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HUMAN HOMING: STILL NO EVIDENCE DESPITE GEOMAGNETIC CONTROLS

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SUMMARY

Baker's highly influential and widely cited studies suggest that people are capable of non-visual navigational performance comparable to that of homing pigeons. Past failures to replicate this work have been attributed by Baker to geomagnetic influences. We report a series of experiments in which both temporal and spatial geomagnetic controls were introduced. We could still find no evidence for blindfold homeward orientation in humans.

INTRODUCTION

In the late 1970s Baker widely publicized his exciting results on human navigation, finally publishing them in *Science* (Baker, 1980) with more detailed analyses appearing elsewhere (Baker, 1981). His basic finding was that people transported up to 60 km from home, along indirect routes and in conditions of sensory semi-deprivation, were able to indicate the true direction of 'home' either in writing or by pointing. It is further claimed that these experiments provide evidence for what Baker terms 'Route-Based' rather than 'Location-Based' *magnetic* navigation since subjects wearing head-mounted bar magnets on the outward journey showed a disruption of homing not seen in controls. The results are therefore qualitatively similar to those obtained on homing pigeons transported in altered magnetic fields (see Gould, 1980 for a recent review). The distinction between Route- and Location-Based navigation corresponds in practice to a compass-based *vs* map-based system. In the former, successive compass readings taken on the outward journey allow the animal to compute the return orientation. In the latter a map is required in addition to the compass which is then only needed at the release point.

In Series I of his experiments, Baker transported blindfold undergraduates in vans to 'release' sites between 6 and 52 km from 'home' (Manchester University). At each release site the students were taken, still blindfold, from the van and asked to state the compass direction of the release site from home. Statistical analysis (Batschelet, 1972) showed significant homeward orientation ($r = 0{\cdot}59$–$0{\cdot}75$, $P < 0{\cdot}01$: z-test) and significant clustering about the home direction ($P < 0{\cdot}05$: V-test). In a second

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experiment of similar design (Series II, Part I) sixth-form (high school) students wrote down an estimate of the compass direction of the release site from home, whilst blindfold and still inside the bus. Again analysis showed that the students' estimates were both significantly non-uniform ($r = 0{\cdot}38$) and homeward directed ($P < 0{\cdot}01$).

Baker concludes that the results of the two experiments show that humans have an ability to recognize homeward direction using route-based non-visual cues. In later experiments (Series III), he went on to show that activated Helmholtz-coil helmets worn on the outward journey significantly affected homeward orientation and that the observed deviations are explicable in terms of the interaction of the earth's magnetic field and that induced by the coils. These results led to the claim that 'Whatever the repercussions, we have no alternative but to take seriously the possibility that Man has a magnetic sense of direction' (Baker 1981, p. 45). The repercussions have been considerable since to date it has not been possible to replicate even the basic finding of blindfold orientation to home.

In 1981 Gould & Able reported eight attempts to repeat the 1980 Manchester experiments with Princeton and Albany undergraduates and staff, in which Baker himself also participated. All of them failed. Blindfold subjects were transported along various routes to sites 4 to 33 km from the campus, mainly using Baker's procedure of obtaining estimates at several stops. In some cases subjects wearing bar magnets behind a headband could be compared with brass bar controls. With one exception (to be expected by chance), homeward orientations at 13 sites were random. Gould & Able (1981) conclude that Baker's students '... either had cues available to them which were absent in our experiments, or are dramatically better than Americans in using whatever cues may be involved in judging displacement'. Baker has replied by presenting data (unpublished conference papers and personal communications) which indicate that geomagnetic disturbances were the cause of Gould & Able's replication failure. He has pointed out that the dates of their experiments coincide with maxima in the cyclic variations in the K-index – a measure of local field strength perturbations resulting from solar activity. We should note here that such fluctuations are too weak to affect a magnetic compass, so this objection could only hold in a map-and-compass system where at least one map component was magnetic – *not* in a 'route-based' compass-only system.

METHODS AND RESULTS

In March 1980 we independently took up the challenge to replicate Baker's findings. Four experiments were performed, ending in February 1983, in which orientation ability under varying degrees of sensory deprivation at the release site were compared. Controls were introduced which enabled us to assess the role of magnetic influences and other details of Baker's procedure, including roof visits before departure and sex of subjects. Both spatial geomagnetic anomalies and temporal variations in the earth's magnetic field produced by solar activity are well known to influence pigeon homing (Keeton, Larkin & Windsor, 1974), so both were controlled for in our later experiments.

In experiment I, 29 Sheffield psychology undergraduates were transported to the same release site 13·5 km NE from the University (point A, Fig. 1) in three blacked-out minibuses or Land Rovers on one of two days. The view from the front of the vehicle was also obscured for the subjects. The route was different for each bus with the road distance varying between 24·6 and 38·4 km. Half the subjects had visited the flat roof of the five floor Psychology building for about 15 min before departure, which affords a near panoramic view of the surrounding cityscape and distant hills. On arrival at the destination (chosen, as in all subsequent release sites, to be devoid of any obvious visual location cues such as tall city-centre buildings, sign posts etc.) the subjects were asked to provide the following estimates while still in the blacked-out van: (a) the direction of 'Home' and (b) North, by drawing an arrow on a record sheet oriented with respect to the front of the vehicle and (c) the bee-line distance to home. [Baker (1980) used written compass orientations. We found that this led to unnecessary confusion, particularly over East/West, so arrow-drawing estimates only were used – a technique subsequently also employed by Baker.] Subjects were then blindfolded, removed one by one from the vehicle and asked to point to Home and North. The process was repeated with blindfolds removed and all other subjects out of sight. Orientations were measured by the experimenters using hand-held compasses. The results are summarized in Table 1 and Fig. 1.

The results for inside homeward orientation were random with a mean vector length of 0·09 ($N = 29$). When location-based cues were available, with the subjects outside, the results showed clustering which just reached significance on the z-test although the mean pointing bearing was over 120° to the right of the true home direction. Removal of the blindfolds, contrary to predictions, did not improve orientation performance. Northward orientation was non-significant under all three conditions.

Experiment II used a much larger sample size. It was also spread over two days and orientations to Home and North at each of *four* release sites were obtained. The sites (B, C, D, E, Fig. 1: filled triangles) were chosen to lie in the four compass quadrants and at similar distances from home. Again the sites were well away from built-up areas and devoid of obvious visual location cues. Each blacked-out bus followed a similar perimeter route joining the four sites but started by driving out radially to a different first site so that the four buses visited the sites in a clockwise order on Day 1 and an anti-clockwise order on Day 2. The exact orientation of each bus at each release site was decided in advance so that adoption of simple rules such as 'always orientate behind' could not produce significant results. Again, half the subjects visited the roof of the department before departure. The pooled results for all subjects at each release site are shown in Table 1 and Fig. 1. Inside homeward orientations were random in every case and were significantly clustered in the homeward direction in only one case when all cues were available (Site B). To examine the possibility, proposed by Baker, that roof visits are an important factor, we also analysed the results separately for the 'Roof' and 'Non-Roof' subgroups. We also compared male and female homing ability to test Baker's claim that '... females are more able than males at non-visual, route-based navigation but that males are more likely to reinforce their route-based estimates by location-based navigation'. Our paradigm allows us to test this directly. In just two cases (sites G, I) there was one sex which showed significant clustering of orientations in the homeward direction. It was males at one site and females at the other. Male/female comparison at these sites, using Watson's $U^2_{n,m}$ two sample test, showed, however, that the difference was non-significant in both cases. No differences in orientation ability were found to be related to roof visits.

Table 1. *Results summary for homeward orientation under the three conditions*

Experiment	Date	Release site	Mean vector error (degrees)	Mean vector length	Statistical significance z-test	Statistical significance V-test
I	10/11.3.80	A: Wentworth (14 km NE)				
	($N = 29$)	Inside	−11·3	0·09	NS	NS
		Outside BF	+121·6	0·38	*	NS
		Outside NBF	+172·0	0·20	NS	NS
II	4/5.12.80	B: Wharncliffe Crags (11 km NNW)				
	($N = 59$)	Inside	−128·0	0·21	NS	NS
		Outside BF	−6·0	0·14	NS	NS
		Outside NBF	−24·0	0·39	***	***
		C: Ulley (12 km ESE)				
	($N = 45$)	Inside	+71·0	0·08	NS	NS
		Outside BF	+83·0	0·11	NS	NS
		Outside NBF	−104·0	0·29	NS	NS
		D: Apperknowle (10 km SSE)				
	($N = 48$)	Inside	+124·0	0·12	NS	NS
		Outside BF	−142·0	0·28	**	NS
		Outside NBF	+51·0	0·37	**	NS
		E: Redmires (7 km W)				
	($N = 59$)	Inside	−124·0	0·11	NS	NS
		Outside BF	−96·0	0·08	NS	NS
		Outside NBF	−70·0	0·13	NS	NS
III	4.11.82	F: Birdwell (14 km NNE)				
	($N = 45$)	Inside	+175·0	0·25	NS	NS
		Outside BF	+19·0	0·23	NS	*
		Outside NBF	+38·0	0·38	**	***
		G: Aston cum Aughton (13 km ESE)				
	($N = 45$)	Inside	+3·0	0·15	NS	NS
		Outside BF	−176·0	0·02	NS	NS
		Outside NBF	−120·0	0·20	NS	NS
		H: Holmesfield (10 km SSW)				
	($N = 45$)	Inside	+166·0	0·16	NS	NS
		Outside BF	+133·0	0·09	NS	NS
		Outside NBF	+61·0	0·10	NS	NS
		I: Under Toft (4 km WNW)				
	($N = 45$)	Inside	+46·0	0·40	***	***
		Outside BF	+62·0	0·41	***	*
		Outside NBF	+62·0	0·34	**	NS

Significance levels: * = $P < 0{\cdot}05$; ** = $P < 0{\cdot}01$; *** = $P < 0{\cdot}005$.

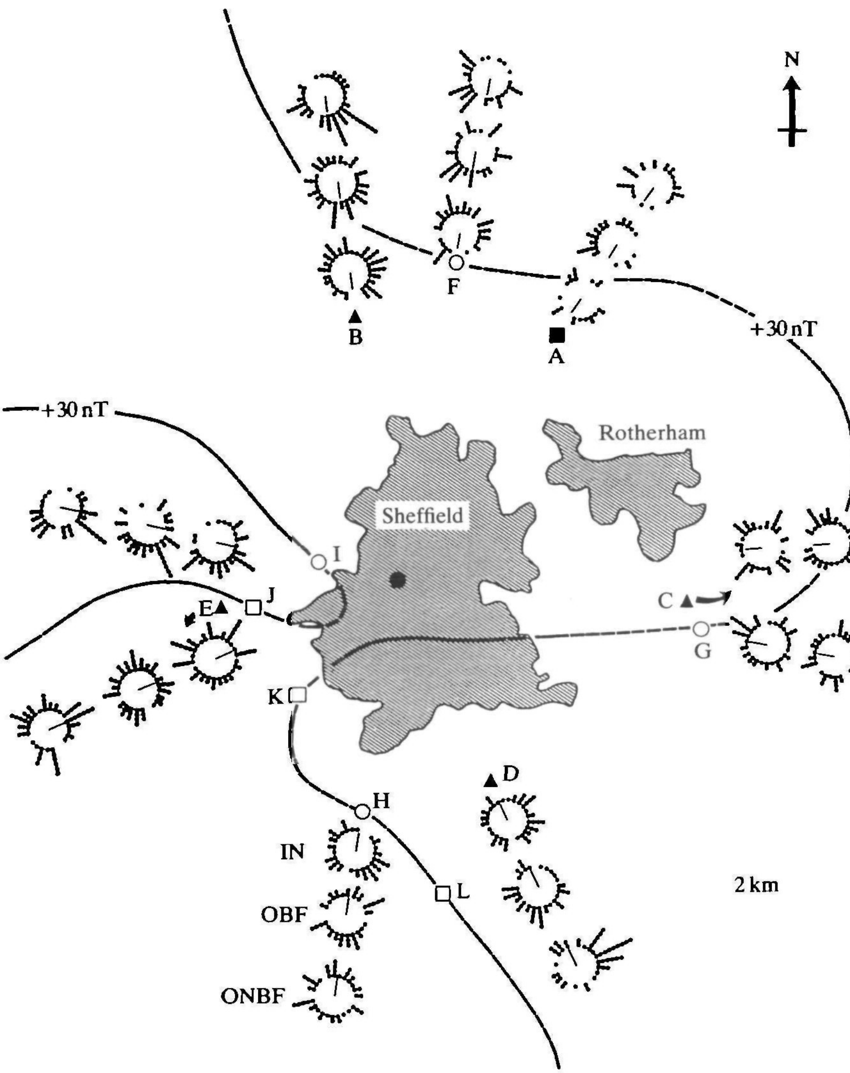

Fig. 1. 450 estimates of homeward direction were made by 133 undergraduates transported in blacked-out vans to 12 sites around Sheffield. Each estimate (represented as a dot on the circular histograms) was repeated inside (IN), outside blindfold (OBF), or outside not blindfold (ONBF). A line marks the direction of 'home' – Sheffield University Psychology Building (filled circle). In experiments III and IV the sites (F–L) were chosen to lie on the same weak magnetic anomaly contour thus eliminating the possibility of magnetic disruption of the putative homing ability. Indices of geomagnetic activity of solar origin for the duration of the experiments were low in every case, 9–15 nT ($K = 1$) for experiments I, II and IV and 30–60 nT ($K = 3$) for experiment III.

All the foregoing results clearly fail to substantiate Baker's claim for a non-visual navigational sense in humans. Indeed it is remarkable that in only very few cases were people able to indicate the homeward direction when all the 'release site' cues were made available (the Outside NBF condition, Table 1). Our results therefore concord well with those reported by Gould & Able (1981). In our third experiment we attempted to accommodate Baker's criticisms by controlling for spatial geomagnetic anomalies with magnetic survey data. Possible effects due to temporal anomalies (magnetic storms) were investigated *post hoc* from observatory data.

This study used another 45 psychology undergraduates, with a follow-up experiment 3 months later. Four further release sites were chosen (F, G, H and I, Fig. 1 open circles). Again they lay in four different compass quadrants from home at distances of between 4 and 14 km. In this case, however, aeromagnetic survey data was used to identify sites lying on the same magnetic contour. We found that the weak 30 nT anomaly contour (Fig. 1) provided ideal sites at the appropriate distance from home. [The Tesla (T) has replaced the previous (non-SI) unit of the Gauss, where $1\,T = 10^4$ Gauss. The nT therefore directly replaces the gamma (10^{-5} Gauss).] 30 nT is a local perturbation of only 0·06% of the local reference field strength of 47 762 nT at Sheffield (53°20′N: 1°30′W). The index of geomagnetic activity (K index) obtained after the experiment showed that the activity was low (< 60 nT) as it had been for experiments I and II. Table 1 summarizes the results. They follow the same pattern as before with random orientation except at one site (I) where highly significant clustering around the predicted home direction was found; however, the sample mean was not significantly homeward directed (Aneshansley & Larkin, 1981). We can therefore conclude that even with spatial and temporal geomagnetic controls, *no evidence* for blindfold homeward orientation could be found. The analysis by sub-group failed again to show any sex or roof-visit related effects.

Two further explanations for our inability to replicate Baker's results were investigated. First the possibility that the subjects were pointing to their 'real' (i.e. parental) homes and secondly that a small proportion of 'poor navigators' may be responsible for statistical non-significance. The first hypothesis was tested by re-analysing the data for experiment III using expected directions for two sub-groups with home towns centred approximately South and West of Sheffield. No effects were found. The second hypothesis was tested by selecting the five 'best' and the five 'worst' subjects from experiment III as measured by the total number of near correct homeward estimates (falling within ± 45° of the predicted direction). Indeed some subjects did perform well above chance and others well below. To see if this pointed to individual differences in orientation ability, both groups were retested after 3 months in experiment IV at three new release sites (J, K, L on the 30 nT contour, Fig. 1 open squares). Both groups failed to reach significance on both z- and V-tests. Using the same criterion for 'correctness' the subjects' rank for orientation performance in experiment III, and on retest in experiment IV, were compared. There was no evidence that subjects who were 'good' in experiment III had any special ability (Spearman Rank Correlation, $r_s = 0{\cdot}07 : N = 10 : \text{NS}$).

DISCUSSION

In conclusion, our results fail to provide any support for blindfold navigation in humans, *despite* the introduction of controls for local magnetic anomalies and temporal fluctuations in field strength, which could have disrupted the magnetic map component in a map-and-compass, 'location-based' system. Along with Gould & Able we must propose that Baker's students had cues available to them that ours did not. There is no support either for Gould & Able's alternative explanation that British students are better than Americans at this task. Perhaps it depends on which side of the Pennine Hills the experiments are conducted? It is obviously extremely difficult to counter all conceivable explanations for a negative result but we are forced to wonder about the ecological importance of a magnetic sense, the existence of which is so difficult to demonstrate.

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NOTE ADDED IN PROOF

Another attempt to replicate Baker's findings has recently been published, carried out this time in Victoria, Australia. Fildes, O'Loughlin & Bradshaw (1984) report experiments which, although they did not control for magnetic anomalies, also used a large number of subjects ($N = 103$) and rigorously controlled for non-magnetic orientation cues. Yet again, no ability to orientate to Home or North was found and no sex differences were detected.

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