Computational study sheds doubt on latest theory of birds' mysterious magnetic compass

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The European robin and other birds know where to migrate by sensing the direction of the Earth's magnetic field. Researchers have recently attributed this ability to a chemical reaction that takes place within the eye and whose success depends on the field direction. However, University of Oxford researchers report October 3 in *Biophysical Journal* that the current form of this "radical-pair mechanism" is not sensitive enough to explain the disruption of the avian magnetic compass by certain radiofrequency magnetic fields, raising new questions about this popular example of quantum biology.

Under most reaction conditions with most molecules, the Earth's magnetic field is far too weak—roughly 200 times feebler than a refrigerator magnet—to have any impact on the amount of products produced. But under special reaction circumstances, a burst of energy, perhaps from a light source, creates two short-lived radicals—compounds with one unpaired electron each. These high-energy intermediates, and consequently the outcome of the reaction, are quite sensitive to even weak magnetic fields. In bird eyes, suitable radicals are believed to be generated within cryptochrome, a light-absorbing protein that produces an as-yet-unidentified signaling molecule in a quantity determined by the field direction, resulting in an avian magnetic compass.

"The radical-pair mechanism of magnetoreception is still just a hypothesis, and arguably the best evidence we have for it so far is the effect of time-dependent radiofrequency magnetic fields on the ability of migratory birds to detect the direction of the Earth's magnetic field," says senior author Peter Hore, an Oxford biophysical chemist specializing in magnetic influences on chemical reactions.

Experimental studies of avian magnetic-compass disruption have largely used two different kinds of field frequencies. One approach involves a field oscillating at a single frequency, whereas the other uses broadband noise spread over a range of frequencies. To date, experimental evidence has been unable to agree on which setups actually confuse avian navigation and to what extent.

Faced with the conflicting body of experimental work, the researchers took a computational approach to the problem and designed a new method to simulate the effects of broadband radio noise along the birds' routes. They applied this method and analogous preexisting methods for single-frequency radiation to three plausible radical pairs that might form within cryptochrome and respond to changes in magnetic intensity.

Although the simulations showed that identical radiofrequency conditions imposed different spin-sensitivity patterns for the different proposed radical pairs, the researchers determined that current experimental evidence is insufficient to identify one responsible radical pair from among the choices. "Even with generous assumptions about the properties of the radicals, we predict tiny effects of these radiofrequency fields, and the main conclusion that we come to is that the current understanding of the radical-pair model can't explain any of the reported behavioral results," says Hore.

This inability to explain the experimental performance of the avian magnetic compass raises a whole series of questions. These include the overall validity of the radical-pair mechanism, whether birds might have evolved to be able to detect minute magnetic changes and have thus become susceptible to human-produced radio noise as a side-effect, or even whether applied electromagnetic fields might be affecting a different behavior—such as motivation—altogether.

"It is possible that we're just barking up the wrong tree and there's a different mechanism entirely," Hore says. "I prefer to think that there is some aspect of the mechanism that we're completely missing that amplifies the effect of time-dependent magnetic fields on the radical pairs and makes them more sensitive to changes than our simulations predict."

To help elucidate the workings of the compass once and for all, the researchers propose a number of experimental conditions inspired by cases they analyzed with their computational methods. In particular, they identify bands of radiofrequency noise not yet studied in behavioral experiments and predict that these would substantially affect specific biologically plausible radicals.

"Those experiments will probably be quite challenging because of the high-frequency fields involved, but their outcome should finally tell us whether it is a radical-pair mechanism or not, and if it is, what the radicals are," Hore says.

More information: *Biophysical Journal*, Hiscock et al.: "Disruption of magnetic compass orientation in birds by radiofrequency electromagnetic fields" www.cell.com/biophysj/fulltext … 0006-3495(17)30859-7 , DOI: 10.1016/j.bpj.2017.07.031

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