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Homing pigeons find their way home by smelling the air

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Instead of looking at visual maps, homing pigeons smell the environmental air to know their way home. Yet, how they achieve this spectacular feat remains mysterious. In a new study, we draw 'olfactory maps' that pigeons may use, identifying candidate odor compounds that likely navigate them homeward.

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Many animals use chemical signals for defense, foraging and mating. However, little is known about the perception of smell by birds. A long-standing question – which we addressed in a new study – is how homing pigeons (or messenger pigeons) can 'smell' their way home over long distances, even up to 200 kilometers.

Homing pigeons can find home from an unfamiliar, even remote location. Over 50 years ago scientists first discovered that the sense of smell (olfaction) was crucial for the homeward orientation of homing pigeons. Studies based on bird releases into surrounding areas have suggested that homing pigeons can develop an 'olfactory map' by smelling the air components brought from different wind directions when they are at the aviary (home). They mentally 'draw' a regional map of what they smell, so that they can use this map like a compass to find the direction home. However, what type of odors they actually smell remains mysterious.

Chemically speaking, when we smell something we inhale and sense volatile organic compounds – organic chemicals that are present as gases at ambient temperature – in the air. In nature, plants release these chemicals into the atmosphere to communicate with the environment – some chemicals for attracting pollinators and some others for keeping predators away.

As atmospheric chemists, we set out to study which odors birds use to know the way home and how they sense these odors at long distances. We carried out experiments at the aviary of the University of Pisa, which is a leading research institute in olfactory

navigation. This aviary provides ideal settings for the study because of various volatile organic compounds released by diverse surrounding environments. It is located in a rural area, where there is the coast facing the Tyrrhenian Sea and the mouth of the Arno river as well as three different forests nearby.

We measured atmospheric volatile organic compounds and collected meteorological observations (temperature, wind direction and wind speed) at the aviary, where pigeons draw 'olfactory maps'. This rich dataset (including more than 20,000 measurements) showed that the wind patterns were stable and repetitive, with marine air transported to the aviary during the day and inland air during early morning and late evening. This characteristic wind circulation pattern results from sea breeze. We discovered that marine air mainly contained a chemical called dimethylsulfide, while inland air contained various compounds that reflected the variety of environmental settings, including isoprene and terpenes emitted from the forests, and aromatic compounds derived from local traffic and industries. These observations allowed us to draw the 'olfactory maps': as different chemicals with different concentrations float at a given site, the mix of those different chemicals creates a unique smell, which is characteristic for that site. Diverse environments surrounding the Pisa aviary – the sources of volatile organic compounds – generate odor gradients that indicate orientations in olfactory maps.

Next we asked whether homing pigeons indeed use those chemicals to learn orientations. To put this to test, we focused on dimethyl sulfide emitted by the sea because it has a sufficiently long atmospheric lifetime (how long a chemical can survive). This makes this chemical a promising candidate for constructing 'sturdy' roads in olfactory maps. By applying the numerical model for available data of previously conducted local pigeon release experiments, we found that this compound likely indicates their homeward orientation at least in the first ten kilometers of flight from the release site. This suggests that emissions from natural sources provide key organic compounds that homing pigeons use to find their way home.

In summary, our study becomes the first to draw homing pigeon's olfactory maps based on measurements of chemical emissions from various natural sources. We identified promising candidate volatile organic compounds that make up the map, including dimethyl sulfide. Further studies should assess other candidates such as isoprene and terpenes to obtain a more complete picture. Moreover, homing pigeons' behavior may be still dynamically evolving under today's climate change that is likely altering patterns of volatile chemical compounds emissions in nature. Our journey to understand pigeons' navigation by olfaction has therefore just begun!