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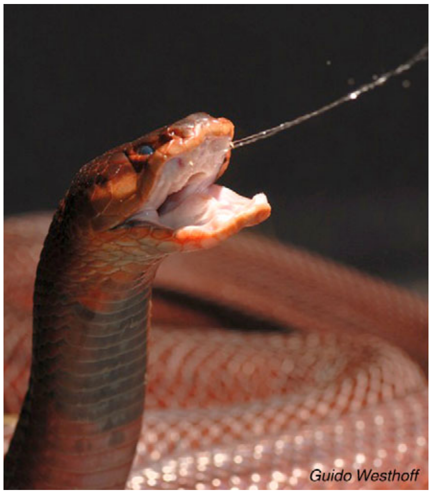
SPITTING COBRAS TRACK FIRST, PREDICT LATER


Guido Westhoff

Most venomous snakes are legendary for their lethal bites, but not all. Some spit defensively. Bruce Young, from the University of Massachusetts Lowell, explains that some cobras defend themselves by spraying debilitating venom into the eyes of an aggressor. Getting the chance to work with spitting cobras in South Africa, Young took the opportunity to record the venom spray tracks aimed at his eyes. Protected by a sheet of Perspex, Young caught the trails of venom and two things struck him: how accurately the snakes aimed and that each track was unique. This puzzled Young. For a start the cobra's fangs are fixed and they can't change the size of the venom orifice, 'so basic fluid dynamics would lead you to think that the pattern of the fluid should be fixed,' explains Young. But Young had also noticed that the snakes 'wiggled' their heads just before letting fly. 'The question became how do we reconcile those two things,' says Young (p. 1797).

According to Young, Guido Westhoff had also noticed the spitting cobra's 'head wiggle', so Young travelled with his research assistant, Melissa Boetig, to Horst Bleckmann's lab in the University of Bonn, Germany, to find out how spitting cobras fine-tune their venom spray. The team had to find out how a target provokes a cobra to spit, and Young was the man for that job, 'I just put on the goggles and the cobras start spitting all over,' laughs Young.

Wearing a visor fitted with accelerometers to track his head movements while Boetig and Westhoff filmed the cobra's movements at 500 frames s^{-1}, Young stood in front of the animals and taunted them by weaving his head about. Over a period of 6 weeks, the team filmed over 100 spits before trying to discover why Young was so successful at provoking the snakes. Analysing Young's movements, only one thing stood out; 200 ms before the snake spat, Young suddenly jerked his head. The team realised that Young's head jerk was the spitting trigger. They reasoned that the snake must be tracking Young's movements right up to the instant that he jerked his head and that it took a further 200 ms for the snake to react and fire off the venom.

But Young was still moving after triggering the snake into spitting and the snake can't steer the stream of venom, so how was the cobra able to successfully hit Young's eyes if it was aiming at a point where the target had been 200 ms previously? Realigning the data to the instant when Young jerked his head, the team compared all of the snakes' head movements and noticed that the cobras were all moving in a similar way. They accelerated their heads in the same direction that Young's eyes were moving. 'Not only does it speed up but it predicts where I am going to be and then it patterns its venom in that area,' explains Young.

So spitting cobras defend themselves by initially tracking an aggressor's movements. However, at the instant that an attacker triggers the cobra into spitting, the reptile switches to predicting where the attacker's eyes will be 200 ms in the future and aims there to be sure that it hits its target.

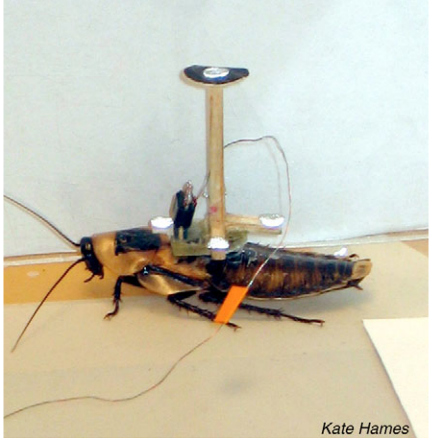
10.1242/jeb.046136

Westhoff, G., Boetig, M., Bleckmann, H. and Young, B. A. (2010). Target tracking during venom 'spitting' by cobras. *J. Exp. Biol.* **213**, 1797-1802.

HOW COCKROACHES RUN ON SOFT SURFACES

Watch human cross-country runners and you can't fail to be impressed by the way they adapt to different surfaces. Andrew Spence explains that human runners achieve this by a subtle trick. 'If you look at the force patterns acting on human runners they look like what you would predict from a pogo stick, which is a point mass with an elastic spring leg coming off the bottom that bounces whenever a foot hits the ground,' explains Spence. When humans run over soft surfaces, they effectively stiffen the virtual 'pogo stick'. But humans are the odd-ones-out in the animal kingdom. Most animals run around on four or more legs, so how do animals with multiple legs adjust to running on soft surfaces (p. 1907)?

Spence became intrigued by this problem when he was working in Robert Full's Poly-PEDAL lab at U. C. Berkeley. Talking to his colleague, Shai Revzen, they realised that they could use the minute accelerometers that Spence was building to


Kate Hames

see if animals also adjust the stiffness of their virtual 'pogo stick' legs. According to Spence, animals also move as if they are bouncing on virtual pogo sticks when running on hard surfaces, no matter how many pairs of legs they have. So how do they cope when the going gets soft?

Gluing one of the tiny accelerometers to a cockroach's back, the duo sent it scuttling off across a sheet of latex. The insect sunk into the soft rubber surface, like we sink into mud, but kept on going at the same speed. And when the duo looked at the wavy acceleration plots generated by the insect, 'we got beautiful wiggly lines,' remembers Spence. But the accelerometer could not give the duo all the information they needed. The team also had to measure the insect's position, orientation and velocity; and the only way they could get that information was by attaching a light balsawood cross to the accelerometer backpack and tracking the insect's movements with video.

After a year of development, the system was ready for Chris Mullens to collect data as the cockroaches scurried across the latex sheet. Having measured the accelerations experienced by the floundering insects, the team had to see if they could reproduce the forces that produced the real cockroaches' accelerations in a computational cockroach.

Building a computer model of a cyber-cockroach with its six legs replaced by a pogo stick that bounced every time three of the insect's feet hit the ground (two pogo stick bounces per stride cycle), the team found that when the cyber-roach ran on latex it didn't look right. The simple pogo stick model could not explain how the insects ran on, and sunk into, soft ground.

The team needed a more representative model, so Justin Seipel, an applied mathematician in Full's lab, suggested adding a clock that drives the pogo sticks with a motor at the hip. Could this model reproduce the forces exerted on the cockroaches as they scuttled across the latex?

Amazingly it did. The cyber-roach kept moving at the same speed as it hit the virtual latex, but as it sunk into the soft surface, the trio of feet moving through the air hit the ground sooner than if the insect was on a hard surface. Instead of reducing the forces on the body's centre of mass by stiffening each virtual pogo stick leg – like human runners – Spence suspects that the insect's inefficient posture, as its feet hit the ground too soon, could reduce the forces acting on the insect's body without having to change the stiffness of its virtual pogo stick legs.

Spence explains that this simplifies control. Instead of sending nervous system signals to stiffen muscles, the cockroach may just be able to continue sending the same control signals and take advantage of the change in posture. 'By putting the intelligence in the mechanics you can reduce the amount of computation you have to do. It's a winner all round,' says Spence.

10.1242/jeb.046144

Spence, A. J., Revzen, S., Seipel, J., Mullens, C. and Full, R. J. (2010). Insects running on elastic surfaces. *J. Exp. Biol.* **213**, 1907-1920.

PYGOPODS HAVE EXCEPTIONAL HEARING

Among the vertebrates, mammals' high-frequency hearing is the best, followed by birds, with lizards having the least sensitive hearing at high frequencies; and this decline in sensitivity is matched by the size of their basilar papillae, the organs that detect sound. Geoffrey Manley, from the Technische Universität München and University of Western Australia, has long been fascinated by the evolution of hearing. According to Manley, geckos have some of the most complex basilar papillae of all lizards, equipped with two sets of high-frequency sensitive hair cells that could respond to different frequency ranges. Knowing that pygopod geckos (*Delma* species), which look more like snakes than geckos, share this relatively complex basilar papillae with their legged cousins, Manley and his colleague Johanna Kraus decided to find out just how sensitive pygopod hearing is (p. 1876).


Johanna E. M. Kraus

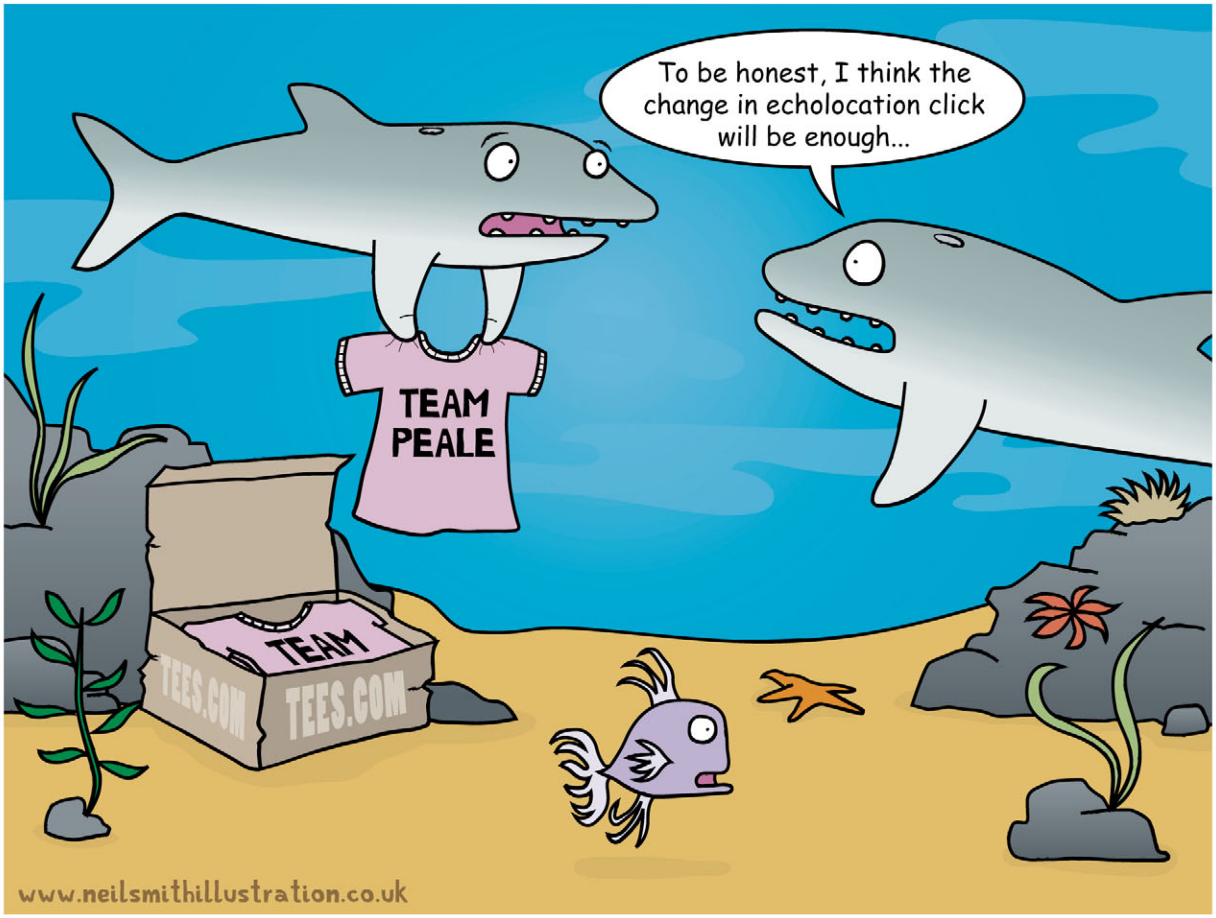
Travelling through the remote Pilbara region of Western Australia with a mobile laboratory, the duo measured the hearing of four pygopod species and found that the reptiles could hear frequencies as high as 12–14 kHz at 75 dB SPL. 'Such a hearing limit has never been observed in any reptile,' explains Manley, and suggests that the lizards' sensitivity could be attributed to 'a unique division of labour between groups of sensory cells within the hearing organ'.

Having found that the snake-like lizards have exceptional hearing, the duo recorded the geckos' squeaks as they released them back into the environment and found that the reptiles could hit notes as high as 20 kHz. 'Our estimates of vocalisation sound pressures and of hearing audiograms suggest that at close range, *Delma* species can hear their own call components up to a frequency of at least 12 kHz,' says Manley.

10.1242/jeb.046151

Manley, G. A. and Kraus, J. E. M. (2010). Exceptional high-frequency hearing and matched vocalizations in Australian pygopod geckos. *J. Exp. Biol.* **213**, 1876-1885.

COHABITING DOLPHINS ADJUST CLICKS TO AVOID CONFUSION



Creatures that navigate by echolocation have two problems: differentiating their calls and echoes from those of related species that live in the same location and reducing interference from echoes generated by cluttered environments. Bats are past masters at dealing with these issues, but what about dolphins? Did closely related species adjust their calls so that they could be distinguished or are the clicks adapted to reduce interference from acoustic clutter? Line Kyhn and her colleagues from Aarhus University, Denmark, and the Woods Hole Oceanographic Institute wondered how two species of toothed whales, Peale's and Commerson's dolphins, have adapted their calls in the waters that they both inhabit around the Falkland Islands (p. 1940).

Designing an array of six hydrophones, the team recorded over 2000 clicks from Peale's and Commerson's dolphins as the animals came to ride the bow waves of vessels. But in order to investigate the characteristics of the clicks, the team had to directly compare clicks that had been recorded when the dolphins were head-on, leaving the team with only 94 Commerson's dolphin clicks and 87 Peale's dolphin clicks.

Analysing the frequency distribution of the animals' clicks, Kyhn and her colleagues found that they were close to 130 kHz. The Commerson's dolphins' clicks were slightly higher pitched (133 kHz) than those of the larger Peale's dolphins (129 kHz), but both were well above the hearing range of killer whales that prey on dolphins. The team also found that both species use narrow sonar beams, reducing the problem of unwanted reflections from clutter, although Commerson's dolphins are quieter than Peale's dolphins and their softer clicks are better suited to foraging in the kelp forests where they hunt.

Considering whether the dolphins have modified their clicks because of their overlapping habitats, the team calculated the frequency distribution that they would expect larger Peale's dolphins to produce and found that the difference between the dolphins' clicks was smaller than expected, based on size alone. The team suspects that the dolphins have deliberately shifted their frequency ranges and that the shifts are sufficient for the animals to distinguish between Commerson's and Peale's dolphins' clicks. However, as the species do not hunt together and their beams of sound are highly focused, the team concluded that it has not been necessary for either to evolve more specialised acoustic mechanisms to overcome jamming by the other's clicks.

10.1242/jeb.046169

Kyhn, L. A., Jensen, F. H., Beedholm, K., Tougaard, J., Hansen, M. and Madsen, P. T. (2010). Echolocation in sympatric Peale's dolphins (*Lagenorhynchus australis*) and Commerson's dolphins (*Cephalorhynchus commersonii*) producing narrow-band high-frequency clicks. *J. Exp. Biol.* **213**, 1940-1949.