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Vergence Hysteresis in Infantile Nystagmus

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ABSTRACT

Our objective was to investigate the previously observed hysteresis effects of multi- and single-step vergence on visual acuity in a subject with infantile nystagmus syndrome. Eye movements were measured using a high-speed digital video system during fixation of targets at 0° as targets stepped in from far (F) to near (N: 60 D) and back out (5 or 20 s/presentation), as well as during single steps (1 to 5 s/presentation). Higher values of the eXpanded Nystagmus Acuity Function (NAFX) were achieved at far if the previous near target was fixated for 5 seconds. Single steps between near and far (1 and 3 s/presentation) did not improve the following far NAFX. Double-near shifts (F-N-F-N-F) yielded some improvement in far NAFX values in one of two trials with 3-second presentations. Hysteresis was still present for 5-second presentations of multiple-step targets, whereas the NAFX values were high at almost all near targets for 20-second presentations; hysteresis was observed only at far. We found that, for better visual acuity at far, a fixation of ≥5 seconds of a near target is required. The time-dependent improvement of visual acuity during convergence or divergence may reflect the time required by the pulleys to reduce the plant's responsiveness, allowing better vision.

Subjects with infantile nystagmus syndrome (INS) may exhibit hysteresis during disconjugate vergence eye movements (i.e., fixation of the same target is associated with a higher eXpanded Nystagmus Acuity Function [NAFX][1] if the subject is diverging rather than converging).[2] Hysteresis was found to occur in the central 20° of gaze at all examined vergence angles between far (4.2 diopters [D]) and near (60 D). A peripheral mechanism located either in the muscles or in the pulleys was hypothesized as the cause of hysteresis. It was also suggested that transient fixation of a nearer target, before focusing on the object of interest, might be useful in the daily activities of subjects with INS.

To better understand the mechanism of hysteresis associated with INS, its time course, and possible clinical implications, we designed a simple experiment to assess the visual acuity changes of a subject with INS during both multi- and single-step vergence trials.

METHODS

Eye movements were measured using a high-speed digital video system (EyeLink II, SR Research, Mississauga, ON, Canada). The NAFX was used to evaluate the IN waveform's foveation quality at all fixation points. The subject was seated in a chair with a headrest and a chin stabilizer, far enough from an arc where the far LED (4.2 D) was placed to prevent convergence effects (>1.5 m). At this distance, the LED subtended less than 0.1° of visual angle. A stimulus bar containing eight vergence targets was placed along the subject's line of sight, at eye level, at different increasing vergence angles (LED 1 = 60 D). The room light could be adjusted from dim to blackout to minimize extraneous visual stimuli. The experiment consisted of different multi- and single-step target trials. Multi-step trials included stepping in from far (4.2 D) to near (60 D) and back out to far, allowing 5 or 20 seconds per target interval, to evaluate the time course of hysteresis. Single-step trials, with the target alternating between the far and near positions, were conducted at short intervals (from 1 to 5 seconds per target) and at long intervals (from 10 to 30 seconds per target).

RESULTS

In the small, multiple-step target trials, the original hysteresis first reported for 5-second intervals was reproduced at all vergence angles (Fig. 26.1A). However, for 20-second intervals, the NAFX values were high during both convergence and divergence at all angles, except for 4.2 D (far) and 7 D, where hysteresis was observed (Fig. 26.1B).

Large, single-step trials between near and far (5 seconds per interval) showed a buildup in the NAFX values measured at far. With shorter intervals (1 and 3 seconds per interval), there was no improvement in the following NAFX at far. Double-near shifts (F-N-F-N-F) with 5-second intervals yielded successively higher NAFX values at both near and far (Fig. 26.2A). With 3-second intervals, some improvement in far NAFX values was seen in one of two trials (Fig. 26.2B). When longer intervals were tested (≈ 30 seconds), each initial increase in NAFX was diminished as fixation was maintained at both near and far (Fig. 26.2C). In particular, hysteresis-induced NAFX improvement started to decay after 10 to 20 seconds for the far targets. Similarly, initial convergence-induced NAFX improvement at near (60 D) began to diminish within 20 seconds.

DISCUSSION

The damping of IN with convergence is well known and documented by eye movement data.[3,4] This effect in both decreasing the intensity of nystagmus and allowing better waveform foveation quality has been attributed to the reduction of plant's responsiveness (i.e., gain) during convergence. This might be, in turn, due to the repositioning of the muscle pulleys.[2,5] IN damping by means of convergence has been shown to take place over a broad range of gaze angles (±20°), with associated improvement in the *high-visual-acuity field*, based on calculated NAFX values.[2]

Hysteresis (i.e., system output is dependent on both the current and the previous inputs) was an unexpected finding in different INS subjects performing vergence tasks. However, neither the time course of hysteresis nor closer simulations of daily-life conditions, where this finding may be useful, had been investigated before this preliminary study. The multi-step trials showed that hysteresis is present only at far targets (4.2 D and 7 D) if a 20-second target interval is presented, suggesting that, at central near targets (between 10.3 D and 60 D), the NAFX stays high for presentation intervals greater than 5 seconds.

Our present study also shows that quickly shifting gaze from a far object of interest to a nearer target, even if done repetitively, might increase the NAFX value for the far target only slightly. The records

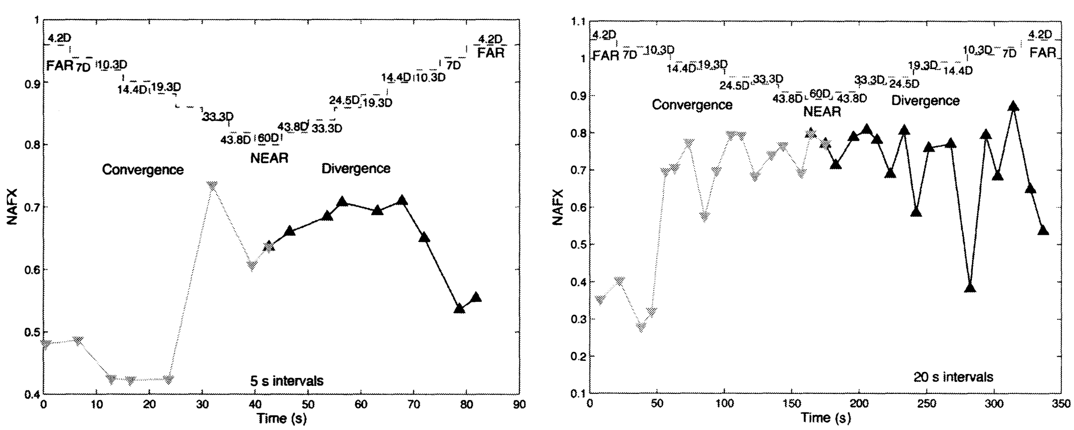

Figure 26.1 Plots of eXpanded Nystagmus Acuity Function (NAFX) versus time during small steps of convergence followed by divergence with interstep intervals of 5 (A, left) and 20 (B, right) seconds. Data from convergence are indicated with down triangles and divergence with up triangles.

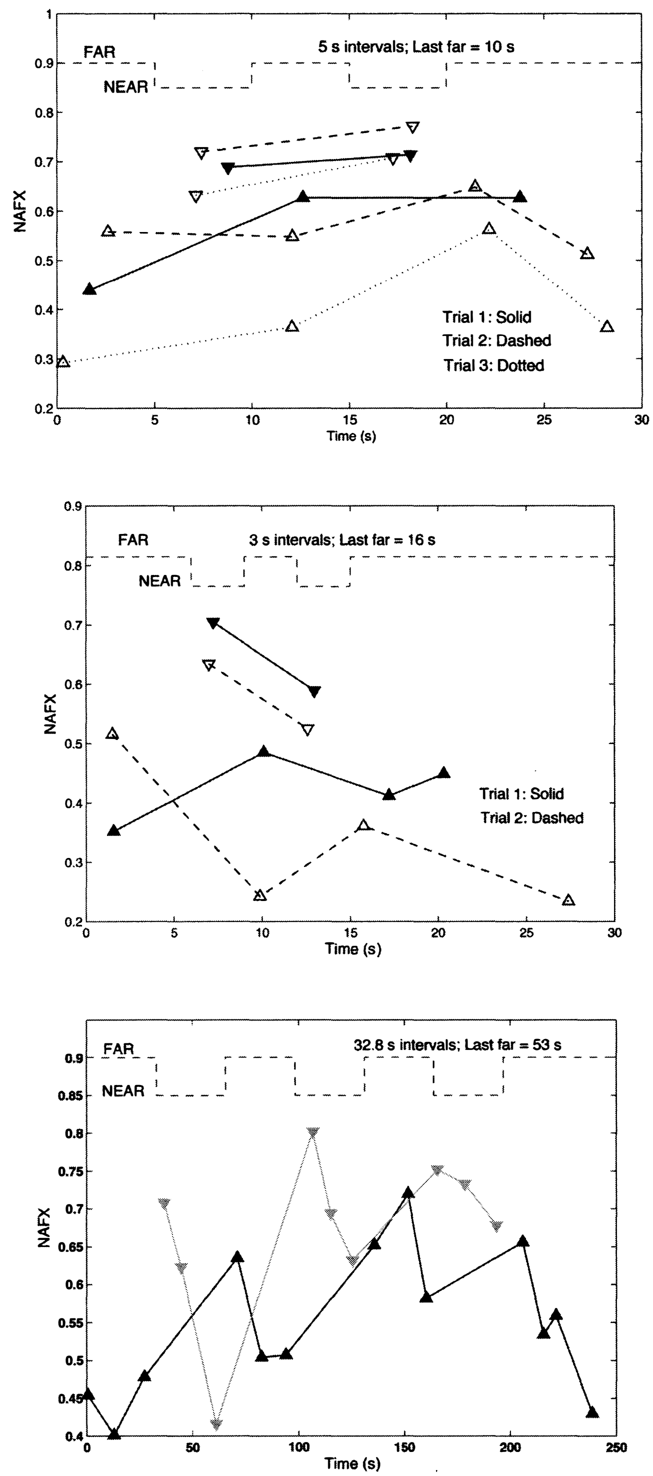

Figure 26.2 Plots of eXpanded Nystagmus Acuity Function (NAFX) versus time during large steps of convergence and divergence between far and near with interstep intervals of 5, 3, and >30 seconds—panels (A, top), (B, center), and (C, bottom), respectively. Data from near are indicated with down triangles and far with up triangles.

showed that higher values of NAFX were achieved for fixation of the far target only when the previous near target was presented for at least 5 seconds. In order to substantially improve visual performance in fixating a far target, the near target must be presented for at least 5 seconds, preferably shifting fixation between far and near twice before finally fixating the far target (Fig. 26.2). Therefore, quickly shifting gaze from a road sign to the steering wheel while driving, as previously suggested,[2] might not be helpful in increasing visual acuity, unless done twice.

Vergence-induced NAFX improvement, with possible associated hysteresis, starts to diminish after approximately 10 to 20 seconds. Therefore, we suggest it is the act of refixation (converging or diverging) that actually provides the initial improvement in visual function in subjects with INS. This also applies under real-life conditions, even in subjects who use baseout prisms to maximize the INS damping associated with convergence.

The time-dependent improvement of visual acuity during convergence or divergence may reflect the time required by a peripheral mechanism, either at the pulley or the muscle level, to reduce the plant's responsiveness to nystagmus. The repositioning of the pulleys going from near to far might take place with a higher time-constant profile (slower loss of plant's stiffness), yielding a transient visual acuity improvement while diverging (hysteresis).

In conclusion, our results help clarify the time course of hysteresis in a subject with INS. Further studies are required to explore the possible occurrence and time course of hysteresis in other forms of nystagmus that damp with convergence, as well as to better characterize hysteresis at different gaze angles.

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