Clinical/Scientific Notes

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JAPANESE STREET PERFORMER MIMES VIOLATION OF HERING'S LAW

Mime artists often use movement to imply the breaking of physical laws: suitcases levitate, air becomes as impermeable as glass. We present the simulated (and actual) violation of a physiologic principle, Hering's Law of Equal Innervation.

To provide stereopsis while avoiding double vision, the movements of forward-facing primate eyes must be closely coordinated. In a 19th-century debate, Helmholtz contended that this coordination is a learned process, taming naturally independent eyes. Hering, meanwhile, believed the eyes to be inherently reined to each other and driven by a single control signal.[1] Hering's view predominated and this final common pathway for horizontal eye movement came to be accepted as a unilateral signal to the abducens nucleus. This directly controls the lateral rectus of the ipsilateral, abducting, eye but also necessarily adducts the other eye, via interneurons to the contralateral oculomotor nucleus.

More recent neurophysiologic evidence, however, indicates that primate saccadic commands can be encoded monocularly,[2] in common with the laterally mounted, independently moving eyes of our distant evolutionary forebears. Binocular coordination might therefore not arise as a necessary consequence of neuroanatomic connectivity. If so, it might be possible to execute voluntary monocular saccades. We present a case of a person with such an ability, generally observed only in response to depth-controlled Müller stimuli in the laboratory.[3]

Methods. Hiroshi Yoshimi is a member of a Japanese mime duo (http://www.gamarjobat.com) and gave consent to have his images published, preferring not to be anonymized "for commercial reasons." We first observed and videoed him, aged 39, at a busking festival in Christchurch. On his next visit 2 years later, we recorded his eye movements using binocular horizontal infrared limbus tracking oculography (Skalar IRIS[4]) at 200 Hz. The IRIS departs from linearity when gaze is more than 20 degrees from center, hence absolute amplitudes and velocities at the extremes of gaze are not quantitatively reliable. He sat, head fixed, approximately 50 cm in front of a CRT monitor, which displayed calibration stimuli but was blank during the recording itself.

Results. A typical performance (see video on the *Neurology*® Web site at www.neurology.org) begins with both eyes deviated to extreme right orbital positions. He then taps his right temple repeatedly, providing a subjective impression of causation to the audience that one eye is being bounced along until it knocks the other into motion. Initially, the right eye moves nasally while the left eye remains stationary. When the right eye reaches its leftmost (nasal) position, it remains fixed while the left eye moves temporally. The effect is then repeated from the other direction. The figure shows apparent monocular abducting saccades of the left eye, with only tiny fast phases of oppositely directed nystagmus in the otherwise stationary right eye. Across several trials, temporally directed motion comprised a series of saccades and fixations (with a mean intersaccade interval of 230 msec). Nasally directed motion, meanwhile, was predominantly a long duration vergence movement, although adducting saccades were occasionally superimposed upon it.

Mr Yoshimi stated that it was reasonably easy to perform the trick if a person can voluntarily cross their eyes. He learned it from watching a female performer on a Japanese television show.

Discussion. Strongly disconjugate eye positions are a prominent aspect of kabuki theater, with a long history documented by contemporaneous artworks.[5] Atypical eye movement control may therefore be unusually common among Japanese performance artists. We recorded what appear kinematically to be monocular human saccades in one such person, but primarily in the abducting direction. This remains consistent with the conventionally accepted unitary saccadic signal to the abducens nucleus. In the figure, the abducting eye saccades freely, but the other eye is fully converged and cannot adduct any further (but does make tiny, oppositely directed divergent saccades). According to Hering's Law, a different mechanism should be used to return the deviated eye to the center, as the saccadic signal would inevitably

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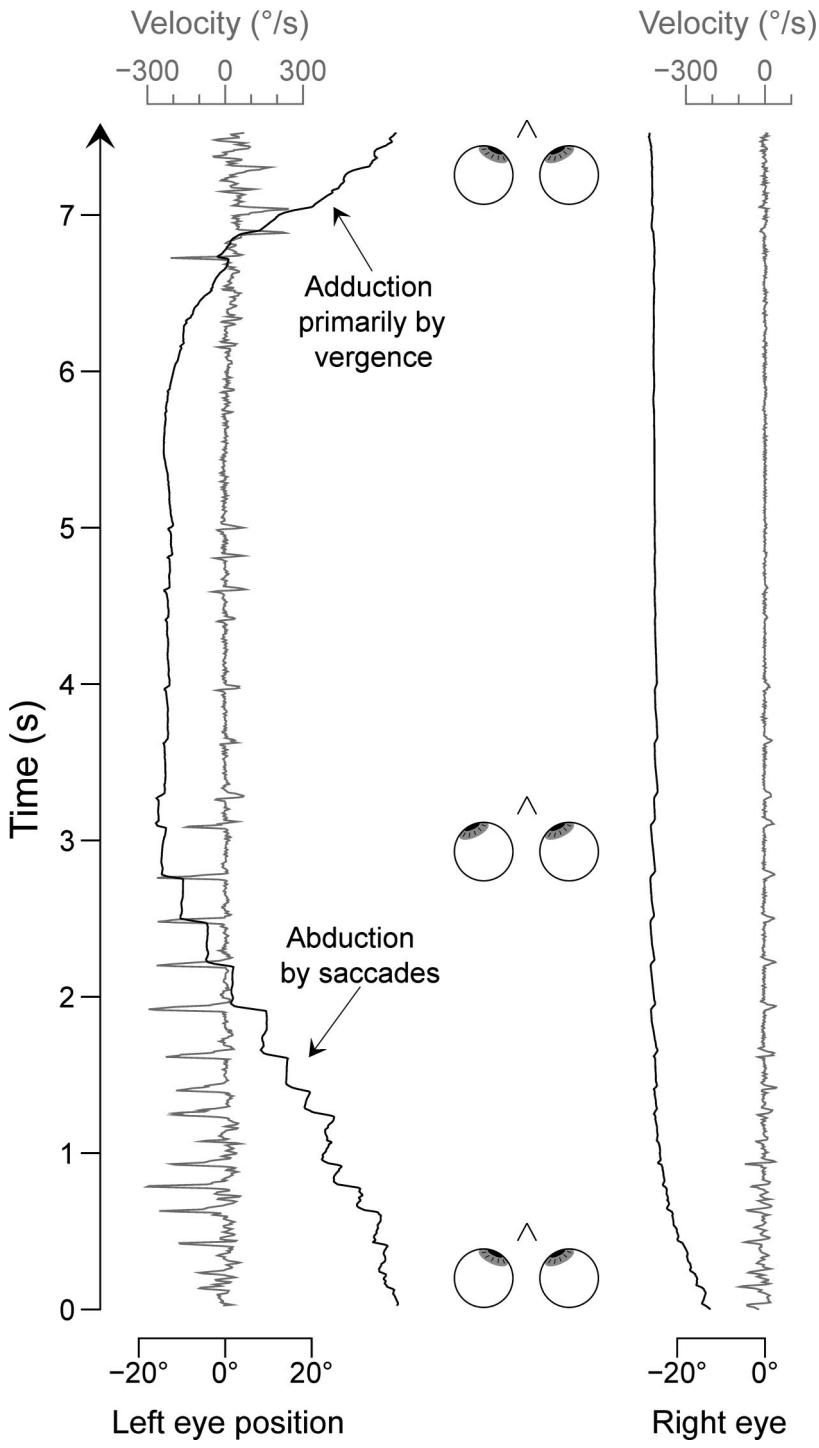
Figure One eye makes saccadic and vergence movements while the other remains stationary



A representative recording of one-half of a performance, showing the positions of each eye (negative values are left of central gaze) as a function of time (running up the page). Spikes in the eye velocity traces (gray lines) indicate saccades. The eyeball diagrams represent eye posture at various time points. At t = 0 s, the eyes are just about to reach maximum convergence. The right eye then remains converged while the left eye executes a series of saccades in the temporal direction. After a pause at its maximum excursion, it then makes a long, slow nasally directed vergence movement to return to central convergence (but with several superimposed adducting saccades). In the remainder of the performance (not shown), the right eye moved while the left remained converged.

also abduct the other eye away from its converged position. The nasally directed movements are indeed primarily composed of vergence as opposed to the saccadic steps of the temporal excursion. The velocity traces indicate, however, that isolated adducting saccades are superimposed on this slow vergence movement. Such saccades should be impossible under the traditional account, as adducting saccades should be initiated by abduction of the other eye, which here remains stationary.

The performance reported is primarily only a mimed violation of Hering's Law, in which the abducting saccades and adducting vergence actually remain consistent with the principle of equal innervation. Pathologic monocular and divergent saccades have provided evidence against the inherently binocular control of saccades.[6] Mr. Yoshimi's isolated adducting saccades indicate that it can also be contravened voluntarily.

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