
End-point nystagmus

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Infrared oculography was performed during sustained lateral gaze in 12 normal subjects to investigate end-point nystagmus while fixating a target light. Five failed to develop nystagmus despite deviation up to 40° from 4 to 5 min. Six subjects developed nystagmus immediately or shortly after reaching the deviated position. In one, the nystagmus (0.5° to 1° and 1.0 Hz) began with only a 20° deviation. In another subject, "fatigue" nystagmus developed after 1 min at 30°, and at 35° nystagmus began within 2 sec. One subject developed only fatigue nystagmus, which began after more than 4 min of sustained deviation. In all instances the slow phase had primarily a linear, rather than exponential, waveform.

Key words: end-point nystagmus, fatigue nystagmus, physiological nystagmus, eccentric gaze maintenance, eye movements

Every classification of nystagmus includes a type occurring during lateral gaze that is not considered pathological. The descriptive terms "physiological," "end-point," and "fatigue" are often used, at times synonymously. Three basic categories are discernible from the literature and are most appropriately designated: fatigue nystagmus, unsustained end-point nystagmus, and sustained end-point nystagmus.

1. Fatigue nystagmus begins *during* the maintenance of extreme lateral gaze deviation. Bárány¹ found that approximately 50% of normals developed nystagmus when gaze was maximally deviated for longer than 30 sec. Nylen² mentioned that fatigue nystagmus became increasingly rotary, the more

extreme and prolonged the deviation. In the same year, Uffenorde³ described fatigue nystagmus developing in normal subjects after a latency varying from 40 to 190 sec. The nystagmus gradually increased in intensity as gaze was maintained and occurred with shorter latency in tired subjects as well as in children where there was also greater intensity.

Schmidt and Kommerell⁴ conducted the only quantitative oculographic investigation of horizontal gaze-evoked nystagmus in normals. They studied six subjects, one of whom had end-position fatigue nystagmus after a latency of 90 sec.

Fatigue nystagmus is rarely encountered clinically, since eccentric gaze is not routinely maintained for prolonged periods during routine examinations.

2. Unsustained end-point nystagmus is perhaps the most frequent clinically encountered "physiological" nystagmus. Its occurrence, however, has never been studied statistically nor its characteristics analyzed by quantitative recordings. The single subject with fatigue nystagmus of the adducted eye studied by Schmidt and Kommerell⁴ manifested transient end-point nystagmus in the abducted eye. Ordinarily, the transient nys-

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tagmus would be habituated during the calibration phase of eye movement recording and would not be discernible during analysis.

3. Sustained end-point nystagmus begins immediately or within several seconds after attaining an eccentric lateral gaze position. There is considerable disagreement as to how this may be distinguished from pathological gaze-evoked nystagmus. Blomberg⁵ found no nystagmus at 40° deviation in 115 normal subjects, 25 of whom were studied with electro-oculography (EOG). Godde-Jolly et al.⁶ studied 260 normal subjects (20 with EOG); he found gaze-evoked nystagmus in 164 (63%), and 95% had the onset of nystagmus between 40° and 65° of lateral deviation. The authors did not mention the minimum gaze angle at which nystagmus appeared but did comment that 3 Hz was the almost invariable nystagmus frequency.

Uemura et al.⁷ were cautious about distinguishing physiological from pathological nystagmus. They stated, "A distinct nystagmus which appears with a lateral gaze at 30° or less from the midline is empirically believed to be pathological. The distinction between physiological and pathological gaze nystagmus is, however, arbitrary, sometimes difficult and may be impossible. . . . Only discrete nystagmus with a sufficiently large amplitude which is easily identified can be said to be unequivocally pathological."

In the previously mentioned EOG study by Schmidt and Kommerell,⁴ five patients manifested sustained end-point nystagmus at the extreme gaze deviation. The nystagmus frequency varied from 1 to 3 Hz and the amplitude from 1° to 3°. One subject had convergence jerk nystagmus, but the four others had conjugate jerk nystagmus with the amplitudes varying between the two eyes. During maintained deviation in darkness one subject manifested a high-amplitude pendular oscillation in the abducting eye, associated with pupillary miosis and 4.00 to 5.00 D of lens accommodation. A major finding by Schmidt and Kommerell was distinct variability within subjects recorded at different times.

There has not been a detailed study of the waveform characteristics of end-point nys-

tagmus. The standard AC-coupled, low-bandwidth recording apparatus used in electro-nystagmography laboratories severely distorts the shape of the eye movement analogue. The DC-coupled, 30 Hz bandwidth EOG used by Schmidt and Kommerell is far superior but remains less than optimal for studying the fine characteristics of eye movements. EOG is limited to relatively low-frequency responses because of artifacts at high bandwidths.

Infrared reflectance⁸ is a technique that permits recording of high-frequency responses and has the further advantages of minimal baseline drift, lack of muscle artifact, and extremely low level of powerline noise. Two major drawbacks of the infrared technique, as it is generally used, are its linearity to only $\pm 20^\circ$ and its unsuitability for recording eye movements beyond $\pm 30^\circ$. The latter limitation would render it impossible to record end-point nystagmus, said to be uncommon at gaze angles less than 40°. We modified the standard infrared calibration techniques to record eye movements to about 40°, enabling us to study, with a high-frequency recording device, end-point nystagmus at less than the extreme lateral gaze angles.

Methods

Twelve subjects, nine male and three female, free of neurological or ocular motor disease were studied, two on two separate occasions and one on three. The subjects ranged from 22 to 47 years of age. They sat in a modified dental chair with chin rest and head support to stabilize the head. Standard infrared spectacles (Biometrics) were used for each eye. The position signal was electronically differentiated to obtain peak velocities. The full system bandwidth for both position and velocity was DC-100 Hz. Subjects viewed an arc situated 1.14 meters away, containing light-emitting diodes as fixation targets. Rather than calibrating the subjects from primary position, we did so about a target at 20° by laterally repositioning the photodiode assembly on one side of midline.

The 20° target was the resting position. Subjects refixated to the 30° target and maintained gaze at that light for at least 4 min (up to 5 min). If no nystagmus developed, the subjects were given a brief rest, recalibrated, and taken to the 35° target. Again, if no nystagmus developed after 4 to

Table I. End-point nystagmus characteristics

Subject ^a	Onset angle (degrees)	Latency (sec)	Amplitude (degrees)	Frequency (Hz)	Waveform
1 ¹	35	0.280	1.5-3	2.8	J (L & R)
1 ²	30	0.600	0.5-1	2.2	J
2 ¹	20	1.2	0.5-1 ^b	1.0 ^c	J
2 ²	20	0.680	1	1.2	J
3	30	None	1	1.7	J
4	30	0.050	0.5-1.0	1.5-2.5	J
5 ¹	30	4.8 ^d	0.5-1.0	2.8	J
5 ²	30	2.4 ^e	0.5-1.0	1.6-2.5 ^f	J, C ^g
6	30 ^h	60 ^{h, i}	0.5	1.0	J
7	35	235 ^h	0.5	2.0	J

J = jerk; C = cycloid; L = left; R = right.

^aSubjects 1, 2, and 5 were studied on two separate occasions.

^bAt 30° the amplitude went up to 3°.

^cBrief bursts of 3.5 Hz occurred at both 20° and 30°.

^dAverage of 2 instances recorded during this session. Individual latencies were 5.2 and 4.4 sec.

^eAverage of 6 instances of nystagmus during this recording session. One was movement from 20° with latency of 4.8 sec. Five instances were movements from 0° with individual latencies of 3.1, 3.5, 0.95, and 2.2 sec.

^fAfter 35° position was maintained for over 45 sec. The position could not be maintained; the eyes drifted in to 30°, and frequency went up to 6.6 Hz and took on a cycloid waveform.^g

^gCycloid waveforms appeared with fatigue.^f

^hExample of fatigue nystagmus.

ⁱAt 35°, nystagmus began in 1.8 sec.

5 min, the subjects were rested, recalibrated, and instructed to gaze at the 40° target (or as far as could be recorded, which was 38° or 39° in some) for 4 to 5 min. If nystagmus developed at any of the targets, gaze was maintained for 4 minutes as the nystagmus was recorded. Each was studied in only one lateral gaze direction. The technique did not permit recording at gaze angles beyond 40°.

Most subjects were studied only when viewing a light and not in darkness. Three subjects were re-recorded while attempting to maintain a given gaze angle in total darkness. They first fixated a target light for several seconds; the target and room lights were then extinguished.

The data were analyzed to determine whether nystagmus was present. If so, the onset gaze angle, latency, frequency, amplitude, and waveform characteristics were determined.

A methodological problem related to the geometry of the infrared spectacles. The adjustment of the photodiode assembly involved shifting them laterally. In so doing, the two diodes for each did not follow the curve of the globe but traveled horizontally along a line perpendicular to the anteroposterior axis of the eye in primary position. This resulted in one photodiode being farther from the eye than the other, a condition which could result in nonlinear responses. Another possible source of nonlinearity was the disappearance of one iris-scleral border into the corner of the palpebral fissure. We checked for gain changes in far lateral gaze by having the subjects make saccades

between targets 1° and 2° apart. An increase in gain sometimes occurred, especially near the 40° limit of the technique. Usable data were adjusted for the gain change; any distorted portions of the records were discarded.

Results

The results are summarized in Table I. Five subjects failed to develop nystagmus despite sustained deviation from 4 to 5 min at the 40° eccentric target. No subject had unsustained nystagmus. Six subjects developed sustained end-point nystagmus; in one, the onset was instantaneous, and in the others, the latency varied from 50 msec to 5.2 sec. (We elected to regard the latter latency (5.2 sec) as end-point rather than fatigue nystagmus because it occurred in Subject 2 who had demonstrated nystagmus with no latency and only 1.0 sec latency on two other recording trials.)

Three of the subjects with sustained end-point nystagmus were recorded on two separate occasions (with one tested a third time), and all again demonstrated the nystagmus. Subject 2 had nystagmus at the onset position of 20° during two separate recording sessions. The others had onset at 30° to 35°.

The amplitude of nystagmus was usually 0.5° to 1° and did not increase substantially

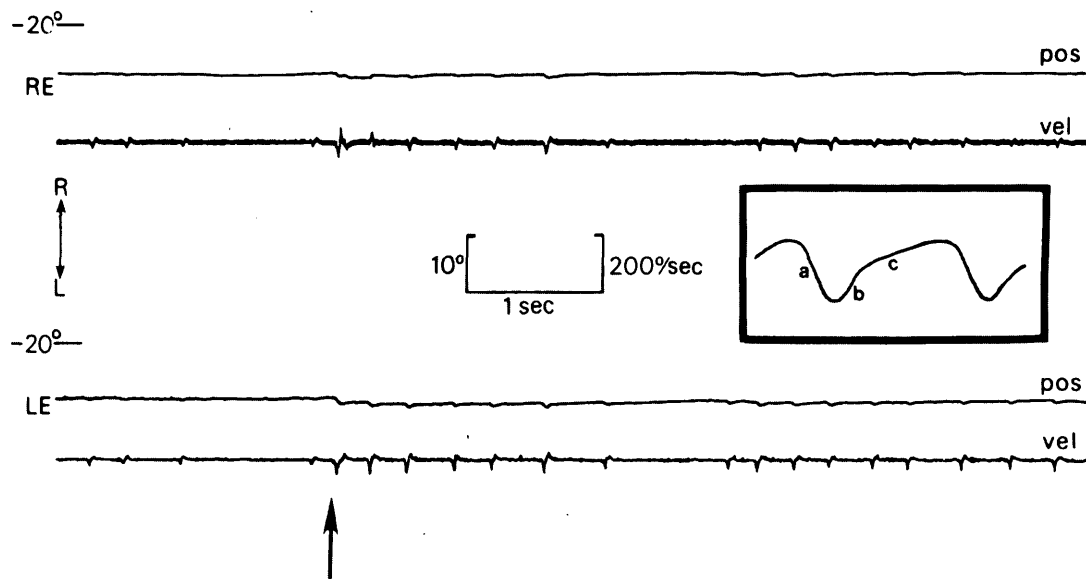


Fig. 1. Subject 5, second recording. End-point nystagmus seen during maintained gaze at 30° and 31° to the left (arrow indicates refixation from 30° to 31°). Note greater amplitude in abducting eye. *Inset:* Schematic drawing of typical end-point nystagmus beat, illustrating (a) fast phase saccade, (b) dynamic overshoot saccade, (c) linear slow phase. *pos*, Position; *vel*, velocity.

over the small range of gaze angles used in this study. The amplitude was usually greater in the abducted eye and often not discernible in the adducting eye. Frequency generally ranged from 1 to 2.8 Hz. The waveforms were jerk with fairly linear slow phases. Dynamic overshoots were frequently evident in the nystagmus fast phases (Fig. 1), requiring a short saccade to return the eyes to target. The latter saccade was particularly evident in the velocity tracings. Also seen in Fig. 1 is the greater amplitude of the nystagmus in the abducting eye. In Fig. 2 gaze was being maintained at 35°, during which the amplitude decreased and the frequency increased. Dynamic overshoots are again quite evident. The gaze angle was quite fatiguing for the subject, and the eyes drifted medially. At the end of the recording, he was unable to make a voluntary saccade to the proper lateral position. Also seen in Fig. 2 is the transition from a jerk to a cycloidal waveform as fatigue increased. The waveform variability is apparent in Fig. 3, which shows alternation between jerk-right, divergent, and jerk-left nystagmus.

Subject 6 developed nystagmus at 30° only

after 1 min but showed nystagmus within 2 sec of beginning 35° gaze, thus demonstrating both fatigue and sustained end-point nystagmus. Subject 7 developed nystagmus at 35° deviation only after almost 4 min of sustained gaze. He was the only subject to demonstrate fatigue nystagmus alone. The characteristics of the fatigue nystagmus were otherwise unremarkable (Table I).

One of the three subjects recorded in darkness had no nystagmus during fixation and none developed in the dark. The other two subjects (5 and 6) were exhibiting end-point nystagmus as the lights were extinguished. The nystagmus initially retained its linear waveform but increased greatly in amplitude. The eye movements then changed to a coarse, irregularly pendular waveform, with the abducting eye drifting in nasally while the adducting eye turned farther out.

Discussion

Seven of the 12 studied subjects developed persistent end-point nystagmus. Six had nystagmus with no or a short latency interval and were classified as sustained end-point nys-

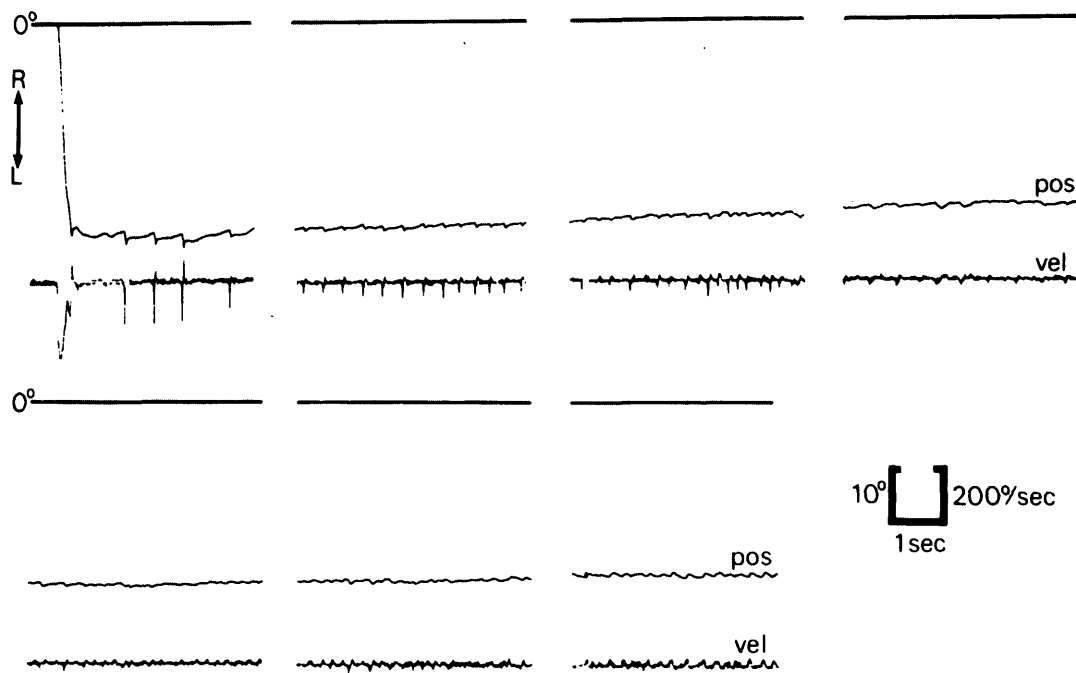


Fig. 2. Subject 5, second recording. Record from left eye during gaze 35° left. Gaps between segments of record are 4 sec. Note medial drift, decreased amplitude, increased frequency, and changed waveform with time.

tagnus. One had nystagmus after almost 4 min of deviation and was regarded as an example of fatigue nystagmus, and one showed fatigue and sustained end-point nystagmus depending on gaze angle.

One of our subjects had the onset of nystagmus at only 20° deviation. This was seen on two separate recording sessions. Although he was the oldest of our subjects (47 years of age), there was no reason to doubt that this was a physiological phenomenon. The nystagmus at 20° did not exceed 1° in amplitude nor 1.2 Hz in frequency. Such could readily be missed in a clinical examination and suggests that with sensitive recording techniques, end-point nystagmus can be detected at gaze angles considerably less than maximal. Some or all of the four subjects without nystagmus within the 40° range might have had nystagmus at more eccentric gaze angles, but our recording system could not be used beyond this point.

The subjects with end-point nystagmus who were recorded in the dark experienced difficulty maintaining the required gaze an-

gles. They reported extreme ocular fatigue and experienced a sense of bodily rotation during the effort. Their nystagmus changed to a pendular oscillation with superimposed convergence resembling that reported by Schmidt and Kommerell. The one subject with no end-point nystagmus in light was free of nystagmus in darkness and maintained the required gaze angle with virtually no drift. The possible relationship between the presence of end-point nystagmus and ability to maintain eccentric gaze in darkness requires further study.

The bandwidth of this recording technique permitted detection of dynamic overshoots, an aspect of the fine structure of saccadic eye movements not seen with more restrictive recording system.^{8a} The increasingly rotary characteristics that Nysten² observed during a sustained deviation could not be verified as rotary movements, since they are not recordable except with photographic techniques. Several subjects did report oscillopsia with vertical as well as horizontal components. We noted less intrasubject variability in two of

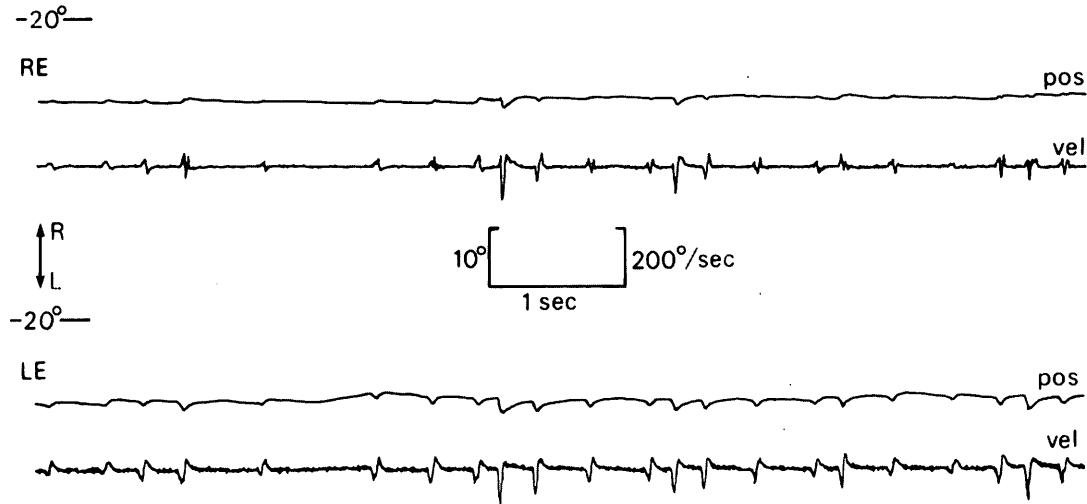


Fig. 3. Subject 1, first recording. End-point nystagmus seen during gaze 35° left. Note variability of direction and waveform in right eye, with jerks to both left and right. Also note greater amplitude in abducting eye, dynamic overshoots, and occasional exponential slow phases.

the three subjects who were recorded more than once than did Schmidt and Kommerell.⁴ The curious pattern of alternating waveforms seen in Subject 1 during her first recording session (Fig. 3) was not present during a second session.

Our study has determined that physiological end-point nystagmus is a phenomenon with variable characteristics but with certain common features of frequency, amplitude, and waveform. The term "end-point" nystagmus is a misnomer, in that sensitive recording techniques revealed nystagmus at gaze angles considerably less than maximal. These techniques also showed a waveform rather unlike the jerk with exponential slow phase seen in gaze-evoked nystagmus,^{9, 10} revealing instead a nearly linear slow phase and a fast phase with a pronounced dynamic overshoot. Only rarely was an exponential waveform seen in our records of end-point nystagmus (an example is shown in Fig. 3).

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