

Occurrence of Physiologic Gaze-Evoked Nystagmus at Small Angles of Gaze

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PURPOSE. Physiologic gaze-evoked nystagmus (GEN) is one of many normal eye movements seen on the neurologic examination. GEN occurring at gaze angles $>45^\circ$ is considered a positive sign in the Horizontal Gaze Nystagmus Test (HGNT) used by United States police officers to determine alcohol intoxication.

METHODS. The authors enrolled 56 subjects after a brief survey and a neurologic examination yielding normal results. Subjects were directed to look at small targets on the wall in primary gaze and at 10° intervals until they reached extreme gaze bilaterally. Eye movements were recorded using infrared videography.

RESULTS. In addition to a high incidence of physiologic GEN at gaze angles 30° and greater (at 30° , $n = 43\%$; at 40° , $n = 73\%$; at extreme gaze, $n = 93\%$), the authors demonstrated that physiologic GEN occurs at smaller gaze angles (at 10° , $n = 21\%$; at 20° , $n = 34\%$).

CONCLUSIONS. A significant number of subjects with normal vision have physiologic GEN at gaze angles as small as 10° . This could potentially refute the "failing" grade that is the hallmark of the HGNT and propagates further testing of the validity of this test in the conviction of intoxicated drivers. (*Invest Ophthalmol Vis Sci.* 2010;51:2476-2478) DOI:10.1167/iovs.08-3241

Gaze-evoked nystagmus (GEN) is defined as nystagmus that occurs when the eyes are held in an eccentric position but not in the primary position. Studies suggest that it is present in more than 50% of the population with normal vision and is more common in fatigued subjects.¹ It is also commonly seen in association with a wide range of central nervous system pathologies, including focal or degenerative abnormalities in the posterior fossa, metabolic changes, and drug effects.¹ Physiologic GEN can usually be distinguished from pathologic GEN by its relatively low amplitude and frequency, relative symmetry of the abducting and adducting eyes, unsustained duration, and lack of other oculomotor deficits.² In addition, physiologic GEN has linear slow phases, whereas pathologic GEN usually has decreasing velocity and exponential slow phases.^{3,4}

The Horizontal Gaze Nystagmus Test (HGNT) is the most widely applied procedure in United States law enforcement for detecting and determining alcohol intoxication as part of a field sobriety test. A special mathematical formula is used to determine that the gaze angle of nystagmus onset can determine with accuracy the blood alcohol concentration of the suspect.⁵

Despite the wide range of conditions other than alcohol toxicity that can cause GEN and even though the test and formulas are under scrutiny, it is accepted by courts as evidence equal to chemical testing.⁵

Review of the current literature reveals minimal evidence of physiologic GEN occurring at small gaze angles. We studied a series of subjects with normal vision to assess the incidence of physiologic GEN at various angles of gaze.

METHODS

Our institutional review board reviewed and approved the study. Seventy-three subjects volunteered to take part; consent was obtained, and all research followed the tenets of the Declaration of Helsinki. All subjects denied any use of alcohol, nicotine, caffeine, or medications such as benzodiazepines known to cause or affect gaze-evoked nystagmus. They did not report any history of neurologic or ocular disease except for migraine. Subjects were excluded if they had had a migraine headache of any type within 3 days of the testing. Screening examination of extraocular movements was performed in all subjects. Three subjects reported a history of vertigo in the past, prompting a complete neurologic examination. Results were normal in all three. Thus, all subjects were included in this phase of the study.

Binocular eye movement recordings were made at 240 Hz with an infrared videographic binocular recording system (ISCAN ETL-500; IScan, Inc., Burlington, MA). The subjects were placed in a chin rest that minimized head movement and wore the recording equipment. Eye movement tracings were then visually inspected for nystagmus waveforms by one investigator and confirmed by another for accuracy. Three nystagmus waveforms in the 10-second duration of gaze were considered acceptable as nystagmus occurrence. For angles smaller than 40° , the equipment has an accuracy of 0.5° . For angles greater than 40° , accuracy is more variable and dependent on corneal reflection. Although values of amplitude and velocities calculated for large gaze angles may be less reliable, the presence or absence of nystagmus can be detected reliably.

For calibration purposes, subjects were asked to fixate on a target in primary gaze; at an eccentric target and then back to primary for 3 to 5 seconds at each location. This cycle was repeated at 10° intervals in both directions from 10° to 50° , with the subject returning to the primary position between each trial. The complete cycle was then repeated with subjects holding gaze for 10 seconds at each interval before returning to the primary position for 3 to 5 seconds. Subjects were asked to limit blinking as much as possible at each eccentric gaze position. We restricted gaze-holding duration to 10 seconds because this corresponds to the usual clinical examination of patients as a screen for nystagmus and extraocular movement deficits. In addition, subjects often complained of discomfort at gaze angles larger than 30° during the 10-second testing cycle and tended to blink excessively or to close their eyes, which might have contaminated the data recording.

The raw position data were processed to remove blinks and then smoothed using a smoothing algorithm. Velocity and acceleration were calculated as the differential of the smoothed position trace and the smoothed velocity trace, respectively. To identify areas of nystagmus, an algorithm was developed based on mean velocity and acceleration

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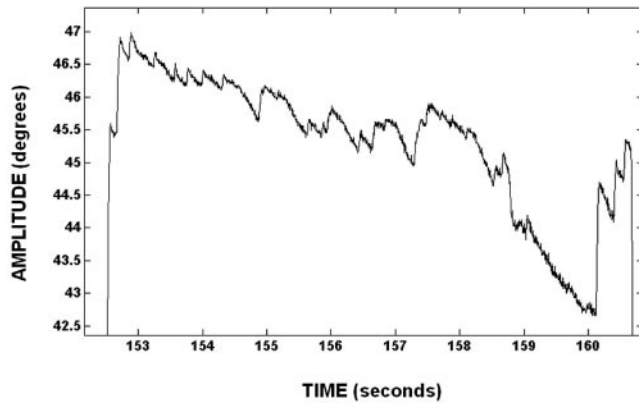


FIGURE 1. An example of recorded nystagmus.

values for each 5-point interval. Each interval was classified as part of a baseline, a slow phase, or a quick phase. The time spent in each phase for each gaze angle was calculated based on the total number of intervals thus classified. We assumed that the slow- and quick-phase velocities for a given gaze angle would be similar and thus calculated these as the average velocity for each phase over all slow- and quick-phase increments identified at that angle. The amplitude of each nystagmus beat at each gaze angle was averaged to give the amplitude of nystagmus at that gaze angle. This method gives smaller values of amplitude and velocity than other methods.

Fifteen subjects were excluded from the study because of excessive blinking, artifacts in the tracings, or both. Two subjects displayed frequent square-wave jerks instead of GEN and were also excluded from the study. This left 56 subjects (age range, 18–82 years; mean age, 48.6 ± 18.5 years) for analysis. Age breakdown by decade was as follows: 1 in the second decade of life, 7 in the third decade, 10 in the fourth decade, 11 in the fifth decade, 9 in the sixth decade, 6 in the seventh decade, 10 in the eighth decade, and 2 in the ninth decade. Incidence was a categorical measure described using frequencies and percentages.

RESULTS

Virtually all waveforms of the recorded nystagmus were jerk, with the saccades moving in the direction of gaze. The mean amplitude was $0.22 \pm 0.33^\circ$ across all gaze angles, which is lower than the accepted maximum of 4° for physiologic GEN.¹ Extreme gaze angle in both directions of all patients actually averaged 42.7° , which was lower than the attempted angle of gaze of 50° . Figure 1 is a sample of the nystagmus recorded. Four subjects displayed directional asymmetry in one or two angles of gaze on direct observation of the recordings.

Figure 2 exhibits the number of subjects who had nystagmus at each angle of gaze. There was a significant incidence of GEN at small gaze angles, not just at the expected angles of 30° and greater. At 10° and 20° , respectively, 21% and 34% of the subjects demonstrated physiologic GEN. There was no significant correlation between age and incidence of GEN at any degree of lateral gaze.

DISCUSSION

We found an unexpectedly high frequency of GEN at 10° (21%) and 20° (34%) that was similar at all ages. Although a single patient with GEN at 20° was noted by Abel et al.,⁴ other studies did not record small angles of gaze, perhaps assuming that GEN occurs only at larger amplitudes of gaze. The term *end-point nystagmus* has been applied to physiologic GEN when clearly it should be removed from usage based not on only our data

but also on those of Abel et al.,⁴ who have suggested is a misnomer because they recorded GEN at angles much lower than end point. Most studies have suggested that half the population with normal vision has GEN on lateral gaze, but there is considerable debate about what interval characterizes lateral gaze. Abel et al.⁴ showed that 7 of 12 subjects exhibited GEN at 30° and 35° excursions (with one occurring at 20°). Furthermore, they added that the system used in the study could not accurately record nystagmus beyond 40° , suggesting that the incidence of GEN might be higher.⁴ In contrast, Shallo-Hoffman et al.⁶ found GEN in only 9 of 20 subjects at angles greater than 40° . Godd -Jolly et al.⁷ found GEN in 63% of their subjects but did not mention the minimum angle that induced the GEN. In 95% of subjects who had nystagmus, the angle was greater than 40° . Although our study found that 43% of subjects had nystagmus at 30° , there was a large increase to 73% at 40° and 93% at extreme gaze, comparable to the results of most of these studies.

Physiologic GEN has been classified as four types: sustained, unsustained, with latency, without latency.^{1,8} After reviewing the available literature, there is no clear definition of normal latency.⁴ In all our subjects and for all targets, if nystagmus was present it began within 5 seconds of reaching the eccentric target. These latencies are in agreement with those of Abel et al.,⁴ who found that in 5 of 7 subjects, GEN occurred in less than 5 seconds.⁹ We suspect that greater latency is more likely secondary to poor refixation efforts than to physiologic or pathologic changes.

We cannot comment on the sustained nystagmus in our subjects because of our restricted duration of gaze holding; however, the nystagmus in our study typically lasted more than “a few beats,” which defines the sustained type.⁹ Although unsustained physiologic GEN is said to be most commonly encountered in practice, it has never been studied quantitatively.⁹ We suspect that most, if not all, unsustained nystagmus is secondary to a cessation of quick phases and a lack of maintenance of fixation on the eccentric target, as discussed.

Many of our subjects had difficulty maintaining extreme eccentric gaze even when prompted to hold their eyes on the target. It is unclear whether this was because of fatigue, pain, or lack of ability to maintain their eyes at a 50° excursion. This might have resulted in subjects surrendering effort to look at the target, effectively ceasing the quick phases. Perhaps sustained GEN is more common than previously thought, but the distinction between unsustained and sustained GEN requires further study.

This finding could potentially be applied to a controversial issue in US law enforcement. The HGNT is used by police officers in their assessment of persons under suspicion for alcohol intoxication. The current minimum gaze angle of appearance of nystagmus at which the person “passes” is 45° . Not

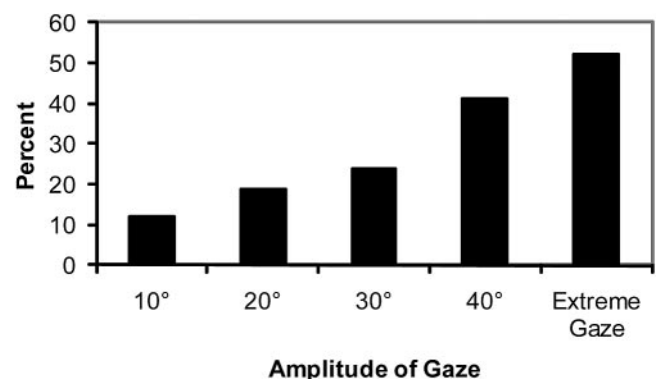


FIGURE 2. Incidence of gaze-evoked nystagmus at amplitude of gaze.

only does our study show that there is a significant amount of nystagmus occurring at smaller gaze angles, our maximum angle on extreme lateral gaze averaged 42.7°, much lower than the minimum amount required to “pass the test.” Most of our subjects (93%) would have failed this test in the field. Therefore, the validity of the HGNT and the effects of alcohol on GEN may have to be questioned again and reexamined in future studies.

Unfortunately, only one examiner, who directed the subject to the angle of gaze, tested the subjects. The examiner was, therefore, unable to assess whether the nystagmus was seen on visual inspection. Although clinically this may not be directly applicable to the HGNT, a future study would involve a secondary observer of the subjects' eyes or an automated visual guide so that visual inspection can be assessed for observed GEN and recorded GEN.

In the absence of other neurologic abnormalities on examination, small amplitude GEN at any age, even at small gaze angles, can be considered normal. Furthermore, the incidence of physiologic GEN at smaller angles of gaze (as low as 10°) is much higher than expected. This has a very important clinical application in the field tests of alcohol intoxication and must be reexamined to be deemed clinically applicable to legal matters.

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