

TITLE: Physiologic gaze-evoked nystagmus occurs at angles of gaze smaller than previously thought

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ABSTRACT

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

Methods: We enrolled 56 subjects after a brief survey and a normal neurological examination. 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 video-oculography.

Results: Besides a high incidence of physiologic GEN at gaze angles 30° and above (at 30° , $n=43\%$; at 40° , $n=73\%$, and at extreme gaze, $n=93\%$), we demonstrated that physiologic GEN occurs at smaller gaze angles (at 10° , $n=21\%$ and at 20° , $n=34\%$).

Conclusions: A significant number of normal subjects have physiologic GEN at gaze angles as small as 10° . This could potentially refute the “failing” grade that is the hallmark of the HSNT and propagates further testing of the validity of this test in conviction of intoxicated drivers.

Gaze-evoked nystagmus (GEN) is defined as nystagmus that occurs when the eyes are held in an eccentric position but is not present in primary position. **Studies suggest that it is present in over 50% of the normal population 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 Also, physiological GEN has linear slow phases whereas pathological GEN usually has decreasing velocity exponential slow phases.^{3,4}

The Horizontal Gaze Nystagmus Test (HGNT) is currently 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 was 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 which can cause GEN and even though the test and formulas are under extreme scrutiny, it is currently 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 normal subjects to assess 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 in this study after 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. Participants did not report any history of neurological or ocular disease, except for migraine. Subjects were excluded if they had had a migraine headache of any type within three days of the testing. A screening exam of the extraocular movements was performed in all subjects. Three subjects reported a history of vertigo in the past, prompting a complete neurological exam. It was normal in all three. Thus, all subjects were included in this phase of the study.

Binocular eye-movement recordings were done at 240 Hz. utilizing the ISCAN ETL-500 Infrared Videographic Binocular Recording system (Iscan, Inc., Burlington, Massachusetts). The subjects were placed in a chin rest minimizing head movement while wearing 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 less than 40° the equipment has an accuracy of 0.5°. For angles greater than 40°, accuracy is more variable and dependent on the 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 very 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 3-5 seconds at each location. This cycle was repeated at 10° intervals in both directions from 10° to 50°, returning to primary position between each trial. The complete cycle was then repeated with subjects holding gaze for ten seconds at each interval before returning to primary position for 3-5 seconds. The subjects were asked to limit blinking at each eccentric gaze position as much as possible. We restricted gaze holding duration to ten seconds as this corresponds to the normal clinical examination of patients as a screen for nystagmus and extraocular movement deficits. Also, subjects often complained of discomfort at gaze angles larger than 30° during the ten-second testing cycle, and tended to blink excessively or close their eyes, which could have potentially contaminated the data recording.

The raw position data was 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 values for each 5 point interval. Each interval was classified as being 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 will give smaller values of amplitude and velocity than other methods.

Fifteen subjects were excluded from the study because of excessive blinking and/or artifacts in the tracings. 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; mean age 48.6 ± 18.5 years) for analysis. There was 1 subject in the second decade of life, 8 in the third decade, 12 in the fourth decade, 12 in the fifth decade, 9 in the sixth decade, 6 in the seventh decade, 13 in the eighth decade, and 2 in the ninth decade. The incidence is a categorical measure that was 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 less 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 less than the attempted angle of gaze of 50° . Figure 1 is a sample of the nystagmus recorded.

Four of the subjects displayed directional asymmetry in one or two angles of gaze on direct observation of the recordings.

Figure 2 exhibits the number of subjects that had nystagmus at each angle of gaze. There was a significant incidence of GEN at small gaze angles and not just at the

expected angles of 30° and above. 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%), which was similar at all ages. Although a single patient with GEN at 20° was noted by Abel et al, other studies did not record small angles of gaze, perhaps assuming that GEN only occurs at larger amplitudes of gaze.⁴ The term “end-point nystagmus” has been applied to physiologic GEN when clearly it should be removed from usage based on not only our data, but also Abel et al’s.⁴ Even he and his colleagues suggested that it is a misnomer, as they recorded GEN at angles much less than “end-point.” Most studies have suggested that 50% of the normal population has GEN on lateral gaze, however there is considerable debate about what interval characterizes lateral gaze. Abel et al’s study showed that 7 of the 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. found GEN in only 9 of 20 subjects at angles greater than 40°.⁶ Goddé-Jolly et al. found GEN in 63% of their subjects, but did not mention the minimum angle that induced the GEN. 95% of those that had nystagmus had it above 40°.⁷ While our study found that 43% had nystagmus at 30°, there was a large increase to 73% at 40° and 93% at extreme gaze. This is comparable to the results of most of the aforementioned studies.

Physiologic GEN has been classified into four types; sustained and unsustained and with or without latency.^{1,8} After reviewing the available literature, there is no clear definition as to what defines a normal latency.⁴ In all of 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 Abel et al's study with 5 of 7 subjects having GEN occurring in less than 5 seconds.⁹ We suspect that a greater latency is more likely secondary to poor refixation efforts than physiologic or pathologic changes.

We cannot comment on prolonged sustenance of the nystagmus in our subjects due to 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 While 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 lack of maintenance of fixation on the eccentric target, as discussed above.

Many of our subjects had difficulty maintaining extreme eccentric gaze even when prompted to hold their eyes on the target. It is unclear whether it was due to fatigue, pain, or a lack of ability to maintain their eyes at a 50° excursion. This may have resulted in subjects surrendering effort to look at the target effectively ceasing the quick phases. Perhaps sustained 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 Horizontal Gaze Nystagmus (HGN) test is utilized 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 only does our study show that there is a significant amount of nystagmus occurring at smaller gaze angles, but our maximum angle on extreme lateral gaze averaged 42.7°; which was much less than the minimum amount required to “pass the test.” The majority of our subjects (93%) would fail this test out in the field. Therefore, the validity of the HGN test and the effects of alcohol on GEN may need to be questioned again and re-examined with future studies.

Unfortunately, one examiner performed the testing of the subjects and the concentration of the examiner was to direct the subject to the angle of gaze and therefore was unable to assess if the nystagmus was seen on visual inspection. While clinically, this may not be directly applicable to the HGN test at this point, a future study would involve a secondary observer to the subjects’ eyes or an automated visual guide so that visual inspection can be assessed for observed GEN compared to recorded GEN.

CONCLUSIONS

In the absence of other neurological abnormalities on exam, small amplitude GEN at any age even at small gaze angles can be considered to be 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 needs to be re-examined to be deemed clinically applicable to legal matters.

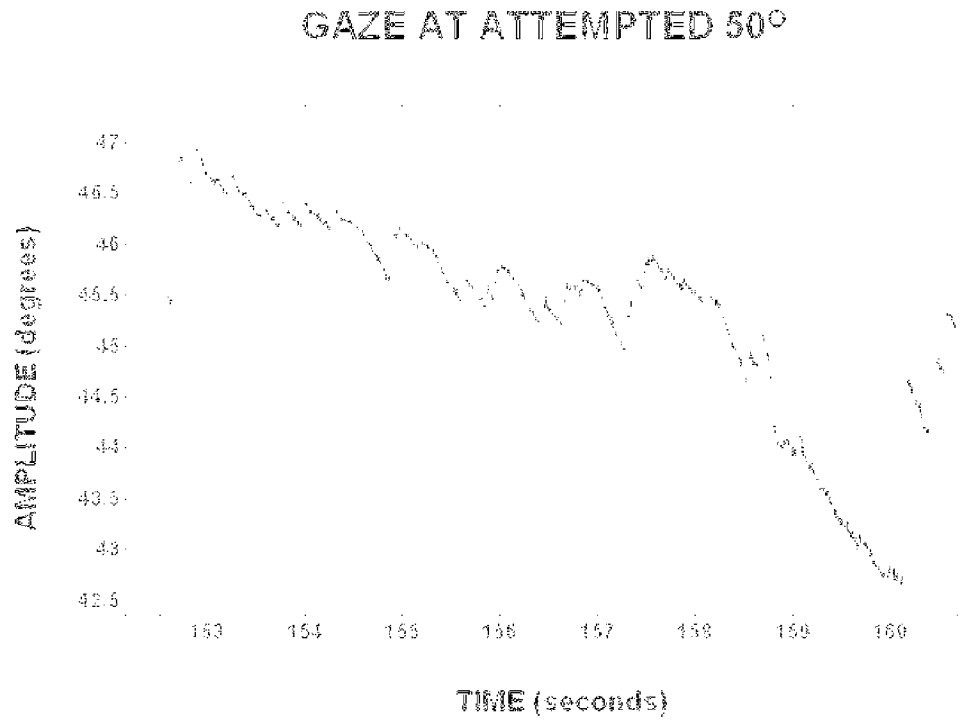


Figure 1

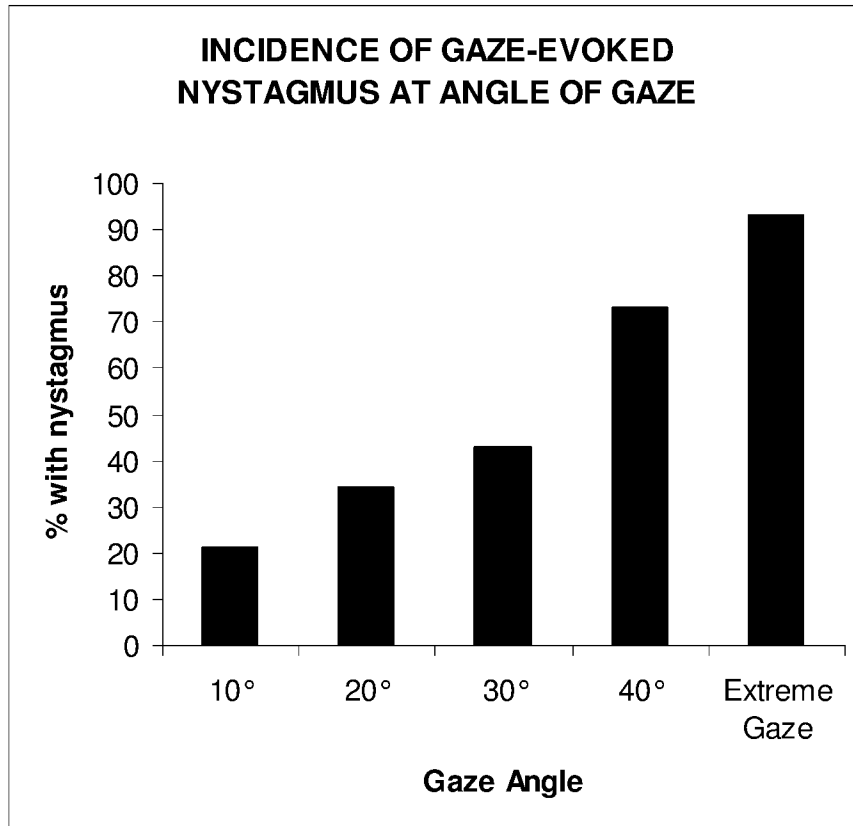


Figure 2

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