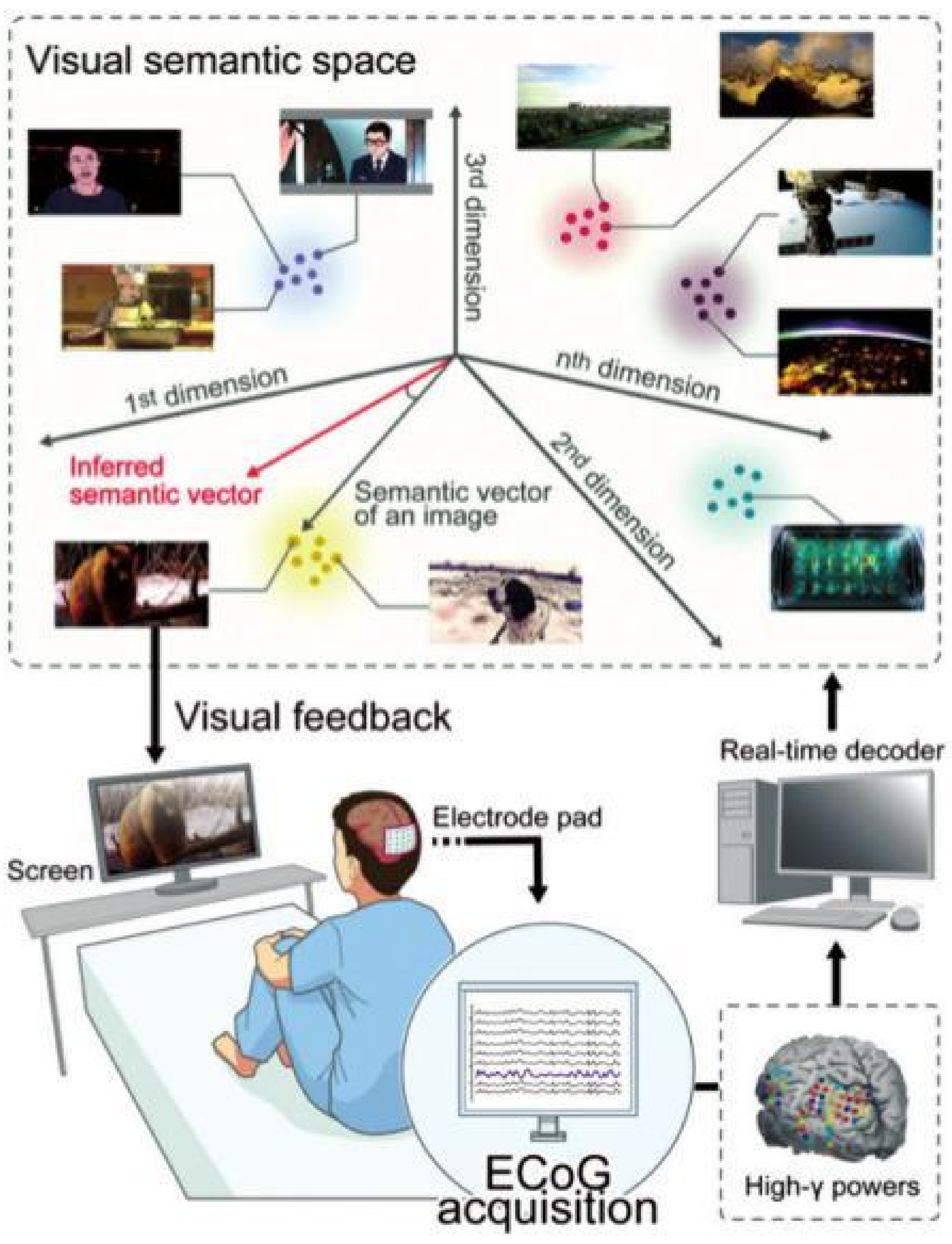
Pictures of the mind at work

Decoding the electrical activity of the brain can help us to understand how we see things

S ANANTHANARAYANAN



When all of us see the same object, we do agree on what it is that we see. But is it the same picture, in our minds' eye, that each one of us sees? This is clearly a question that we cannot answer, for we cannot make out the forms that things take inside the minds of others.

Yet, Ryohei Fukuma, Takufumi Yanagisawa, Shinji Nishimoto, Hidenori Sugano, Kentaro Tamura, Shota Yamamoto, Yasushi Iimura, Yuya Fujita, Satoru Oshino, Naoki Tani, Naoko Koide-Majima, Yukiyasu Kamitani and Haruhiko Kishima, from Osaka, Juntendo, Kyoto and Nara Medical Universities, ATR Computational Neuroscience Laboratories, Seikacho, Japan and National Institute of Information and Communications Technology, Suita, Japan, peer inside the brain in what amounts to mind reading. Their paper in the journal, *Communications Biology*, describes patterns of electrical activity in the brain that correspond to the way we see, either when we imagine things, which are thoughts, or when the things are before us.

Images that form on the retina are perceived in the form of pixels, each picked up by a separate nerve cell. And the information from all the cells is conveyed through the optic nerve to the brain, where it is processed, and stored. Processing involves deriving meaning from the image perceived, and we have some ideas of how the brain learns to understand images, through a process of repetition and feedback. The process itself, however, is not known, nor is the mechanism of storage and memory.

What we do know, and can measure, however, is that there is electrical activity in the brain whenever there is a stimulus, like an image before the eyes, or a thought. Although the link between the activity and things like images is too complex for ordinary methods to unravel, it turns out that patterns can be discerned by the methods of Artificial Intelligence, which are, in fact, simulations, in powerful computer networks, of how we believe the animal brain works.

The concept is that when nerve cells receive a stimulus, they first randomly fire signals to other nerve cells, which do the same to further layers of nerve cells. The cells then receive feedback, of whether the signal they sent out led to a desirable result. And every time the feedback is good, the probability of that response increases. Over millions of trials, which may be the case when an infant interacts with surroundings during a year of life, for instance, certain responses, which we could term as "intelligent", become routine. The infant thus learns to recognise objects to reach out for, sounds that mean food is at hand, then words, sentences, and so on.

Machine Learning, or Artificial Intelligence, consists of software objects that behave like brain cells, with multipliers of the probability of a response increasing or reducing according to the feedback. The snippets of software are called neural cells, as they stand in for neurons, or brain cells. They are arranged in groups which receive the different features of the input, to process and send signals to another group, and so on. And the feedback passes in the reverse direction, to tweak the processes of each cell, till the ensemble begins to find the correct responses to inputs more often.

Methods of AI were hence applied to the electrical activity in brain cells. As picking up the activity calls for placing electrodes, or metal probes within the brain, the team carried out the experiments with patients of epilepsy, or seizures, where such probes are already in place, as part of investigation and treatment. With help of the probes, the team could record electrical activity in the region of the cerebral cortex, as electrocorticograms, or ECoGs. The cerebral cortex, incidentally, is the outer layering of the brain, which receives most sensory information and connects to brain structures within the cortex.

And then, the paper says, by exposing the AI system to a large number of ECoGs arising from different objects that the participants saw, the system can be "trained" to make out the perceived images that result in particular ECoGs -- or "neural representations" of the images perceived. And further, the paper says, the ECoGs arise not only from perception of images, but also from just concentration, or imagining the image. A case of ECoGs arising from "bottom-up" perception of images and from "top-down" cerebral activity!

How attentive one is or where one's attention lies, while one sees and perceives an image, is known to modify the patterns of electrical activity, the paper says. In this context, the team looked into what happens when what is imagined is in conflict with what is perceived. For this trial, the participants were asked to create mental pictures of faces, landscapes or words that were different from what was being shown to them. Not only were the ECoG readouts when pictures were imagined seen to be distinct from the readouts when the images were perceived, it was found that the difference became wider if the participants received feedback while the trials were in progress.

What these amount to is that the ECoG can lead to a representation of the thoughts of a person, a means of communication without the intermediate stages of speech or action.

AI has been used earlier, to make sense of the complex nerve signals that drive the larynx and tongue to generate speech. Persons, like patients of ALS, who lose the capacity to speak, manage for some time with a keyboard, and then with a means of spelling out words by movements of the eyes. But even these methods, known as brain-computer interaction, or BCI, are not possible after a stage. This is where decoding nerve signals could become a means of directly synthesising speech.

While this possibility is still to be actualised, the current work, which deals with brain processes, could enable communication even in patients who are more seriously compromised. "Because visual cortical activity persists for a long time even in patients with ALS, rBCI (representational BCI) using visual cortical activity might be used as a stable communication device for patients with severe ALS," the paper says.

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What is ALS?

ALS stands for amyotrophic lateral sclerosis. "A" is a Greek prefix for "no", "myo" refers to "muscle", "trophic" means "nourishment". "Lateral" is the part of the spinal cord which controls muscles and movement, and "sclerosis" means hardening or damage.

ALS thus leads to a breakdown of communication from the brain to muscles. Patients progressively lose the ability to move, eat, speak and even breathe. The inability to communicate aggravates patient discomfort and increases the challenges for caregivers. Technology that could display a patient's thoughts as images would hence provide substantial relief.

APOCALYPSE NOW?

There are several reasons for the decline in insect numbers but concerted efforts can mitigate the situation

MARTIN J BABU & BIJU DHARMAPALAN

'If all mankind were to disappear, the world would regenerate back to the rich state of equilibrium that existed 10,000 years ago. If insects were to vanish, the environment would collapse into chaos." -- Edward O Wilson

There have been reports of insect population decline and that has elicited worry across the world. The deep concerns of people and the press are understandable as one is talking about the most abundant, diverse and adaptive animals on Earth. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services estimates that 10 per cent of all insects are endangered and an annual decline of one to two per cent is also being reported.

That said, the credibility of an "insect armageddon" is debatable as the argument is based on a questionable methodology, biased sampling and weak extrapolations of the sampled data. One notices that the "apocalypse" projections are based on studies conducted in a few countries in Europe and North America and a few insect orders. Moreover, insect populations from tropical countries have been scarcely assessed. Hence, claims of an "insect apocalypse" are weak, especially on a global scale.

Population assessment of insects is complex and challenging, considering the inherent stochasticity associated with insect populations. Spatial and temporal aspects of insect populations show trends as the diversity and abundance of insects vary with geographical and ecological conditions. Gaps in our knowledge about the natural history and other biological aspects of insects persist, and our taxonomic knowledge is also modest in this regard.

We are still in the dark about approximately four million insects or more. Our efforts to carry out relevant research or track insects taxonomically have not been rigorous enough, which can be attributed to the scarcity of taxonomists and ecologists. Paradigm shifts in our approaches and innovative strategies in scientifically assessing and understanding insect populations are the need of the hour.

Insects are intricately involved in the processes of ecosystems, so their decline in huge numbers would disrupt trophic-level interactions and may affect the functioning of ecosystems. The ecosystem services of insects are numerous -- they pollinate approximately 85 per cent of the plants on Earth and recycle the dead and decomposed back to the soil as nutrients. They are also soil tillers -- as agents of biological control or predators, insects play a crucial role. They are a natural feed for many species of lizards and birds, and many aquatic insects and their larvae are taken as good ecological indicators of aquatic ecosystems.

Despite these facts, people consider insects as mere pests, vectors of diseases, or creatures that need to be eliminated. As reports of them being wiped out are doing the rounds, we should be aware of the dire consequences that may follow in terms of species abundance, diversity or biomass. Let's look at the reasons for a decline in the numbers of insects.

Agricultural intensification & deforestation

The Anthropocene is defined by drastic and detrimental environmental changes caused by the mindless activities of humans. Anthropogenic activities pose severe threats to insects through changes in land use, agriculture expansion, deforestation, and urbanisation. As human populations increase worldwide, land areas undergo large conversions to meet agricultural demands. Rampant agricultural intensification has thus been considered one of the significant reasons for insect population decline.

Pesticides & pollution

Modern agriculture trends promote unsustainable practices causing irrevocable damage to the environment. Chronic exposure to pesticides is lethal for most insects through the toxic effects of direct exposure or by behavioural and physiological problems. Bioaccumulation is also a severe threat to insects as food chains turn noxious. Pesticides and fertilisers have drastically affected the quality of insects' niches, particularly bumblebees, honeybees and many other pollinators.

Several freshwater insect taxa are affected by pollution, which is around 41 per cent of species on the International Union for Conservation of Nature's Red List. On the other hand, light pollution interferes with insects, particularly the temporal niches of many nocturnal insects. Light disrupts navigation and activities such as foraging and egg-laying. In the same manner, noise pollution significantly changes the acoustic landscape. It interferes with the acoustic communication of insects and their auditory surveillance of the environment.

Climate change

Climate change is considered the most significant threat for insects in the Anthropocene. Rising temperature changes and precipitation patterns are believed to have severe consequences for plants and animals, affecting their abundance and distribution. Consequently, this can affect the process of insect-plant interactions. Insects depending on plants for food, shelter, and oviposition will be deprived of such resources in changing environmental conditions.

Temperature rise may also lead to prolonged and unpredictable periods of droughts, thereby altering the habitats of insects. Further, water scarcity problems could pose serious physiological challenges to their survival.

Being ignorant about two-thirds of insects, both taxonomically and ecologically, however, underscores the precarious situation we are in. We need to establish a consortium of scientific organisations, entomological research institutes, universities, colleges, non-governmental organisations and all those interested in the subject to collaborate on an "insect monitoring programme". Citizen science initiatives worldwide have highlighted the need to assess insect populations and popularise the conservation of many species. In India, such initiatives on cicadas, dragon flies, moths and butterflies have taken off well and should be encouraged.

The Zoological Survey of India and other scientific bodies of the country should take up this cause and convince the government to constitute a task force for monitoring insects. The ZSI, with its conspicuous roots of regional centres and a large brigade of animal taxonomists, can lead the task force.

In addition, entomological science should be modernised by adopting new technologies for surveying insect populations better. For example, sophisticated insect traps with automated monitoring and counting systems are in the offing, which promises identification at the species-level using sound recognition or image analysis. We also need to extensively develop our molecular database of genetic barcodes for setting up vast molecular taxonomic data of insects.

Minimising insecticides and pesticides is crucial for the future of ecosystems; hence, adopting sustainable practices such as integrated pest management, or IPM, strategies can reduce the harmful effects of pesticides and fertilisers. Unfortunately, IPM mainly remains confined to the agricultural fields of some universities or on paper.

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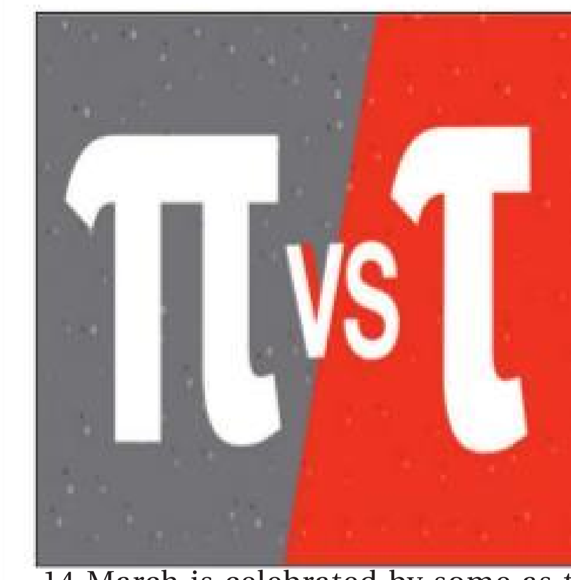
PLUS POINTS

Circle constant



14 March is celebrated by some as the most exciting day in mathematics -- when the date lines up in the numbers of the famous constant, Pi. But some people would rather it isn't celebrated at all.

The day looks like 3.14 for those that write dates in the month then day format, but that is rarely used outside of the Americas. Many people instead opt to celebrate the potentially more interesting Pi approximation day, which takes place on 22 July or 22/7 -- a way of working out an approximate value for Pi for use in rough calculations.

And still others would rather that Pi Day was not celebrated at all, and say that the number should not be treated with such reverence. Instead, they say that we should use Tau -- a number that serves much the same purpose and can be celebrated on 28 June, or 6/28 in America.

The complaints about the date are relatively obvious. Most places around the world use a different system to the United States, where Pi Day was born. By far the most popular date format is day/month/year. It is not possible to write Pi Day using that format, but it is easy to write Pi approximation day.

But the complaints about the competitor to Pi Day, Tau Day, are much more aggressive -- and campaigners for the change have made a website and a full manifesto. Written by Tau fan Michael Hartl, it is dedicated to the "true circle constant", which he says should be referred to by the Greek letter, Tau.

The number itself is simply Pi, but doubled -- 6.28318, and so on. That makes it easier to use in many applications, campaigners claim. But those behind the Tau manifesto admit that they are facing a difficult challenge, "a powerful conspiracy, centuries old, determined to propagate pro-Pi propaganda".

The Independent

Stereo vision

It had been previously thought that the inner workings of fruit flies' eyes were immobile, since the insect's compound eyes appear stationary from the outside. Therefore, it has been long thought that they could only see a low-resolution, "pixelated" image of the world with little or no depth perception.

Scientists at the University of Sheffield in the United Kingdom have now discovered that photoreceptors, cells in the eye which react to changes in light, twitch in an organised way, which create a fine detailed image.

The team discovered that flies can see in high-resolution stereo vision because their photoreceptors gather more information about the surroundings than previously thought possible. The photoreceptors do this by responding to light changes with ultrafast mirror symmetrical movements, called photoreceptor microsaccades, so when the fly moves forward, they are gathering images that both simultaneously move with the world and against it.

The image information the photoreceptors gather is therefore not coarsely "pixelated" but continuous and much more detailed, which is then sent to the brain and processed into what the flies see.

Professor Mikko Juusola, from the University of Sheffield's School of Biosciences, said, "Our findings could have implications for human eyesight, as the nervous system of a fruit fly has evolved to perceive the three-dimensional world efficiently and it's very likely that us and fruit flies use similar principles in order to see in stereo. Furthermore, the mathematical theory about mirror-symmetric visual information sampling that we present with these results can be used to improve man-made sensors and is directly applicable for machine vision and robotics."

The research has been published in the journal, *Proceedings of the National Academy of Sciences of the United States of America*.