

# End-position nystagmus as an indicator of ethanol intoxication

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The Horizontal Gaze Nystagmus test is used by law enforcement agencies in the United States to determine whether drivers are intoxicated. It has a high baseline error and a dose/response relationship that varies greatly according to whether the subject's blood alcohol concentration is rising or falling. Confusion exists among practitioners of the test about whether it quantifies alcohol concentration or evaluates impairment. Fatigue exacerbates one component of the HGN test, end-position nystagmus. Video tapes recorded by cameras in police vehicles revealed that police officers rarely comply with the minimum requirements of the nystagmus examination procedures for which they were trained and certified.

Le test du nystagmus horizontal évoqué par le regard (HGN) est utilisé par les forces de polices aux Etats-Unis pour déterminer si les conducteurs sont sous l'effet de l'alcool. Cette méthode a une erreur de base élevée et une relation dose / effet qui varie grandement selon que la concentration d'alcool dans le sang du sujet est en augmentation ou en diminution. La confusion existe parmi les praticiens de ce test de savoir s'il mesure la concentration d'alcool ou évalue l'influence négative sur la conduite (état d'ébriété). La fatigue augmente l'un des composants de ce test, la position finale du nystagmus. Des enregistrements vidéos, par les caméras dans les véhicules de police, ont révélé que les agents de police ne se conforment que rarement aux critères minimaux requis pour les procédures d'examen nystagmus, pour lesquels ils ont pourtant été formés et certifiés.

In den Vereinigten Staaten von Amerika wird mit Hilfe des HGN-Tests (Horizontal Gaze Nystagmus) bestimmt, ob Führer von Kraftfahrzeugen betrunken sind. Der Test besitzt einen hohen Grundfehler und zudem eine Beziehung von Dosis und Wirkung, die stark von einer ansteigenden oder abfallenden Blutalkoholkonzentration abhängig ist. Es herrscht Unsicherheit dahingehend, ob der Test Alkoholkonzentrationen quantifiziert oder die durch den Alkohol hervorgerufene Beeinträchtigung bewertet. Müdigkeit erhöht den Endpositionnystagmus, eine Komponente des HGN-Tests. In Dienstwagen aufgenommene Videofilme zeigen, dass Polizeibeamte die Minimalanforderungen der Nystagmusuntersuchung, für die sie ausgebildet und zertifiziert wurden, oft ignorieren.

Las agencias gubernamentales de Estados Unidos utilizan el test del Nistagmus de la Mirada horizontal para determinar si los conductores están intoxicados. Tiene un gran error de línea de base y la relación dosis/respuesta varía mucho dependiendo de si el alcohol en sangre está creciendo o decreciendo. Existe confusión entre los que lo practican sobre si el test cuantifica la concentración de alcohol o evalúa la afectación. La fatiga exagera un componente del test HGN, el nistagmus de posición final. Cintas de vídeo tomadas por cámaras de vehículos policías, revelaron que los oficiales de policía raramente cumplen los requerimientos mínimos de los procedimientos de examen de nistagmus, para los que fueron entrenados y certificados.

## Introduction

For more than fifteen years the Horizontal Gaze Nystagmus Test (HGN) has been used as evidence of intoxication in the United States. From its inception this test has been promoted and accepted for stand-alone use only for the purpose of evaluating the chemical concentration of alcohol in the blood as being greater and less than 0.10% (100 milligrams per 100 millilitres) [1], but its most common application is based on the belief that '... the HGN test is an excellent indicator of impairment' [2].

Laboratory studies by Carlson [3] and Goldberg [4] indicated that simple tests of any kind were essentially worthless at a blood alcohol concentration (BAC) of 0.10% or lower, and there has never been a significant reason to believe that a method simple enough for use in the field and discriminating enough for evidentiary use would be found [5,6]. Nevertheless, in 1974 the Southern California Research Institute (SCRI), under contract to the National Highway Traffic Safety Administration (NHTSA), developed a test based on optical nystagmus [7] that they considered to be very promising for the purpose of determining both the presence and concentration of alcohol in the blood of drivers suspected of driving while intoxicated (DWI). In 1981 the original nystagmus test (which was called the Alcohol Gaze Nystagmus [AGN] test in the 1977 report) was replaced with a completely different nystagmus test, the Horizontal Gaze Nystagmus test [1]. The HGN test, it was claimed, was capable of being used to determine an accurate blood alcohol concentration ( $\pm 0.03$  w/v%) ( $\pm 30$  milligrams per 100 millilitres) of drinkers and, by implication, qualitatively identifying ethanol as the intoxicant by correlating the lateral angle of nystagmus onset with BAC. It was also claimed that observers trained to accurately measure the angle of nystagmus onset could classify 78% of laboratory test subjects as having a BAC greater or less than 0.10% (100 milligrams per 100 millilitres) using the criterion of observable nystagmus appearing before the eyes were turned outwardly for  $45^\circ$ . In 1983 NHTSA reviewed the SCRI data and established the current criteria of (1) observable nystagmus appearing before the eyes were turned outwardly for  $45^\circ$ , (2) breakdown of smooth eye pursuit as the eyes were deviated laterally at a rate of approximately  $25^\circ$  per second and (3) presence of distinct end-position nystagmus, factors that are now the 'standardized' elements of the current test with an officially estimated accuracy of 77% [8].

A critical part of the HGN test is the examination for end position nystagmus (called 'nystagmus at maximum deviation' by law enforcement personnel), the distinct nystagmus that is present when the eyes are turned to their maximum horizontal deviation. The protocol for this portion of the test has remained unchanged since the inception of the test, requiring only that each eye be observed for at least four

seconds while held in its most lateral aspect. Nystagmus of this type is reported to be present in about half (55–60%) the general population [9], a value noted without dispute by the developers of the HGN test. Nystagmus also has been reported to appear at a very low BAC (about 0.03%) (30 milligrams per 100 millilitres) [10] and is found in people with no exposure to alcohol or drugs [11].

It has never been clear what community of scientists would be called upon to review and comment upon the HGN test. In one of the earliest legal opinions, there was debate about whether the appropriate peer group would be 'law enforcement and highway safety agencies and behavioural psychologists' or 'scientists in the fields of neurology, ophthalmology, pharmacology and criminalistics' [12]. Since the work was never submitted for peer review, the researchers at SCRI and NHTSA offered no insight into their preference. Recently, however, the American Prosecutors Research Institute, in a report co-authored by Marcelline Burns, one of the authors of the SCRI reports, recommended that experts for HGN tests should be an optometrist, ophthalmologist, neurologist, emergency room or urgent care physician (or possibly a toxicologist or pharmacologist) [2]. Apparently none of the parties involved ever found a peer group because virtually the entire body of publications on this subject has escaped peer review.

In this study, two experiments were conducted to test under laboratory conditions the validity of the HGN test, and videotaped evidence was evaluated to judge how the procedure is administered by police officers under real life conditions.

## Experimental

### *Confirmatory assays*

Breath alcohol concentrations were determined using CMI Intoxilyzer 5000 instruments with wet-bath reference units operated at  $34^\circ\text{C}$ .

Blood and urine assays were conducted by gas chromatography using the procedure described by Penton [13].

### *Procedure for evaluating end-position nystagmus*

End-position nystagmus was evaluated using the procedure described in the student and instructor's manuals used to train police officers to test for nystagmus at maximum deviation [14,15]. Nystagmus was attributed only if a strong beat was maintained for at least four seconds to compensate for the few transitory nystagmus beats that occasionally occur when the eyes of non-drinking, normal test subjects are fully deviated.

### *End-position nystagmus: a study on the effect of fatigue*

A test population of 66 healthy, well-rested volunteers (44 men and 22 women) between the ages of 20 and 57 years of age (average = 43 yr) who denied use of alcohol or drugs within the preceding 24 hr was assembled to determine

whether fatigue and lack of sleep affected the prevalence of end position nystagmus. Each of the test subjects completed 5.5 to 8.0 hours of sleep (average = 7.3 hr) and was examined for the presence of distinct end position nystagmus after being awake for a period of time between 9.0 and 14.5 hr (average = 11.2 hr). After 13 to 14 hr of continuous mental and physical activity with no consumption of alcohol, the entire population was re-examined (average awake time = 24.5 hr).

#### *End-position nystagmus: A dose/response study*

Eighty-nine volunteers (79 men and 10 women) between the ages of 22 and 67 (average = 34 yr) who were well-rested, in good health, and had not consumed alcohol or drugs within the previous twenty-four hours were dosed with alcohol and tested periodically to determine the presence of end-position nystagmus. Each of the test subjects consented to the test after being informed of the nature of the study and of the possible health risks. All drinking subjects were provided with safe transportation after the tests were completed. Breath, blood, or urine samples were simultaneously collected and assayed for all subjects. Subjects were tested prior to the introduction of alcohol, as their blood alcohol concentration (BAC) increased, as it decreased, and after it returned to zero.

#### **Results**

In the fatigue tests, subjects had distinct nystagmus in one or both eyes after being awake for an average of 11.2 hours. Distinct end position nystagmus was observed in one or both eyes of 55% of the group examined after being awake for an average of 24.5 hours.

In the dose/response study, 19% of subjects exhibited nystagmus in one or both eyes prior to the introduction of alcohol; 62% of the dosed subjects exhibited nystagmus in one or both eyes at BAC levels of 0.00% (zero milligrams per 100 millilitres) when tested immediately after all alcohol was cleared from their blood. Fifty-six percent of the dosed subjects exhibited nystagmus in one or both eyes at BAC levels of 0.00% (zero milligrams per 100 millilitres) when tested one hour after all alcohol was cleared from their blood.

While absorbing alcohol and exhibiting a rising BAC, 37% of subjects exhibited nystagmus in one or both eyes at BAC levels of 0.01% to 0.05% (10 to 50 milligrams per 100 millilitres); 68% exhibited nystagmus in one or both eyes at BAC levels of 0.01% to 0.05% (10 to 50 milligrams per 100 millilitres) while eliminating alcohol and exhibiting a decreasing BAC.

Of the subjects tested, 73% exhibited nystagmus in one or both eyes at BAC levels of 0.08% to 0.12% (80 to 120 milligrams per 100 millilitres) while absorbing alcohol and exhibiting a rising BAC; 81% exhibited nystagmus in one or both eyes at BAC levels of 0.08% to 0.12% (80 to 120

milligrams per 100 millilitres) while eliminating alcohol and exhibiting a decreasing BAC.

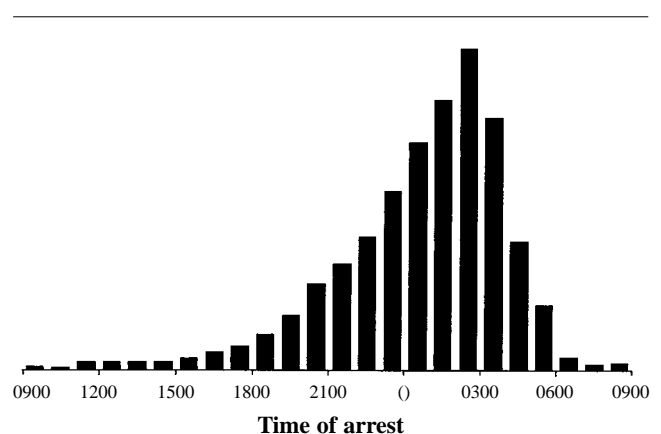
Of the subjects tested, 83% exhibited nystagmus in one or both eyes at BAC levels greater than 0.15% (150 milligrams per 100 millilitres) while absorbing alcohol and exhibiting a rising BAC; 91% exhibited nystagmus in one or both eyes at BAC levels greater than 0.15% (150 milligrams per 100 millilitres) while eliminating alcohol and exhibiting a decreasing BAC.

#### **The HGN test as applied in field testing situations**

One source of objective information about the application of the HGN test in arrests comes from the car-mounted video cameras employed by a number of law enforcement agencies. Fifty-two arrest tapes leading to trials in which 49 traffic enforcement officers testified that the defendant was intoxicated were studied.

The video tapes obtained from these cameras are usually of poor technical quality, but the total time elapsed during the officer's administration of the HGN test could usually be measured, and distinct pauses in the motion of his stylus could also be timed. It takes a minimum of 48 seconds to properly conduct a complete standardized HGN test and the officer should stop the motion of the stylus for approximately four seconds four times during the testing process. Overall officer performance was evaluated simply on the time he took to conduct the HGN test and the number of times he stopped the motion of his stylus for at least four seconds.

The total elapsed times for administering the tests recorded on the arrest tapes ranged from nine to 83 seconds with the average being 21 seconds. In only eight of the 52 (15%) tests did the officer stop the motion of the stylus even once for an observation period of four seconds. Only one officer conducted his test in a manner consistent with the approved procedure.



**FIGURE 1** Time of arrest for 2,648 driving while intoxicated suspects 1998–2000.

## Discussion

Considering that about 70 percent of DWI arrests are made between 11:00 p.m. and 5:00 a.m. (Figure 1), that end position nystagmus is a symptom of fatigue [16], and that the SCRI developers produced experimental data showing nystagmus onset to be a function of the time of day of the test [1], it is remarkable that no investigation was conducted into the possibility that the prevalence of non-alcohol induced end-position nystagmus might be a function of time of day. Because this issue was ignored, the HGN test has routinely been applied in situations where a high incidence of false positives is to be expected. (Subjects exhibiting congenital nystagmus are not commonly found among the ordinary population of drivers because these individuals are ordinarily considered to be legally blind.)

The HGN test is supposed to be 77% accurate in discriminating between subjects having blood alcohol concentrations above or below 0.10 w/v% (100 milligrams per 100 millilitres), but these facts, derived from the studies described above, suggest that the estimate is inflated and erroneous:

1. The baseline error (up to 55% false positives for fatigued, non-drinking subjects) for end-position nystagmus component of the HGN test is high, especially considering that the result of the test is often used without a confirming chemical assay as the primary evidence that alcohol is present at a concentration greater than 0.10 w/v% (100 milligrams per 100 millilitres).
2. The dose-response relationship of alcohol and distinct end-position nystagmus varies widely (37% to 68% in the very low BAC subjects) according to whether the subject is absorbing or eliminating alcohol – a factor impossible to determine in field situations.
3. Distinct end-position nystagmus is exhibited by more than half the test subjects an hour or more after the subject's BAC returned to 0.00% (zero milligrams per 100 millilitres).

From the videotapes viewed for this paper, more than 98% of the roadside HGN tests administered to drivers by police officers were improperly conducted, implying that either the test protocol or the training procedure employed for police officers is inadequate to assure proper administration of the test when it is applied to drivers suspected of being intoxicated.

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