How studying (robot) pigeon navigation changed my mind about their intellect

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Feral Pigeon (Columba livia domestica) in flight. Credit: Alan D. Wilson/Wikipedia.

The cycling infrastructure in the Netherlands is fantastic, and cyclists in my hometown of Utrecht would have been the happiest in the world if it wasn't for one thing: pigeons.

One moment you're pedaling in the sun with a cool breeze in your face, and the next you're breaking and swerving. A pigeon casually strolled onto your path, seemingly oblivious to the danger it put itself in. Growing up, I often wondered just how stupid they must be to blindly walk into traffic. Many years later, I found myself once again puzzling over pigeon intellect, but this time in a new paper in the journal *PLOS Biology* on collective intelligence and flight paths.

While this research generally suggested that my preconceptions could be right, some details in my new study findings suggested pigeons may be more intelligent than I gave them credit for.

Several years ago, when I was still unimpressed by pigeon intellect, I happened upon a 2017 research paper by biologists Takao Sasaki and Dora Biro. Their study outlined how pigeons fly back home when released from a specific site. At first, the birds find a somewhat roundabout way. Then, on every consecutive release, they seemed to remember and reproduce that exact same path.

But Sasaki and Biro showed that when naive pigeons were paired with more experienced ones, their new route was slightly more efficient. Over several generations, the researchers replaced the most experienced bird in a pair with a naive one. While stable pairs kept flying the same (more roundabout) routes over and over, generational turnover made each generation edge slightly closer to the most direct route from A to B.

Some scientists have taken this as an example of cumulative culture. This is new behavior that is passed on to others through social learning, which improves performance and is repeated over time to generate sequential improvements. This last concept is also known in psychology as a ratchet.

Whether pigeon cumulative culture is the same as ours remains hotly debated among scientists. However, these pigeons and their cumulative route improvements interested me, and I wanted to know how they did it. Sasaki and Biro suggested that the birds could pool information and evaluate their performance.

I, on the other hand, wondered if there could be a path to cumulative route improvements that didn't require an intellect. I turned to computer simulation, and developed a simplified model of avian navigation. I wanted to create robot pigeons who could show route improvements without communication or complex thought.

The robot pigeon model was made of four components. Pigeons know roughly where their home is using the sun and Earth's magnetic field (we know this because people have glued magnets to pigeons' heads, which disrupted their navigation). They also seem to love flying together, and the alignment of their direction of travel is a crucial part of flocking behavior. The third element was route memory. When released from the same site, pigeons fly the same way home, apparently using landmarks along the route. Finally, their flight paths tend to have continuity. This reduces the chance of abrupt sharp turns, which avoids erratic patterns.

Just like Sasaki and Biro did with real pigeons, I let my robot pigeons "fly" solo, in pairs, and with generational turnover. In each generation, the most experienced robot was replaced by a naive one. Despite being highly simplified versions of pigeons (without communication or thought), the robots successfully flew from A to B, remembered idiosyncratic paths, and showed cumulative improvements.

The neat thing about computer models, is that you can break them to see how they work. By tweaking the robots' settings, I could show the conditions in which pairs with generational turnover generally outperformed those in a control condition (without generations). I also could turn off each of the components to show that goal direction, social proximity and route memory were necessary for cumulative route improvements to emerge.

The final question was why piegons in Sasaki and Biro's study kept finding more efficient routes. Part of this is obvious. Each new naive robot pigeon could learn an established path from their more experienced colleague. However, this doesn't explain why the routes improved. It turns out that naive pigeons actually helped experienced pigeons here.

They had no preconceived path to follow, but they did know roughly where the goal was. This made them just a bit more likely to go off route in the direction of the goal, which subtly biased the new pair's route to be slightly more efficient.

The study showed that cumulative route improvements over generations can occur in the absence of communication or complex thought. It relies on pigeons' rough idea of where the goal is, their memory for past paths, and their tendency to stick together.

Does this mean pigeons really are stupid?

My model produced similar paths to Sasaki and Biro's pigeon data and showed that birds could operate in a dumb way. That said, the model's parameter estimates were quite varied. They were also subtly different when pigeons flew by themselves, in stable pairs, or with generational turnover.

This means that pigeons are not automatons: individual birds behaved in different ways, and they might even have adapted to circumstances. While pigeon behavior generally aligns with the model, they might also be doing clever things that the model does not capture.

An example of this can be found in a 2021 study by engineering scientist Gabriele Valentini and colleagues, using data from Sasaki and Biro. It analyzed who takes on the "leadership" in pairs of naive and experienced pigeons. They found that navigation in pairs is surprisingly democratic, with both naive and experienced pigeons initiating exploration for route improvements.

That sure sounds like it could be a form of intelligence—even if those new routes sometimes accidentally cross a bicycle lane.

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