LIFE-SPAN CHANGES IN THE VISUAL ACUITY AND RETINA IN BIRDS

W. Hodos and R. F. Miller
Dept. of Psychology, Univ. of Maryland
College Park, MD 20742-4411 USA

K. V. Fite
Dept. of Psychology, Univ. of Massachusetts
Amherst, MA 01003, USA

V. Porciatti
Istituto di Neurofisiologia del CNR
Via S. Zeno 51, 56127 Pisa, Italy

Dept. of Biology, Imperial College
London, SW7 2BB, UK

Birds offer a number of important advantages for the study of life-span development of the visual system. Their vision is excellent (Hodos, et al., 1985; Wright, 1972; Blough, 1956) and their life span often is considerably shorter than that of humans (Altman and Ditman, 1974). They also are relatively inexpensive to obtain and maintain, especially domesticated species such as pigeons, canaries, chickens, budgerigars and quail from which individuals at nearly all stages of the life span can frequently be obtained. In the article that follows we shall describe a series of anatomical, behavioral and electrophysiological studies we have carried out on pigeons (Columba livia) and Japanese quail (Coturnix coturnix japonica). The behavioral studies consisted of the measurement of visual acuity with operant-conditioning techniques as a function of age. The electrophysiological studies evaluated the retina's contribution to life-span changes in acuity by means of the flash electroretinogram and the pattern electroretinogram. The anatomical studies investigated life-span changes in cellular components of the retina in birds of known visual acuity.
Behavioral Acuity

Pigeons were trained to peck the center key of a conventional three-key pigeon operant-conditioning chamber that had been modified by the addition of a motorized filter wheel behind the center key (Hodos, et al. 1976; 1985; 1991). The wheel contained a series of square-wave optical gratings, each of which was matched to a glass, neutral-density filter to within 0.01 log unit of luminous transmission. The gratings ranged in spatial frequency from 1-20 lines/mm. The gratings were viewed directly through the center key, which had been fabricated from optically neutral glass, against a uniformly illuminated screen.

The psychophysical procedure was a variation of the method of constant stimuli in which the pigeon was required to discriminate the presence of a grating from its matched neutral-density filter. After a series of pecks on the center key to maximize the likelihood that the bird was paying attention to the target, the pigeon was then required to make a single peck on one of the two side keys. One key was "correct" if the grating had been present and the other was "correct" if the blank had been present. Correct responses were rewarded with grain; incorrect responses were mildly punished by a short delay in the progress of the experiment and an obligatory repetition of the trial. Such correction repetitions were not included in the calculation of the bird's percentage of correct responses to each grating frequency.

At the end of each testing session, the data were plotted to form a psychometric function of the percentage of correct responses at each grating frequency. The bird's visual acuity was taken to be that spatial frequency at which the psychometric function had a value of 75% correct, which is the midpoint between chance performance and perfect detection of the grating. Testing was continued until the pigeons' performance satisfied a criterion of stability. The birds were periodically videotaped as they performed in the chamber from which the distance from the eye to the target could be determined. This permitted us to convert acuity in lines/mm to acuity in degrees of visual angle subtended by the least resolvable bar or cycles per degree, which is the number of just detectable lines and adjacent spaces per degree of visual angle.

Data were collected from 20 pigeons that ranged in age from 2-16 years. Two-year-old pigeons are regarded by breeders as prime breeding stock. Pigeons generally are culled from commercial breeding stock at 5-7 years because of a decline in reproductive efficiency. Sixteen-year-old pigeons show signs of aging such as dullness of the scales of the feet and occasional stiffness of leg joints. An important feature of this research project was that the breeder (Palmetto Pigeon Plant, Sumter, SC, USA) attaches a leg ring to all of its breeding pigeons that identifies the bird with a unique number and gives the year of its birth.

The results of this study are shown in Figure 1, which indicates a progressive decline in acuity from an average of 15 cycles/degree (18-19 cycles/degree in the best of the young old birds) to approximately 3 cycles/degree in the oldest birds. The acuity of the youngest pigeons is not far from the normal acuity of untrained human observers (30 cycles/degree). But a human with a visual acuity of 3 cycles/degree