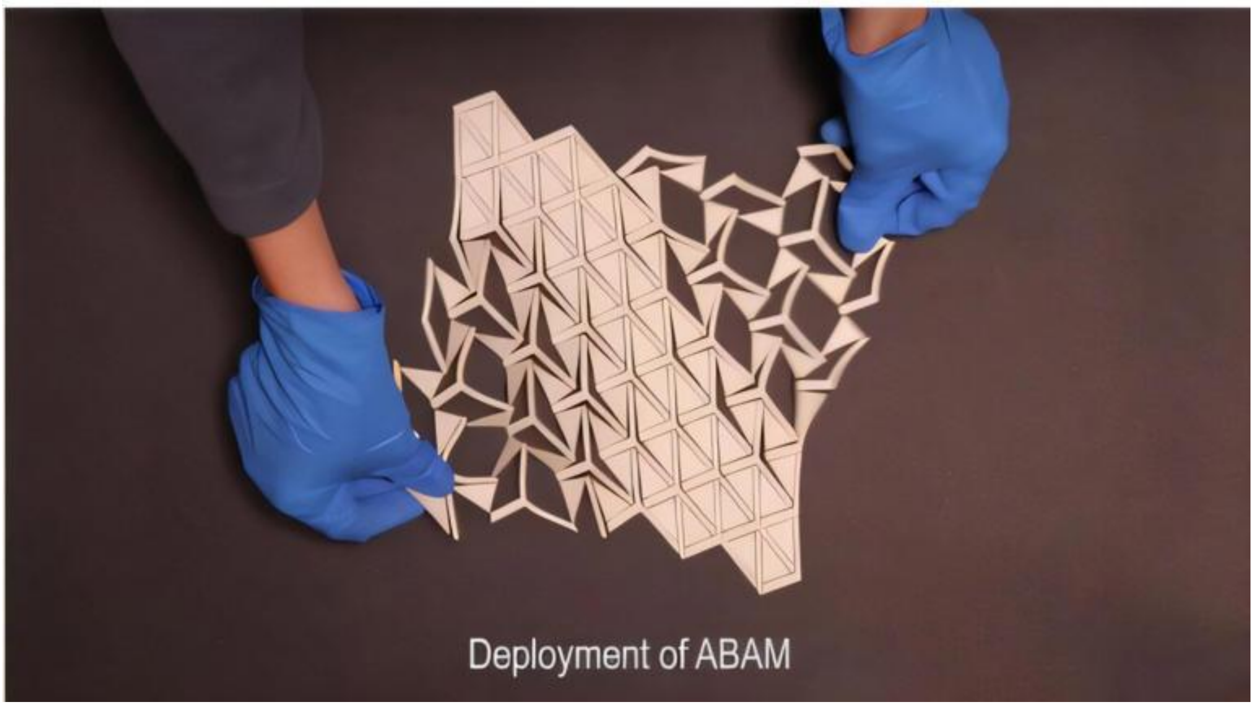
"Our most prominent way of remembering something is to turn it into an image. The more bizarre the image, and the more we follow the story," Restak says.

Storytelling comes naturally to most people, he adds. "We like to hear stories. We like to tell stories. So we'll remember the story."

Restak came up with a short tale and associated each of the words with a mental visualization. One of the words he chose was "yo-yo," and to remember it, he imagined a yo-yo giving a lecture in Chico, Calif., home of the National Yo-Yo Museum.

Memory exercises like these keep Restak entertained on his morning walks and help him to keep his memory sharp. "Avoid boredom, stay challenged," he says.

More versatile shape-shifting materials offer new possibilities for soft robotics and wearable tech



Credit: Advanced Materials (2024). DOI: 10.1002/adma.202313198

Finding new angles on an old artform, McGill researchers have increased the number of stable shapes that kirigami-based engineered materials can take, opening the way to a range of new applications. Their study is published in *Advanced Materials*.

What makes these metamaterials special is not what they are made of—they can be plastic, cardboard or anything else—but how, thanks to shapes cut into them, they are able to morph from one form to another. To begin to understand the concept, think of pop-up illustrations of cut paper in books or greeting cards.

Drawing inspiration from kirigami, the Japanese art of paper cutting, and using laser cutters on such materials as plastic, the researchers explored the interior geometry, such as the angles of the triangles that serve as the basis for the kirigami forms.

Current kirigami patterns when deployed undergo uniform scaling, meaning, for example, that a square shape grows in size to become a larger square. What the researchers have done is to enable a square shape to transform into other forms, such as a rectangular or trapezoidal shape. This is known as arbitrary scaling, leading to what is sometimes referred to as anisotropic morphing.

As a result, the McGill team has significantly expanded the number of stable yet morphable shapes that can serve as the building blocks for new metamaterials that arbitrarily scale during morphing. The researchers say their discovery could lead to the creation of new products in fields ranging from soft robotics and wearable technologies to deployable structures. They have already filed some patent applications based on their discoveries.

"Once pulled, these kirigami shapes with slits can stretch and, if rationally designed, can transform into other shapes that retain their forms of equilibrium. This opens the door to the creation of objects that can save storage space in one form and morph into another shape to fulfill different functions," explained Damiano Pasini, the Canada Research Chair in Mechanical Metamaterials and a professor at McGill University's Department of Mechanical Engineering. He is the corresponding author of the *Advanced Materials* paper.

"As a result, a single piece of material with rationally designed slits can offer versatility, anisotropic morphing and multi-functionality that is not seen in conventional materials." He said the development has been attracting considerable attention from the world of science and technology.

"While this work offers a foundational understanding of the physical mechanisms involved in the formation of multi-stable forms with distinct degrees of anisotropic deployment and opens a new world of possibilities, it is not tied to a specific application," Pasini said.

"Our next step is to work on applications in everyday technology."

More information: Chuan Qiao et al, Anisotropic Morphing in Bistable Kirigami through Symmetry Breaking and Geometric Frustration, *Advanced Materials* (2024). DOI: 10.1002/adma.202313198

Provided by McGill University

Nasopharyngeal lymphatics found to be crucial for draining cerebrospinal fluid from the brain

Connections of nasopharyngeal lymphatic plexus and features of deep cervical lymphaticsA. The drawing shows intracranial upstream lymphatic regions #1, #2, and #3 that drain through the nasopharyngeal lymphatic plexus (NPLP) en route to medial deep cervical lymphatics and deep cervical lymph nodes in mice. Upstream lymphatic region #1 includes lymphatics near the pituitary gland and cavernous sinus that drain to the NPLP. Upstream lymphatic region #2 includes lymphatics in the anterior region of the basolateral dura near the middle meningeal artery and petrosquamosal sinus (PSS) that course along the pterygopalatine artery (PPA) to the NPLP. Upstream lymphatic region #3 includes lymphatics near the cribriform plate that drain to lymphatics in the olfactory mucosa en route to the posterior nasal lymphatic plexus and NPLP. In contrast, lymphatics in the posterior region of the basolateral dura around the sigmoid sinus do not drain to the NPLP but instead, pass through the jugular foramen to lateral deep cervical lymphatics en route to deep cervical lymph nodes. Anatomical positions are indicated in the lower corner. Ant., anterior; Post., posterior; Sup., superior; Inf., inferior anatomical position.B. The drawing highlights the lymphatic connections of the nasopharyngeal lymphatic plexus to the deep cervical lymphatics and deep cervical lymph nodes for cerebrospinal fluid in humans, based on the findings obtained from the mice and monkeys in this study. Credit: Nature (2024). DOI: 10.1038/s41586-023-06899-4© Provided by Medical Xpress

In a study published in *Nature*, South Korean researchers led by Director Koh Gou Young of the Center for Vascular Research within the Institute for Basic Science (IBS) have uncovered a distinctive network of lymphatic vessels at the back of the nose that plays a critical role in draining cerebrospinal fluid (CSF) from the brain.

The study sheds light on a previously unknown route for CSF outflow, potentially unlocking new avenues for understanding and treating neurodegenerative conditions.

In the brain, waste products generated as byproducts of metabolic activity are expelled through cerebrospinal fluid (CSF). Accumulation of waste in the brain, if not properly expelled, can damage nerve cells, leading to impaired cognitive function, dementia, and other neurodegenerative brain disorders. Hence, the regulation of CSF production, circulation, and drainage has long been a focus of scientific attention, especially in relation to age-related conditions like Alzheimer's disease and other neurodegenerative diseases.

The brain produces around 500 mL of this fluid per day, which is drained from the subarachnoid space. Among the known drainage routes are lymphatic vessels around the cranial nerves and the upper region of the nasal cavity.

Despite well-documented evidence of lymphatics aiding CSF clearance, identifying the exact anatomical connections between the subarachnoid space and extracranial lymphatics has posed a challenge due to their extremely complex structure.

Koh's team tackled this problem using transgenic mice with lymphatic fluorescent markers, microsurgeries, and advanced imaging techniques.

Their efforts revealed a detailed network of lymphatic vessels at the back of the nose that serves as a major hub for CSF outflow to deep cervical lymph nodes in the neck. These lymphatics were found to have distinct features, including unusually shaped valves and short lymphangions.

Lead researcher Jin Hokyung said, "Our study identified the nasopharyngeal lymphatic plexus as a hub for CSF outflow. CSF from specific cranial regions drained through these lymphatics to deep cervical lymph nodes in the neck. This discovery could have significant implications for understanding and treating conditions related to impaired CSF drainage."

The study also demonstrated that pharmacological activation of the deep cervical lymphatics enhanced CSF drainage in mice. The researchers were able to successfully modulate cervical lymphatics using phenylephrine (which activates α1-adrenergic receptors, causing smooth-muscle contraction) or sodium nitroprusside (which releases nitric oxide, inducing muscle relaxation and vessel dilation).

Importantly, this feature was preserved during aging, even when the nasopharyngeal lymphatic plexus had shrunk and was functionally impaired.

Yoon Jin-Hui, the co-first author of this study, said, "The deep cervical lymphatics, which remain intact with aging, offer a potential target for therapeutic interventions aimed at improving CSF outflow in individuals with compromised brain health."

This endeavor was not without its own challenges, however. Deep anesthesia and removal of neck musculature were required to expose the lymphatics in the mice. These delicate procedures themselves had problems altering the physiological dynamics of CSF drainage because cerebral blood flow and blood pulsing through the vasculature contribute to CSF circulation, which in turn influences CSF outflow.

Also, while the imaging techniques used were informative, researchers believe more advanced methods for imaging live animals (such as synchrotron X-ray imaging) may reveal more features of the dynamics of CSF drainage under physiological conditions.

Director Koh Gou Young of the Center for Vascular Research said, "We plan to verify all the findings from the mice in primates, including monkeys and humans. We aim to investigate in a reliable animal model whether activating the cervical lymphatic vessels through pharmacological or mechanical means can prevent the exacerbation of Alzheimer's disease progression by improving CSF clearance."

More information: Jin-Hui Yoon et al, Nasopharyngeal lymphatic plexus is a hub for cerebrospinal fluid drainage, *Nature* (2024). DOI: 10.1038/s41586-023-06899-4

Provided by Institute for Basic Science

Altermagnetism: First conclusive evidence of an elusive third class of magnetism found

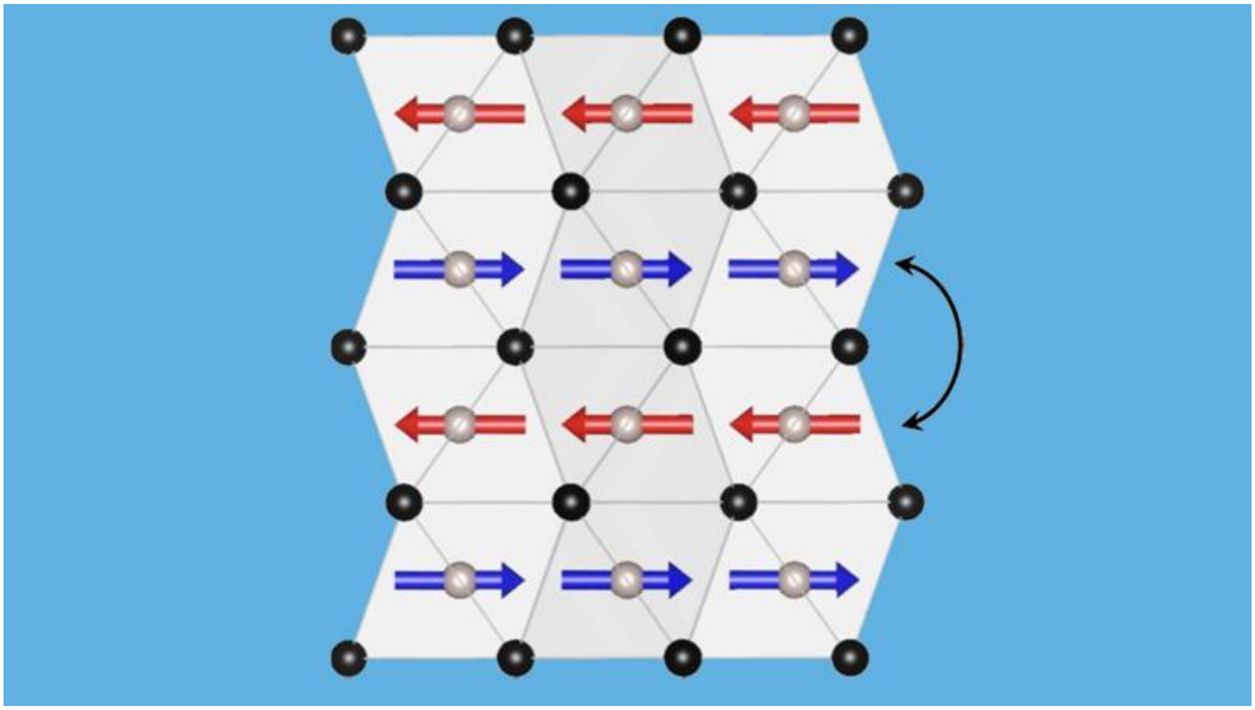
Magnetism plays a crucial role in enabling various applications, ranging from memory storage devices to advanced medical imaging, energy-efficient electric motors, magnetic sensors, and emerging quantum technologies.

For a long time, it has been believed that magnetism is of only two types; ferromagnetism and anti-ferromagnetism.

Both forms have their own importance, for instance, without ferromagnets one cannot imagine speakers, telephones, generators, hard drives, etc. Whereas anti-ferromagnetism is essential for various types of sensors, detectors, and quantum computing applications.

However, there's a hidden third type also known as altermagnetism. This was first proposed in 2022, however, no solid evidence was found at the time. Now a proof-of-concept study shows that altermagnetism exists for real.

Detecting altermagnetism in manganese telluride



Magnetic moment

The type of magnetism a material exhibits is decided by the spin of its electrons. If the magnetic moments resulting from the spins are in the same direction, a material is ferromagnetic. However, if magnetic moments are in the opposite direction, it indicates antiferromagnetism.

The magnetic moment refers to the strength and direction of the magnetic field a material produces.

The study authors suggest that when it comes to altermagnetism, the magnetic moments of adjacent atoms are aligned in opposite directions, but they are not perfectly antiparallel. Instead, they are slightly tilted or exhibit a complex alignment due to time-reversal symmetry breaking (when the reverse of a process doesn't appear the same as the original).

The study authors noticed altermagnetism when they used photoemission electron microscopy (PEEM) to study manganese telluride (MnTe). PEEM involves using X-rays to eject electrons from the surface of a material, and then image those electrons to reveal several properties of the material.

The researchers used X-rays with different polarizations to hit MnTe. For instance, when a circularly polarized light struck the material, it highlighted MnTe's unique magnetic regions, or domains, caused by time-reversal symmetry breaking.

Whereas, when horizontally or vertically polarized X-rays were used, they revealed the orientation of magnetic moments, within the material. Surprisingly, when the study authors combined the results from these events, they noticed altermagnetic states.

"We demonstrate nanoscale imaging of altermagnetic states from 100-nanometre-scale vortices and domain walls to 10-micrometer-scale single-domain states in manganese telluride (MnTe)," the study authors said.

The power of altermagnetism

Altermagnetism is an unusual and rarely observed phenomenon but it combines the best characteristics of ferromagnetism and antiferromagnetism.

For instance, altermagnets have "the speed and resilience of an antiferromagnet, but they also have this important property of ferromagnets called time-reversal symmetry breaking," Alfredo Dal Din, one of the study authors and a postdoc researcher at the University of Nottingham, told *Live Science*.

A combination of such properties could lead to many exciting developments. For example, the study authors suggest that altermagnets have the potential to boost the speed of microelectronic components by a thousand times.

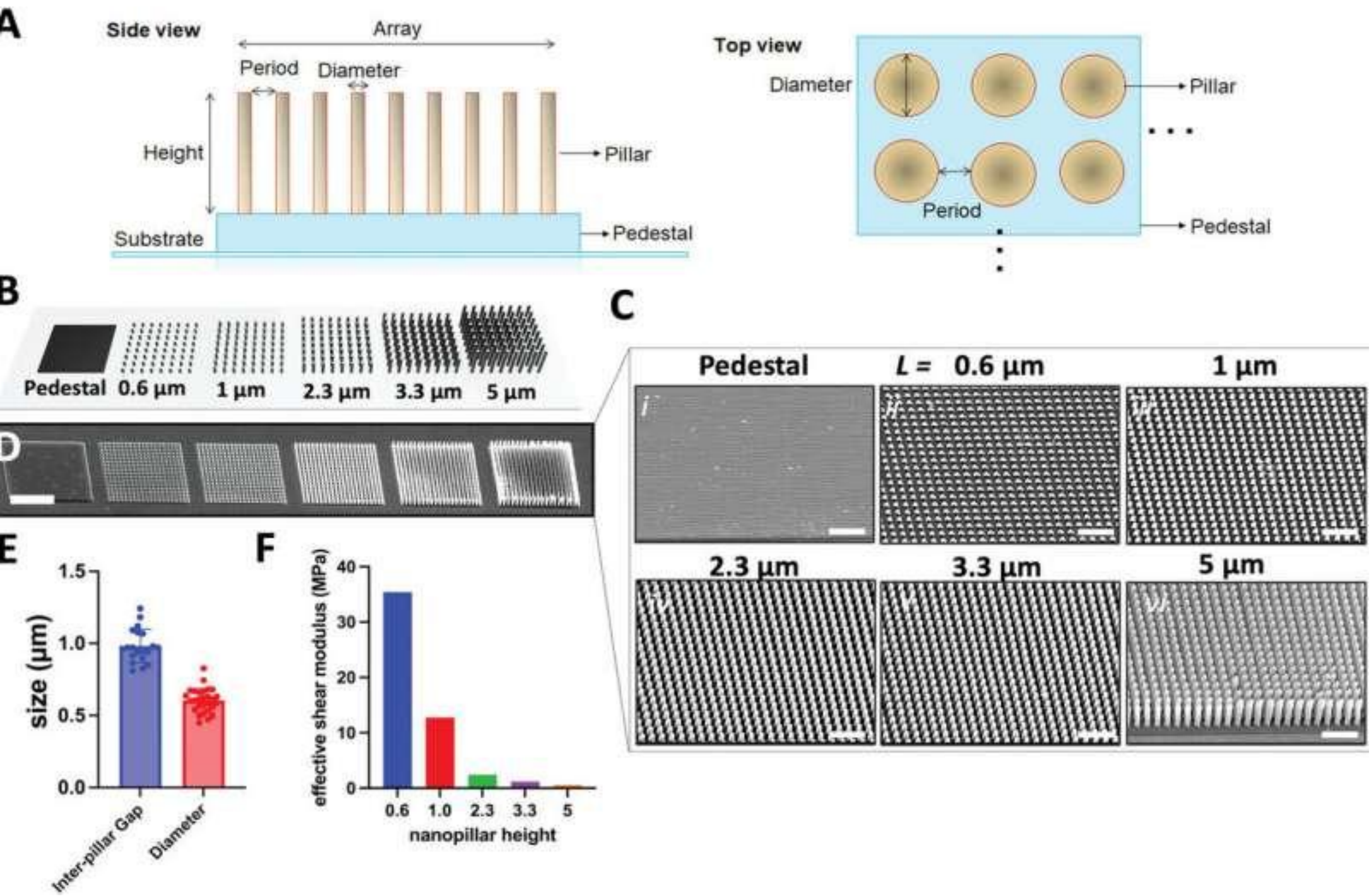
Plus, they can lead to the development of advanced magnetic applications and help scientists realize powerful phenomena such as superconductivity.

"Our experimental work has provided a bridge between theoretical concepts and real-life realization, which hopefully illuminates a path to developing altermagnetic materials for practical applications," Oliver Amin, first author of the study and a senior research fellow at Nottingham University, said.

The study is published in the journal *Nature*.

3D-printed nanopillars mimic brain environment to promote neuron growth

by Delft University of Technology



Nanopillar arrays fabrication and characterization. A) Schematic representation of the array parameters. B) 3D rendering of the nanopillars "strip." C) SEM images of the nanopillar arrays with different heights: i) pedestal, ii) 0.6 µm, iii) 1 µm, iv) 2.3 µm, v) 3.3 µm, and vi) 5 µm). Scale bars correspond to 5 µm. D) SEM image of the nanopillars strip (areas of 30 × 30 $µm^2$ in this picture). Scale bar corresponds to 15 µm. E) Measured interpillar gaps and diameter (in µm). The average and standard deviation are based on *n* = 50 nanopillars measurements. F) Effective shear modulus (in MPa) related to different nanopillars' arrays heights (in µm). Credit: *Advanced Functional Materials* (2024). DOI: 10.1002/adfm.202409451

Key cells in the brain, neurons, form networks by exchanging signals, enabling the brain to learn and adapt at incredible speed. Researchers at the Delft University of Technology in The Netherlands (TU Delft) have developed a 3D-printed brain-like environment where neurons grow similarly to a real brain.

Using tiny nanopillars, they mimic the soft neural tissue and the brain extracellular matrix fibers. This model provides new insights into how neurons form networks, as well as a novel tool to understand in future how this process may change in neurological disorders such as Alzheimer's, Parkinson's disease, and autism spectrum disorders.

The work is published in the journal *Advanced Functional Materials*.

Neurons, like many cells in the body, respond to the stiffness and geometry of their surroundings. Traditional petri dishes are flat and rigid, unlike the soft, fibrous extra-cellular matrix environment of the brain. To resemble the geometric and mechanical properties of this environment, the team of associate professor Angelo Accardo designed nanopillar arrays using two-photon polymerization, a 3D laser-assisted printing technique with nanoscale precision.

These pillars, each of which is a thousand times thinner than a human hair, are arranged like tiny forests on a surface. By changing the width and height (aspect ratio) of the pillars, the researchers tuned their effective shear modulus, a mechanical property sensed by cells when crawling on top of micro- or nano-structures' arrays.

"This tricks the neurons into 'thinking' that they are in a soft, brain-like environment, even though the nanopillars' material itself is stiff. While bending under the crawling of neurons, the nanopillars not only simulate the softness of brain tissue but also provide a 3D nanometric structure that neurons can grab onto, much like the extra-cellular matrix nano-fibers in real brain tissue," says Accardo. This influences how the neurons grow and connect with each other.

From random growth to ordered networks

To test the model, the researchers grew three different types of neuronal cells, derived either from mouse brain tissue or from human stem cells, on the nanopillars. In traditional flat petri dishes and 2D biomaterials, neurons grew in random directions. But on the 3D-printed nanopillar arrays, all three cell types grew in more organized patterns, forming networks at specific angles.

The study also revealed new insights into neuronal growth cones.

Accardo notes, "These hand-like structures guide the tips of growing neurons as they search for new connections. On flat surfaces, the growth cones spread out and remain relatively flat. But on the nanopillar arrays, the growth cones sent out long, finger-like projections, exploring their surroundings in all directions—not just along a flat plane but also in the 3D space, resembling what happens in a real brain environment."

"In addition, we found that the environment created by the nanopillars also seemed to encourage neurons to mature," highlights George Flamourakis, first author of the study. Neural progenitor cells grown on the pillars showed higher levels of a marker of mature neurons, compared to those grown on flat surfaces.

"This shows that the system not only influences the direction of growth but also promotes neuronal maturation," adds Flamourakis.

A tool for studying brain disorders

However, if softness is so important, why not just grow neurons on soft materials like gels?

"The problem is that gel matrices, like collagen or Matrigel, typically suffer from batch-to-batch variability and do not feature rationally designed geometric features. The nanopillar arrays model offers the best of both worlds: It behaves like a soft environment with nanometric features, and holds extremely high reproducibility thanks to the resolution of two-photon polymerization," explains Accardo.

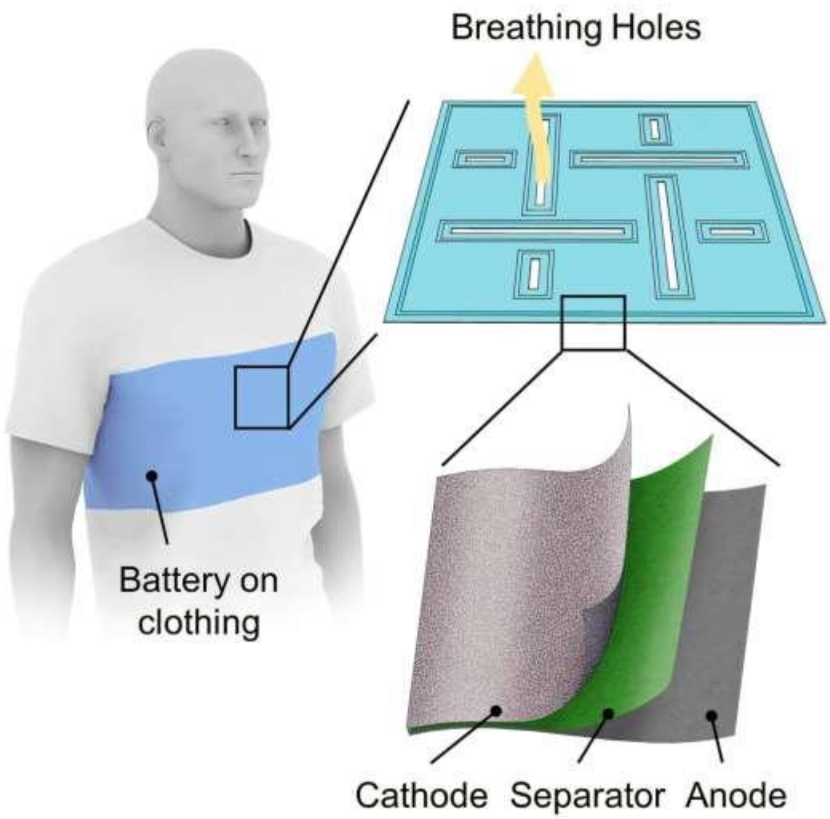
By better replicating how neurons grow and connect, the developed model could offer new insights into the differences between healthy brain networks and those associated with neurological disorders, such as Alzheimer's, Parkinson's disease and autism spectrum disorders.

More information: George Flamourakis et al, Deciphering the Influence of Effective Shear Modulus on Neuronal Network Directionality and Growth Cones' Morphology via Laser-Assisted 3D-Printed Nanostructured Arrays, *Advanced Functional Materials* (2024). DOI: 10.1002/adfm.202409451
Journal information: Advanced Functional Materials
Provided by Delft University of Technology

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.

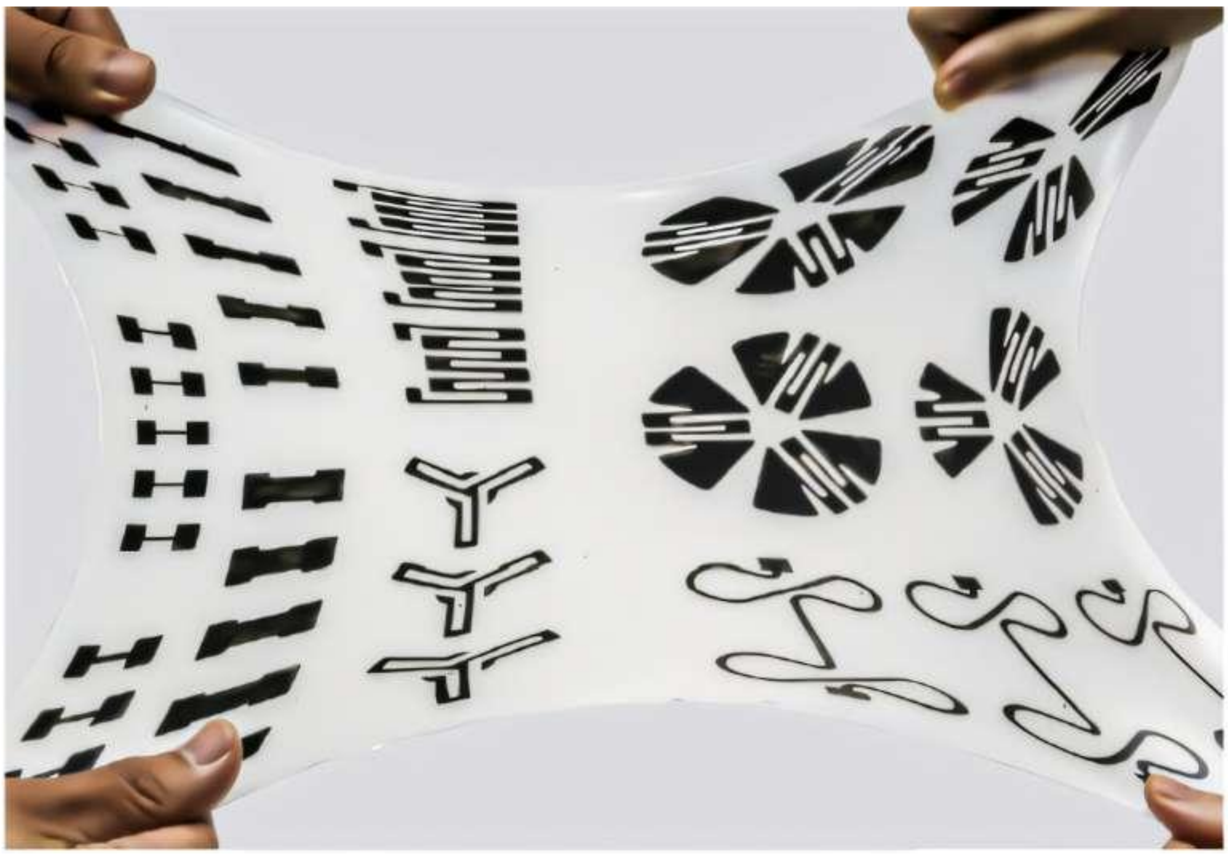
The resulting battery has longer and shorter rectangular holes of the right size and placement. Testing showed it was capable of holding a charge when folded 180 degrees, and could be stretched by as much as 10% of its length. The researchers also found that it held up without fail after 100 folds/unfolds,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

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