the birds to take off or keep flying. That this effect varied with distance suggests a correlation with the birds' degree of familiarity with the landscape.

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Murray raises several points that we will discuss in order: (i) Did the tracks follow prominent landmarks, especially highways? (ii) Did the birds know the landmarks throughout the area, including Worcester? (iii) Do all our data suggest that our pigeons used landmarks at all times?

One pigeon's (Blue's) five consecutive training-point tracks began at Fitchburg Airport, and four of them passed through the same valley as the major highway, Route 2, which extends eastward to Boston. Most of the tracks clearly crossed various roads without reorienting to them, but how close must a pigeon fly to a major highway in order to see it? Route 2 forms a gap about 150 feet (46 m) wide in the otherwise hilly, forested area. The pigeons we observed almost always flew within 100 feet of the treetops. If the trees were 50 feet tall and the highway 150 feet wide, a pigeon flying as high as 250 feet above the ground could see the roadway only when less than 750 feet (1/7 mile or 0.23 km) from it. These calculations were confirmed by direct observations from aircraft 1000 feet above the ground: it was nearly impossible to see Route 2 when only ¾ mile from it, even when we knew exactly where to look.

In our report we mentioned several definite reactions to landmarks, including those near the Merrimack River. We concluded that our pigeons did orient by landmarks within 10 miles of the loft, but at greater distances (including releases from Worcester) three different kinds of evidence suggest that birds do not respond to previously encountered landmarks:

1) When Blue was released the second time from Worcester, it flew south, parallel to its previous three courses from another release point. Had it learned this major city on its release 14 days earlier it should have flown toward the loft at least as well as it did on its first flight. Instead, it departed 80 deg from the home direction.

2) On three occasions, pigeons released from new places flew incorrect courses, on which they passed through the region directly between Fitchburg and the loft. As they crossed their previous tracks, they turned neither more toward home nor more toward their previous paths.

3) In all cases when the sun was obscured by clouds and the pigeons were more than 10 miles from the loft, each bird perched and did not resume flying until the sun became visible again. Hitchcock (*1*) found that his pigeons homed under total overcast, and our recent results show that pigeons trained on overcast days will fly home, but they take between 10 and 50 times longer to cover a given distance.

These three points suggest that our pigeons do not use landmarks alone to find their loft.

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Reference

1. H. B. Hitchcock, *Proc. Amer. Phil. Soc.* **96**, 270 (1952).

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Optical Environment in Gemini Space Flight

In their report [*Science* **153**, 297 (1966)] Ney and Huch conclude from Fig. 1 that the first-magnitude stars are at threshold of visibility with a background luminance of the order of 10^{-8} of the sun's surface brightness [10^{-8} ssb is approximately equal to 6 mlam (5.6 ft-lam)]. Since the space sky is much darker and also since the corona of the spacecraft does not raise the background luminance to and above this limiting level, the authors assume that the scattered sunlight and earthlight in the window of the spacecraft are responsible for the background luminance that makes the stars invisible. Argyle, in his comment, calls our attention to a very important factor, namely, scattering within the eyes of the observer. I would like to add some explanatory remarks: sunlight or earthlight, when acting as a source of glare, produces a veiling luminance within the eye which adds to that of the sky and of the stars, thus diminishing contrasts and also decreasing the light sensitivity of the eye. I do not agree with Argyle's statement that the disturbing illuminance at the eye should be at least 1000 lux (100 ft-c), since a much lower illuminance would be sufficient in case the glare angle is small. When sun or sunlit earth is out of view, the disturbing effect will not stop immediately, as in Argyle's example with the street lamp, but recovery to the previous level of sensitivity will require some time, depending on luminance, duration, and position of the glaring light.

Light sensitivity of the eyes is a fundamental factor when one is observing lights of near-threshold intensities. When the astronaut shifts his gaze from some illuminated area, for example, the interior of the space capsule, toward the dark sky, he should wait a few minutes in order to increase the sensitivity of his eyes. The conical sunshade on the viewing window, suggested by Argyle, would definitely help to avoid veiling glare in the eyes and scattered light in the window, although it would restrict the field of view.

I would like to emphasize that the curve of Fig. 1 derived by Ney and Huch from Tousey's paper is valid only when the eyes are perfectly adapted to the background luminance. When the eyes are adapted to a background of 10^{-8} ssb, first-magnitude stars can be perceived by the foveal region only, whereas the periphery of the retina is not sensitive enough. Therefore, it would be difficult to locate weak lights at this stage of vision when the observer does not know exactly where to look.

The authors do not discuss the losses of intensity through the window of the spacecraft by absorption and by reflection, which may be appreciable depending on the material, the multilayered structure, and the inclination of the window to the line of sight of the astronaut. A loss in intensity of a star would lower the required background luminance for its visibility at threshold and would require a longer adaptation time. In case there are inhomogeneities (for example, by scattering) the "noise level" of the window may contribute to the difficulties in perceiving stars during daytime in space.

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