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Magnetic Fields Affect Pigeon Navigation Only While the Birds Can Smell Atmospheric Odors

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Initial homeward orientation of pigeons can be drastically impaired by exposing the birds, for one to several hours before release, to either an oscillating magnetic field or near-zero magnetic intensities [1, 2]. A satisfying explanation of this effect has not yet been given. Apparently it is not based on interference with some mechanism recording movements during displacement (i.e., with a route-based navigation), as it can be observed after treatment at the home site or at the release site as well as during transport [2]. It seemed unlikely that the effect is based on interference with the magnetic compass, as it occurred in situations in which the sun compass could easily have been used. Magnets or Helmholtz coils, attached to the pigeons' heads during flight, affect magnetic-compass functions under overcast skies, but have little influence under sunny conditions [3]. The effect of pre-release magnetic treatment could be observed under sun as well as under overcast, so that interference with the sun compass also appeared unlikely. Finally, interference with a "magnetic map", which makes use of positional information mediated by direct magnetic-field perception [4], appeared questionable, as the existence of such a mechanism in pigeons has been shown to be doubtful [5].

The experimental findings were best compatible with the assumption that in some way the "map" step of navigation is involved, i.e., the process of site localization. The only known physical clues used in this process, however, are airborne substances perceived by olfaction [5–7]. Although, at first glance, olfactory navigation seemed to have nothing to do with magnetism, we considered the possibility that magnetic parameters might be involved in the process of site localization by means of olfactory clues. This idea was supported by the finding that initial orientation of pigeons could be influenced by changing either the composition of the air breathed by the birds, or the magnetic field to which they were subjected, for an extended period of time *before* their release [1, 2, 7, 8]. So we tested whether pre-release magnetic treatments fail to affect birds that are prevented from smelling natural atmospheric odors.

The pigeons used were 4–5 months old and housed in two lofts, Arnino and Montefoscoli (10 km SW and 33 km ESE of Pisa). They were experienced in homing, but always new-to-site. In each experiment, two groups subjected to magnetic treatment were used, one which could smell the natural odors of the atmosphere (MSm), and another group which was olfactorily impeded (MOI). In addition, one or two groups of control birds were released which were not subjected to magnetic treatment. They were either allowed to smell local odors (CSm) or were olfactorily impeded during magnetic treatment of the experimentals (COI). All groups were transported in the same conditions, i.e., on top of the same van, well ventilated, and allowed to perceive the odors of the crossed areas.

Magnetic treatment was applied, for a period of 3 h, at the release site or very near to it by means of two identical devices within two vans of the same type. Each device consisted of a pair of horizontal and two pairs of vertical Helmholtz coils (diameter 95 cm), which were concentrically and orthogonally arranged. During treatment the pigeons were kept in a crate in the center of the coils. In experiments 1–6, polarity and intensity (ranging from 0 to 0.6 gauss) of the field, produced by each pair of coils, oscillated sinusoidally with a different period for each pair (15, 23, and 29 s), so that an almost random variation of field direction and intensity emerged (for details see [9]). In experiments 7 and 8, the horizontal and one vertical pair of coils produced a static field which reduced the resulting magnetic intensity inside the bird crate to a level near zero.

In all experiments, except 5 and 6, the nostrils of MOI and COI birds were plugged with cotton and sealed with adhesive tape during the 3 h of treatment. In experiments 5 and 6 all the birds were kept, during treatment, in airtight aluminum containers, abundantly ventilated either with purified air blown from a compressed-air bottle (MOI and COI) or with natural air sucked in from the outside (MSm and CSm). After treatment until release, all the pigeons were kept outside the car in crates which allowed airflow.

The birds were tossed up individually and observed with binoculars (10 × 40) until they vanished from sight. All the releases were carried out with clear skies or, at least, with the sun disc visible. Standard methods of circular statistics were applied [10].

All the experiments produced similar results (Table 1). The bearing distributions of the two control groups (Fig. 1A, B) were always clearly oriented with little directional scatter. Resulting mean vectors deviated only little from the beeline towards home. Distributions of CSm and COI bearings were never significantly different from each other.

Orientation of one of the two groups exposed to artificial magnetic fields, MOI, was very similar to that of the two control groups (Fig. 1D). Mean

Table 1. Means of initial orientation in experiments 1–8. Loft M = Montefoscoli, A = Arnino. Directions towards home are given clockwise from north; of = oscillating field, sf = static field, np = nostril plugs, ba = bottled air, na = natural air sucked through container (–, no particular treatment, i.e. no field/open to natural air). *N* is the number of bearings recorded. Mean bearings are given as deviations from home (+, to the right; –, to the left). Home component = cosine bearing × length. Levels of significance under the Rayleigh test (vector length), the V test (home component), and the Watson U^2 two-sample test (MSm vs. related group) are indicated by asterisks: *** $P<0.001$, ** $P<0.01$, * $P<0.05$, – $P>0.05$

Exp. No.	Loft	Home		Treatment		*N*	Mean vector			U^2 test MSm/...
		Dist. [km]	Dir. [°]				Bearing [°]	Length	Home comp.	
1	M	68	294	MOI	of/np	14	0	0.960***	+0.960***	***
				MSm	of/–	14	–4	0.379–	+0.378*	
				COI	–/np	14	0	0.977***	+0.977***	***
2	M	31	111	MOI	of/np	12	+27	0.949***	+0.842***	**
				MSm	of/–	12	+58	0.695**	+0.372*	
				COI	–/np	13	+33	0.974***	+0.820***	**
				CSm	–/–	13	+27	0.950***	+0.847***	**
3	A	45	298	MOI	of/np	13	+1	0.954***	+0.953***	**
				MSm	of/–	13	+28	0.841***	+0.740***	
				COI	–/np	13	+5	0.973***	+0.969***	**
4	A	51	152	MOI	of/np	12	+19	0.798***	+0.753***	*
				MSm	of/–	11	+19	0.476–	+0.451*	
				CSm	–/–	13	+13	0.884***	+0.862***	**
5	M	81	344	MOI	of/ba	12	+53	0.901***	+0.541**	–
				MSm	of/na	13	+112	0.266–	–0.099–	
				COI	–/ba	8	+31	0.833**	+0.714**	*
				CSm	–/na	12	+44	0.912***	+0.654***	*
6	M	67	133	MOI	of/ba	12	+24	0.956***	+0.872***	***
				MSm	of/na	13	+71	0.455–	+0.148–	
				COI	–/ba	12	+19	0.844***	+0.797***	**
				CSm	–/na	12	+27	0.942***	+0.836***	***
7	A	40	161	MOI	sf/np	11	+18	0.914***	+0.867***	*
				MSm	sf/–	12	+45	0.403–	+0.285–	
				COI	–/np	12	+32	0.941***	+0.802***	**
8	A	105	326	MOI	sf/np	11	–46	0.747***	+0.522**	–
				MSm	sf/–	11	–80	0.287–	+0.052–	
				COI	–/np	11	–25	0.849***	+0.768***	*
Summary (all bearings pooled)				MOI		97	+14	0.820***	+0.796***	***
				MSm		99	+38	0.372***	+0.293***	
				COI		83	+13	0.870***	+0.847***	***
				CSm		50	+28	0.906***	+0.802***	***

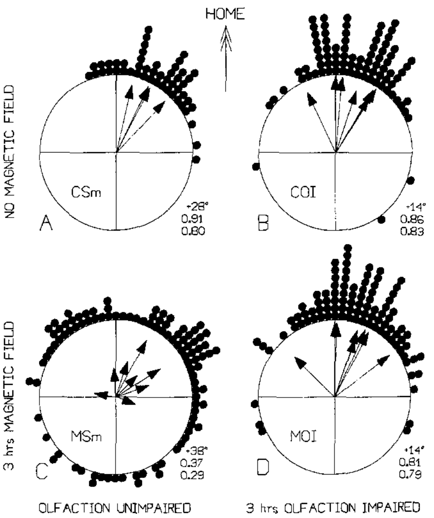

Fig. 1. Initial orientation data of all experiments pooled. Each *peripheral dot* represents the vanishing bearing of one pigeon. *Arrows* indicate mean vectors of the individual releases; maximally possible length 1 = radius. Direction, length, and homeward component of second-order mean vectors (calculated from single-release mean vectors) are given by *numbers*

vectors were long and close to home. Differences between MOI and controls (COI and CSm) were never statistically significant under any of the tests used, either in any individual experiment or after pooling of the data.

Clearly worse than all the other groups were the MSm pigeons, which could smell natural air during magnetic treatment (Fig. 1C). Their bearing distributions were not significantly different from a random scatter in six out of eight experiments (Rayleigh test), and in all eight cases their homeward component was the smallest (Table 1).

In 18 out of 19 possible two-sample comparisons between MSm and the other groups, at least one of the four tests used yielded $P<0.01$. Levels of significance under the Watson U^2 test are given in Table 1. The pooled data (Fig. 1, peripheral dots C compared with A, B or D) differ significantly, with $P<0.0001$, under each of the tests used. Second-order analysis based on samples of eight mean homeward components per group revealed $P<0.001$ for MSm compared with MOI (Mann-Whitney U test).

The results obtained with the magnetic treatment on pigeons with unrestricted perception of odors (MSm) confirm previous findings in similar experiments [1, 2]. The fact that restriction of olfaction during 3 h at the release site does not, by itself, affect initial orientation, as shown by COI compared with CSm, was also expected, as all the birds could smell natural odors before and after impairment.

New, however, is the finding that the behavior of pigeons with restricted perception of odors (MOI) was never affected by the magnetic treatment. This finding indicates that the effect observed under normal conditions is not due to a direct influence of magnetic fields on the animals per se, but is linked to specific functions of the sense of smell. It is noteworthy that the same results were obtained regardless of whether the birds were prevented from smelling any odor by the nostril plugs or whether they were able to smell odors originating inside the container (e.g., their own odor), but not those of the natural environment (experiments 5 and 6). Thus, the effect of magnetic treatment proved to be missing, not because the birds were unable to smell, but because they did not come into contact with one or more particular substances dispersed in the natural atmosphere. These one or more substances are presumed to form material substrates for olfactory navigation. We feel bound to conclude that magnetic pre-release treatment in MSm birds did not only temporarily interrupt the flow of necessary information (as nostril plugs and bottled air did, without effect on orientation, in COI and MOI birds), but produced some false information or irritation whose influence lasted over several hours beyond the treatment.

The results imply some general explanation of effects which hitherto were considered as isolated phenomena without recognizable connection to other parts of the pigeons' navigational mechanism. Now it seems that magnetic fields and atmospheric odors should not only be seen as alternative or supplementary clues; in some respect, they might be components of an integrated system. (Their linkage, however, is certainly restricted to quite specific functions. Our experiments suggest neither that olfaction might generally be involved in magnetoreception nor that magnetic fields generally affect olfaction.)

At the present stage of research it is impossible to realize the way in which the two components are linked to each other. We feel it conceivable that magnetic fields might modify interactions between odorant molecules and receptor sites (of molecular dimensions) at the olfactory membrane. Without presuming functional connections, we recall in this context that magnetite-rich, or at least iron-rich, structures have been found to be particularly concentrated in the area of the olfactory nerves, with bristles even projected into the nasal cavity [11]. It seems also possible that magnetic fields do not act at the peripheral level, but influence central processing of olfactory stimuli.

Support was provided in part by the Ministero della Pubblica Istruzione.

Received October 23 and December 10, 1985

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Naturwissenschaften Buchbesprechungen

AIDS – Etiology, Diagnosis, Treatment and Prevention. Ed by V. de Vita jr., S. Hellmann and S.A. Rosenbery. Philadelphia-New York: Lippincott 1985. 352 pp., US $ 38.–.

Dies ist ein Vielmännerbuch (29 Autoren) über die heute in Patienten- und Ärztekreisen meistdiskutierte Erkrankung, die an einer Stelle sogar als Pandemie bezeichnet wird. Dem muß energisch widersprochen werden, denn im Vergleich zu Pest, Cholera und Pocken ist eine solche Bewertung nicht zulässig angesichts der Empfindlichkeit des Virus und der damit verbundenen spezifischen Übertragungswege.

Wie der Untertitel sagt, reicht der Bogen von Epidemiologie über Ätiologie, Diagnostik, Immunologie, Pathologie, infektiöse Komplikationen, mit AIDS in Zusammenhang stehende bösartige Geschwülste, Behandlung der immunologischen Störungen bis zu Vorsichtsmaßnahmen für Patienten und Menschen hohen Risikos, den psychosozialen Problemen von AIDS-Patienten und deren Umwelt.

Das Center for Disease Control (CDC) in Atlanta (Georgia, USA) definiert AIDS (acquired immunodefiency syndrome) als eine Erkrankung des Immunsystems, die durch das Auftreten des Kaposi-Sarkoms bei jüngeren Menschen (<60 J.) oder ein primäres Lymphom des ZNS gekennzeichnet ist. Andere Symptome sind Infektionen mit opportunistischen Erregern wie dem Parasiten *Pneumocystis carinii,* ausgebreitete *Herpes-simplex*-Virus-Infektionen von Haut und Schleimhäuten, die länger als fünf Wochen anhalten. Dazu zählen Infektionen mit verschiedenen Pilzen wie *Candida-* oder *Aspergillus*-Arten, *Cryptococcus*-Arten, *Nocardia, Toxoplasma gondii,* Mykobakterien – selbst Vogeltuberkelbazillen – schließlich solche durch das *Cytomegalie-* und *Herpes-simplex*-Virus.