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Smarter than the average bug

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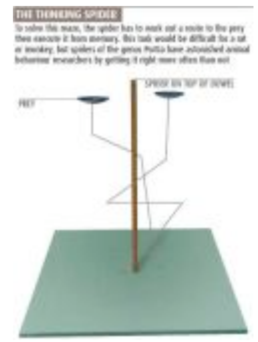
LOOKING more like a flake of bark than a spider, *Portia labiata* stops to have a think. Portia is a jumping spider that makes a living by eating other spiders - a risky business at the best of times. Luckily Portia has brains.



Enlarge image
The thinking spider

Right now it needs them. Portia, no bigger than a thumbnail, is perched on a branch with its beady eyes trained on a *Scytodes pallida*, another spider that specialises in eating other spiders. Scytodes is a spitting spider. It can squirt zig-zag jets of poison-coated silk from its mouth glands that would snare Portia in the blink of an eye.

They are like two high-rolling gamblers about to bet all their chips on a single throw of the dice. Fortunately for Portia, Scytodes doesn't know it is being watched. Spitting spiders have weak eyes and Scytodes is content to lurk in its web in the cup of a curled leaf in the forests of the Philippine island of Luzon, until some unwitting passer-by stumbles in. Portia, on the other hand, has excellent eyesight, with spatial acuity better than a cat or a pigeon. From a safe distance about half a metre away, Portia sits scanning Scytodes.

First it needs to know whether Scytodes is carrying a sac in its fangs. This is how Scytodes protects its eggs. And to do any spitting, it has to drop them first. If the spider had eggs, Portia would mount a frontal assault. It would creep to the edge of the web and gently tickle the threads, luring Scytodes into the open for the pounce.

On this occasion there is no egg sac. Worse, there is no way Portia can execute its regular plan B - crawl around the web and jump Scytodes from behind. So perched on its branch, Portia begins to plot. For a good quarter of an hour it scans the undergrowth, its tiny brain working out possible pathways across boulders and branches. The retinas of its two principal eyes have only a few thousand photoreceptors, compared to the 200 million or so in a human eye. But Portia can swivel these tiny eyes across the scene in a systematic fashion, patiently building up an image. Eventually Portia makes up its mind and disappears from sight. A couple of hours later, the silent assassin is back, dropping down onto Scytodes on a silk dragline attached to a rocky overhang, like something out of *Mission: Impossible*. Once again, Portia's guile wins the day.

Back in the lab, the story has a different ending. "Oh, that wasn't meant to happen!" cries Simon Pollard, a spider researcher at University of Canterbury in Christchurch, New Zealand. A Portia in a little plastic flask has just been dispatched by a white-tailed spider that was supposed to be its supper. "I guess a bottle isn't a very complex environment, so Portia doesn't really get the advantage of its greater intelligence," says Pollard, more than a little aggrieved.

The Portia genus, which is found across Africa, Australia and Asia and makes up about 20 of the 5000 known species of jumping spider, is fast becoming something of a celebrity in animal cognition research. Honeybees, with their intricate social behaviour and waggle dance, have long been considered smarter than the average bug. But neuroscientists have generally been dismissive of creepy-crawlies. Their nervous systems were supposed to be capable of no more than hard-wired reflexes, and certainly no one would talk in terms of thinking, planning, trial-and-error learning, attention span or - shudder -

consciousness. Insects and spiders could never have anything approaching a mind. Yet Portia does stuff that doesn't fit with the idea of invertebrates as automatons.

Watching Portia crouched in its flask, it is easy to understand why its abilities have been overlooked for so long. Ragged, hairy and drab, it wouldn't attract a second glance. Yet since researchers woke up to the fact that Portia had exceptional eyesight and unusually flexible behaviour, the surprises have just kept on coming.

One of Portia's principal skills is luring other spiders from the safety of their webs. Portia will pluck out rhythms at the edge of a web to mimic a trapped insect or a hostile intruder. If it has encountered the resident spider before, it sometimes knows what rhythm to use - a remarkable ability in itself. If it hasn't, Portia will try out various patterns by trial and error. It can tickle the web lightly, strum it vigorously, bob up and down as if on a trampoline - whatever it takes to persuade its target to move into the right position for an attack. Sometimes the foe will be two to three times Portia's size. The trick is then to arouse its curiosity without provoking a full-blooded rush.

Duane Harland, another researcher at the Canterbury lab, says this web plucking reveals cognitive skills that were thought to be beyond such a small creature. He contrasts Portia with web invaders such as the white-tail, which are all brawn, no brains.

"The white-tail can pluck, but only in a programmed, stereotyped, way. It doesn't bother with tactics, or experimenting, or looking to see which way the other spider is facing. It just charges in and overpowers its prey with its size. Portia is a really weedy little spider and has to spend ages planning a careful attack. But its eyesight and trial-and-error approach means it can tackle any sort of web spider it comes across, even ones it has never met before," says Harland.

While Portia's deception skills are impressive, what is most remarkable is its ability to plot a path to its victim. For an animal operating on instinct, out of sight is usually out of mind. Yet Portia can take several hours to get into the right spot, even if that means losing sight of its prey for long periods.

This capacity has been tested with mazes in the lab, both at Canterbury and at the University of Sussex, UK. In a typical experiment, researchers create a choice of two paths with coat-hanger wire (see Diagram). The set-up simulates a pair of branches growing out of the forest floor and crossing over each other in a confusing way. At the end of each wire is an identical prey-holding dish. Into one the experimenters place a dead spider, spray-coated to remove odour cues. Then they release a hungry Portia onto the top of a tall, wooden dowel that commands a view across the whole apparatus. To get to the bait, the spider has to work out which branch to take, climb down the dowel and onto the floor and then climb up the correct wire. Once off the platform, though, it can no longer see the prey and has to rely on memory.

This would be a tall order even for a rat or monkey. Yet more often than not, Portia succeeds - though it takes its time. Portia sits on the viewing platform for up to an hour, twisting to and fro as it appears to track its eyes across the possible routes. Sometimes it gives up. But once it has a plan, it clambers down and heads for one of the wires, even if this means walking past the other.

Harland says it seems that Portia knows where it wants to go and ignores distractions along the way. This is strengthened by the fact that on trials where Portia starts climbing up the wrong wire, it often gives up as soon as it reaches the first bend - even though it still cannot see the bait. It is as if Portia knows where it should be and can tell straight away when it has made a mistake.

In another experiment, Robert Jackson, head of Canterbury's spider lab, placed Portias on an island in the middle of a water-filled tray. The shore was too far to reach in a single leap, so Portia had to decide whether to jump some of the way and swim the rest, or swim all the way. Once in the water the researchers made waves that either hindered its progress - favouring the jump/swim strategy, or helped it, which favours swimming all the way. Jackson found that spiders would remember what happened on their first trial and either use the same strategy again or switch it, depending on whether it had been successful. Again this seems a rather dynamic, unprogrammed response for such a small brain.

Recent experiments by behavioural ecologist Daiqin Li at the National University of Singapore have demonstrated yet more startling cognitive abilities. He has found that after Portia makes a kill, it finds it easier to spot prey of the same species and becomes less attuned to other types of prey. This looks very much like selective attention; Li controversially describes it as the formation of a "search image", meaning that Portia has some kind of mental picture of its prey. Many psychologists would baulk at granting such abilities to cats or even chimps, never mind spiders.

How clever?

Crazy talk, obviously. There just isn't room in Portia's head for anything approaching an inner mental life. The human brain has some 100 billion brain cells, and a mouse has around 70 million. Harland says no one has done a precise count on Portia but it is reckoned to have about 600,000 neurons, putting it midway between the housefly's 250,000 and the honeybee's one million.

So what do the researchers conclude? Does Portia have some inkling of a mind? Or can every behaviour be explained away in terms of instinctive responses? Harland says many of Portia's cognitive abilities may eventually be explained by the design of its eyes - specifically by their inbuilt limitations.

All jumping spiders have excellent vision and Portia's is 10 times better than the average, making it sharper than that of most mammals. Being so small, though, there is a trade-off: Portia can only focus on one view at a time. It has to build up a picture of the world by scanning a scene point by point, as if peering through a keyhole.

Harland thinks that understanding the serial nature of the spider's vision makes it easier to imagine how prey recognition and other processes could be controlled by hard-wired programs. When Portia is looking for an egg sac, for example, it wouldn't need to deal with the scene as a visual whole. Instead it could check a template, ticking off critical features in a sequence of fixations. Perhaps the less the eye sees with each fixation the better.

The human brain, on the other hand, has to cope with a flood of information, and much of the work lies in deciding what to ignore. The laser-like focus of Portia's eyes might do much of this filtering by default. So what seems like intelligent decision-making could really be an evolved selective blindness.

But this doesn't necessarily make Portia any less remarkable. Harland says there is still a disconcerting plasticity in its behaviour. His next step in understanding Portia's cognitive abilities will be to use eye-tracking equipment to find out exactly how Portia scans the world as it is pondering its choices.

There is a lot to learn. As Jackson points out, only a few years ago no one would have believed a spider could show such clever behaviour. Today we are having to ask whether creepy-crawlies are a jump closer to being mental beings. Look into the eyes of a spider and who is to say it is not, in some sense, looking back?

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