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Pigeon homing: effect of oscillating magnetic fields during flight

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Etologia. — *Pigeon homing: effect of oscillating magnetic fields during flight.* Nota di FLORIANO PAPI (*) e PAOLO IOALÉ (*), presentata (**) dal Corrisp. F. PAPI.

RIASSUNTO. — Sono stati condotti esperimenti di rientro da luoghi sconosciuti su colombi viaggiatori che portavano bobine di Helmholtz generanti un campo magnetico intorno alla testa. Il trattamento magnetico avveniva sia durante il trasporto al luogo di rilascio, sia durante il volo. Il trattamento ha disturbato l'orientamento iniziale, ma non la velocità ed il successo nel ritrovare la colombaia. Si conclude che, con il sole visibile, i colombi non ricavano dal campo magnetico terrestre informazioni importanti ai fini della navigazione.

INTRODUCTION

It has been repeatedly suggested that homing pigeons, besides compass information, may obtain position-finding information from the earth's magnetic field (see for references Walcott, 1982; Lednor and Walcott, 1983; Wallraff 1983). To test this idea, Lednor and Walcott (1983) released pigeons carrying packs that generated a varying magnetic field around their heads, but failed to find any consistent influence of the magnetic disturbance on initial orientation; homing success was reduced only by one of the two types of treatment.

On the other hand, our team has for several years been testing the effect of keeping pigeons in oscillating magnetic fields before release and found that the treatment was effective in producing increased scattering and/or deflection of the vanishing bearings, whereas homing performance was unaffected (Benvenuti *et al.*, 1982; Papi *et al.*, 1983). Therefore, one had to conclude that the disturbance following treatment was compensated for or passed off shortly after the birds vanished from sight. This has indeed been confirmed by radio-tracking recording (Teyssèdre, 1986).

To test whether a persistent magnetic treatment could reduce homing ability, we have tested pigeons carrying packs similar to those employed by Lednor and Walcott, but generating oscillating fields of higher frequency. One of our treatments (first series), consisting of a sine wave with a frequency of 0.14 Hz, had proved to be ineffective when pigeons were subjected to it before release (Ioalé and Guidarini, 1985), whereas a similar field with higher fre-

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quency (0.42 Hz) disturbed initial orientation (unpubl. data). It appeared to be worth testing whether the lower frequency was effective when applied to the bird aloft. The treatment used in the 2nd series, a square wave with the same frequency of 0.14 Hz, had been found by Ioalé and Guidarini to strongly affect initial orientation of birds treated before release, probably because of the harmonics to which the square wave is reducible.

MATERIALS AND METHODS

Pigeons were five to seven months old and housed in the Arnino lofts (10 km from Pisa). Before the experiments, they had been released for training nine times. The farthest release sites were 15 km North, 15 km South and 20 km East from the lofts. When three and a half months old, pigeons began to be trained to carry a dummy pack on their backs and a pair of dummy coils at the loft and during training flights. One coil was applied to the top of the head and the other around the neck, as described by Walcott and Green (1974). Pigeons carried the pack in the last five training flights, both pack and coils in the last flight.

The device used to produce an oscillating field around the pigeon's head consisted of two Helmholtz coils connected in parallel, fed by a wave generator applied to the back of the pigeon. Details are given in Ioalé and Guidarini (1985). In the first and second series the characteristics of the field were those described for their Exp. A 1 and A 2, respectively. The induced magnetic oscillation in the first series was roughly sinusoidal in shape with an amplitude varying between $+0.65$ and -0.35 Gauss and a frequency of 0.14 Hz. In the second series the induced magnetic oscillation consisted of a square wave of 0.14 Hz with a magnetic flux varying between $+0.70$ and -0.35 Gauss.

The generator and the coils were applied to the experimental birds (E) before leaving the loft and immediately connected to produce the field. Birds were never released until two hours of treatment had passed. The functioning of the device was checked at the release site and when the bird homed. Control pigeons (C) carried dummy pack and coils. All the birds participating in an experiment had the same flight experience and were not familiar with the site. Birds acting as controls in one test were used as experimentals in the following release, and viceversa.

Test releases were performed on sunny days with no or moderate wind. Standard methods to record vanishing bearings and times were used (see f.i. Papi *et al.*, 1983). In the first series we alternated the release of one C-with that of one E-bird; in the second series the release of 5 C-with that of 5 E-birds. The homing data of pigeons arriving together were not taken into account if they belonged to different groups. In 45 of the 49 E-birds who homed on the day of release the packs were still functioning upon arrival at the home loft. The 4 birds with the dead pack were not taken into account when homing performances of E- and C-birds were compared.

For the statistical treatment of the initial orientation data (Batschelet, 1981), direction and length of the mean vector were calculated for each group of vanishing bearings. They were tested for randomness by the V-test, which leads to significance only if there is a significant component in the predicted (home) direction. The homeward component was calculated as the product of the mean vector length by the cosine of the angle between the mean vector and the home direction. Comparisons between sets were made using the Watson U^2 test. Vanishing intervals and homing performances of single experiments were compared using the Mann-Whitney U test. The pooled data for both vanishing times and homing performances were compared using the sign test (Siegel, 1956).

The first series of experiments consisted of three releases, the second series of four. Distance and home direction are given in Table I-II and figs. 1-3. Both the second and the third release of the first series had to be performed over two different days.

Results

Initial orientation. Data concerning releases and initial orientation are given in Tables I and II; bearings as recorded in the single tests and their pooled distributions (home direction $= 0^{\circ}$) are shown in figs. 1 and 3.

In all releases the homeward component value for the E-birds was lower than for C-birds. This is attributable to the increased scattering of the E-bearings; in one case (first series, release A) a counterclockwise deflection was observed, typical of magnetically treated birds setting off from that site.

In the first series, all the groups were non-randomly oriented except E-birds in release A. E-birds and C-birds were significantly different from each other in one of the three releases (B) and comparing pooled data.

In the second series three of the four E-groups were not different from random, whereas the C-groups always were. Moreover, a significant difference between the bearing distributions of E- and C-birds was reached in three of the four tests as well as the pooled data.

Vanishing intervals. A significant difference was found only by pooling the data of both series ($P < 0.05$), the E-birds vanishing later.

Homing performances (figs. 2, 4). In all the tests, C-birds performed a little better than E-birds, but the difference never reached significance, even considering the pooled data of the two series, separately or as a whole.

Discussion

As mentioned in the introduction, previous experiments with treatment before release had shown that a sine wave of 0.14 Hz had no effect, whereas waves of the same shape and amplitude but of higher frequency (from at least

TABLE I.

Results of the first series.

Release No.	Date	Home distance (Km)	Home direction	Group	Birds released and (bearings recorded)	Mean bearing	Mean vector length	Homeward component	P (V test)	P (U^2 test)
A	Aug. 11, 1982	54.8	336°	C	11 (10)	296°	0.844	0.647	< 0.01	> 0.10
				E	12 (10)	264°	0.604	0.187	> 0.10	
B	Aug. 13+19, 1982	40.4	161°	C	23 (19)	169°	0.876	0.867	< 0.001	< 0.05
				E	22 (21)	164°	0.474	0.474	< 0.01	
C	Aug. 23+26, 1982	59.6	243°	C	18 (17)	210°	0.711	0.597	< 0.01	> 0.10
				E	20 (16)	212°	0.340	0.291	< 0.05	
A-C				C	52 (46)	— 17°	0.750	0.717	< 0.001	< 0.05
				E	54 (47)	— 26°	0.391	0.352	< 0.01	

TABLE II.

Results of the second series.

Release No.	Date	Home distance (Km)	Home direction	Group	Birds released and (bearings recorded)	Mean bearing	Mean vector length	Homeward component	P (V test)	P (U^2 test)
A	Sept. 6, 1983	23.3	180°	C	15 (13)	208°	0.905	0.799	< 0.001	< 0.001
				E	15 (12)	236°	0.350	0.196	> 0.10	
B	Sept. 8, 1983	28.8	324°	C	15 (12)	312°	0.898	0.878	< 0.001	< 0.001
				E	16 (15)	283°	0.245	0.185	> 0.10	
C	Sept. 15, 1983	45.5	241°	C	17 (15)	224°	0.966	0.923	< 0.001	> 0.10
				E	16 (14)	234°	0.777	0.772	< 0.001	
D	Oct. 4, 1983	54.8	336°	C	16 (13)	325°	0.821	0.806	< 0.001	< 0.05
				E	15 (12)	249°	0.190	0.099	> 0.10	
A-D				C	63 (53)	— 3°	0.855	0.854	< 0.001	< 0.005
				E	62 (53)	— 9°	0.306	0.302	< 0.01	

0.42 Hz) did affect orientation. In the present experiments the lower frequency treatment also disturbed orientation. A plausible explanation is that the low frequency influences the birds without an hysteresis effect. In the second series, the disturbance in orientation appears stronger than in the first one.

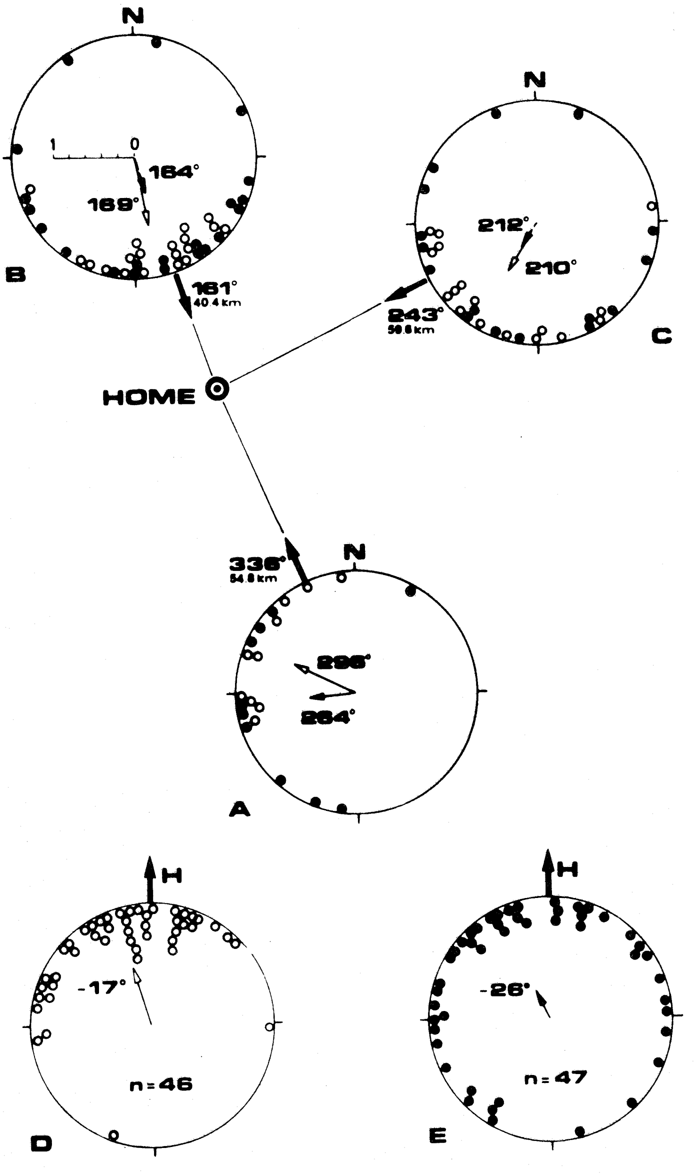

Fig. 1. – Initial orientation in the first experimental series. Diagrams A, B, and C refer to single experiments; diagrams D and E represent bearings of the three experiments pooled by setting home direction to 0°. Each dot represents the bearing of one bird, open dots refer to C-, filled dots to E-birds. Inner arrows are the mean vectors of the two groups. Vector length can be read using the scale given in one of the diagrams.

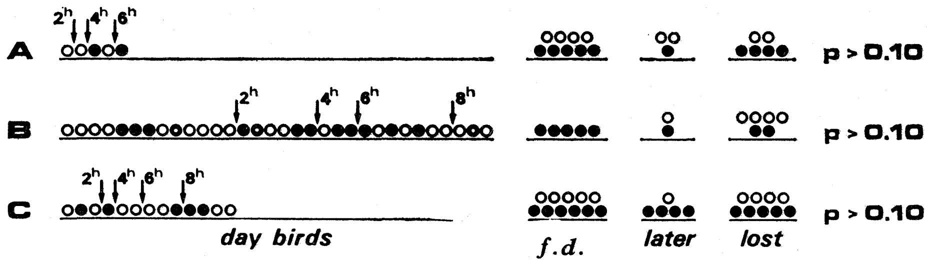

Fig. 2. – Homing performances in the first series. Open symbols refer to C-birss solid symbols to E-birds, dotted symbols to E-birds that arrived on the day of releade with the coils disconnected. The significance level of the difference between the homing times of the two groups (Mann-Whitney U test) is given at the right of each diagram. Only symbols of day birds are located according to the time taken to return home; f.d. = following day.

The increase of the vanishing intervals for the E-birds is in agreement with the increased scattering of their bearings. Both phenomena may be the outcome of troubles in position fixing or in selecting the deduced bearing.

The main result of the present experiments is the lack of a significant difference in homing performance between C- and E-birds. It must hence be inferred that the E-birds quickly made up for the initial failure, just as birds treated before release. The fact that in each test the E-birds performed a little worse in homing is attributable to their poor initial orientation.

Lednor and Walcott (1983) failed to find any influence of their treatments on initial orientation. This fact can be explained by either the different characteristics of the field applied or a lesser sensitivity in Cornell pigeons. The latter hypothesis is in agreement with the fact that initial orientation in both Cornell and Bavarian pigeons is not influenced by magnetic treatments that affect Arnino birds (H.G. Wallraff and S. Benvenuti, pers. comm.). In one of Lednor and Walcott's experiments, experimental birds homed with the same speed but with different success, as 12 of the 31 experimentals and only 2 of the 29 controls were lost. This failure remains unexplained; in the second experiment the performance of E-birds was normal.

Some hypotheses have been put forward (Papi *et al.*, 1983) about the nature of the disturbance produced by the magnetic treatment, but the phenomenon remains unexplained. Some recent experiments (Benvenuti *et al.*, 1985; Wallraff *et al.*, 1986) suggest a link with the mechanism of olfactory navigation, since the magnetic treatment fails to have an effect if the birds are simultaneously prevented from smelling natural odorants dispersed in the atmosphere.

The present findings provide new evidence arguing against the idea of magnetic navigation. The main conclusion we can draw is that, under sunny conditions, pigeons do not seem to depend on magnetic cues to find their way home. Considering the parameters of the field across the heads of our pigeons, it seems very improbable that they could either deduce the direction of displa-

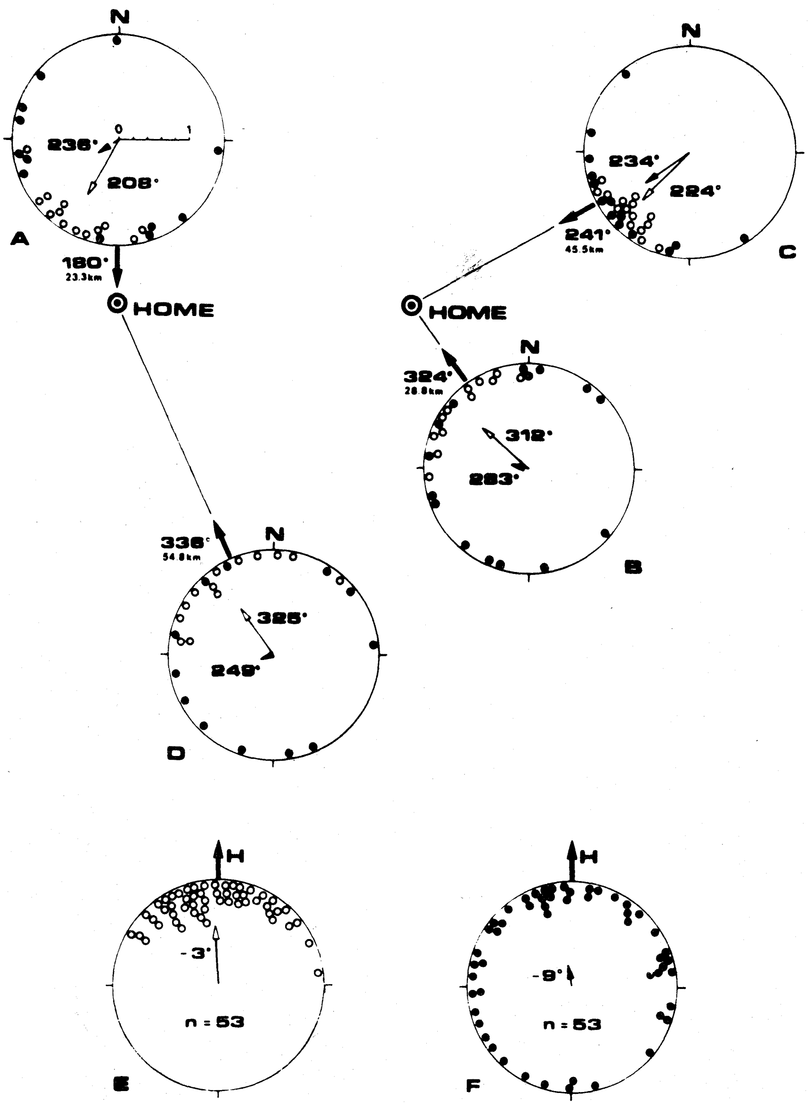

Fig. 3. – Initial orientation data for the second series. Other explanations as in fig. 1.

cement during the outward journey by means of their magnetic compass or establish their position after release by comparing some parameters of the earth's magnetic field with those at the loft.

As shown by a long series of reports (see for references Papi, 1976, 1982; Wallraf, 1980, 1984), pigeons rely on olfactory cues to navigate and are heavily impaired when rendered anosmic. Magnetic navigation cannot be considered an alternative or back-up mechanism. It remains possible, however, that magnetic cues are a component of an integrated system, in which they play a minor role.

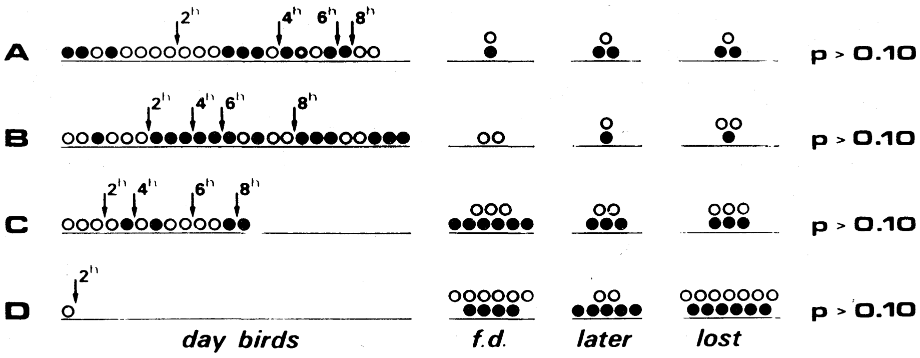

Fig. 4. – Homing performance data for the second series. Other explanations as in fig. 2.

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