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OUTSIDE JEB

City characteristics hinder squirrels' puzzle skills

The unpredictable nature of cities makes some animals better than others at responding to changes in their environment. But, there are very few studies that examine which aspects of city life influence the flexibility of an animal's behavior. Recent work by Pizza Ka Yee Chow from Max Planck Institute for Ornithology, Germany, and an international team of colleagues from Japan, the UK, the USA and Germany suggests that urban environments can hinder the Eurasian red squirrels' problem-solving abilities. To investigate how different characteristics of a modern human settlement affect squirrels' adaptability, the team created puzzles for the rodents to solve, across the city of Obihiro, Japan.

First, the team selected 11 sites around the city that differ in the number of human passers-by, man-made buildings and grassy areas. The researchers used Google Maps to determine the size of each site, the number of neighboring buildings and the amount of green space. To get a sense of the number of humans a squirrel might encounter at each site, a researcher recorded the number of people in the area 5 times a day, rain or shine, for about a month. The scientists also set up cameras to determine the number of individual squirrels living in each area.

Next, Chow and colleagues built food puzzles to test the squirrels' problem-solving skills. The puzzles consisted of clear Plexiglas boxes with a series of levers that squirrels could push or pull with their nose, teeth or paws to release hazelnuts trapped inside. Using a camera placed nearby, the team measured how many squirrels were able to solve the puzzle, how long it took them to succeed, and how well each squirrel learned a puzzle's solution.

It turned out that squirrels in areas where there were fewer people or buildings were, on average, more successful at extracting nuts from the plastic contraptions. When there were fewer passers-by and towering structures, more squirrels solved the puzzle on their first attempt. More people and buildings, in contrast, led to fewer successful squirrels. This suggests that human disturbance negatively impacts a squirrel's problem-solving abilities in cities.

Surprisingly, the researchers discovered that the squirrels reacted in one of two ways to throngs of people. They either failed to get the nuts from the boxes or became masterminds that rapidly deciphered the food puzzles. This suggests that urban squirrels either are prepared to spend time learning to solve problems in return for delicious nuts or will put up with any old food they can find easily, no matter how inferior. The rapid pace at which some squirrels solved the puzzles might also be caused by pressure they feel to work quickly before someone approaches.

The researchers also examined whether the size of local squirrel populations affects an individual's flexibility and discovered that squirrels in areas with lots of other squirrels were worse at solving problems, but a handful of individuals could solve the puzzle rapidly. This means that competition between squirrels for food further deepens the divide between the few speedy squirrels that are great at finding food and those that can't distinguish push from pull. In addition, the amount of grass in city areas didn't affect the squirrels' adaptability, but squirrels in concrete jungles were very slow learners. This suggests that a lack of green space could be a stressor, though it doesn't directly impact squirrels' problem-solving performance.

As cities continue to expand across the globe, policymakers need to understand how urban environments influence an animal's ability to adapt to change and to survive. For Eurasian red squirrels, human disturbances in the presence of other squirrels impair the essential skills that are necessary for them to find food.

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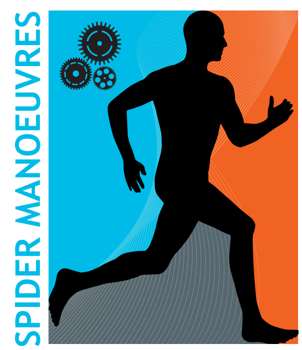
Large spiders don't stop under pressure



Most animals have a need for speed so that they can stay safe and nourished, defend their homes or find a mate. But what determines how fast an animal can run? Previous research has revealed that body mass is key; bigger animals tend to outrun smaller ones. This relationship between speed and mass is well studied in animals with a backbone – vertebrates – whereas it is only recently that similar studies have been conducted in invertebrates such as insects, centipedes or spiders. Spiders are particularly interesting animals to study as their movement mechanism is unique; they lack extensor muscles in two of their three main leg joints. Instead, they use internal pressure to push a blood-like liquid into their legs, which in turn

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expands the soft tissue within these joints to extend the limbs. Curious to see whether this unique limb extension mechanism limits the speed of spiders as they get larger, Charlotte Boehm and her colleagues from the University of the Sunshine Coast, Australia, headed out into the field to collect some athlete spiders.

Bedecked with head torches, the researchers hand-collected 71 wolf spiders (*Tasmanicosa godeffroyi*) and 57 huntsman spiders (*Heteropoda jugulans*) ranging from as small as 5 mg up to 3 g. After returning to the lab, they filmed the spiders running on a racetrack and analysed their footwork. The researchers found that the larger spiders have a significantly faster maximum speed, while their average speed also increases with size but at a lower rate. For example, a spider with a mass of 1 g can run at the same speed as an average human walking (~1.4 m s^{-1}). What's more, the fact that some spiders were missing legs didn't seem to matter, as long as they had at least five. Looking at the spiders' footwork to understand whether they also adjust their movement characteristics revealed that as their mass increases, spiders take larger strides that last longer, similar to mammals.

Next, the researchers broke down the spiders' movements into limb bending – achieved by muscles – and limb extension – achieved by the pressure-driven mechanism. Boehm and her colleagues suspected that the pressure-driven mechanism might affect the spiders' speed by limiting how fast two of the three main leg joints can extend in bigger spiders. Using software that allowed them to automatically track each animal's posture – the position of the joints on all four pairs of legs – the researchers observed the opposite; larger spiders were just as able to quickly stretch their legs as smaller ones. However, they did note a decrease in how fast spiders bent the joint closest to their claws, potentially because the muscles in that portion of the leg were competing directly against the internal hydraulics.

But do all spider legs play the same role as they scamper? In a final experiment, the authors tracked how quickly the spiders manoeuvred each limb joint, suspecting that their joint use might vary. They spotted that the largest movements occurred in the muscle-mobilised joints for limbs 1 and 3, counting from the head towards the belly, but in the joints with the combined muscle–pressure mechanism in limbs 2 and 4. This alternating pattern of joint use could be a strategy that spiders have developed to avoid collisions between neighbouring legs that would slow them down. However, the authors also discovered another potentially speed-limiting factor; larger spiders have larger bellies that slow down their back legs. While the question of how spiders from even larger-bodied families solve this problem remains unanswered, one thing is apparent: the impact of increasing size on an invertebrate's speed is far more complex than we ever imagined.

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Long telomeres of youth encourage optimism

Optimism is a trait often associated with youth, with tough life experiences jading us towards pessimism as we age. The link between age and pessimism may originate from some of our smallest components: our chromosomes, which are capped by protective structures called telomeres. In humans and other animals, telomeres degrade as we age, increasing the risk of damage to the important genetic information that these caps defend, affecting an individual's health and lifespan. Anecdotal evidence also links age-related changes in behavior with telomere shortening, particularly greater pessimism. But whether this change is directly linked to activity down at the level of the telomere remains unclear. To better understand the link between telomeres and behavior, Felipe Espigares (Instituto Gulbenkian de Ciência, Portugal) and colleagues from institutions in Portugal, Spain and France dug into these ideas with genetically altered zebrafish.

Espigares and his collaborators focused on the enzyme telomerase, which is responsible for delaying, or even reversing, the process of cellular aging in telomeres. Telomerase is often thought of as an 'anti-aging potion', as its main purpose is to protect and repair our telomeres from the gradual shrinkage that comes with age. Yet, production of this enzyme declines just when we need it most – as we get older. The researchers took advantage of the powerful action of this 'immortality' enzyme to test how telomere shortening alters our behavior, by breeding zebrafish that lacked telomerase altogether and hence fast-forwarded individuals to have the telomere length typically experienced by much older fish. They then tested where these telomerase-deficient individuals sat on the optimism–pessimism spectrum compared with normal fish.

Using red and green cards, the team trained the fish to associate one color with a tasty reward and the other with a less pleasant experience (capture in a net). Then, the researchers tested how optimistic or pessimistic each fish was by recording how long it took them to approach an ambiguous half-red/half-green card. They reasoned that the optimists would approach the card more quickly, keen to pick up the reward that they interpreted the card to signal. The pessimists would err on the side of caution, believing that the confusing card would accompany a nasty net surprise. If their hypothesis rang true, telomerase would encourage optimism, while the lack of teleromase would generate pessimism.

When the fish were young (4 months old), telomerase absolutely encouraged optimism, as individuals with abundant telomerase (and the hefty telomeres that this enzyme supports) made a beeline towards the mixed-signal card, with an optimistic expectation of the reward that they would reap. Telomerase deficiency, in contrast, made the fish do the opposite – drag their heels in approaching the card, wary of what they might encounter. While the researchers expected to see this telomerase-generated optimism even at an older age (9 months), the magic of telomerase had seemingly worn off, with fish equally pessimistic whether or not their telomeres benefited from the protection and repair of telomerase.

These results imply that telomere shortening encourages premature pessimism in young individuals. While telomerase helps to prevent some of the effects of aging, it isn't the magic, fountain-of-youth potion for long-term physical and behavioral health. So, maybe a touch of pessimism is inevitable with age, but growing evidence proposes that we should still help to protect our telomeres (and potentially our optimism) through a generally healthy lifestyle, including a balanced diet and exercise.

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Wiggling robot lizards mimic geckos climbing up walls

House geckos across southern Asia hang out at night, waiting for a meal to appear. Blink and you might miss one scurry up a wall and vanish. This brief moment hides a complex story, played out over at least 40 million years of evolution. Climbing lizards like the Asian house gecko must be speedy, but at the same time grippy and energetically economical. These qualities are engaged in a tug of war – one improves at the expense of another.

Johanna Schultz and colleagues from the University of the Sunshine Coast, Australia, and Bremen University of Applied Sciences, Germany, wondered how these performance qualities – speed, grip and efficiency – play off against each other as climbing lizards optimise their ascent. One way to find out would be to watch real lizards scampering. The trouble is, lizards aren't the best at taking instructions; 'climb faster!' or 'be more bendy!' will probably be met with an unblinking stare. This is where the robots come in.

Schultz and colleagues decided to test their ideas on four 300 g robots, designed to mimic the climbing abilities of lizards such as Asian house geckos. The robots were each kitted out with on-board sensors, motors to move their limbs and spine, and claws to grip onto carpeted walls. They were then programmed to climb vertically, taking 10 full steps over and over again, varying their speed, the angles of their feet against the wall, and their limb and spine range of motion. Sometimes the robots fell, sometimes they climbed high. Schultz and colleagues studied how the robots performed and compared their achievements with those of real-life house geckos.

The best climbing robots didn't move especially fast or especially slow. Those moving at a moderate speed climbed the furthest; at slower speeds, they tended to slip and, at their maximal speed, they also detached. This mirrored the real geckos, which prefer to ascend at intermediate speeds, hinting that moderate speed is important for their feet to get a grip. At the slowest speeds, climbing was energetically most expensive, tending to drain the robots' batteries after three ascents. Of course, real geckos aren't battery powered, but excessive power use is still best avoided.

The robots walked a tightrope between grip and stability. Their claws best engaged with the carpet when aligned parallel to the body – imagine gripping your fingers onto a ladder. The trouble is that this foot angle wasn't good for bracing the robot against their side-to-side wiggle, and that meant the robots were prone to slipping and falling. Instead, the robots climbed best when their back feet were turned outwards or inwards, with their front feet only slightly so. This configuration of grippy front feet and splayed back feet was found in the real geckos, showing that they face similar trade-offs between grip and stability.

Lastly, Schultz and colleagues varied the robots' limb and spine range of motion, from no movement at all to very wiggly, and watched what happened. They found that the robots made the fastest and most economical climbs when the motions of the limb were larger than the side-to-side motion of the spine. This was also how the geckos climbed in real life, revealing how their wiggle is tuned towards speed and efficiency.

The robots showed the team how peak performance can be achieved and real-life lizards amazingly seem to follow the same recipe for success. That said, climbing is draining work for the robots, but despite these challenges it is clear that quintessentially synthetic creations can help us to understand the mechanisms of the flesh and blood world.

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Caring midshipmen fathers probably make antimicrobial compounds for the kids

Single parenting is not easy; just ask toadfish (*Porichthys notatus*, also known as plainfin midshipman) fathers. These fish have a peculiar reproductive and parenting strategy where mothers leave the nests soon after laying their eggs while fathers adopt one of two different parenting styles. Guarder males care for their eggs, protecting them against marauders, whereas sneaker males fan their sperm into a guarder's nest or slip in stealthily, fertilize the eggs and make a hasty exit, leaving the guarder males to care for the young in the nest. However, males can also provide for their youngsters by producing protective antimicrobial compounds. Caring fish fathers in two other fish species make antimicrobial compounds in glands, known as accessory glands, that are projections of the testes or the sperm duct, and rub the compounds on their eggs. Intriguingly, midshipman guarder fathers collected from the field also had large accessory glands and these glands remained large while they were caring for their nests, raising the question whether midshipman are part of the same antimicrobial parenting club. Meghan Pepler and researchers from McMaster University, Canada, investigated whether midshipmen fathers' accessory glands make antimicrobial compounds that may increase their offspring's survival.

First, the team had to figure out which type of bacteria live on midshipman eggs. After collecting healthy and unhealthy eggs from beaches in British Columbia, Pepler and colleagues grew the bacteria found on the eggs in the lab. They also collected guarder and sneaker males from British Columbia, removed their accessory glands and collected fluid from the glands with a syringe. To test whether these extracts could halt bacterial growth, the team dispensed the liquid onto the bacteria isolated from the eggs, and then measured bacterial growth.

They found that the extracts from both guarder and sneaker males targeted the bacteria that live on unhealthy eggs but did not affect the bacteria that live on healthy eggs. Additionally, the fluid that came from guarder males was far more potent with stronger antibacterial properties than the fluid that came from the sneaker males. The result is that stay-at-home guarder dads offer their eggs protection from damaging bacteria that could make their offspring sick. However, the protective guard and sneaker fathers' secretions are harmless for the bacteria that reside on healthy eggs. And, when the team compared the bacteria growing on the healthy and sick eggs, they found that the bacteria were different. It seems that some species of bacteria might be beneficial for the development of healthy eggs, while others are not. The accessory gland fluid from caring fathers could help maintain the healthy bacteria by preventing unhealthy bacteria from growing. And, the guarder fathers' secretions were so potent that they halted bacterial growth over a range of conditions, from brackish water to high salt and temperatures ranging from 4 to 30°C.

These antimicrobial compounds can certainly help to maintain the developing youngsters' safety, regardless of the environmental conditions, by keeping infections at bay. The next step is to figure out why some guarder nests still succumb to infections despite the fathers' protective attentions. Do fathers need to continue applying their protective secretions during the entire 60 day incubation period? And, if dads run out of juice, are their young almost certainly doomed? Regardless, guarder fathers try to give all the eggs in their nests a good start in life, even the cuckoos left behind by devious sneaker dads.

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