Technical Papers

Test of the Magnetic Theory of Homing

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Yeagley's magnetic-vertical-Coriolis theory of homing (*1, 2*) supposes that pigeons are able to home to their lofts because of three essential factors: (i) sensitivity to the effect of flying through the earth's magnetic field, (ii) sensitivity to the forces produced by the earth's rotation acting on masses moving over its surface in a straight line (Coriolis effect), and (iii) visual sensitivity to ground speed. Yeagley asserts that by correlating these three factors, a bird is able to recognize its home locality at the intersection of "a characteristic line in the earth's magnetic vertical field with a characteristic line of latitude" (*1*, p. 1039).

Yeagley and his collaborators have done a good deal of research in the past several years in an attempt to test the validity of his theory. Their various experiments have been of a large-scale, statistical type; and many have provided suggestive but by no means conclusive results. The experiments of Gordon (*3*), Matthews (*4*), and Van Riper (*5*), on the other hand, appear to contradict Yeagley's results. Moreover, Wilkinson (*6*) has raised theoretical objections to a magnetic theory, and Thorpe (*7*) has criticized Yeagley's experimental designs.

The study described here represents a laboratory attempt to test the hypothesis that pigeons are sensitive to the effect of passing through a magnetic field. Specifically the experiment tests the effect of magnetic lines of force moving through stationary pigeons, but from the standpoint of the electromagnetic effect it makes no difference whether a conductor cuts lines of force or *vice versa*.

The conditioning technique was employed throughout the experiment with electric shock used as the unconditioned stimulus. Two female homing pigeons, *Columbia livia* (L), were given preliminary training in buzz-shock and then light-shock sequences. The birds were placed in a Lucite cage 18 in. square. The floor of the cage consisted of an electric grid constructed of parallel ⅛-in. brass rods spaced ½ in. apart. Grid current could be varied from 0 to 1600 v by means of a variac. Voltages were obtained from a step-up transformer energized by 60 cy/sec alternating current.

The conditioned stimulus for the buzz-shock sequence was a door buzzer placed 2 ft from the cage. For the light-shock sequence the buzzer was replaced by a 200-w bulb suspended 2 ft above the cage. Timing and duration of both conditioned and unconditioned stimuli were by automatic control; the trials were conducted in a sound-insulated room. Training was continued (at 20 trials per day) until both animals were conditioned to walk or run at the sound of the buzzer *and before the onset of shock* in 19 out of 20 trials (95 percent).

For the magnetic field-shock sequence, a solenoid 20 in. square and 54 in. long was constructed on a wooden frame. This was achieved by winding the frame with No. 16 Formvar magnet wire, 5 turns to the inch. The axis of the coil was vertical, and the conditioning cage rested in its center. The solenoid thus extended 18 in. above and below the cage, so as to surround it with a uniform field.

Table 1. Number of trials for subjects to reach criterion for learning under three experimental conditions.

Experimental condition	Trials		Criterion reached	
	Bird A	Bird B	Bird A (%)	Bird B (%)
Buzz-shock	820	820	95	95
Light-shock	180	260	95	95
Magnetic-shock	1000	860		

The magnetic field generated by the solenoid rose from 0 to 5 gauss in the same direction 120 times/sec. This varying field was produced by passing 60-cy/sec alternating current through a full-wave rectifier and a 1 : 1 transformer. The strength of the field was then kept constant during the training by means of a variac and ammeter in the solenoid circuit. Its presence and strength were checked by a gaussmeter. The magnetic field thus produced was substituted for the buzzer and light used previously. Procedure was as before.

The results of the three types of training are presented in Table 1. Figure 1 presents Vincent curves (*8*) of the learning that took place under the three experimental conditions. These results show clearly that no apparent learning occurred during the mag-

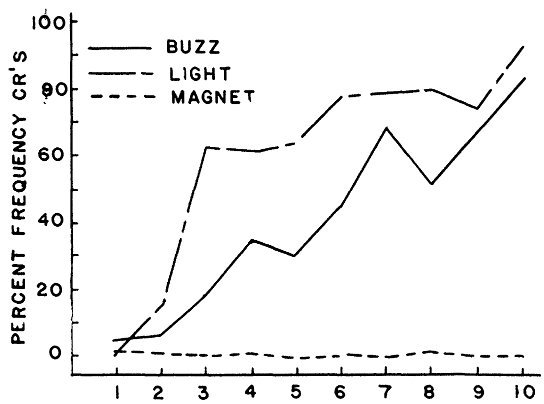

Fig. 1. Vincent curves of the acquisition of conditioned responses in both subjects under three experimental conditions.

netic field-shock sequence, despite the fact that training was continued for a longer period than in the other two sequences. The results gain added significance from the fact that the buzz- and light-shock sequences might be expected to facilitate the learning of a later sequence in which there is only stimulus substitution; that is, positive transfer of training should occur.

However, any conclusions drawn from the obtained results must be qualified in that the experimental design did not duplicate conditions as they are in nature and, consequently, as they are treated in Yeagley's theory. Although the magnetic stimulus used here passed through the intensity of the earth's magnetic field to a value of approximately 25 times the earth's field and did this 120 times/sec, it may have presented these intensities too rapidly, too intermittently, or in some other way that might affect their reception. Nevertheless, the failure to obtain any learning with the magnetic stimulus would seem to cast some doubt on a magnetic theory of homing.

References and Notes

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Relationship of Dental Cavities to General Health

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A concept of bodily health that might be termed *Gestalten* has generally been accepted for many years. Applications for school, employment, insurance, and even personal communications typically contain an assessment of the state of a person's general health. The condition of health is described in broad terms, such as good, fair, or poor, dependent mainly on the number or severity of bodily disorders a person has. Type or types of disorders leading to this designation are not necessarily considered. Furthermore, in all such descriptions the oral cavity and its pathology are almost always neglected. This may be largely due to the fact that dental disease and its treatment is a highly developed specialty which appears to be peripheral to the rest of medicine. A person who has numerous dental cavities filled during a year's time is rarely thought to be in "poor" health. Therefore, the possibility of a relationship between dental pathology and other bodily dysfunction on this level has never been seriously considered. The following are the results of a study undertaken to ascertain whether such a relationship exists.

Table 1. Comparison of DMF score for criterion group and unselected sample.

Group	N	$\bar{x}$	s	t	P
Criterion group	121	31.09	14.76	2.597	.01
Unselected group	1019	27.22	15.55		

The 8-mo cumulative medical histories of a sample of Naval Aviation Cadets were examined. This group comprised a total of 1080 subjects (26 consecutive classes). The name, serial number, complaint, diagnosis, treatment, and disposition of the case were tabulated for each man. It was found that five or more dispensary visits were made by approximately 15 percent of the total population. Assuming frequency of medical complaints as a health index, these 178 subjects could be assumed to represent the "poorest" on a general health evaluation.

The complete dental records, including roentgenographs, of this criterion group were then collected where possible. DMF (decayed, missing, or filled teeth) ratings were made from these records. The DMF rating represents a subject's total past and present dental caries experience. It is compiled by scoring 1 point for each surface of a tooth containing caries or a filling and 3 points for each missing tooth. The resultant mean DMF score of the criterion group was then compared with the mean Naval Aviation Cadet DMF rating formerly established.

Of the 178 subjects in the criterion group, complete dental records were found on 121. The other 57 records were unavailable because the cadets had dropped from the program (*1*). Table 1 presents the sample statistics for the criterion group and for a large sample representative of the over-all population of Naval Aviation Cadets. As may be seen, the mean DMF established on an independent sample of 1019 unselected Naval Aviation Cadets is 27.22 with a standard deviation of 15.55. The mean DMF of the criterion group is 31.09 with a standard deviation of 14.76. The t-test for the difference between these means yielded a value of 2.60, which is significant at the .01 level of confidence. We should note in passing that this difference was established on a population that can be considered above average in general health, having been screened by a rigorous physical examination prior to admission.

In recent years, dentistry, as well as other branches of medical science, has postulated that certain chronic illnesses affect dental conditions, and conversely (*2*). The present study therefore provides an interesting relevancy. It presents empirical evidence of a relationship between general health, as measured by frequency of medical complaints, and oral pathology