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Prevalence and Characteristics of Positional Nystagmus in Normal Subjects

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Abstract

Objective. In clinical practice, patients are often referred due to a finding of positional nystagmus that does not always appear to correlate with clinical symptoms of benign paroxysmal positional vertigo. To know when to consider nystagmus to be of clinical relevance, it is necessary to know the prevalence and characteristics of positional nystagmus in a healthy population.

Study Design. Case series of 75 healthy subjects.

Setting. Two tertiary referral centers in Norway.

Subjects and Methods. Seventy-five adult subjects aged 40 ± 13 years (mean ± SD; range, 21-87) without a history of vertigo or balance disorder were included from 2013 to 2015. The subjects underwent 6 different standardized positional tests in a repositioning chair. Videonystagmography was used to record eye movements. Of 1350 recordings, 1329 were included and analyzed.

Results. Positional nystagmus was detected in 88% of the subjects. The most common finding was nystagmus in the Dix-Hallpike position, which occurred in 55% of the subjects. The 95th percentile of the maximum slow-phase velocity for each subject was found to be 5.06° per second (n = 54) in the horizontal plane and 6.48° per second (n = 48) in the vertical plane.

Conclusion. Positional nystagmus is a common finding in normal subjects and occurred in 88% of the healthy subjects in the present study. Horizontal direction-changing apogeotropic or geotropic nystagmus may occur in asymptomatic subjects. However, nystagmus that is of the paroxysmal type or has a slow-phase velocity greater than approximately 5° per second in the horizontal plane or 6.5° per second in the vertical plane should be considered outside the 95th percentile.

Keywords

positional nystagmus, videonystagmography, normal population, rotational chair

Newer and more sensitive methods of nystagmus tracing lead to increased detection and referrals of dizzy patients with different types of positional nystagmus (PN), even without a clinical history of benign paroxysmal positional vertigo (BPPV). It is hypothesized that the widespread use of video Frenzel and videonystagmography (VNG) to detect PN leads to overdiagnosis of this condition, particularly if the patients are diagnosed and treated by medical personnel without sufficient clinical understanding of the disorder. Misdiagnosis may lead to poor treatment results, which in turn will tend to undermine the status of BPPV as a scientifically based and treated disease. A solution to this problem is to develop evidence-based diagnostic criteria that can reliably separate BPPV from PN as an incidental finding without clinical significance.

BPPV is characterized by brief episodes of spinning vertigo triggered by certain head positions or certain head movements. BPPV is the most common vestibular disease, and it is usually treated by canalith repositioning procedures, the reported success rate for which is 50% to 90%.[1-3] Technological advances have led to improved diagnostic and therapeutic possibilities. In particular, the widespread use of infrared video goggles for VNG has improved the sensitivity of nystagmus detection.[4] Additionally, biaxial rotational chairs allow effective treatment of certain subgroups of

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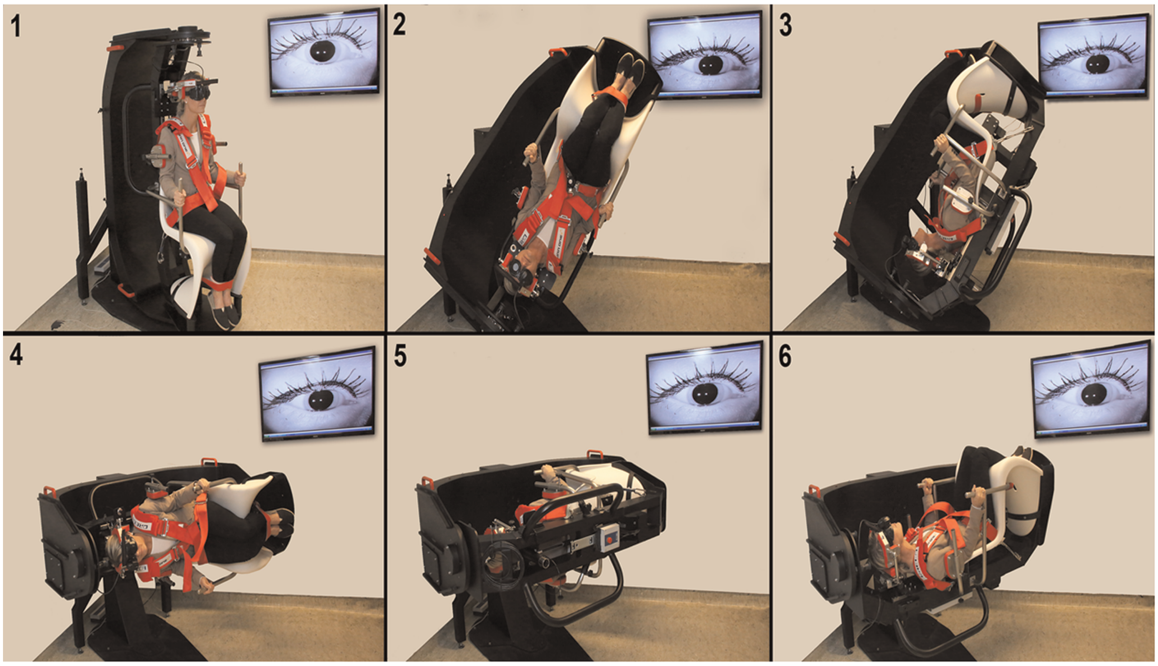

Figure 1. Positional tests: (1) upright; Dix-Hallpike, (2) right and (3) left; Pagnini-McClure, (4) right and (5) left; (6) supine.

BPPV patients who are difficult to manage on a standard examination bench.[5]

The diagnosis of BPPV is based on the demonstration of PN beating in the plane of the affected semicircular canal. Based on the current understanding of the mechanisms of BPPV, nystagmus should occur when the head is rotated in the plane of the canal around an earth-horizontal axis (canalolithiasis) or when the cupula is placed horizontally (cupulolithiasis). Nystagmus should be paroxysmal in canalolithiasis or prolonged in cupulolithiasis. This is sometimes referred to as positioning and PN, respectively. Paroxysmal PN is a short-latency burst of nystagmus that decays within 1 minute after head positioning. Prolonged PN persists after head positioning. In clinical practice, the diagnosis of PN—and, hence, BPPV—is not always clear-cut.

Pathologic nystagmus is usually defined according to direction and slow-phase velocity (SPV). With electronystagmography (ENG) nystagmus intensity defined as SPV, is sometimes considered abnormal when $\geq 6°$ per second[6-8] for nystagmus that is not direction changing within a given test position. There have been limited previous studies on PN using VNG in normal subjects, and many of these do not measure the SPV.[9-11] There are a few studies discussing the findings of the SPV in normal subjects[12,13]; however, to date, no criteria have been established to define the cutpoint levels of underlying pathology in conjugation with VNG in specific head positions. This study aims to investigate and define the 95th percentile of SPV in standardized positions.

Materials and Methods

Seventy-five adult subjects aged 40 $\pm$ 13 years (mean $\pm$ SD; range, 21-87) were included. Sixty-one percent were women. The subjects were recruited among healthy hospital staff and volunteers. Exclusion criteria were alcohol consumption within the last 48 hours, a history of neurologic or vestibular disorder, or current chronic ear disease.

The study was performed at 2 university hospitals (Bergen and Oslo). Two authors performed the examinations, and the same setup and equipment were used at the 2 centers. All subjects underwent a clinical examination, including otomicroscopy, head impulse testing, and static posturography (Synapsys, Marseille, France). The subjects were seated in a biaxial rotational chair (model TRV; Synapsys) and secured with a 4-point safety harness as well as straps for the legs. The head and trunk were stabilized with padded plates on each side to ensure that no movement in the cervical spine would occur during testing. The subjects were examined in 6 positions and instructed to keep their eyes open while looking straight ahead (**Figure 1**).

Eye movements were recorded with an infrared camera mounted in a standard VNG mask. VNG was used to record the eye movements in 3 planes via a dark pupil tracking system (Synapsys). With the mask on, the patients had no visual references. Eye movements were also visually inspected in real time on a wall-mounted monitor. Recordings of 30 seconds were taken with a sampling rate of 25 Hz each time the subject was moved into a new position. The total recording time with VNG was 3 minutes for each subject. The transition time of movement from one position to another was approximately 5 seconds. Recordings were taken from the right eye. The subjects were asked to keep their eyes open and to blink as little as possible while looking straight ahead. To keep the subjects mentally alert, they were asked various questions during the test. The subjects were asked if they had used nicotine products 12 hours prior to examination.

Table 1. Prevalence and Direction of Positional Nystagmus in Healthy Population (n = 75).

Direction of Positional Nystagmus	n	%
Horizontal		
Right beating	25	33.3
Left beating	43	57.3
Vertical		
Up beating	41	54.7
Down beating	15	20.0
Oblique	31	41.3

Table 2. Prevalence of Positional Nystagmus in 6 Head Positions (n = 75).

Position	n	%
Upright	20	26.7
Dix-Hallpike		
Right	41	54.7
Left	41	54.7
Pagnini-McClure		
Right	33	44.0
Left	33	44.0
Supine	29	38.7

Nystagmus intensity was defined as SPV, measured in degrees per second. Nystagmus seen during the transition time of movement from one position to another was ignored. Nystagmus was considered to be present when at least $\geq$5 consecutive nystagmus beats with slow and fast components were identified in each 30-second VNG sequence. Geotropic and apogeotropic nystagmus was defined, respectively, as nystagmus beating toward the lower and uppermost ear in one or both side-lying positions.

Six nystagmus time series—one in each head and body position—were recorded for each subject. The time series were further analyzed with software developed in LabView for this study. Two authors evaluated the VNG signals. If there were any doubts interpreting the nystagmus, the series were reviewed independently by 2 of the other authors. The reviewers also checked for crosstalk, to see if any of the horizontal eye movements generated software responses in the vertical channel or opposite, caused by tilt of goggles or the camera. PN was described in terms of direction as horizontal and vertical. The horizontal and vertical component of PN was quantified by VNG. Due to limitations in the VNG system's ability to measure ocular torsion, it was observed only visually.

SPSS 22.0 (IBM, Chicago, Illinois) was used for statistical evaluation. All the subjects were fully informed about the aim of the study and the test procedures. Written informed consent was obtained from all subjects. The study was approved by the Regional Committees for medical and health research ethics and registered at clinicaltrials.gov.

Results

A total of 75 participants were tested in 6 positions (**Figure 1**) producing 450 video recordings that each contained a file for horizontal, vertical, and torsional nystagmus, making a total of 1350 files. Twenty-one recordings were of insufficient quality for analysis. Of the remaining 1329 recordings, 443 torsional recordings were inspected visually, while 886 horizontal and vertical recordings were analyzed by VNG. None of the subjects reported positional vertigo during testing. All subjects had normal otomicroscopy and reported normal hearing. The head impulse test was normal in all subjects. No patients had spontaneous nystagmus when fixating with the unrecorded eye.

A complete table of the nystagmus combinations with SPVs is available in the appendix (at www.otojournal.org/supplemental). Prolonged PN was found in 88% (n = 66) of the subjects in at least 1 test position. The recordings showed nystagmus in 18% (n = 252) of the files. Nystagmus was always prolonged and never paroxysmal. In no cases were nystagmus accompanied by vertigo. All cases of different PN types were counted across the test sets and then expressed as a percentage of the total (n = 75). The most common type of nystagmus was horizontal left-beating nystagmus. The second-most common type was vertical up-beating nystagmus. Torsional nystagmus was rare (**Table 1**).

Oblique nystagmus, defined as nystagmus with a horizontal and a vertical component, was present in 12% of the recordings and in 41% of the subjects in at least 1 test position. There was a difference in prevalence of nystagmus in the different positions. The most common finding was nystagmus in the Dix-Hallpike position, which occurred in 55% of the subjects (**Table 2**). Nystagmus was detected in all 6 test positions. The prevalence of nystagmus was approximately the same in left- and right-sided positions.

In the Dix-Hallpike position, 27 of 66 subjects (41%) displayed an up-beat nystagmus. In 17 subjects, the up-beat nystagmus was present when the head was turned to both sides. In 1 subject, the up-beat nystagmus turned to down beat after sitting up.

In the Dix-Hallpike position, 3 of 66 subjects displayed a down-beat nystagmus. In 1 subject, this was present when the head was turned to either side. In no subject did the down-beat nystagmus change direction to up-beat after returning to an upright position.

In the lateral positions, 15 of 66 subjects (23%) displayed a geotropic horizontal nystagmus, but in only 2 subjects was this present in both lateral positions. In 21 of 66 subjects (32%), an apogeotropic horizontal nystagmus was observed, and in 3 subjects, this was present in both lateral positions.

The mean SPV was 2.4° per second. Four participants displayed nystagmus in all 6 positions. The 95th percentile

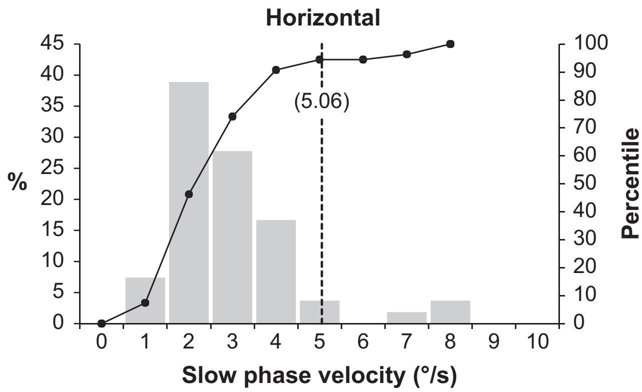

Figure 2. Slow-phase velocity of horizontal positional nystagmus in normal subjects. Histogram (gray bars and left axis) and cumulative percentage (black line and right axis). The dashed line represents the 95th percentile.

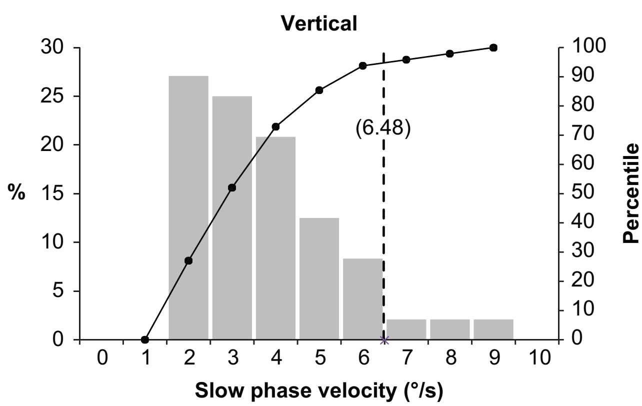

Figure 3. Slow-phase velocity of vertical positional nystagmus in normal subjects. Histogram (gray bars and left axis) and cumulative percentage (black line and right axis). The dashed line represents the 95th percentile.

of the maximum SPV for subjects with nystagmus was found to be 5.06° per second (n = 54) in the horizontal plane and 6.48° per second (n = 48) in the vertical plane (**Figures 2** and **3**).

There was no significant correlation between age and maximum SPV, neither when we included all the subjects (linear regression: P = .42, R^2 = 0.0088) nor when we included only the subjects with nystagmus (linear regression: P = .65, R^2 = 0.0052).

Discussion

This study shows that prolonged PN is a common finding in the general population and that the nystagmus pattern is variable, in some cases mimicking that of BPPV. None of the normal subjects displayed PN of the paroxysmal type, while 88% had prolonged PN. The result is important because it demonstrates the complexity, indeed difficulty, of diagnosing BPPV reliably based on PN alone. In particular, there was a high prevalence of up-beat nystagmus (41%) in the Dix-Hallpike position, which may indicate BPPV affecting the posterior semicircular canal. None of the subjects, however, reported vertigo. However, it is conceivable that the up-beat nystagmus was caused by a subclinical variety of BPPV—for example, cupulolithiasis of the posterior canal, since cupular deposits have been demonstrated in several temporal bone studies.[14-16] Indeed, in 1 subject, the up-beat nystagmus reversed direction after returning to an upright position.

Down-beat nystagmus in the Dix-Hallpike position was less common, occurring in only 5% of the subjects. Again, none of these subjects reported vertigo, and never did the nystagmus reverse direction after returning to an upright position. This questions the reliability of using down-beat nystagmus alone as a sign of anterior canal BPPV without demonstrating the typical paroxysmal time course in case of suspected canalolithiasis or nystagmus reversal in case of cupulolithiasis.

In the lateral positions, horizontal nystagmus of both geotropic and apogeotropic varieties abounded. However, nystagmus reversal, which is characteristic of BPPV affecting the lateral canal, was less common, and none of the subjects reported vertigo. This stresses the point that neutral buoyancy of the cupula should not be taken for granted in the general population. Small differences in the density of the cupula and endolymph may indeed be quite common. This was clearly shown by Tomanovic et al[17] in the case of PN after ingestion of alcohol. Only when nystagmus is of a certain velocity and accompanied by vertigo should the diagnosis of BPPV be made.

The results showed that PN occurred in 88% of the participants in at least 1 test position. Previous studies found a prevalence of 48% to 100%[9-13,18] of PN in normal healthy adults. The variability may be related to how nystagmus is defined. In the studies that found PN in 73% to 100% of the normal population,[11,13] the nystagmus definition was unclear. We chose to use the same definition as Geisler et al and Levo et al.[9,12] Both found nystagmus in 55% subjects in at least 1 test position. They performed studies of PN without standardized positions in a normal population, where PN was reported when $\geq$5 consecutive beats were detected.

Using a biaxial rotational chair has some strengths and some limitations. A strength is that positioning was performed in an exact and reproducible way. Such chairs are specifically designed to allow for precise diagnostic and therapeutic maneuvers in the plane of each semicircular canal, even in patients who are unable to cooperate for different reasons, such as decreased mobility, anxiety, and obesity. They are thus ideally suited to identify clinical or subclinical canalolithiasis or cupulolithiasis. The patient is not required to turn the head, so the neck is kept in a fixed position. This prevents cervical proprioceptive signals from interfering with the results. For these reasons, the chair offers some advantages when PN is examined as originating from the inner ear.

Another strength is related to the diagnostic maneuvers and nystagmus measurements. Previous publications of PN measured by ENG have often used static head positions rather than diagnostic maneuvers for BPPV. Yet, studies of BPPV rarely use recordings to identify and quantify the SPV of nystagmus. In this study, nystagmus was measured both immediately after the positioning and for 30 seconds, making it possible to identify and quantify both positional and positioning nystagmus.

The chair may be particularly sensitive for detection of BPPV. Aoki et al[19] found that nystagmus provocation rates were twice as high when the patient's head and body were turned together, as compared with just turning the patient's head with the positional test. In our experience, it is not uncommon to find PN of patients with suspected BPPV during examination in the biaxial chair, even after a negative examination on the bench. We hypothesize that the same may apply to the healthy population. PN after the Dix-Hallpike maneuver might vary depending on how far below the horizontal level the head is lowered. Some authorities recommend a deep, head-hanging position approximately 40° below level of the bench.[20] This is an advantage when examining the anterior semicircular canal and when performing the Epley maneuver, preventing reentry of otoliths into the inferior part of the posterior canal. In their original paper, Dix and Hallpike recommended lowering the head of the patient ''some 30 degrees below the level of the couch.''[21] We performed the Dix-Hallpike maneuver so that the head was lowered approximately 40° to 45° below the horizontal plane. Many clinicians prefer to lower the head of the patient just slightly. This is sometimes dictated by necessity, as in elderly patients with decreased neck mobility. Since the chair allows consistent head positioning, independent of neck mobility, we preferred the deep head-hanging position for the Dix-Hallpike maneuver. In our opinion, as well as others,[20] this is the ideal that one should strive for when performing the maneuver on the bench.

A consequence of using a biaxial chair is that not only the head but also the rest of the body is turned to either side, and the body ends up in a downward-tilted position during the Dix-Hallpike maneuver. Some researchers believe that somatosensory signals from the trunk affect graviception and thus might also affect nystagmus, but this is controversial.[22] One cannot exclude the possibility that factors that are unique to rotational chairs—such as the deep Dix-Hallpike position, the elimination of neck extension and rotation, and the lowering of the body—and not only the head could influence the prevalence, direction, or velocity of PN. However, previous studies of PN in normal subjects indicate a prevalence similar to ours.[7,11,13]

Barber and Wright[23] indicated that one could expect to find PN in 82% of the normal population. They used ENG with a motor-driven examination table. Nystagmus was considered present when ≥3 consecutive beats were found. This is higher than other reports of nystagmus tested with manual maneuvers.

Our study found a similar prevalence of PN in the normal population. Two subjects reported that they had been using nicotine products within 12 hours before examination. There has been research suggesting transient PN after use of nicotine products lasting up to 10 to 20 minutes.[24] Pereira et al showed that nicotine-induced nystagmus was dependent on head position and that nystagmus had a low range of SPV (range, 0.5°-3.0° per second).[25] Nicotine-induced nystagmus does not seem to occur in every subject after nicotine use.[26] The documentation of nystagmus hours after smoking is controversial. We included the 2 subjects who reported that they had been using nicotine products hours before examination. The nystagmus found in these subjects did not differentiate from the rest of the group. It is, however, interesting to notice that both subjects displayed nystagmus under testing.

We found a high prevalence of vertical up-beating and horizontal left-beating nystagmus. This also correlates with other studies.[7,18] A significant torsional component was rare. It has been speculated that the predominance of left-beating nystagmus is an adaptation to reading from left to right.[27] The sequence of the positions should also be considered, but the order was not the same in these studies.

Guidelines on ENG interpretation sometimes give normal limits of nystagmus velocity, persistence, as well as limits on the number of head positions in which nystagmus is supposed to occur. For example, nystagmus is considered to be significant when it has a SPV >5° per second in 1 position or <6° per second and is persistent in at least half the positions tested or intermittent in all positions tested. Some authors consider nystagmus that is suppressed by visual fixation to provide evidence of a nonlocalized peripheral vestibular disorder.[8] It has been debated whether the same limits should apply to VNG.[28,29] VNG is generally thought of as more sensitive than ENG due to higher spatial resolution and greater stability.[29] The VNG recordings can be recalled as needed for later analyses. Currently there is no established normal limit for measuring vertical or torsional nystagmus with VNG. We found a 95th-percentile SPV value of 5.06° per second for horizontal nystagmus and a value of 6.48° per second for vertical nystagmus, suggesting 95th-percentile SPV value may vary depending on direction (horizontal/vertical). This correlates with earlier findings.[18,29]

Torsional PN seems to be rare in the normal population as referred in previous studies; however, video-based systems continue to have problems measuring the torsional component precisely. Scleral search coils may be necessary to obtain accurate measures of torsional nystagmus components, but for practical reasons, this method is rarely used in the clinic.

Brandt[30] recommends an observation period of 20 seconds after positioning maneuvers to allow positioning nystagmus (during and right after movement) to be clearly differentiated from true PN. We observed all our subjects for 30 seconds in each test position and found that the nystagmus was persistent during 30 seconds in all of the cases. This indicates that nystagmus of the paroxysmal type is less common in healthy subjects. For this reason, particular care should be exercised when diagnosing conditions such as cupulolithiasis (heavy cupula) or light cupula, in which nystagmus is persistent.

It has been theorized that subjects without BPPV symptoms might still have asymptomatic debris in their semicircular canals or attached to the cupula, with one theory being that the amount of debris is too small to cause classic symptoms.[31] In this study, 2 subjects displayed a geotropic horizontal nystagmus, and 3 subjects displayed apogeotropic horizontal nystagmus that was present in both lateral positions. This finding might easily have been taken as a sign of cupulolithiasis of the lateral canal if presented with symptoms. None of them had any problems with vertigo, and the SPV was approximately 2° per second. No subject reported motion sickness or discomfort during the procedure.

Conclusion

PN is a common finding in normal subjects and occurred in 88% of healthy subjects in the present study. Horizontal direction-changing apogeotropic or geotropic nystagmus may occur in asymptomatic subjects. However, nystagmus that is of the paroxysmal type or has a SPV greater than approximately 5° per second in the horizontal or 6.5° per second in the vertical plane should be considered outside the 95th percentile.

Author Contributions

Camilla Martens, designed study, collected data, analyzed data, wrote article; **Frederik Kragerud Goplen**, designed study, revised article, analyzed data; **Karl Fredrik Nordfalk**, collected data, revised article; **Torbjørn Aasen**, analyzed data, revised article; **Stein Helge Glad Nordahl**, designed study, revised article, analyzed data

Disclosures

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Supplemental Material

Additional supporting information may be found at http://otojournal.org/supplemental.

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