Magnetoperception and the olfactory system in pigeon

Virginia Meskenaite (1), Wolfer DP (1,2), Lipp HP (1)

(1) Institute of Anatomy, University of Zurich, Switzerland
(2) Institute for Human Movement Sciences and Sport, ETH Zurich, Switzerland

It’s widely accepted that long-distance migrating birds and homing pigeons sense geomagnetic fields and use them for navigation. Magnetic stimulation does activate neurons in various brain structures linked to visual and vestibular input, and integrating brain regions. Yet, natural or artificial disturbance of the earth magnetic field is often compensated in pigeons and seabirds, while permanently blocking olfactory input impairs homing of pigeons drastically. The same is observed after lesions of the piriform (olfactory) cortex. These findings gave rise to the olfactory hypothesis of navigation, which recently is being demoted to its role of neuronal activation only. Here, we show that the olfactory system in pigeon integrates magnetosensory information received both from other magnetosensitive structures and, most likely, sensed directly.

We have exposed homing pigeons moving freely in a box to either magnetic fields varying periodically at 0.5 Hz between 16 and 187 µT at the pigeon’s head, or to sham stimulus, and counted stereologically neurons expressing the immediate early gene ZENK, a marker of neuronal activity. In intact birds, magnetic stimulation induced a bilateral increase of ZENK-expressing neurons in the olfactory bulb (+40%), the olfactory cortex (+64%), the hippocampus (+46%), the nidopallium caudolaterale (+27%), and in the densocellular part of the hyperpallium and the mesopallium (+14%). No increase was observed in the wulst (hyperpallium apicale), in posterodorsal thalamic nuclei, and in amygdaloid nuclei; a significant decrease occurred in vestibular nuclei (-18%). In anosmic pigeons, 20-24h after $ZnSO_4$ treatment of the olfactory epithelium, ZENK-expressing granule cell numbers dropped below 10% in the olfactory bulb; no response to the magnetic stimulus was detected. The olfactory cortex, however, sustained partial response (+ 26.7%) to magnetic stimulation indicating significant input from other magnetosensitive areas and a loss of directly-derived olfactory composite.

Interestingly and unexpectedly, the microscopic study of brain sections of $ZnSO_4$ treated birds’ revealed massive degeneration foci confined specifically to the most ventral part of hyperpallium and to the mesopallium, which to a lesser degree extended into multiple small foci, mainly, within the nidopallium caudolaterale. The latter yet again points at the driving force of the olfactory input behind many steps of sensory processing.

Our study implies an essential integrating role of the olfactory system for pigeon navigation, and calls for further investigation of concomitant processing of olfactory and magnetic information.