THE FLIGHT OF BLINDFOLDED BIRDS

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Studies with radar have shown that at times birds appear able to fly for considerable distances either within clouds or between cloud layers (Bellrose and Graber, 1963; Eastwood, 1967; Griffin, 1972; Williams et al., 1972). Beyond the problems of orientation under these conditions, birds might have problems maintaining normal flight. Without visual reference to the horizon, a bird should have difficulty discriminating a banked turn from level flight. Human pilots often make such errors and must depend upon instruments in the absence of visual reference to a horizon. Hochbaum (1955) investigated the ability of birds to fly without visual reference by fitting birds with opaque paper hoods and tossing them into the air. He concluded that most birds could fly without a visual reference but that they could not orient their flight in any direction and were carried down wind. In the present paper we report a repetition of Hochbaum's experiments with species other than those used by him. We also have been able to extend the range of our observations by following birds flying over water and by tracking blindfolded birds equipped with radio transmitters.

METHODS

All small birds were caught in mist nets. Herring Gulls (*Larus argentatus*) were trapped on the nest, as described by Griffin (1943), during the nesting season on Greater Weepecket Island in Buzzards Bay, Mass. (Fig. 1).

Blindfolds were made from black photographic masking tape or black plastic electrical tape. The blindfold covered the entire area from the back of the head to the base of the bill. The portion of the blindfold over the eyes was double thickness, and the edges of the blindfold were sealed to the feathers as tightly as was compatible with the comfort of the bird. Careful inspection of these blindfolds indicated that the blindfold itself was opaque to sunlight but that diffuse light might enter the forward edge of the blindfold near the bill in the smaller birds. Blindfolds on Herring Gulls could be more closely fitted than those on smaller birds, and we believe that no significant leakage of light occurred around these blindfolds. We could not, however, prove this, and it is possible that the birds could distinguish full sunlight from shadow. Form vision was not possible in any case.

Blindfolds were carefully examined just prior to the release of the birds and, in almost all cases, just after recovery of the birds. The blindfolds were then removed and the birds released. There was never any observable damage to the bird from the blindfold.

The gulls were tracked either visually or by radio. For visual tracking the Herring Gulls were released from a 4 m "Boston Whaler" skiff 100 m upwind of the 12 m power boat "RV Asterias." Both boats then followed the gull. The small skiff kept within 200 m of the bird at all times and the larger boat within 500 m. Eight

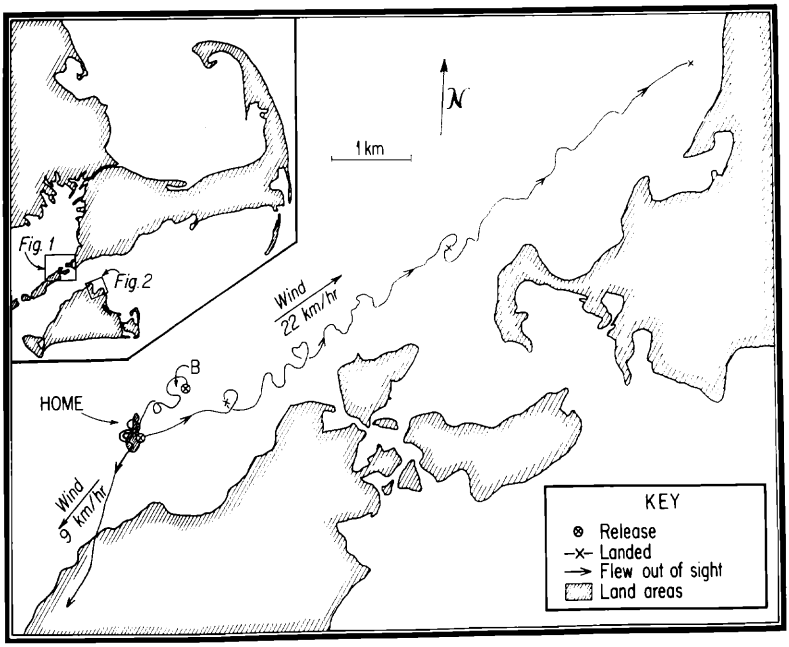

FIGURE 1. The two longest tracks of blindfolded gulls released near their home island. Bird flying northeast carried a radio transmitter. "B" indicates the position of the "RV Asterias" when bird circled boat. "Home" indicates the island on which the birds were trapped while incubating eggs. The inserts show the geographical location and orientation of Figs. 1 and 2 with regard to Cape Cod and Martha's Vineyard, Mass.

mm color films were taken of the birds' flight from the Asterias whenever the bird passed within 75 m of the boat. Position and behavior of the blindfolded bird were recorded continuously with a small tape recorder by an observer on the Asterias. Details of the flight behavior were added to this record by the observer on the skiff immediately following the end of each experiment.

The 400 MHz telemetry transmitter (Williams and Lawson, MS.) weighs 50 g and apparently does not hinder flight of gulls. For the present experiments best results were obtained by affixing the transmitter with its nylon mesh harness to the bird immediately after capture. The bird was then allowed to acclimate to the transmitter for 15 to 30 minutes before being blindfolded and released. Receiving equipment consisted of a 2.1 m parabolic reflector on the 12 m boat and an 8-element Yagi antenna hand-held in the skiff.

Flight behavior of Herring Gulls was recorded at 18 frames/sec. on Kodachrome II film with Super 8 mm cameras equipped with 8 to 64 mm lenses. The shorter flights of Domestic Pigeons (*Columba livia*) were analyzed in greater detail on 16 mm Tri-X film. A Bolex camera with a 50 mm lens was used at 64 frames/sec.

We released 25 blindfolded birds of six species over land, then 11 more Herring Gulls over water (Table 1). Release of blindfolded birds was accomplished by a gentle upward toss of less than 1 m. Herring Gulls were sometimes tossed upward with a spiral motion to test for the ability to right themselves (see below).

RESULTS

When first released, most birds would either drop to the ground or hover and flutter with rapidly beating wings (Table 1). Some White-throated Sparrows (*Zonotrichia albicollis*) and Slate-colored Juncos (*Junco hyemalis*) rarely progressed beyond this stage. Others, such as some House Sparrows and Domestic Pigeons, were able to gain altitude and make flights as far as 600 m. The data in Table 1 are insufficient to demonstrate interspecific differences in the small birds tested. No orientation was indicated; all flights appeared random without correction for drift by the wind. In a series of six releases within one hour, most birds showed improvement in take-off, flight, and landing.

Stability of the flying birds appeared to be due to an abnormally high dihedral angle of the wings. This was confirmed in Domestic Pigeons with 16 mm films taken at 64 frames per second. The birds' wings were always held above the center of gravity.

Some birds indicated that, like human pilots, they became disoriented when deprived of reference to a visual horizon. The most striking example of this was those birds that flew upside down for a considerable portion of their flight (Table 1). Upon release these birds failed to right themselves, or in some cases actually rolled to an upside down position. The birds continued to flutter in this position, losing altitude rapidly until, probably due to the high dihedral angle of their wings, they righted themselves. These upside down flights lasted from about 0.5 sec. to a maximum of 2.0 sec. Such upside down flights appeared to be due to disturbance of the inner ear because upside down flights and rolling in flight could be reliably induced in blindfolded pigeons by rapid rotation of the hand-held bird.

In general, the Herring Gulls seemed less affected by the blindfolds than did the smaller birds, and some exhibited apparently normal flight. The small birds we tested made short flights and returned rapidly to the ground (Table 1). Herring Gulls, however, usually made flights of more than 100 m. Herring Gulls also flew higher than any other birds we tested. Most flew 10 to 100 m above the water, and two birds were lost from sight at more than 300 m height. We never saw a blindfolded gull fly upside down. If tossed upwards in a tumbling fashion, these birds righted themselves before they started to fall. Analysis of 16 mm films showed that during the upward toss, a gull tried to keep its head level. The same also occurred if a hand-held bird were rotated rapidly. Although gulls rarely flew well on their first release after blindfolding, on subsequent releases they gained altitude rapidly, flew with full wing strokes, or glided. Although smaller birds and pigeons flew with their legs held out from the body as though about to land, some Herring Gulls, particularly those making longer flights, pulled their feet up to their body as in normal flight.

TABLE 1. Number of blindfolded birds exhibiting various flight behaviors

Species	N	Fluttering	Dropped	Flew upside down	Level flight	Gained altitude	Gliding	Took off	Maximum distance flown (m)
Song Sparrow (*Melospiza melodia*)	2	0	0	0	2	0	0	2	30
White-throated Sparrow (*Zonotrichia albicollis*)	4	4	4	1	1	0	0	1	30
Slate-colored Junco (*Junco hyemalis*)	7	6	4	3	0	1	0	1	7
House Sparrow (*Passer domesticus*)	5	3	2	0	5	3	0	3	600
Domestic Pigeon (*Columba livia*)	5	5	0	2	1	1	0	0	30
Herring Gull (*Larus argentatus*)	13	4	3	0	10	9	5	7	7780

In contrast to the majority of gulls we released, two Herring Gulls could not fly when blindfolded, dropping to the ground when released. On the ground they had difficulty standing upright. When the blindfold was removed, the birds' lack of equilibrium persisted for about 10 minutes. The birds did not take off and sat quietly. The cause of this behavior is not clear, but might be due to factors other than the blindfold. D. R. Griffin (pers. comm.) reports that he occasionally saw similar behavior in Herring Gulls he released (without blindfolds) after several hours in captivity.

The blindfolded small birds we tested did not show any awareness of impending landing. Except for those that dropped passively, they merely maintained hovering flight until they struck the ground. The gulls released on land often made hard landings. Over water, the first few landings were not graceful, but on subsequent releases most gulls could descend to within a few feet of the water and then hover to the surface.

Almost all the tested birds responded to auditory cues. A sitting blindfolded bird oriented toward a sudden sound and flying birds turned away from a loud noise such as clapping hands or the sound of the outboard motor on the skiff. Recaptures both on land and at sea had to be made quietly to avoid scaring the birds into flight.

The apparently normal flight of some blindfolded Herring Gulls prompted us to investigate the possibility of long flights without vision. The gulls were released over water and were followed either visually or by radio tracking. Tracks of 6 of the 10 birds released in the vicinity of Woods Hole, Massachusetts are shown in Figures 1 and 2. These figures include the two longest flights we observed, and two shorter flights with frequent landings. In no case did a gull maintain a compass heading for more than three minutes. The distance covered by a blindfolded bird could, in all cases, be explained by drift due to the prevailing wind, with the actual flight direction of the bird changing in a random fashion. All birds, except the two indicated by tracks ending in arrowheads in Figures 1 and 2, were recaptured, and the blindfold was examined and found to be well attached. All gulls flew normally upon release without a blindfold.

Five gulls appeared to hold their position against the winds of up to 25 km/hr for brief periods of time. Three of these circled near the Asterias and the other two circled over their home island. We assume they were using sounds to maintain their position, either the boat's diesel engine, or the loud cries of gulls from the nesting area.

When first released, the blindfolded gulls usually flew with more rapid wing strokes than normal. This appeared to attract non-experimental birds, and often in the first few minutes after release, two to four gulls circled the blindfolded bird, often diving at it. This might not be a direct result of the blindfolding. Non-experimental gulls carrying large fish also tend to have rapid wing beats and are mobbed by other gulls trying to steal the food. This was apparently the reason for the behavior we observed since the non-experimental birds soon lost interest and flew away. We never saw a blindfolded bird follow non-experimental birds.

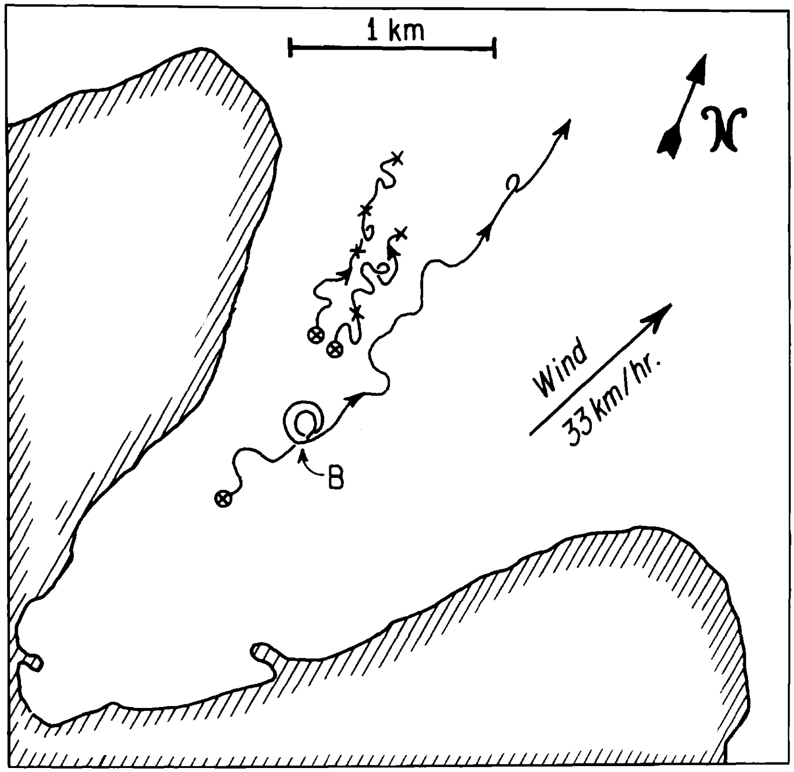

FIGURE 2. Three representative tracks of blindfolded gulls released 15 km east southeast of their home island. Fig. 1 gives the longest track from this release point and two short tracks for comparison. See Fig. 1 inset for location. Symbols as in Fig. 1.

DISCUSSION

In general our results agree with those of Hochbaum (1955) in that birds are able to maintain flight without visual reference but usually drift downwind. We found poorer performance in the small birds tested. Hochbaum did not report upside down flight, and he stated that 88 per cent of the birds he tested made gentle landings. With the exception of gulls over water, our birds made hard landings. Hochbaum indicated that little improvement occurred in the flight of birds he observed, but we found that most birds flew longer in later releases, and Herring Gulls learned to take off and land with some skill. Hochbaum mentioned that blindfolded birds at times flew toward or away from certain sounds, but he did not report that they could maintain their position against the wind by using these cues.

The differences between our results and those of Hochbaum might be due to different species tested; only House Sparrows and Domestic Pigeons were common to both studies, and our results do not differ with his for these species. Hochbaum believed the superior flight of his blindfolded ducks was entirely due to their high wing loading which made it impossible for them to flutter like the passerines. The Herring Gulls we tested were fully capable of fluttering like passerines, but after some experience most blindfolded gulls appeared to fly normally with full wing strokes. We believe that the ability to fly without visual cues would be of importance to Herring Gulls frequently encountering dense fog. Our experiments and those of Hochbaum (1955) have shown that at least some species of birds are able to maintain apparently normal flight through low visibility conditions such as in or between cloud layers. To date, this has been shown only for Herring Gulls in our experiments and for four species of ducks in Hochbaum's work. It is possible, however, that the poor flights of passerine birds were due to the trauma of capture, handling, blindfolding, and under more natural conditions passerines might also be able to fly without visual reference cues. Our experiments indicate that blindfolded birds can use auditory cues for orientation. If Herring Gulls can maintain their position against a 25 km/hr wind, migrating birds might use acoustic landmarks to maintain course without visual cues. D'Arms and Griffin (1972) report an abundance of sounds that can be heard by humans more than one km above the earth. Calling of birds during low visibility conditions could also be of great importance during migration as discussed by Griffin (1969). If only a small percentage of birds were able to use visual cues, this information could be transferred to the other birds by calling.

SUMMARY

Thirty-four birds of six species were able to fly while wearing opaque blindfolds. The passerines tended to use hovering or fluttering flight with a high dihedral wing angle to maintain stability in flight. Some of these briefly flew upside down. Herring Gulls were followed by radio tracking for distances of up to 7.78 km. The gulls showed improvement with practice and were able to maintain their position against a wind at times, probably by reference to acoustic cues.

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