Title
Unilateral visual deprivation and avian optic lobe development

Journal
Life Sciences, 8(21)

ISSN
0024-3205

Authors
Margolis, FL
Bondy, SC

Publication Date
1969-11-01

DOI
10.1016/0024-3205(69)90048-4

Life Sciences Vol. 8, Part I, pp. 1195-1199, 1969. Pergamon Press
Printed in Great Britain

UNILATERAL VISUAL DEPRIVATION AND AVIAN OPTIC LOBE DEVELOPMENT

F. L. Margolis and S. C. Bondy

Departments of Medical Microbiology and Immunology and Biological Chemistry,
and the Brain Research Institute, School of Medicine,
University of California, Los Angeles, California 90024

(Received 7 July 1969; in final form 15 August 1969)

THE SEARCH for biochemical changes in the central nervous system which can be correlated with differential sensory input often suffers from the difficulty of choosing appropriate controls. No matter how carefully conditions are controlled, experimental and control animals are exposed to different conditions which may obscure subtle biochemical differences between the two groups. An experimental model which permits each animal to be used as its own simultaneous control in studies of this nature is provided by the avian visual system. Thus, the complete decussation of the optic tracts in many birds (1) suggests that unilateral manipulation of visual input may result in differential effects in the two optic lobes of the avian brain. Differences detected between the two lobes should be the result of experimental variation of sensory input and not due to any systemic or humoral variations which should effect both lobes equally.

Long-term histological changes occurring unilaterally in adult avian optic tracts following removal of one eye in very young birds have been described earlier (2,3). More recently, short-term biochemical changes in optic lobes of young birds following this operation have also been noted (4). We have examined the differential effects of unilateral eye removal on the two optic lobes of the chick brain at relatively short times after surgery.

Materials and Methods

Fertile eggs from White Leghorn strain K137 (Kimber Farms, Pomona, California) were incubated and newly hatched chicks maintained as previously described (5). Within 24 hours of hatch chicks were anaesthetized with pentobarbital sodium and divided into seven groups. One eye was removed from birds in three of these groups (6). Equal numbers of left and right enucleations were performed. Two days after enucleation a brooder cabinet containing one group of enucleated chicks, as well as a control group, was transferred to a totally dark room and maintained there for the following 15 days. The remaining group of enucleated and control birds were maintained under normal lighting conditions which consisted of 12 hours of fluorescent illumination and 12 hours of darkness per day. Birds were killed by decapitation and individual optic lobes were dissected out (5), weighed and frozen. Acetylcholinesterase activity was determined on homogenates of individual lobes, using acetylthiocholine as a substrate (7).

Results and Discussion

Seven days after surgery, in the light maintained birds, the wet weight of the optic lobe contralateral to the extirpated eye was 20% less than that of the ipsilateral lobe. To simplify discussion of the data, the optic lobe contralateral to the extirpated eye is referred to as the blind lobe while the other, ipsilateral lobe, is referred to as the visual lobe (Table 1). This difference increased to 34% within 17 days after surgery. The striking difference between the sizes of the two lobes was easily seen upon visual inspection of the whole brain. No differences were observed in the weights of paired optic lobes on control chicks maintained in light or dark for 1, 7 or 17 days. Thus, the weight differences in the experimental animals resulted from the enucleation. The difference in weights of paired lobes 17 days after unilateral enucleation was similar whether the animals were light or dark maintained. This result suggested that these differences were primarily due to absence of the eye rather than to variable photic stimulation (Table 1, lines 1 and 2).

TABLE 1

Effect of unilateral eye removal on weight and acetylcholinesterase activity in chick optic lobes

	Weight (mg)			Acetylcholinesterase (μmoles/min/100 mg Lobe)		
Enucleated	B	V	$^V/_B$	B	V	$^V/_B$
Light 17 day (9)	66.4	89.2	1.34^*	3.75	3.88	1.04^*
Dark 17 day (6)	68.5	88.2	$1.29^{\dagger}$	3.88	3.87	0.99
Light 7 day (8)	61.5	73.9	1.20^*	3.65	3.87	$1.06^{\ddagger}$
Controls	L	R	$^R/_L$	L	R	$^R/_L$
Light 17 day (5)	87.1	85.0	0.98	4.18	4.25	1.02
Dark 17 day (3)	86.9	87.6	1.01	4.25	4.20	0.99
Light 7 day (4)	73.1	74.3	1.01	3.81	3.80	1.00
Light 1 day (7)	66.9	67.6	1.01	2.60	2.63	1.01

* $P < 0.005$ † $P < 0.025$ ‡ $P = 0.05$

B--optic lobe contralateral to the removed eye; V--ipsilateral lobe; L and R--the left and right optic lobes respectively of the control animals. The ratios $^V/_B$ (Visual/Blind) and $^R/_L$ (Right/Left) are the averages calculated for each individual bird and not from the ratio of the final pooled average presented in the table. The numbers in parenthesis indicate the number of birds in each group. P values within each group were calculated by the Wilcoxon Signed Rank Test (8).

Moreover, the mean weight of the blind lobes 17 days after surgery (66.4 mg) was the same as that of the normal lobes (67.3 mg) of one day old chicks (at which age the surgery was performed). In contrast, the mean weight of the visual lobes of these operated birds was the same as that of the normal lobes of 17 day old unoperated chicks. Thus removal of the eye appeared to result in arrested development of the blind lobe while permitting normal development of the visual lobe. The intermediate effect which was observed one week following eye removal supported this concept. In view of the short time interval involved, the major effect of enucleation was probably to slow or arrest development of the blind lobe rather than to cause gross degenerative changes. Butyrylcholinesterase activity in light maintained birds 17 days after enucleation was 0.176 and 0.171 µmoles/min/100 mg lobe in the visual and blind lobes respectively. Thus there was no evidence of the glial proliferation which accompanies gross degenerative changes.

Seventeen days after hatching, the activity of acetylcholinesterase in the optic lobes of the control birds had increased 60 per cent (Table 1, lines 4 and 7). No differences were detectable between the paired lobes of dark maintained operated or unoperated control birds at any age. However, in the operated light maintained birds the enzyme activity in the blind lobe was consistently 4 - 6% lower than that in the paired visual lobe. By the use of paired lobes from individual animals, small differences that were always in the same direction thus became highly significant.

In contrast to the lobe weight differences following unilateral enucleation, the acetylcholinesterase activity differences between the paired optic lobes were light dependent. This effect was presumably a result of differential visual stimulation.

This internally normalized system has proven very useful for studying effects of eye extirpation in newly hatched chicks. One of the major effects of enucleation is to arrest or retard developmental increases of tissue weight and acetylcholinesterase activity respectively in the developing avian optic lobes. This experimental system should permit evaluation of the effect of various forms of visual deprivation on the biochemistry of cerebral development.

Summary

The total decussation of avian optic tracts offers a system in which biochemical correlates of visual deprivation in one tract can be compared with the opposite tract as a normal control. The short term effect of unilateral eye removal in new hatched chicks was to prevent the normal increases in tissue weight and to modify the level of acetylcholinesterase activity in the contralateral optic lobe.

Acknowledgements--We thank Dr. S. Roberts (grant from the United Cerebral Palsy Research and Educational Foundation) and Dr. S. Zamenhof (NIH grants HD01909 and NB-08723-01 and American Cancer Society Grant P-503A) for kind and generous support during the course of this study and Mrs. B. Morelos for expert technical assistance.

References

1. C.U. ARIENS KAPPERS, G.C. HUBER and E.C. CROSBY, Comparative Anatomy of the Nervous System of Vertebrates Including Man (Hafner Publishing Co., New York 1960, reprint of 1936 edition), p. 1044.

2. R. PERLIA, Archiv für Ophthalmologie (Von Graefe's) **35**, 20 (1889).

3. G. JELGERSMA, Neurol. Central. **14**, 290 (1895).

4. P.C. MARCHISIO, J. Neurochem. **16**, 665 (1969).

5. F.L. MARGOLIS, J. Neurochem. **16**, 447 (1969).

6. M. MENAKER, Proc. Natl. Acad. Sci. U.S. **59**, 414 (1968).

7. G. ELLMAN, K. COURTNEY, V. ANDRES, JR., R. FEATHERSTONE, Biochem. Pharmacol. **7**, 88 (1961).

8. F. WILCOXON and R. WILCOX, Some Rapid Approximate Statistical Procedures (Lederle Labs., Pearl River, New York 1964), p. 9.