Dispatches

Bird Navigation: A Clear View of Magnetoreception

Experiments with robins wearing frosted goggles have revealed a tantalising relationship between object vision and magnetoreception, shedding further light on the close interconnection between the two senses in migratory birds.

Dora Biro

The reliable turn of every compass needle tells us that the Earth's magnetic field provides constant information on geographic direction — yet the field itself remains, to us, a wholly intangible cue. Not so for many species for whom magnetoreception is of fundamental importance in orientation [1,2]. While we share most of our senses (acuity aside) with other animals, and subjective experience tells us which of our organs are responsible for detecting sights, sounds, and smells, it takes a fair stretch of the imagination to conceive of the experience of sensing a magnetic field. Presumably, no-one reading these words is simultaneously aware of the inclination, polarity, or intensity of the magnetic field in which he or she happens to be sitting. However, a robin viewing the same page would at the same time be able to point out the magnetic north — as long as it had (at least) its right eye on the page, or indeed as long as it had its right eye on any natural scene. So a set of remarkable new results in this issue of *Current Biology* [3] suggest: for the first time, experiments with robins have revealed a surprising connection between detailed object vision and magnetoreception in a migratory bird, the latter sense being heavily dependent on the former.

These new experiments link two fascinating aspects of birds' sensory and neural organisation: the role of light-activated receptors in detecting magnetic field information, and the extreme lateralisation of the avian brain. The first is one of the principal ways in which birds' sensitivity to magnetic information is purported to operate. The phenomenon has been identified also in amphibians and insects [4,5], and is based on a so-called radical-pair mechanism [6,7]: photopigment molecules experience a change in state in response to light, with the scale of these changes varying according to the receptors' alignment with ambient magnetic conditions. An organism able to measure these changes across differently oriented receptors can thus glean information about the magnetic field in a way that facilitates its use as a global directional reference, or compass. The light-dependent nature of the mechanism, patterns in its sensitivity to different wavelengths of light, and the fact that in birds the receptors are almost certainly located in the eye [8–11] have prompted the perhaps overly simplified but certainly evocative interpretation that birds can 'see' the magnetic field.

But the birds' two eyes do not contribute equally to the task. A fundamental feature of avian brain organisation is that the two hemispheres receive input contralaterally from the eyes, along entirely separate neural pathways: the right eye projects to the left hemisphere only, and the left to the right hemisphere only. Because the two hemispheres are specialised for different functions, how birds respond in tasks involving visual input depends on whether this input arrives from one or the other eye. This holds true across a range of abilities, including object recognition and categorization, spatial cognition, and individual recognition (see [12] for a review).

Lateralized functions linked to visual input have been most elegantly demonstrated in experiments with a simple manipulation, in which a patch is placed over one or the other eye, and the birds' performance compared under the left-eye-only or right-eye-only conditions to controls with both eyes open (for example, [13–17]). For robins, eye-patch studies have already revealed that the magnetic compass shows a right-eye/left-hemispheric advantage: essentially, birds with only their left eye open are unable to read their light-dependent magnetic compass, while those with their right eye open suffer no decrement in their ability to orient [18]. Now, by delving further into the subtleties of the lateralized mechanism, and exploring its relationship with another function known to be right-eye dominant in birds, Stapput *et al.* [3] have uncovered a fascinating and hitherto unsuspected facet of robins' sensory world.

Hypothesising a link between light-dependent magnetoreception and object vision (both right-eye dominant), Stapput *et al.* [3] devised a new twist on eye-patch experiments. Instead of the all-or-nothing manipulation of covering eyes up entirely, they applied frosted goggles to one eye, which allowed ambient light to pass through but disabled the perception of any contours. For the opposite eye, clear lenses with equal translucence as the frosted lens were fitted (Figure 1). They then placed each bird in an 'orientation funnel' — a long-time favourite in navigation studies, utilising migrants' convenient tendency to exhibit directional preferences appropriate to their species-typical migratory movements, even in the confines of captivity. By placing birds inside circular funnels and recording their persistent, small hopping movements, it is possible to evaluate this directional preference quantitatively. The simplicity of this setup — and how amenable it is to experimental manipulation — is what makes it a fantastically elegant research tool.

The prediction of the goggle-experiments was clear: if light-activation is the only necessary condition for the correct perception of the magnetic field, then birds wearing frosted lenses over their right eye and clear on their left should have hopped no differently from birds who wore their goggles the other way round (or indeed from controls who wore no goggles at all). But the results emphatically suggest otherwise. Birds only hopped in the correct migratory direction if their right eye had access to non-degraded vision; with the left eye clear and the right blurred they were disorientated and unable to pinpoint the direction.

Figure 1. A subject of the experiments of Stapput *et al.* [3].

European robin, fitted with goggles that allow equal amounts of light to reach both eyes, but vary between the eyes in permitting access to detailed vision. This bird has a frosted lens over its left eye and a clear lens over the right: Stapput *et al.*'s [3] results suggest that its ability to perceive object contours by the right eye means that it also has access to a fully functioning magnetic compass. (Photo by K. Stapput.)

In other words, they could only correctly interpret their magnetic compass as long as their right eye had access to visual contours rather than just light alone — a remarkable result clearly indicating not only a strongly lateralised but also a more complex interaction between the two senses than hitherto suspected.

What are we to make of this unexpected, but also satisfyingly clear-cut result? One of the authors' [3] proposed explanations for how detailed vision may mediate magnetoreception is perhaps where the relationship between the two senses becomes most elegantly clear. They argue that high-contrast visual contours aid in the processing of information when the same organ (the retina) receives input simultaneously from two sources (light and the magnetic field). A retina viewing a featureless scene with only vague shades of relative light and dark would generate a pattern similar to what the magnetic field, as 'seen' by the bird, is suspected to produce. In such a case, the individual may be prone to confusions between sources of activation. Introducing more detailed vision — sharper edges and contrasts — may then aid in partitioning the overall input into its separate components, and thus in reading the magnetic compass correctly. At what level(s) this interaction takes place and where lateralization exerts its influence — whether (at one extreme) it is a unique feature of the right eye, or whether subsequent setting of the appropriate flight direction occurs primarily in the left hemisphere — remain intriguing open questions.

One challenge will now be to test whether similar effects are evident in other species whose compass sense is known to rely on light-dependent magnetoreception. It may be that the type of interplay between the two senses uncovered by Stapput *et al.* [3] is a derived characteristic in birds, one possible solution to the problem of separating information superimposed on the retina from two distinct sources. Nonetheless, when it comes to imagining how a migrating bird might sense magnetic information, knowing that contour perception plays a role will hardly make the task any less of a tall order for us. But certainly more intriguing.

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Motor Control: Correcting Errors and Learning from Mistakes

How do we learn from errors during complex movement tasks with redundancy? A new study shows that ambiguous mistakes in bimanual movements are corrected by the non-dominant hand, and responsibility for the error is assumed to fall to the effector with a recent history of poor performance.

Chris Miall

In recent years, there have been a number of important theoretical developments which have revised the way we think about the control of human movement. Imagine a task such as playing a game of tennis. The