Making sense of perception

Nerve signals morph into meaning

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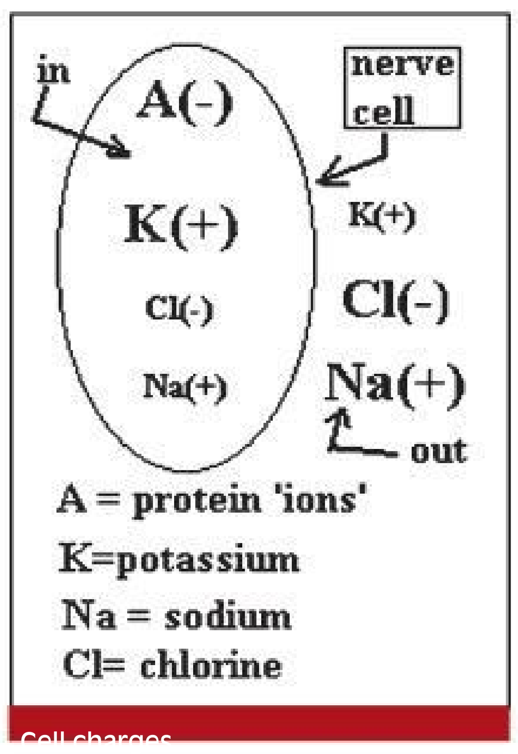
Do you and I perceive the same image when we see an object? We both call it with the same name, but what in fact do we see? By what process does the brain interpret signals from the senses?

Researcher Jerry N Chen, from Boston University, with colleagues, Cameron Condylis, Abed Ghanbari, Mikita Manjrekar and Karina Bistrong, and Sehnqin Yao, Zizhen Yao, Thuc Nghi Nguyen, Hongkui Zeng and Bosiljka Tasic from Allen Institute for Brain Science, Seattle, describe, in the journal, *Science*, their sally into the unknown territory of cells in the brain, to unravel a part of the mystery. And they identify a kind of brain cell that plays a role in routing nerve signals from a first layer to specified cells in the next layer.

Nerve cells, or neurons, are different from other cells in that they are channels of communication. What this means is that they can receive signals from another cell and then transmit signals to yet another cell. Unlike a muscle cell, for instance, which reacts by contracting, when triggered, not by passing on the message to another cell.

How nerve cells go about this action is through electrical activity in the cell and parts of the cell that communicate with other cells. In the normal state, the nerve cell has an excess of positive, potassium ions and some large, negatively charged protein molecules. And a deficiency of positive, sodium ions and negative, chlorine ions. The relative concentration of the charged "ions" is the reverse in the medium outside the cell. The cell is hence some 70-80 millivolt negative compared to the outside and there is electrical "tension" across the two sides of the cell wall.

The arrival of a signal, from the environment or a neighbouring cell to the "receptor" of a cell, however, causes gaps, called *gateways*, in the material of the cell wall to open. This allows positively charged sodium ions outside the cell to rush in, and the net change is reversed to about 40 mV positive. When this level is reached, the cell "fires" a signal to the next cell, and the charge level drops. The change opens another set of gateways that allow positive potassium ions to rush out, to the potassium deficient exterior, and the negative polarity of the cell is restored.



Cell charges

There is, however, great diversity in the types of neurons, for different purposes, and hundreds of thousands of kinds within the brain. "The diversity of cell types is a defining feature of the neuronal circuitry that makes up the areas and layers of the mammalian cortex," say the authors, about the structure of the brain. There are now methods to identify both the genetic clippings that cells generate, in single cells. Using those methods, the cells in layers in the cortex, or outer surface of the brain have been "profiled" and classified, the paper says, into some 300 different groups.

A question that the group was seeking to answer was how nerve signals that are received from peripheral sources, in the present case, the whiskers of experimental mice, are passed from layer to layer in the brain, to be integrated with records of earlier encounters, stored in deeper layers of the brain. The task, the paper observes, calls for measuring the activity of neurons while the animal is sensing things, which is to say while it's alive and active. The existing methods, although they can deal with individual neurons, can only identify the type of the neuron, not its function, the paper says.

The team has then developed a technique, *Comprehensive Readout of Activity and Cell Type Markers*, with the acronym, *Crack*, which evokes the idea that this may help "crack" the code the brain employs to combine nerve signals with memory and arrive at perception. Crack has two components -- *two-photon calcium imaging*, followed by multiplexed *fluorescent in situ hybridisation* (also known as "*Fish*").

The first component works with charged calcium ions, which form a signalling mechanism, in addition to the sodium ion channel. The experimenters detect activity of calcium ions by a sensitive and accurate imaging technique called two photon microscopy. Imaging of cells usually employs fluorescence, where certain atoms absorb light of one frequency, and de-excite by emission, but at a lower frequency.

An example is the domestic tube lamp, where electric discharge creates ultraviolet light. The coating of the tube absorbs UV and emits at frequencies in the visible range. In two-photon imaging, the excitation is not by one high energy photon, but by a pair of lower energy photons, generated in quick succession by a laser. This method permits more focused imaging, with less "background", and imaging a little deeper within a tissue sample.

Calcium ion detection is combined with imaging markers that attach to specific parts of the deoxyribonucleic acid, or DNA, of cells, the technique called "Fish", referred to earlier. With both components working, ***Crack*** is able to image the action of cells and identify the type of the cell's nature.

The team used Crack to observe the working of specific cell types in layers one and two of the brain cortex of experimental mice. As the imaging is done non-invasively, the team could record neural excitation when the mice were active, feeling around themselves with their whiskers, which are their sensitive, tactile equipment.

The team started with an existing catalogue of neuron types found in the mouse brain, created by the Allen Institute of Brain Science, which listed the cell types, but only the types, without their function. The work of the team hence adds a layer of information, the activity pattern of the different cell types -- the reason for "comprehensive," the first "C" in the acronym, ***Crack***.

The team profiled the activity of 11 kinds of neural cells in the mouse cortex, in terms of changes in task-related properties, along with differences in molecular type. One particular cell type, Bazla, was found to be "a highly active detector of tactile features." Simultaneous imaging of activity of more cells then revealed relationships between groups of cells. And it was found that Bazla acts as a kind of "hub", to "orchestrate local neural activity patterns," the paper says. And other tests, with mice where the whiskers had been removed, showed that Bazla was able to adapt and compensate for the change.

"The ability to map functional and transcriptional relationships across neuronal populations provides insight into how the organising principles of the cortex give rise to the computations it performs," the paper says. The exponential growth of capacity for computing has prompted Artificial Intelligence, which finds its inspiration in theories of how the brain functions. The relationships between the software "neurons" in an AI system are programme defined, but that is not so in the animal brain. The current work is a step towards understanding how it works.

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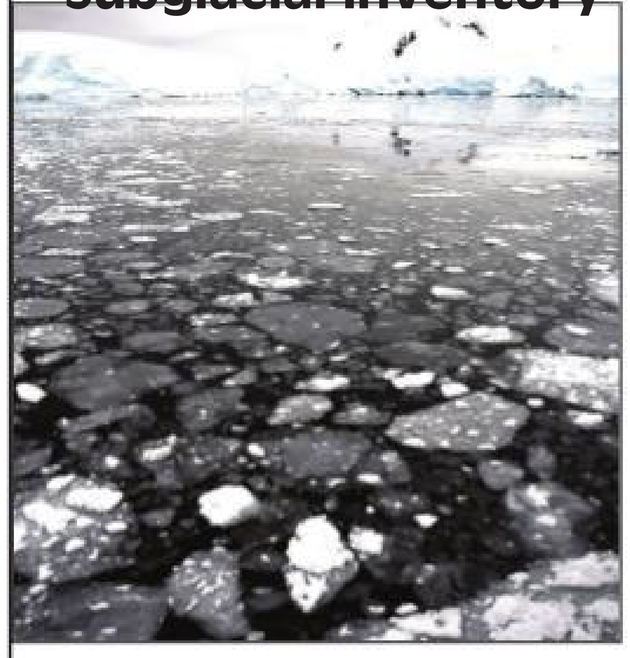
PLUS POINTS
PLUS POINTS

Subglacial inventory
Subglacial inventory



The world's first inventory of subglacial lakes has been compiled by an international team, providing researchers with a comprehensive directory of where the lakes are and how they are changing in a warming climate.

Subglacial lakes can form underneath ice sheets or glacial valley regions. They can play a critical role in the speed at which ice flows into oceans and, when on land in mountainous regions, could pose a major risk to populations downstream if they were to drain and cause flooding and landslides. It is believed that there are many thousands of subglacial lakes worldwide but, until now, their details were not collectively held and there was no clear picture on the size, stability and characteristics of the lakes.

An international team of researchers led by Stephen Livingstone, from United Kingdom-based University of Sheffield's department of geography, has now catalogued data on almost 800 lakes in Antarctica, Greenland and Iceland, as well as in glacial valley regions such as the Alps. The inventory, which has just been published in the Nature Reviews journal *Earth & Environment*, details the lake environments and dynamics, their size, how they behave and the impact on their local area.

The inventory provides a knowledge base of the current status and location of the lakes, allowing scientists to assess any future changes as the climate warms. It also highlights the gaps in collective knowledge that will help researchers to focus on new areas in future.

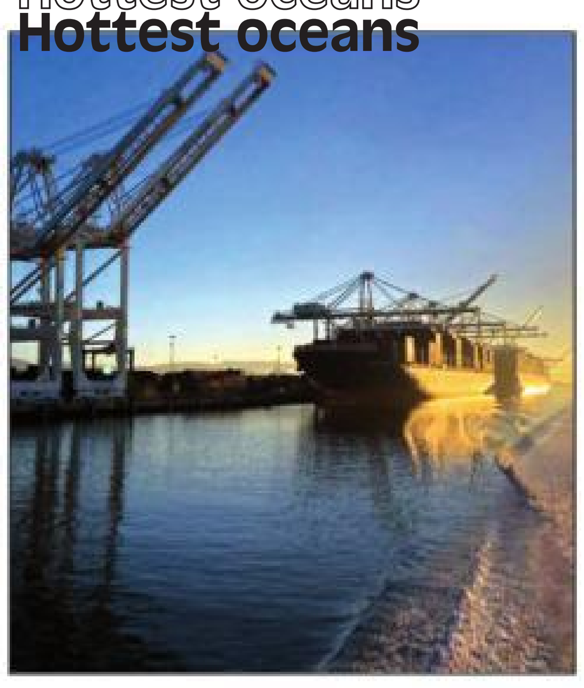
While 80 per cent of the lakes were found to be stable -- meaning they have no addition or removal of water at all, or they have a balanced inflow and outflow -- the researchers also observed that 20 per cent of lakes are active. This means they can drain suddenly and catastrophically, posing a hazard to human populations and infrastructure downstream.

Geophysical data currently available mean that most lakes included in the inventory are in Antarctica. The researchers have called for future studies to focus on valley glaciers, ice caps and the Greenland Ice Sheet to gain a better understanding of water storage and drainage beneath glaciers in vulnerable areas.

Livingstone said, "Innovations in radio-echo sounding, swath radar technology, satellite altimetry and high-resolution time-stamped digital surface models have confirmed the widespread existence of subglacial lakes over the last five decades. Our inventory will enable researchers to evaluate subglacial lake environments and their dynamics across different regions."

The 773 lakes catalogued in the inventory include 59 which have been newly identified in Antarctica -- some of which measure up to six miles in length and are under 3,000 metres of ice. The paper "Subglacial lakes and their changing role in a warming climate" is now available in *Nature Earth & Environment*.

Hottest oceans
Hottest oceans



Last year was the hottest for the world's oceans in recorded human history, according to a study led by an international team of scientists who track the data.

Published last week in the journal *Advances In Atmospheric Sciences*, it was conducted by 23 researchers from 14 institutes in China, the United States and Italy. They found that the upper 2,000 metres in all oceans absorbed a greater amount of heat in 2021 than the previous record set just the year before, equal to 145 times the world electricity generation in 2020.

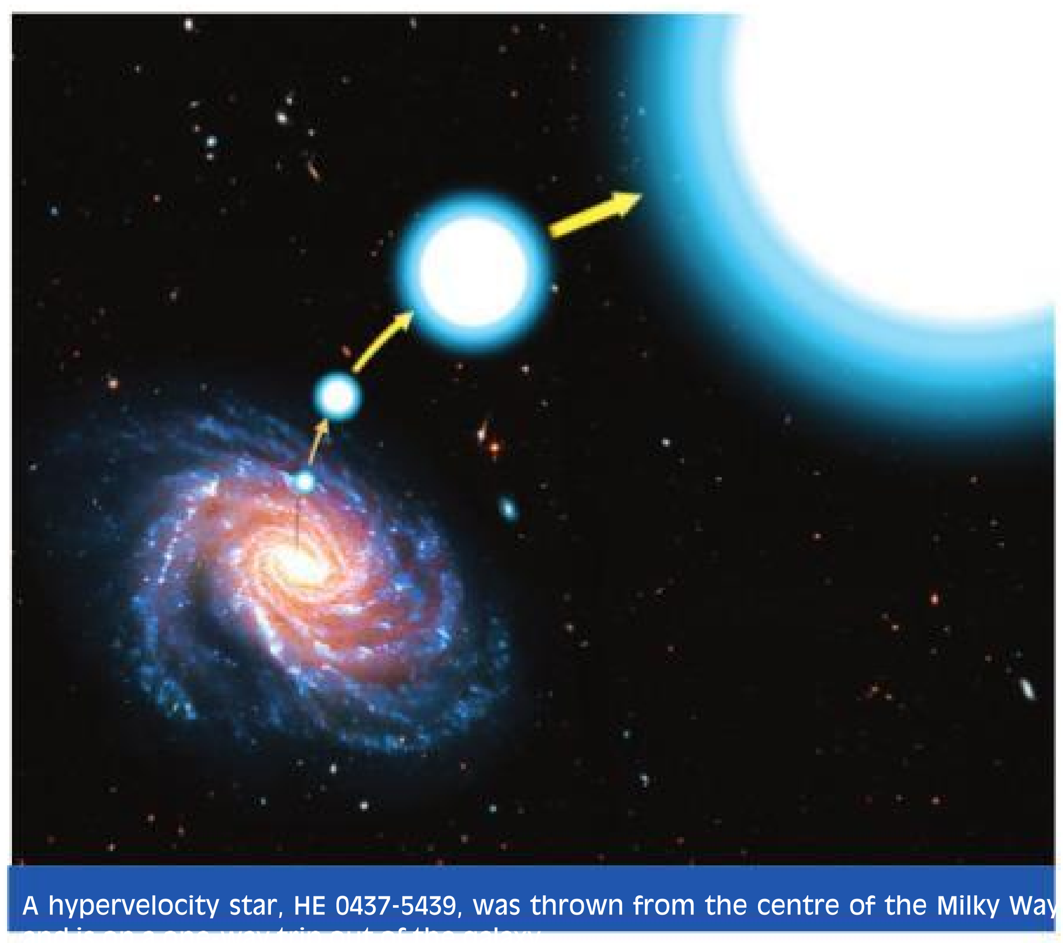
As more than 90 per cent of the excess heat due to global warming is absorbed by the oceans, ocean heat content is a primary indicator of global warming, said Kevin Trenberth, a scientist with the U S National Centre for Atmospheric Research and co-author of the study.

The straits times/ann

FURIOUSLY FAST

Real shooting stars exist, but they aren't the streaks you see in a clear night sky

Shooting stars – such as those produced by the Leonid meteor shower depicted in this print from 1889 – are beautiful, but they have nothing to do with real stars.



A hypervelocity star, HE 0437-5439, was thrown from the centre of the Milky Way

'I see thy glory like a shooting star." So says the Earl of Salisbury as he ruminates about the future in William Shakespeare's *Richard II*.

During the English Renaissance, people believed shooting stars were luminaries falling from the heavens and harbingers of calamity. But by the end of the 19th century, scientists had established the truth to be far more mundane. What today are commonly called shooting or falling stars are simply small pieces of rock or dust that quickly burn up upon entering Earth's atmosphere.

But nature has a surprise for you -- shooting stars really do exist.

I am an astrophysicist who studies celestial mechanics -- how objects like stars, planets and galaxies move. From 2005 to 2014, a monumental observing programme incorporating the Sloan Digital Sky Survey and telescopes at the United States' Fred Lawrence Whipple Observatory confirmed a new class of stars that move with such incredible speed that they can escape the gravity of their home galaxies. Astronomers are just beginning to understand these real-life shooting stars -- called hypervelocity stars -- that zoom through the cosmos at millions of miles per hour.

Spinning stars and slingshots

The story of hypervelocity stars begins in 1988, when Jack Gilbert Hills, a theoretician at Los Alamos National Labs, had an inspired idea: What would happen if a binary star system -- that is, two stars that are gravitationally bound to each other and orbit a common centre of mass -- travelled near the massive black hole at the centre of the Milky Way? Hills calculated that the tidal force of the black hole could rend the binary system in two.

Imagine two ice skaters holding hands and spinning around until they all of a sudden let go. The two skaters will fly away from each other. Similarly, when two stars in a binary system are wrenched apart by a close encounter with a black hole, they will fly apart. In such an encounter one star might gain enough energy to be slingshot out of the galaxy entirely.

Astronomers now know that this is how hypervelocity stars are born.

Theory, observations and simulations

After the publication of Hills' prescient paper, the astronomy community considered hypervelocity stars an intriguing possibility, albeit one without observational evidence. That changed in 2005.

While observing stars in the Milky Way's halo, a team of researchers using the MMT Observatory in Arizona came across something most unexpected. They observed a star escaping the Milky Way at nearly 3.2 million kilometres an hour. This was HVS1, the first known hypervelocity star.

Observations tell part of the story, but to help answer other questions -- such as what happens to the companion after it separates from the hypervelocity star -- my adviser and I turned to computer simulations. Our models predict that the other star in the former pair is often left orbiting the black hole in much the same fashion as the Earth orbits the Sun. Another exciting result from these modelling efforts was the discovery that sometimes the two stars can crash into each other. When this happens, the stars may coalesce into one very massive star.

If you were wondering what might befall a planet orbiting one of these stars, we modelled that too. In a short paper from 2012, my colleagues and I showed that the black hole in the centre of our galaxy can blast planets out of the Milky Way at nearly five per cent the speed of light.

As of today, no hypervelocity planets have been detected, but they very well might be out there, waiting for some happy astronomers to chance upon them.

Not all fast stars leave the galaxy

Utilising data from the Gaia spacecraft, launched in 2013, my colleagues and I discovered that some of the stars that the astronomy community had previously considered "hypervelocity stars" are in fact likely bound to the Milky Way galaxy.

While this result may sound disappointing, it actually reveals two critical points. First, there are different mechanisms to accelerate stars to high speeds. Today astronomers know of thousands of speedy stars. Just because a star is moving fast, however, does not necessarily make it a hypervelocity star unbound from the Milky Way. Second, true hypervelocity stars that are escaping the Milky Way may be rarer than previously thought.

The future is bright and fast

I find it beautiful that true shooting stars exist. It's equally amazing that studying their trajectories and velocities can help answer some of the foremost questions in science today.

For instance, hypervelocity stars could offer clues to the nature and distribution of dark matter in the universe. Hypervelocity stars may also be the key to answering whether there is more than one black hole at the centre of the galaxy.

My students are using the National Aeronautics and Space Administration's Transiting Exoplanet Survey Satellite to search for planets around these blisteringly fast stars. The discovery of even one planet around a hypervelocity star will forever change ideas of planetary formation and survivability.

These stars are speedy, but slowly they are shedding light on nature's secrets. While you may not be able to see a real shooting star with your own eyes, you certainly can make a wish upon one.

The writer is an academic faculty in physics and astronomy, Georgia State University, United States. This article first appeared on www.theconversation.com