Man-Made Electromagnetic Noise Disrupts a Bird's Compass

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For three years, the experiment wouldn't work, and Henrik Mouritsen couldn't figure out why.

He had captured European robins and placed them in funnel-shaped cage in a windowless room. The funnel was lined with blotting paper, which preserved the marks of the robins' feet as they tried to escape. Typically, the birds would try to flee in a consistent direction. Robins, after all, can sense the Earth's magnetic field with an internal compass in their heads. Even when they can't see the sun, moon, stars or any other landmark, this compass helps them find their way.

Scientists first noticed this in the 1950s, and they've used the funnel experiment ever since to study the magnetic sense of robins and many other birds. It's a classic. Mouritsen had done it many times before.

But when he moved to the University of Oldenburg around a decade ago, the experiment stopped working. "We tried all kinds of things. We changed the light intensity, the size and shape of the funnels, the food the birds were getting, whether they were kept indoors or outdoors," says Mouritsen. "We tried it all but it didn't work. I had a very frustrating time."

Then, in 2006, his postdoc Nils-Lasse Schneider said, "Should we try putting a Faraday cage around them?" That's a conductive enclosure that shields its contents from electric fields by channelling electricity through its own walls (here's a demo). If electric fields were somehow disrupting the birds' compass, a Faraday cage would fix the problem. "I thought that probably wouldn't help but I was desperate," says Mouritsen. The team laboriously erected a grounded aluminium cage around the robins' hut and connected it to an electrical supply.

When the birds were exposed to background electromagnetic noise in their unscreened huts, they flew in random directions. When the Faraday cage was on, their compass started working again. "It was like flipping a switch," says Mouritsen.

It was an astonishing result, and one that Mouritsen knew he needed to check carefully. As he writes, "seemingly implausible effects require stronger proof". Many small studies have claimed that man-made electric and magnetic fields could affect animal biology and human health, and many people have anecdotally claimed that they're highly sensitive to such fields. But whenever scientists investigate those claims through proper experiments—double-blind trials with a large sample size—the effects vanish. (Here's a good PDF summary of the evidence.)

"I had no intention of publishing study number 225 of that kind," says Mouritsen. So, his team, led by Schneider and student Svenja Engels, repeated the experiment, again and again. It took a long time—they were already three years behind and had other work to pursue. But after 7 years, they had run many double-blind trials involving many birds. Several generations of students independently worked on the study. The results were always the same.

At one point, someone forgot to connect the grounding to the cage, and the birds stopped orienting again. When Mouritsen discovered the problem, he decided to make it part of the experiment. Without telling the students who were checking the birds, he and Schneider would randomly disconnect or connect the grounding. The birds still behaved as predicted: switching off the cage disrupted their bearings. "My first reaction was, 'It can't be', and the first reaction of most people to this paper will be, 'It can't be'," says Mouritsen. "But I'm sure it is."

This has nothing to do with wi-fi, mobile phones, or power lines. By deliberately adding electromagnetic fields inside the grounded huts, the team showed that they were sensitive to frequencies between 2 kilohertz and 5 megahertz. With that range, the culprits are likely to be either AM radio signals or fields produced by electronic equipment in the university, although it's hard to narrow the source down any further.

It's not clear if wild birds are being affected. It's not clear. Populations of night-time migrating songbirds are falling, but there could be many causes for that including hunting and light at night. Disrupting a bird's magnetic compass isn't even a dealbreaker; it could still use the sun and stars to navigate. But if skies are overcast and these other cues are lost, a faulty compass might become a bigger impediment.

If man-made electromagnetic fields *are* affecting wild birds, they would only do so in very specific places. When the team moved their huts to a rural location 1 kilometre outside of Oldenburg, with natural background levels of electromagnetic noise, the robins could orient themselves even when the Faraday cage was off. This suggests that the disruptions only happen near cities, where electronic devices are common.

But Roswitha Wiltschko has done 40 years of successful experiments with robins in a downtown district of Frankfurt. "We never used any shielding, and our controls were excellently oriented," she says. "The situation at the University of Oldenburg must be particularly bad, and it makes one wonder about the source of this disrupting field. It doesn't seem to be the usual case within cities."

Mouritsen's results are also puzzling because the electromagnetic fields around his university are very weak. They're weaker than the Earth's own magnetic field. They're 100-1000 times below the exposure limits that the World Health Organisation recommends. They're so weak that they really shouldn't be able to affect biological tissues. And yet they're altering the sensory system of a bird.

That's weird, but it also supports a longstanding idea about how a bird's magnetic compass works—one that involves quantum physics.

Birds have a molecule called cryptochrome in their eyes. When light strikes cryptochrome, it shunts an electron over to a partner molecule, creating a pair of 'radicals'—molecules with solo electrons. These unpaired electrons have a property called "spin" and they can either spin together, or in opposite directions. The two states can flip from one to another, and they lead to different chemical outcomes. This is where the Earth's magnetic field comes in. Weak though it is, it has enough energy to influence the flips of the radical pair. In doing so, it can affect the outcome of the pair's chemical reactions.

The cryptochrome idea was proposed in 2000 and it's still controversial, even among biologists who study magnetic sense. If it's right, it could explain how electromagnetic field as weak as those Mouritsen measured could affect his caged robins. "This is speculative, but I think our findings are very strong evidence that the magnetic compass sense of these birds must be fundamentally quantum mechanical," he says.

These results don't mean that electromagnetic fields are negatively affecting human health. "We are certainly not saying that," says Mouritsen. "We don't know, but I'm pretty sure that there's not going to be a dramatic effect."

Indeed, the magnetic compass of birds is a special sense—one that can exploit (and be disrupted by) the tiny energies of low-level electromagnetic noise. The same isn't true for vision, smell or touch, which is why the robins couldn't orient but were otherwise unaffected. Mouritsen's discovery might apply to animals that also have magnetic senses, and it's still unclear if humans have such a sense.

"The results are very intriguing, but it is unknown whether they are relevant to humans," says Maria Feychting from the Karolinska Institute, who studies the health effects of magnetic fields. "They suggest that migratory birds may be sensitive, and these birds may have a specialised system that is not present in mammals/humans."

Reference: Engels, Schneider, Lefeldt, Hein, Zapka, Michalik, Elbers, Kittel, Hore & Mouritsen. 2014. Anthropogenic electromagnetic noise disrupts magnetic compass orientation in a migratory bird. Nature http://dx.doi.org/10.1038/nature13290

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