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Short communication

The relationship between relative eye usage and ocular dominance shifts in cat visual cortex

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Abstract

A novel modification of the alternate monocular deprivation paradigm was used to quantitatively define the relationship between relative eye usage and the shift in visual cortical ocular dominance toward the advantaged eye. Both eyes of cats were alternately occluded by contact lenses during daily visual exposure sessions with varying ratios of relative eye usage: 1:1, 1.7:1, 3:1, 7:1, 50:1, 100:0. Only 100:0 and 50:1 ratios produced an ocular dominance shift in favor of the more experienced eye. The ocular dominance shift in 100:0 cats occurred in all cortical layers but only in extragranular layers of 50:1 cats. A steep power function described the data, indicating that an extreme imbalance in relative eye usage (>90%) is required for an ocular dominance shift.

Theme: Development and regeneration
Topic: Visual system

Keywords: Alternate monocular deprivation; Visual development; Critical period; Amblyopia

With normal postnatal development, most cells in visual cortex are activated by stimulation of either eye. Abnormal monocular experience during the postnatal critical period alters the physiology of visual cortex (see Ref. [10] for review). If one eye is deprived of vision (monocular deprivation) throughout the critical period, nearly all cells in visual cortex come to respond to only the open eye. If on alternating days, one or the other eye receives visual input (alternate monocular deprivation), the result is a U-shaped ocular dominance distribution with a marked reduction of binocular cells a bias among the monocular cells in favor of the contralateral eye in both hemispheres. The paradigm of unequal alternate monocular deprivation, where one eye receives 8 h of stimulation on 1 day and the other eye receives 1 h of stimulation on the alternate day, produces an intermediate effect with a loss of binocular cells and a bias in favor of the more experienced eye in both hemispheres [11]. Relative eye usage, therefore, produces a continuum of changes in visual cortical ocular dominance ranging from a U-shaped distribution to complete takeover by the non-deprived eye.

The present study used a novel modification of the unequal alternate monocular deprivation paradigm to quantitatively define the relationship between relative eye usage and the shift in visual cortical ocular dominance toward the advantaged eye. Overnight consolidation effects on abnormal monocular visual experience have long been implicated and a more recent study demonstrated that sleep enhances the effect of monocular deprivation [3]. In alternate monocular deprivation, therefore, the eye receiving stimulation must overcome a monocular deprivation effect in favor of the other eye from the previous day. To directly assess the role of relative eye usage in ocular dominance changes, we reared animals such that each eye received visual input on each day rather than on alternate days. Another aim was to determine an equation relating the

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magnitude of the deprivation effect to the degree of eye usage.

Nineteen cats were reared in complete darkness from birth until 4 weeks of age, at which time monocular exposures were initiated. Vinyl contact lenses that prevent form vision and reproduce the effects of monocular deprivation in visual cortex [1] were used to occlude the eye. On each day, the more experienced eye was occluded first. The contact lens was then removed and placed over the more experienced eye. Visual exposure sessions lasted 8 h/day, 5 days/week, during which the cats experienced an open laboratory room with toys and other cats and were monitored continuously to prevent naps and ensure that the contact lens was intact.

At the conclusion of the rearing period (4 months), the ocular dominance and orientation selectivity of cells in area 17 was assessed by standard single unit electrophysiological procedures [6,7] in the hemisphere contralateral to the less experienced eye of anesthetized cats (sodium pentobarbital, 25 mg/kg initial dose, supplemented as necessary). Briefly, a five-point scale was used for ocular dominance classification: category I cells responded only to the ipsilateral eye, category C cells responded only to the contralateral eye, and intermediate categories represented varying degree of responsiveness to both eyes, with category I=C representing cells equally responsive to each eye. Cells were considered orientation selective if they failed to respond to visual stimuli (slits of light) oriented perpendicular to the optimal orientation. Two to three electrolytic lesions (−5 μa for 3–5 s) were made along electrode tracks to allow subsequent assignment of single units to visual cortical laminae. Cells were considered to be in layer IV if they were located between the large layer V pyramidal cells and the large pyramidal cells at the base of layer III (O'Leary's border pyramids).

Initially, we studied cats reared with 1:1 (4 h right eye, 4 h left eye, 50% usage of each eye), 1.7:1 (3 h right eye, 5 h left eye, 63% more experienced eye usage), and 3:1 (2 h right eye/6 h left eye, 75%) eye usage ratios (n=1 at each ratio) expecting to see ocular dominance shifts within this range. These three cats showed similar ocular dominance distributions with a loss of binocular cells and a bias in favor of the contralateral eye (Fig. 1, top), but no evidence for a shift in favor of the more experienced eye. Higher ratios of relative eye usage: 7:1 (1 h right eye. 7 h left eye, 87%, n=4), 50:1 (9.5 min right eye, 7 h 50.5 min left eye, 98%, n=4), and 100:0 (8 h right eye, 0 min left eye, 100%, n=8, reanalyzed from Ref. [1]) were studied in greater detail. Within litters, animals were assigned pseudorandomly to the different eye usage groups (1:1 to 100:0) to fill experimental cells.

As shown in Fig. 1, the various ratios of unequal alternate monocular deprivation resulted in a graded shift from a U-shaped ocular dominance distribution with a bias toward the contralateral eye in the 1:1, 1.7:1, 3:1 cats to near complete takeover by the more experienced (ipsilateral) eye in the 100:0 condition. As a summary ocular dominance shift index (ODSI) for each animal, the percentage of cells dominated by the ipsilateral (more experienced) eye was calculated (leftmost two ocular dominance categories as in Fig. 1). The 1:1, 1.7:1, 3:1 cats were grouped together for

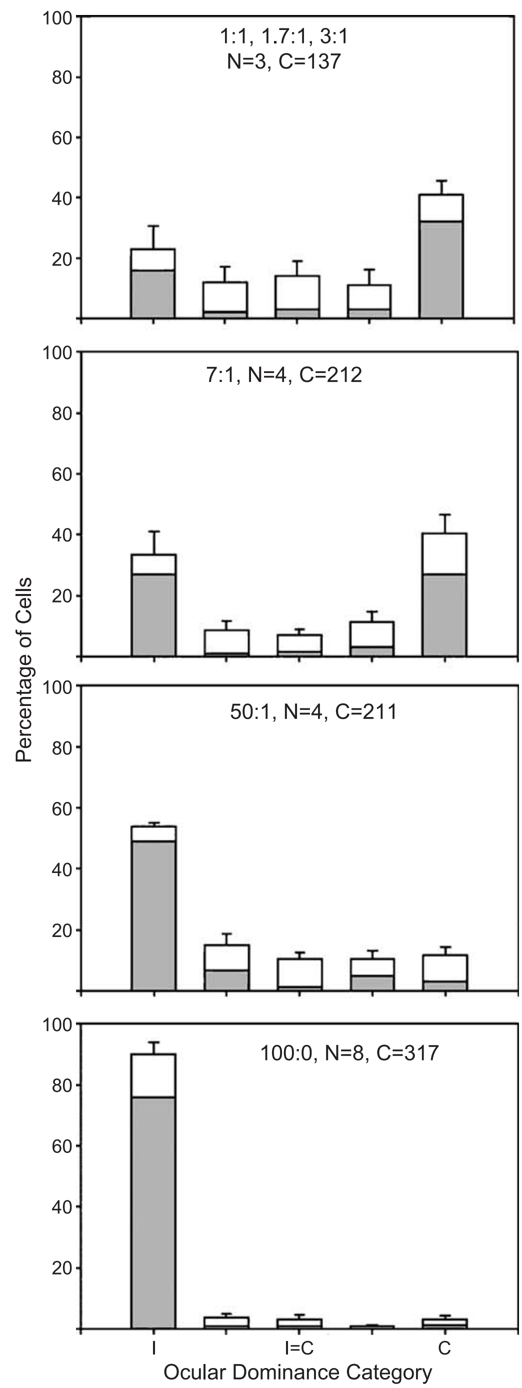

Fig. 1. Ocular dominance distributions of visual cortical neurons in the various relative eye usage groups. Ocular dominance categories defined in text. For each cat, the percentage of cells in each category was determined. These values were averaged by category among animals in each group and each bar in a histogram represents that mean and its standard error. Shading indicates the proportion of cells in each category that were orientation selective, as defined in text. N=number of cats, C=number of cells.