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Myopia in the lid-sutured tree shrew *(Tupaia glis)*

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Many mammals reared with visual deprivation display abnormally poor visual behavior while using their deprived eyes[1–4,9,10]. These results typically have been attributed to defective development of the central visual pathways during the deprivation[6–8,11,13]. However, it is important to consider non-neural (e.g., optical) sources which might contribute to their poor visual capacities. For example, Wiesel and Raviola[14] report that monkeys reared with lid suture exhibit considerable myopia in the deprived eye. In the course of other studies of lid-sutured tree shrews, we discovered that the deprived eye was consistently and considerably myopic with respect to either the open eye or the eyes of normally reared tree shrews.

Our data are from 11 tree shrews *(Tupaia glis)* raised with the lids of one (9 animals) or both (2 animals) eyes sutured shut. The lids were sutured after trimming the lid margins during the 7th postnatal day (eye opening normally occurs on about day 20). They were maintained in this fashion until other terminal experiments in adulthood (4–36 months of age). In addition to the lid-sutured tree shrews, 15 normally reared adults served as controls. The animals were prepared for electrophysiological recording using our previously described methods[12]. These included initial anesthesia with halothane followed by N_2O–O_2 (70:30), topical placement of atropine into the eyes, paralysis, artificial ventilation, and placement in a stereotaxic headholder.

Retinoscopy. Carefully calibrated contact lenses were placed on the corneas, and streak retinoscopy was performed. The lenses were replaced as needed until both eyes were deemed emmetropic (i.e., after the correction suggested by Glickstein and Millodot[5]; also see our previous discussion of this point[12]). At least two different observers evaluated the retinoscopy with no substantive discrepancy (i.e., always $\leq$ 1 diopter). In the 15 normally reared tree shrews, we found that the eyes required contact lenses of 99.2 $\pm$ 3.2 diopters (mean $\pm$ S.D.) to achieve emmetropia, and the average interocular difference was 0.5 $\pm$ 1.5 diopters. Table I expresses these values for the lid-sutured tree shrews. For each of the monocularly sutured animals, the deprived eye required much less (15–28 diopters) power to achieve proper focus. This presumably indicates myopia in the deprived eyes since the values for the non-deprived eyes were in the normal range. In two of the animals (Nos. 175 and 178), retinoscopy was quickly performed after

TABLE I

Tree shrew	*Dioptric power of contact lens for emmetropia*		*Difference (diopters)*
	Non-deprived eye	*Deprived eye*	
Monocularly sutured			
131	98	82	16
133	103	82	21
134	95	72	23
135	101	86	15
171	99	77	22
175	97	82	15
176	102	82	20
177	100	72	28
178*	—	80	—
Mean ± S.D.	99 ± 2.7	79 ± 4.8	20 ± 4.5
Binocularly sutured	*Left eye*	*Right eye*	
200	82	89	7
201	75	79	4

* A measure of the contact lens for the non-deprived eye of tree shrew No. 178 was inadvertently omitted.

anesthesia and atropine instillation, but before placement of contact lenses. In both cases, the deprived eye was well over 10 diopters myopic*, whereas the non-deprived eye was essentially emmetropic**. Finally, the binocularly deprived tree shrews exhibited myopia in each eye, and they had larger than normal interocular differences (see Table I).

Eyeball length. Since this myopia for the deprived eyes persisted after the placement of spherical contact lenses (which largely negate the cornea as a refractive surface), abnormal corneal curvature seemed an unlikely source for the myopia. An explanation suggested for a similar result in the rhesus monkey was a greater axial length for the deprived eye[14]. We checked for this in 3 of the monocularly sutured tree shrews by measuring the axial lengths of the eyes after the completion of other, terminal experiments. The animals were perfused with saline followed by 10% formol–saline, and the eyes were carefully removed. Intraocular pressure, and thus the natural ocular shape, was maintained by inserting a fine needle into the vitreous and injecting saline under moderate pressure. Axial lengths were measured with a micrometer approximately along the optic axis from the front surface of the cornea to the back of the sclera. Table II shows that, in each case, the deprived eye was longer than the non-deprived eye.

* These estimates were achieved with spectacle lenses, and for the large myopia evident in each case, we could not obtain a precise estimate of the myopia with the available lenses.

** Glickstein and Millodot[5] argued that one must correct the retinoscopic estimate by subtracting several diopters, depending upon eyeball length. This obtains because retinoscopy focuses the eye on the vitreal-retinal interface, and not on the receptors which are further back. We previously calculated this correction to be 3–4 diopters for the tree shrew, and indeed found that retinoscopy of normal tree shrews without contact lenses required such a correction[12]. We assume that this represents emmetropia. The non-deprived eyes of the two monocularly deprived tree shrews were emmetropic by this criterion.

TABLE II

Axial eyeball lengths (mm)

Animal No.	*Non-deprived eye*	*Deprived eye*	*Difference*
175	7.76	7.95	0.19
176	7.74	8.27	0.53
177	7.79	8.18	0.39

Conclusions. To achieve the average 20 diopters of relative myopia seen in the deprived eyes by an elongated optical path, about 1.5 mm of increase length would be needed. Clearly none of the pairs in Table II approaches this difference. Furthermore, a comparison of Tables I and II suggests no correlation between the quantity of myopia and axial length. We thus conclude that, while axial length probably plays an important role in the myopia, other factors presumably also exist. Perhaps the shape and location of the relaxed lens, thickness of the cornea, etc., are also abnormal in the lid-sutured eyes.

Lid suture induced myopia is not limited to tree shrews. Wiesel and Raviola[14] have described an almost identical result in the rhesus monkey, and Wilson and Sherman[15] reported an analogous, but smaller ($\sim$ 2 diopters) myopia for the deprived eye of monocularly sutured cats. Many reports[1-4,9,10] point to the behavioral visual deficits these animals suffer while using their deprived eyes. To our knowledge, in none of these studies was the possibility of severe myopia ruled out as a contributing or sole factor responsible for these deficits. The deficits instead were attributed exclusively to abnormal neural development in the central visual pathways. We believe that it is important, in future behavioral studies of visually deprived animals, that care be taken to avoid serious ametropia in the deprived eyes during testing.

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