elevated MOPEG concentrations in the tissue (*14*).

The quantitative relation found between blood alcohol concentration and the MOPEG level in the CSF of the alcohol addicts further supports the view of a causative effect of alcohol for this biochemical alteration. Whether alcohol has a direct stimulating effect on unit activity of some central noradrenergic neurons or stimulates them by secondary effects on afferent systems to these neurons has not been determined.

Our study supports the idea that ethanol influences brain noradrenergic mechanisms in man. The data also support previous results of animal experiments (*2*). Further studies of the effect of ethanol on central noradrenergic mechanisms may be useful in elucidating mechanisms for psychological changes that occur in connection with alcohol intoxication and withdrawal. A comparison of the time sequences for the euphoriant and anxiety-producing effects of alcohol, the blood alcohol concentrations, and the CSF MOPEG elevation may elucidate the possibly causal relations between these variables.

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Functional Restoration of Vision in the Cat After Long-Term Monocular Deprivation

Abstract. *Recovery of visual acuity was studied in six long-term monocularly deprived cats after removal of the nondeprived eye or reverse lid suture. Although both manipulations improved visual acuity, removal of the nondeprived eye was associated with more rapid recovery and higher final acuity than in reverse suture. These results are in agreement with the known electrophysiological effects of these recovery conditions and are also similar to the effects of reverse occlusion or loss of the nonamblyopic eye in human amblyopes.*

In normal cats, the majority of cells in the striate cortex can be excited by visual stimulation of both eyes (*1*). However, after being reared with monocular deprivation (MD) achieved by lid suture through the first 3 to 4 months of life, only about 5 percent of the cells in the striate cortex respond to visual stimulation of the deprived eye and only a few of these have normal receptive field properties (*2–6*). Correlated with these abnormalities in cortical physiology are the observations that MD cats using the deprived eye are grossly deficient in visually guided behavior, especially in situations requiring form or pattern vision (*7*).

Initial investigations indicated a critical developmental period during which the cells in the striate cortex are sensitive to the effects of MD and that this period ends by 3 to 3.5 months of age (*2*). Most investigations of the ability to reverse the effects of MD outside of this developmental critical period have found little or no effect (*2, 8*). However, Kratz *et al.* (*4*) discovered that removing the nondeprived eye in 4- to 5-month-old MD cats results in an immediate and permanent sixfold increase in the percentage of cells responding to the deprived eye. Recent studies have confirmed this finding in MD cats (*6, 8, 9*) and mice (*10*). The receptive-field properties of these responsive cells are, for the most part, abnormal (*4–6*) and do not improve after visual experience (*6*).

The purpose of this study was to determine whether the increase in the percentage of cells responding to the deprived eye after removal of the nondeprived eye in MD cats was associated with a functional improvement in vision using the deprived eye.

Six kittens from two litters born in the laboratory breeding colony were studied. Lid suture and enucleation procedures have been detailed elsewhere (*4–6*). All kittens had the lids of one eye sutured closed before the time of natural eye opening. The duration of deprivation was 7 months (four cats) or 12 months (two cats) (Table 1).

Training methods have been described elsewhere (*11, 12*). In the jumping stand described by Mitchell *et al.* (*11*), modified to accommodate larger cats, each cat was trained 20 to 30 trials per day, 6 or 7 days a week, first with the nondeprived eye for all discriminations and later with the deprived eye (Fig. 1). Each cat was trained with its nondeprived eye to a criterion of 90 percent correct on a luminance discrimination followed by a striped discrimination, and then visual acuity was assessed (*13*). Approximate threshold acuity was established by a modified staircase procedure (*11, 12, 14*). Final acuity was then determined by giving a minimum of 20 trials at each of three or four spatial frequencies around the approximate threshold randomized in blocks of five trials. Final acuity was defined as the spatial frequency at which

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Table 1. Visual acuity of nondeprived and deprived eyes, established after a minimum of eight reversals in the staircase procedure. Days of practice for the deprived eye before enucleation of the initially nondeprived eye are given in parentheses.

Subjects	Duration of deprivation (weeks)	Acuity (cycle/deg)			
		Nondeprived eye	After reverse suture	Before enucleation	After enucleation
MD-DE-1	28	4.3			2.5
MD-DE-2	27	6.1			2.75
MD-DE-3	48	6.3			1.75
RSE-1	27	3.8	1.3	1.25 (11)	2.8
RSE-2	27	6.5	1.77	2.89 (33)	2.99
RSE-3	50	5.5	0.83	0.90 (10)	1.44

the animal responded correctly 70 percent of the time (*11, 12*).

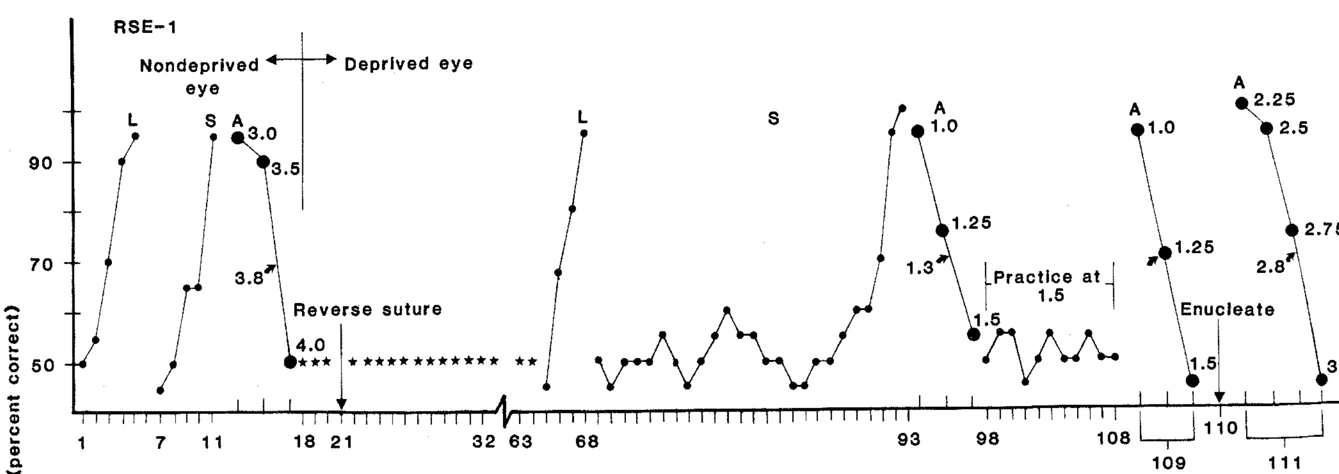
Immediately after acuity measurement through the nondeprived eye, each cat had the lids of the deprived eye parted (*15*) and was randomly assigned to one of two recovery conditions. Cats in group MD-DE had the nondeprived eye enucleated, whereas cats in group RSE had the lids of the experienced eye sutured closed (reverse suture). All cats in each group were trained on the same discriminations and in the same order as before, now using only the originally deprived eye.

In addition to the between groups comparisons, each RSE animal was used as a within animal test of the effects of removing the initially experienced eye. After the reverse-suture acuity had been measured, each RSE cat was given 20 trials of practice per day at a suprathreshold spatial frequency (Fig. 1, days 98 to 108), in addition to five interspersed trials at a subthreshold spatial frequency. This was repeated for many days until it was certain that acuity was stable (Table 1). At the end of the practice runs, threshold visual acuity was again measured (Table 1 and Fig. 1). The next day, each RSE cat had the initially nondeprived eye (now sutured closed) removed. Threshold visual acuity was assessed over the subsequent 6 days.

Several controls were included to ensure that the experimenter was not unwittingly influencing the cat's behavior (*11, 12*). After the luminance discrimination, the cat was tested on unsolvable light-light discrimination and performance always fell to chance. More important, for the acuity measures each cat was tested by a minimum of two experimenters, each of whom was unaware of the acuity value obtained by the others; the acuity values thus obtained were consistently within 0.1 cycle per degree.

The MD-DE and RSE groups did not differ on any of the measures of the nondeprived eye (Table 1); however, in every case, final threshold acuity was higher for MD-DE cats (after enucleation) than for RSE cats deprived for the same initial duration (after reverse suture) (compare cats MD-DE-1 and MD-DE-2 with RSE-1 and RSE-2, and MD-DE-3 with RSE-3 in Table 1).

Animals RSE-1 and RSE-3 showed increases in threshold visual acuity after enucleation (Fig. 1 and Table 1). Visual acuity for cat RSE-2 continued to improve with time or practice and stabilized after 33 days of practice. Enucle-



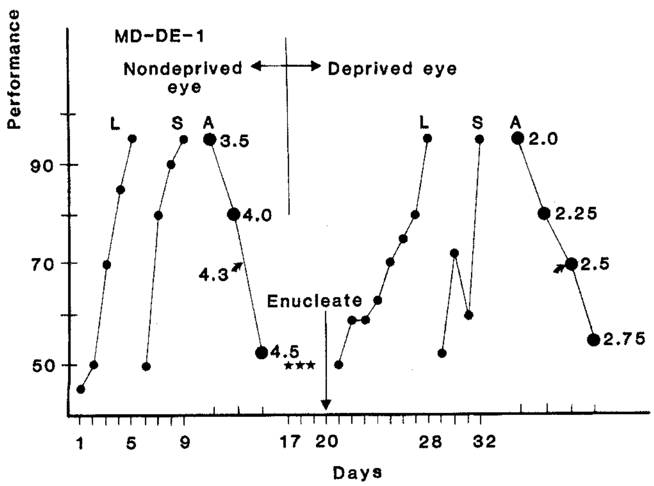


Fig. 1. Order of testing and results for one cat in each condition. Abbreviations: *L*, luminance discrimination; *S*, stripe discrimination (0.3 cycle/deg or equal-luminance gray). Final threshold visual acuity (70 percent correct) is marked with an arrow in the acuity (*A*). Upward marks on the abscissa indicate the spatial frequency of the stimuli in cycles per degree used to determine final acuity. Neither cat was able to perform visually directed jumps after the lids were parted (stars), and animal RSE-1 did not make visually directed jumps for 44 days after reverse suture.

ation of the initially nondeprived eye had little, if any, effect in this animal (Table 1); however, its acuity had already risen to a value equal to that of the MD-DE animals deprived for the same duration. In this regard, it has been observed that the electrophysiological effects of reverse suture after the critical period are apparently variable between animals and that reverse suture is sometimes as effective as removing the nondeprived eye; however, the effects of reverse suture take longer to develop (*6*). Thus, the removal of the initially nondeprived eye in a reverse-sutured MD cat was sometimes, but not always, accompanied by a further increase in visual acuity. Whether or not this increase occurs may be determined by the final acuity reached after the reverse suture.

Combining all animals' visual acuity after enucleation, established after eight reversals in the staircase procedure with visual acuity measured in exactly the same way (*16*) after reverse suture, indicates that removing the nondeprived eye after the critical period was associated with higher final levels of a visual acuity than was reverse suture (Mann-Whitney U test, $U = 2$, $P = .048$ one-tailed test).

These results indicate that enucleation of the nondeprived eye in adult MD cats results in greater final visual acuity than does merely suturing closed the lids of the nondeprived eye. These behavioral results parallel increases in the percentage of responsive cells in the striate cortex of MD cats after enucleation (*4–6*) or reverse suture (*6*) of the nondeprived eye outside of the "critical period." The main differences between these recovery conditions is that the electrophysiological increase in the percentage of responsive cells seen after removal of the nondeprived eye is more rapid and usually greater (*6*). These same relationships were observed in the behavioral results of this study. These results are also in agreement with the effects of reverse suture or destruction of a portion of the central retina of the nondeprived eye in MD monkeys, in terms of both rate of acquisition and final acuity (*17*).

Experimentally induced monocular deprivation has been suggested as a model of human amblyopia (poor vision in one eye not due to refractive error or organic abnormality of the eye) (*18*). While comparisons from animal to human behavior must always be viewed cautiously, the correlation between the results of the present study and the literature in clinical ophthalmology further support the similarity between monocular deprivation in animals and human amblyopia. For example, in clinical treatment of human amblyopia, occlusion of the nonamblyopic eye is frequently used to improve vision using the amblyopic eye. This seems analogous to the effects of reverse suture in the MD cat and monkey. Moreover, it is a well-known but poorly documented finding (*19*) that some human amblyopes who suffer a loss of the nonamblyopic eye showed improved visual acuity through the amblyopic eye. This finding is also similar to my finding that removal of the nondeprived eye in an MD cat usually, but not always, results in improved visual acuity. Our knowledge of the neurophysiological correlates of these effects in the MD cat (*4–6*) may lead to a better understanding of the mechanism involved in human amblyopia and thus to improved techniques for correcting this disorder. Deprivation amblyopia in humans is the only condition that is directly analogous to monocular deprivation in animals; however, other types of amblyopia, while certainly different in cause, may be similar in terms of the effects on the brain.

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Retinal Ganglion Cell Classes in the Old World Monkey: Morphology and Central Projections

Abstract. *Labeled ganglion cells were studied in whole-mount retinas of Old World monkeys after electrophoretic injections of horseradish peroxidase into physiologically characterized sites. A number of different morphological classes have been identified, each of which has a distinctive pattern of central projection. Since different functional classes of primate retinal ganglion cells also have distinctive patterns of central projection, correspondences between functional and morphological cell types have been inferred. There prove to be parallels between morphological types of cat and monkey ganglion cells.*

In both the cat (*1–8*) and the monkey (*9–12*), different functional classes of retinal ganglion cells have different patterns of central projection. A number of morphological classes of ganglion cells have also been described in both species (*13–17*), but much less is known of their central projections. Recently, a number of studies have described the sizes of the cell bodies of ganglion cells labeled by

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