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Bird collisions: a visual or a perceptual problem?

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Many species of birds are prone to collisions with human artefacts such as wind turbines and power lines, especially where these obstacles occur as prominent features in open airspace (Drewitt & Langston 2008). In an effort to reduce collisions power lines have been marked with objects such as reflective balls, flapping flags and wire coils. Despite more than 30 years of using such devices the probability of mortality caused by power line collisions remains high for certain species (Drewitt & Langston 2008, Shaw 2009).

Why are power lines and wind turbines a problem to birds? In the majority of birds (as in humans) vision is regarded as the dominant sense, an idea captured by the epithet, 'A bird is a wing guided by an eye'. But what does an eye do? Although the eyes of all vertebrates share a common design, they differ between species in their structure, physiology and placement in the skull. The result is that no eye is 'all seeing'; different animals see different worlds depending upon the characteristics of their eyes and how the information they provide is interpreted by the brain (Land & Nilsson 2002, Martin & Osorio 2008).

Birds' eye views

What we need is a birds' eye view of collisions. A human-based view of the problem is likely to be misleading. How do birds' eyes views differ from the human view? Colour vision (spectral information) and acuity (spatial detail) can vary markedly between species. But eyes and visual systems may also differ markedly in their field of view, which determines what information may influence behaviour at any one instant. Some bird species may have comprehensive vision of the world around and above them whereas others may have extensive blind areas to the front, above and behind the head (Martin 2007). Furthermore there are often marked differences in visual capacities within a field of view with the highest spatial resolution and most acute colour vision typically occurring laterally. Furthermore in birds binocular/frontal vision is primarily concerned with near tasks rather than the control of tasks involving distant objects. The characteristics of binocular/frontal vision are shaped primarily by the requirements of controlling the position of the bill when foraging, chick provisioning or nest building; not the control of locomotion (Martin 2009).

Birds typically use their lateral visual fields rather than binocular/frontal fields for many key tasks. For tasks requiring high spatial resolution birds typically fixate upon a target with their lateral visual field, with behavioural control passing to frontal (binocular) vision for final seizure of an object only at close range. This can be seen for example in thrushes Turdidae foraging on the ground, or in Peregrine Falcons *Falco peregrinus* which fix prey with lateral visual field and stoop along a curved path holding the item in the lateral field until just before capture when control passes to frontal vision.

What do flying birds use vision for?

We need to ask what birds are using vision for when flying in the open airspace. Are they looking ahead for obstacles? Looking below/laterally for conspecifics/predators? Looking below for food/habitat patches? What information are they retrieving?

Humans and collisions

Humans exemplify a problem of perception with respect to collisions. Even when 'looking ahead' they may 'look but fail to see'. This is a consequence of perception and attention, not a failure of 'vision' as such. It is a well-known phenomenon in car driving. Modern roads, by design, are highly predictable environments in which people frequently travel beyond their 'perceptual limit'. In essence drivers predict that the world will not change; to a great extent the environment is known. Because of this the rate of gain of information about the way ahead does not always match the real perceptual challenge that the environment may present. The result is that drivers are often not looking for/expecting to see a hazard. Travelling beyond the perceptual limit means that drivers typically have to be warned ('primed') in order to detect a hazard and one consequence of this is the apparent overload of road signs that warn of a hazard ahead. The response to such warnings is (or should be) to adjust the rate of gain of information so that it more closely matches the perceptual challenges posed by the hazard; this is usually achieved by decreasing travel speed.

Birds and collisions

Are there similar perceptual and attentional problems posed by power wires and wind turbines for birds?

Two key questions:

1. *Can birds adjust their rate of gain of information to meet the perceptual challenge of the environment? That is, can a flying bird slow down sufficiently to meet a new perceptual challenge presented by decreased visibility or a sudden increase in complexity posed by the intrusion of obstacles into an otherwise open airspace?*

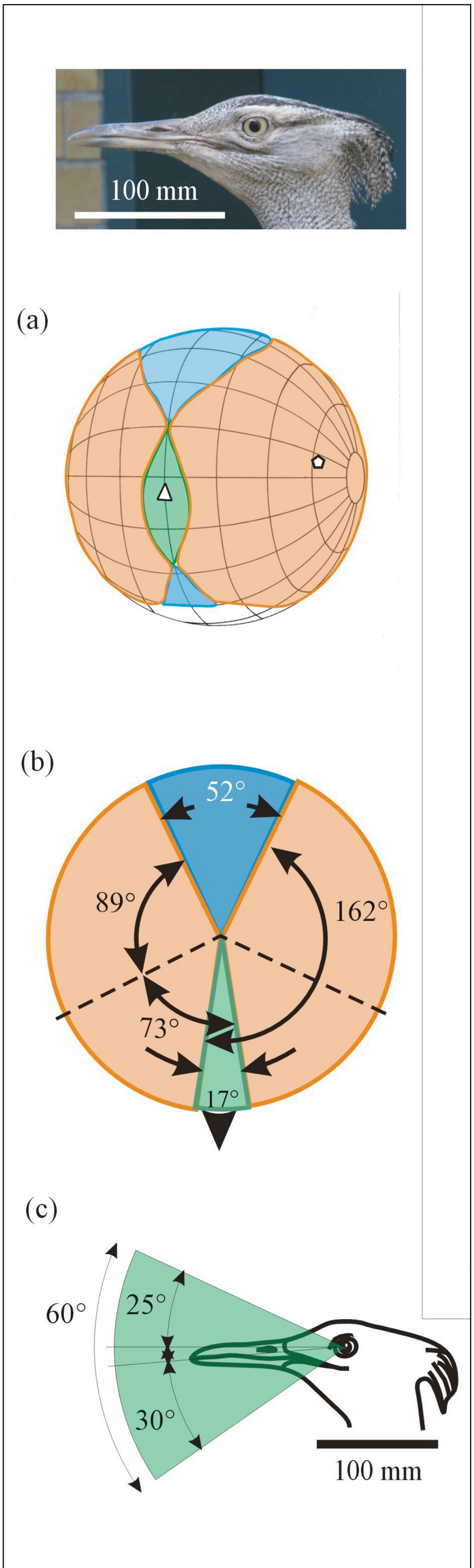
The aerobic range of flight speed in birds is restricted. The typical 'U-shaped' function of aerodynamic power requirement versus flight speed is well understood. It predicts that each species will fly within a narrow range of velocities. In practice this range is quite restricted, especially for birds with high wing loadings. Importantly, the 'U-shaped' function indicates that birds cannot readily decrease speed; in essence they cannot readily slow down to match their rate of gain of visual information to the perceptual challenges that lies ahead, i.e. just because the environment restricts the information available (e.g. rain, mist, low light levels) does not mean that birds can fly more slowly to gain sufficient information to control their flight.

2. *Do birds sometimes fail to see the way ahead?*

There is evidence that this may indeed be the case in certain species and these species may be particularly prone to collisions.

Depending upon the task that the birds are engaged in, they may not be looking ahead when in flight. For example, Gull-billed Terns *Gelochelidon nilotica* are known to forage with the head pitched downwards by 60° and the head may be further turned from the direction of flight in both yaw and roll. Hunting Peregrine Falcons track prey with lateral vision and this may require movements of the head in pitch, roll and yaw from the position expected from an assumed symmetrical placement of the head about the direction of travel.

Although some birds may gain comprehensive coverage of the frontal visual field, it has been shown that the forward-facing visual fields of bustards, cranes and eagles (which are particularly prone to collisions (Shaw 2009)) contain a large blind sector that projects forward (Martin & Shaw 2010). The result of only small (25–35°)



downward pitch movements of the head is to bring the blind sector to project directly forwards. Thus in these collision-prone birds, simply moving the head to look more downwards (as is often anecdotally observed in many birds) will leave them blind in the direction of travel (Fig. 1).

Figure 1 Visual fields in Kori Bustards *Ardeotis kori*. (a) The visual fields when the head is in the position typically adopted in flight, perspective views of an orthographic projection of the boundaries of the retinal fields of the two eyes; the line of the eye–bill tip projection is indicated by a white triangle. The diagram uses conventional latitude and longitude coordinate systems with the equator aligned vertically in the median sagittal plane of the bird (grid at 20° intervals). It should be imagined that the bird's head is positioned at the centre of a transparent sphere with the bill tips and field boundaries projected onto the surface of the sphere with the head in the orientation shown in the photograph. (b) Horizontal section through the visual fields. (c) Vertical section through the binocular field in the median sagittal plane of the head. Green areas = binocular sectors; pink areas = monocular sectors; blue areas = blind sectors; downward pointing black arrowhead in (b) = direction of the bill. It is clear from both (a) and (c) that when in flight a downward pitch head movement of ≥25° will render a Kori Bustard blind in the direction of travel. Modified from Martin & Shaw (2010)

Why do birds collide with obstacles?

In attempting to understand why birds frequently collide with obstacles it is necessary to acknowledge that:

- In flight, some birds may be blind directly ahead; turning the head to look downwards for prey, foraging areas, conspecifics, roost sites, etc., may not be unusual, and may render many species temporarily blind in the direction of travel.
- Even if birds are looking ahead frontal vision is unlikely to be high-resolution vision; high resolution is typically found in the lateral fields of view.
- Birds may preferentially employ lateral vision for the detection of conspecifics, foraging opportunities, predators, etc.
- Birds flying through open airspace (above the level of the surrounding vegetation) may predict that the environment ahead is not cluttered. Even if birds are 'looking ahead' they may fail to see an obstacle as these are not predicted; perceptually a bird may have no 'prior' for power wires or wind turbines in open airspace.
- Birds have only a restricted range of flight speeds and slowing may not be available as a strategy to adjust the rate of gain of visual information when this might be required by decreased visibility.

Solutions to collisions?

- If devices are to be used to draw attention to the actual obstacle these should incorporate movement and be large, well in excess of the size calculated to be detectable based upon acuity measures.
- 'Warn' birds of the obstacle well in advance: prime attention.
- 'Divert' or 'distract' birds from their flight path: assume that birds are more likely to be looking down and laterally rather than forwards. Perhaps use foraging patches, conspecific models or warning sounds to distract birds from the flight path in areas of high collision incidence.
- Something on the ground may be more important than something on the obstacle.
- Recognize that a bird's world is not the human world. Adopt a bird's eye view which recognizes that for birds the scene ahead may be less important than the scene laterally or below, and that frontal/binocular vision may have its prime function in the control of behaviour towards near, rather than distant, objects.

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