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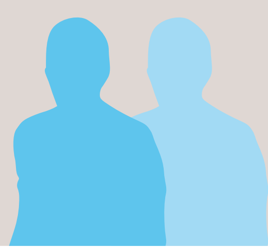

# Eye by night

*For animals that need to be able to see in the dark, it helps if they can slow down the way their eyes experience light, says* **Eric Warrant**

On a moonless night, light levels can be just a tiny fraction – as low as a 100 millionth – of what we are treated to on a bright day. Yet while we humans are nearly blind and quite helpless in the dark, cats use night time to go out stalking prey, while millions of other animals rely on their visual systems to survive after the sun has gone down.

The same is true of animals who inhabit the eternal darkness of the deep sea. In fact, the overwhelming majority of the world's animals are primarily active in dim light.

How is their formidable visual performance possible, especially in insects with tiny eyes and brains less than the size of a grain of rice? What optical and neural strategies have they evolved to allow them to see so well in dim light?

Despite their diminutive visual systems, nocturnal insects see amazingly well in dim light. In recent years we have discovered that nocturnal insects can avoid and fixate on obstacles during flight, distinguish colours, detect faint movements, learn visual landmarks and use them for homing. They can even orient themselves using the faint celestial polarisation pattern produced by the Moon, and navigate using the constellations of stars in the sky.

In many cases, this visual performance seems almost to defy what's physically possible. For example, the nocturnal Central American sweat bee, *Megalopta genalis*, absorbs just five photons (light particles) into its tiny eyes when light levels are at their lowest – a vanishingly small visual signal. And yet, even with so little light to guide its path, the bee can navigate the dense and tangled rainforest on a foraging trip and make it safely back to its nest – an inconspicuous hollowed-out stick suspended within the forest understorey.

To find out how this kind of performance is possible, my research group and I recently began to study nocturnal hawkmoths. These beautiful insects – the hummingbirds of the invertebrate world – are sleek, fast-flying moths that are constantly on the lookout for nectar-laden flowers. Once a flower is found, the moth hovers in front of it, sucking the nectar out using its proboscis, a mouth-like tube.

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The nocturnal European Elephant hawkmoth, *Deilephila elpenor*, is a gorgeous creature cloaked in feathery pink and green scales and does all its nectar gathering in the dead of night. A number of years ago we discovered that this moth can distinguish colours at night, the first nocturnal animal known to do so.

But this moth recently revealed another of its secrets: the neural tricks it uses to see well in extremely dim light. These tricks are certainly used by other nocturnal insects such as *Megalopta*. By studying the physiology of neural circuits in the visual centres of the brain, we discovered that *Deilephila* can see reliably in dim light by effectively adding together the photons it has collected from different points in space and time.

> **The nocturnal Elephant hawkmoth moth can distinguish colours at night**

This is a little like increasing the shutter time on a camera in dim light. By allowing the shutter to stay open longer, more light reaches the image sensor and a brighter image is produced. The downside is that anything moving rapidly – like a passing car – will not be resolved and so the insect won't be able to see it.

To add together photons in space, the individual pixels of the image sensor can be pooled together to create fewer but larger (and so more light-sensitive) "super pixels". The downside of this strategy is that even though the image becomes brighter, it also becomes blurrier and finer spatial details disappear. But for a nocturnal animal straining to see in the dark, the ability to see a brighter world that is coarser and slower is likely to be better than seeing nothing at all, which would be the only alternative.

Our physiological work has revealed that this neural summation of photons in time and space is immensely beneficial to nocturnal Deilephila. At all nocturnal light intensities, from dusk to starlight levels, summation substantially boosts Deilephila's ability to see well in dim light.

In fact, thanks to these neural mechanisms, Deilephila can see at light intensities around 100 times dimmer than it could otherwise. The benefits of summation are so great that other nocturnal insects, such as Megalopta, very likely rely on it to see well in dim light as well.

The world seen by nocturnal insects may not be as sharp or as well resolved in time as that experienced by their day-active relatives. But summation ensures that it is bright enough to detect and intercept potential mates, to pursue and capture prey, to navigate to and from a nest and to negotiate obstacles during flight. Without this ability it would be as blind as the rest of us.

**Eric Warrant is a professor of zoology at Lund University in**

# Now here's a brainwave: open your online bank account just by thinking

**By Palaniappan Ramaswamy**

Biometric technology that can recognise individuals from their faces, voices or fingerprints has become increasingly important in combating financial fraud and other security threats, as PINs and passwords are proving too easily compromised.

For example, Barclays lets customers log on to internet banking using fingerprint scanners on mobiles.

However, this is not foolproof either. Fingers can, after all, be chopped off and used by impostors to gain fraudulent access, and prints lifted from glass on cellophane tape can be used with gelatine to create fakes.

One promising alternative is the electrical activity of the brain. Over the years, a number of studies have found that "brainprints" – readings of how the brain reacts to certain words or tasks – are unique to individuals as each person's brain is wired to think differently.

In fact, a study using functional magnetic resonance imaging (fMRI), which measures brain activity by tracking changes in blood flow, was able to recognise individuals with up to 99 per cent accuracy when performing certain mental tasks such as relaxing or listening to a story.

However, the cost and difficulty of using fMRI – you have to lie very still in the scanner for a fairly long time – means it is clearly not practical for everyday authentication. For that reason, researchers have instead looked at a test called EEG, which uses electrodes to track and record brainwave patterns.

Technological advances mean EEG can now be carried out using electrodes placed on the surface of standard earphones. One downside is that it can't be used by twins – they have near-identical EEG patterns. But the main problem is the lack of stability of brainprints over time.

It seems it is not enough to have an EEG done just once – re-enrolment (say, monthly) is necessary. However, in ongoing work at the University of Kent, we have shown that specific tones (which can be played using earphones) can be used to minimise these changes.

Brainprints can also be used to generate replacements for conventional passwords or PINs. For example, rather than keying in the PIN at an ATM, one would connect earphones and be shown a series of numbers on the screen. Brain patterns would change when the correct one showed up – activating the transaction. By doing so, one would not have to worry about others looking over your shoulder. Moreover, in coerced situations, brainprints will not work due to the stress – making them even more fraud-resistant.

Given the advances in the technology, we are likely to see uptake of biometric applications based on brainprints soon – especially as one part of a security system using multiple identifiers. Don't be surprised to receive EEG earphones from your bank shortly.

**Dr Palaniappan Ramaswamy is a reader in signal analysis at the University of Kent**

# The 'Indian Niño' means East Africa must adapt to cope with more droughts

*Its name may not be as familiar as El Niño, but the Indian Ocean Dipole will threaten lives for years, warns* **Rob Marchant**

A severe drought threatens millions of people in East Africa. Crop harvests are well below normal and the price of food has doubled across much of Ethiopia, Kenya, Somalia and nearby countries. The last major drought in the region, in 2011, caused hundreds of thousands of deaths. They are becoming more frequent and more intense – and each has a disastrous impact on the economies of nations and livelihoods of people. So what is causing these droughts? And why are they becoming more common?

At least part of the explanation lies with a climate phenomenon known as the "Indian Ocean Dipole". Often called the Indian Niño due to its similarity with El Niño, the dipole is not as well known as its Pacific equivalent. Indeed, it was only properly identified by a team of Japanese researchers in the late 1990s. The dipole refers to the sea's surface temperatures in the eastern Indian Ocean off Indonesia, cycling between cold and warm compared to the western portion of the ocean. Some years the temperature difference is far greater than others.

We are currently coming out of a particularly strong dipole. At its peak, in summer 2016, the sea off the Indonesian coast was 1C or so warmer than waters a few thousand kilometres to the west. Warmer seas mean more water evaporation and, on this sort of vast scale, a relatively small temperature difference can have a big effect. In this case, it meant a lot more moisture in the atmosphere above the eastern Indian Ocean.

As moist air is cooler than dry air, this in turn affected the prevailing winds. Wind is simply the atmosphere trying to equalise differences in temperature, density and pressure. Therefore, to "even out" the unusually cool air, a warm, dry wind began to blow eastwards from Africa across the ocean.

This is disastrous for farmers in the Horn of Africa who rely on moisture from the Indian Ocean to generate the "short rains" that run from October to December and the "long rains" from March to June. With winds blowing out to sea, the air was even drier than usual. The 2016 short rains were a month late and in some places failed entirely. Aid agencies warned that the failure of these rains could trigger mass famine across northern Kenya,

**Aid agencies are warning that people across eastern Ethiopia, South Sudan, northern Kenya and Somalia are at risk from mass famine**

South Sudan, Somalia and eastern Ethiopia.

Things will not improve any time soon. As with El Niño, global warming means the Indian Ocean Dipole has become more extreme in recent years. In East Africa, these severe droughts will become the norm.

There are no easy answers. However, while we cannot control the Indian Ocean, we can change the way humans interact with the East African environment, making communities more resilient to climate change. Past land use offers us some important clues. For example, a number of sites across East Africa demonstrate the impact of having switched to more drought-sensitive New World crops such as maize.

Since being introduced to Africa in 1608, maize has largely replaced more traditional and drought-resistant crops such as cassava or sorghum. It provides excellent calorific returns in good years, but it often fails, with infestation and storage problems during drought years.

Further lessons from history show us that pastoral communities have become less mobile. Livestock farmers are settling down and becoming increasingly reliant on irrigation and crop growing, which makes them more sensitive to drought. Competing demands to conserve land for wildlife add to the problems.

There are a few things East Africans can do to ease the impact of climate change, especially droughts. Livestock farmers could share large communal "grazing banks" to act as an insurance scheme and spread the risk of pasture failure. Pastoral movements could be better managed to ensure areas do not become overgrazed, and conflicts with conservation areas are minimised.

Mountain forests could be better managed to capture useful water without the need for costly and vulnerable irrigation systems. And, finally, farmers could switch to varieties of crops that are better at coping with climate variability.

The "Indian Niño" isn't going anywhere, along with the regular and severe droughts it causes. We must all be prepared.

**Dr Rob Marchant is a reader in tropical ecosystems at the University of York**

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