

Neural Circuits That Drive Binocular Eye Movements: Implications for Understanding and Correcting Strabismus

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Strabismus is the misalignment of the eyes and is estimated to be present in ~2% to 4% of the North American infant population. Surprisingly, to date, there is no consensus regarding the cause of strabismus. While it is commonly thought to be the result of dysfunctional orbital and/or eye muscle properties (reviewed in Refs. 1, 2), recent work emphasizes that strabismus can also be caused by the brain's inability to transform binocular visual inputs into the motor commands required for coordinated eye motion at cortical as well as subcortical levels (reviewed in Refs. 3, 4).

To gain a better understanding of the underlying changes in sensorimotor control that are responsible for strabismus, researchers have begun to perform studies in nonhuman primates. Typically, eye misalignment is induced using either surgical or visual methods (e.g., the weakening of the eye muscles or nerves versus the wearing of prism goggles). As adults, these strabismic monkeys make eye movements much like strabismus patients (i.e., consistent with esotropia or exotropia).^{5,6} A study in this month's issue of *IOVS* by Walton et al.⁷ demonstrates that when strabismus is induced in young monkeys either by the wearing of prism goggles or by medial rectus tenotomy, the activity of individual abducens nucleus neurons is reduced compared to that observed in monkeys raised with normal visual input. Since abducens neurons control the eye muscles that drive horizontal eye movements, these results provide evidence that changes in either sensory input or the eye muscles during development can have profound effects on the set point of the motor pathways required for accurate binocular control.

In normal animals, the premotor and motoneurons that control eye movements preferentially encode the movement of an individual eye rather than the conjugate component of each eye movement (reviewed in Ref. 8). In their current study, Walton and colleagues⁷ found that this is also true for abducens neurons in strabismic monkeys. Moreover, both neuronal monocular tuning and eye movement sensitivities were normal. Instead, the authors' data indicate a marked loss of tonic activity in the motoneuron input to the eye muscles. While premotor pathways are also altered in strabismic monkeys (the stimulation of premotor saccadic neurons in the pons produces abnormally disconjugate eye movements,⁹ and neurons in the supraoculomotor area [SOA] statically encode the angle of strabismus¹⁰), there is currently no clear explanation for the observed loss of tonic activity in abducens. In this context, further studies of visuomotor pathways, as well as the abducens internuclear neuron to medial rectus motoneuron pathway, will likely reveal key abnormalities. For instance, Van Horn et al.¹¹ recently identified a subclass of neurons in the rostral superior colliculus that robustly encode vergence angle in normal animals, suggesting this as a potentially interesting site to explore. Ultimately, such targeted experiments, comparing how the brain is normally circuited to how it develops in animals with different forms of strabismus, are needed to develop more optimally directed therapies for correcting this relatively common condition.

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