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PIGEON HOMING: EFFECTS OF X-RAY RADIATION TO THE HEAD AND FOREBRAIN

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ABSTRACT

In an attempt to determine what role the forebrain of a pigeon has in homing behavior, portions of the forebrain were damaged by X-ray irradiation. At first the effect of 600 R of X-rays to entire heads of racing pigeon was studied. These birds did home in 80 km test flights as well as the controls and continued to do so for three summers following the irradiation for a total of 1780 km. A group of pigeons were then treated with 1500 R of X-rays to the whole head and these birds also homed for a total of 1725 km as well as the controls for several years. However, some birds that received 600 R and a year later 1500 R to the head homed the first and second summers, but premature senility appeared by the third year following radiation. These birds that received whole head irradiation of a total of 2100 R were test flown 1440 km. With the use of appropriate lead hoods, 10,000 R were administered to delimited 2, 10 or 15 mm diameter regions of the forebrain. No influence on homing behavior compared to controls could be detected in flights from 19 to 164 km. These birds flew 1474 to 2116 km over a 2-year period. Radiation induced lesions and damaged to olfactory nerves were detected upon autopsy of irradiated birds.

INTRODUCTION

Considerable attention has been given to the homing be-

havior of birds (Matthews, 1951; Hitchcock, 1952, Alexander and Keeton, 1972) and indications exist that besides visual cues, magnetic fields (Merkel and Wiltschko, 1965; Southern, 1972) may play a role in this activity. Papi et al. (1973) have proposed that olfaction plays an important role in the homing mechanism of pigeons. However, Keeton and Brown (1976) reported that a strong odorous substance (α-pinene) failed to cause a decrement in homing performance. The homing behavior of a pigeon is complex and the birds probably use whatever cues they can in homing. In an attempt to evaluate the role which the forebrain may play in homing, X-ray irradiation was used to injure this region of the central nervous system. The effect of X-ray radiation to the entire head was first determined. Then the forebrain alone was exposed by using appropriate lead hoods. A practical reason for testing the forebrain was that a small portion could be damaged without blinding the birds or rendering them incapable of flight.

METHODS

Prior to experimentation on the forebrain, the effect of radiation to the entire head with respect to homing was determined. One to 2 year old racing pigeons were intensively trained to home over a period of two to three months by releasing 16 to 80 km west of the campus loft. Six of these pigeons were then irradiated with 600 R of X-rays to the entire head. The X-rays were produced by a General Electric Maximar III at 225 KV, 15 amp, 32 cm., 245 R/min no filters. The pigeons were wrapped in a woolen sleeve to prevent wing beating and movement, and placed in a paper-padded wooden box lined with lead. The box had a small hole so only the head could protrude. A plastic ring was placed around the neck to prevent the bird from withdrawing from the X-ray beam. (Shown in Figure 1).

Since DeKalb, Illinois, is 97 km west of Chicago, releases of birds were either NW, W, or SW of the loft to prevent the birds from flying over a congested metropolitan district. They were released singly and the next bird was released only when the first one was out of sight. Distances ranged from 19 to 164 km. The direction of vanishing and time of arrival were recorded. If rain was predicted or the temperature was below 4°C, the birds were not released for testing. The homing tests were done once or twice a week from mid-April to early November for three years. On non-test days, the birds were exercised around the loft building. In individual experiments, equal numbers of control birds were employed. These were of the same age and sex as those exposed to radiation.

The following summer, eight pigeons were exposed to 1500 R of X-rays to the head. Six of these birds had never been irradiated, but the other two had been exposed to 600 R. These birds were observed and flown for three years.

In the forebrain experiments, a lead hood (Figure 2) was placed over the head of the bird while its body was still enclosed in the lead box. The hood was positioned so that the hole (either 2, 10 or 15 mm diameter) would permit the X-rays to enter the head only in the region of the forebrain. Precaution was taken not to injure the eyes and optic nerves. Five birds received a 10,000 R-exposure of X-rays to a 2 mm diameter region in the middle of the forebrain, while another five birds were exposed to 10,000 R to a 10 mm region of the forebrain. These two groups along with appropriate controls were flown an average total of 1474 km and were observed over a 2 year period.

An additional 19 pigeons received 10,000 R of X-rays to a 15 mm diameter region of the forebrain and were flown 33 times for an average total of 2116 km. Twenty different flight release sites were used. Three of these were for training and were used prior to head irradiation. The treated birds were thus released from 17 sites for the first time.

Pigeons receiving irradiation to the forebrain were autopsied and damage was noted.

RESULTS

The six pigeons whose entire heads were irradiated with 600 R of 225 KV X-rays homed as efficiently as the six controls when released an hour after irradiation at a distance of 32 km west of the loft. These birds had good reflexes as demonstrated by avoiding reactions to captives in the loft. Two days later when the same birds were released 48 km to the west, they disappeared from view at single releases in the correct direction and homed as quickly as the controls. These birds continued to act normally, leaving the loft for their daily exercises and were flown at release points 24 to 80 km west of the loft. By the following summer the irradiated birds and the controls had logged an average of 480 km and none had been lost. They mated, their general behavior was normal; however, they could easily be distinguished from the rest of the flock by white head feathers induced by the radiation (Figure 3). Eventually these birds homed for an average total of 1780 km, showing no significant differences from the controls. The summary of their homing data is presented in Table 1.

Table 1. Summary of the Results of Homing Tests

Radiation exposure	Test period years	Total cummulative distance flown, km.	Number of releases	Number of birds	Number lost or (failed to return)	Mean deviation in disappearance from view in degrees	Mean speed (if the bird arrived the same day of release) km/hr.
Series No. 1 600R to entire head	3	1780	31	6	1	23°	29.4
Controls	3	1780	31	6	1	27°	28.7
Series No. 2 1500R to entire head	3	1725	30	8	1	21°	26.7
Controls	3	1725	30	8	1	27°	25.5
600R + 1500R to entire head	2	1440	26	2	0	41°	15.2
Series No. 3 10,000 to 2 mm of forebrain	2	1474	27	5	0	22°	27.6
Control	2	1474	27	5	1	19°	25.5
Series No. 4 10,000R to 10 mm of the forebrain	2	1474	27	5	1	18°	28.1
Control	2	1474	27	5	0	24°	26.9
Series No. 5 10,000 to 15 mm of the forebrain	1	2116	38	19	2	30°	25.1
Control	1	2116	38	19	2	27°	24.5

Pigeons which received 1500 R and those that were irradiated for a total of 2100 R (1500 R + 600 R) to the entire head were released at points 48 to 80 km west of the loft over a period of 3 years. No differences in homing ability between controls and these irradiated birds were noted for three years in those birds receiving 1500 R of X-rays. Further, 1500 R to the entire head failed to interfere with mating behavior and rearing of the young. A month after exposure, loss of and changes in the colors of head feathers were noticed, and two months later, light spots and pale discolorations were observed in the irises (Figure 4). The discolorations of the irises and the induced white head feathers persisted for the entire life of the bird.

Birds receiving a total of 2100 R (Figure 5) homed as well as controls during the first summer after irradiation. However, by the next year they began to home slower (Table 1) and showed behavioral signs of premature aging. Three years after the first head irradiation, one of the birds had become potently senile and this group was then excused from the test flights. By this time, birds receiving 2100 R had homed an average total of 1440 km.

Birds which had received 10,000 R to portions of the forebrain through 2, 10 or 15 mm openings in the lead hood were not at all affected in their ability to home (Table 1). Although these birds had different colored leg band markers, they could easily be distinguished from the rest of the flock by the whitish feathers in the exposed regions of the head. Autopsies of these birds did indicate radiation damage to anterior portions of the forebrain and to olfactory nerves.

DISCUSSION

The central nervous system of adult animals is generally regarded as being highly resistant to ionizing radiation. Whether one accepts 920 R as the LD_{50-30} day for pigeons (whole body radiation) as determined by Skala and Hill (1952) or 2050 R as the LD_{50-30} day as reported by Stearner and Tyler (1962), the evidence obtained in the present studies of whole head irradiation indicates that the homing ability is fairly resistant to X-ray irradiation. Conflicting views are presented in the literature with respect to the sensitivity of the nervous system to radiation. Lebedinsky et al (1958) state that low doses of radiation, 10 R or less can affect biolectrical activity and reflex time. However, Stahl (1960) reported that alterations in these indicators of damage are resistant to moderate amounts of radiation. Krabbenhoft (1955) found that supralethal doses above 1000 R must be given to produce detectable changes in brain structure, while Caster et al (1958) claim that although the central nervous system is resistant to radiation, small populations of sensitive cells can be detected. In a study reported by Kramer

and Michaelson (1972) in which 1000 R was given to the heads of beagles, this exposure failed to result in abnormal behavior in these dogs 30 months later; however, diffuse neuronal alternations and changes in the electroencephalogram were detected.

Pigeons which received a total of 2100 R, whole head irradiation, did not home as well as the controls during the second year and were also easier to catch in the loft. However, during the first year, no differences were evident in the behavior of these birds with respect to the controls both in avoiding capture and in homing speed. The latent senility was not detected in those birds that received 600 or 1500 R whole-head irradiation after 3 years of flying.

In mammals, whole body doses of 10,000 R or higher usually produce death in a day or two after exposure as a result of damage to the nervous system. This is usually termed central nervous system, (Casarett, 1968). Although portions of the forebrain were severely damaged by 10,000 R of X-rays, the birds in the present experiment did home and were behaviorly unaffected. In positioning the hood with 15 mm diameter opening to irradiate the forebrain and in avoiding the optic region to prevent blindness, the olfactory nerves were exposed to radiation. These birds homed and reacted as well as controls. This evidence supports the conclusions of Keeton and Brown (1976) that olfactory cues do not play an important role in pigeon navigation.

The forebrain was selected as part of the nervous system that could be damaged and partially destroyed but which would not interfere with vision and the ability to fly. Apparently, this region does not specifically house the ability to detect or interpret magnetic cues. Subjecting the anterior region of the forebrain to 10,000 R failed to affect the homing behavior even when the birds were released from distant sites for the first time. The homing behavior thus appears to be property of a larger portion of the brain or some other specific region. Several components of this behavior probably exist in the trained bird and as in general learning, it is likely that the entire brain may be involved, with cues arising from anatomical sensors even outside the central nervous system.

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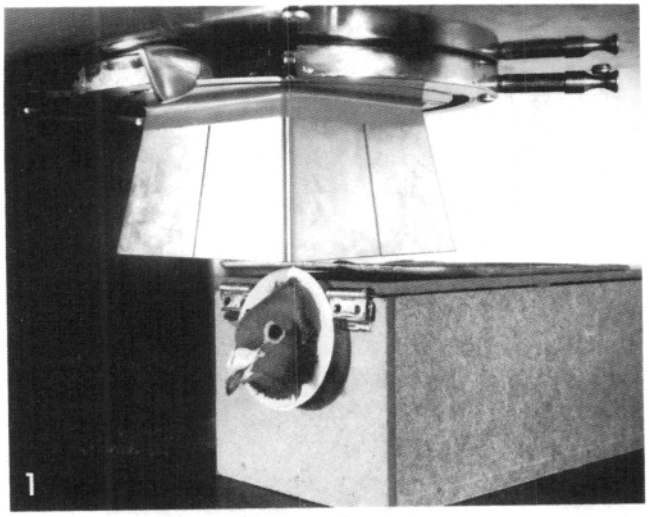


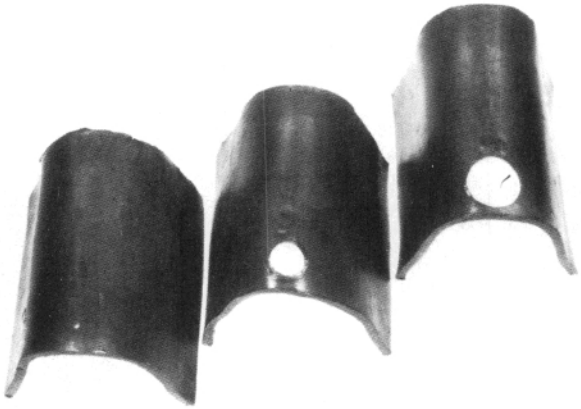
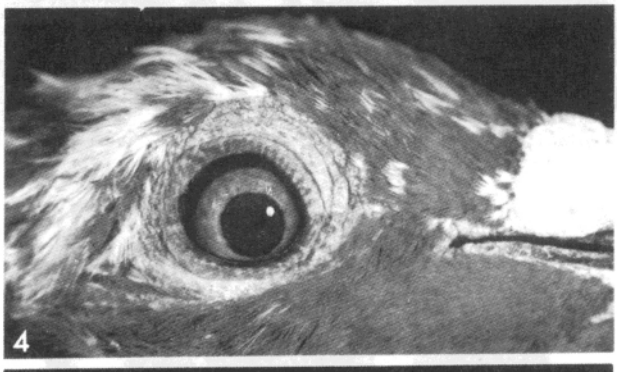


Plate 1

Figure 1. Pigeon in position to receive whole head X-ray radiation.

Figure 2. Hoods with 2, 10 and 15 mm diameter openings used to irradiate portions of the forebrain.



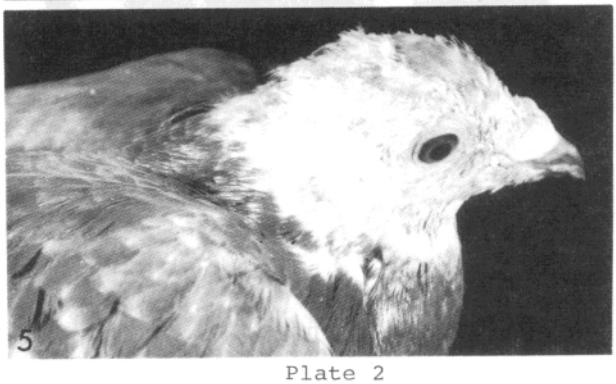


Plate 2

Figure 3. Head of pigeon three months after receiving 600 R of X-rays. Some of the feathers grew back white and gray.

Figure 4. Discoloration of the iris and white feathers induced by 1500 R of X-rays.

Figure 5. Head of pigeon six months after receiving a total of 2100 R.