Development of a Smartphone-Assisted Nystagmus Recording System to Record Vertigo Attacks Anytime, Anywhere: A Pilot Study

Yumi Dobashi, Masao Noda, Tatsuaki Kuroda, Noriaki Miyata, Makoto Ito, Reiko Tsunoda, Hiroaki Fushiki

Submitted to: JMIR Formative Research
on: March 12, 2025

Table of Contents

Development of a Smartphone-Assisted Nystagmus Recording System to Record Vertigo Attacks Anytime, Anywhere: A Pilot Study

Yumi Dobashi[1] MT; Masao Noda[1, 2] MD, PhD; Tatsuaki Kuroda[3] MD; Noriaki Miyata[1] MT; Makoto Ito[2] MD, PhD; Reiko Tsunoda[1] MD, PhD; Hiroaki Fushiki[1] MD, PhD

[1] Department of Otolaryngology Mejiro University Ear Institute Clinic Saitama JP
[2] Department of Otolaryngology and Head and Neck Surgery Jichi Medical University Shimotsuke JP
[3] Kuroda ENT Clinic Yatsushiro-shi, Kumamoto JP

Corresponding Author:
Masao Noda MD, PhD

Department of Otolaryngology
Mejiro University Ear Institute Clinic
320 Ukiya, Iwatsuki-ku, Saitama-shi
Saitama
JP

Abstract

Background: The widespread adoption of smartphones and tablet devices, along with advancements in data communication technology, has resulted in a paradigm shift in the treatment of dizziness. External factors, such as the spread of COVID-19, have accelerated this transformation in recent years. We have been pursuing telemedicine and online medical care for treating dizziness and have developed different products and services necessary for each treatment process stage. Several patients face difficulties in accessing medical facilities during severe vertigo episodes. Furthermore, clinical findings, such as nystagmus or other symptoms, may be absent when symptoms subside by the time of their appointment.

Objective: Creating a smartphone application development designed to capture eye movements during vertigo attacks, enabling recordings at any location, including home or work.

Methods: We developed an application named “iCapNYS” that leverages the iPhone’s front camera and gyro sensor to record eye movements and head positions. This application uses features that encourage spontaneous eye movements to reduce nystagmus suppression caused by fixation. Additionally, we designed lightweight, recyclable cardboard goggles that would securely hold the smartphone and block ambient light, thereby optimizing the recording conditions.

Results: The “iCapNYS” system successfully captured subtle peripheral vestibular nystagmus in a patient with vertigo. The recorded nystagmus characteristics are comparable to those obtained using traditional infrared CCD cameras.

Conclusions: This application is an effective tool for treating vertigo and is easy for the elderly to use, as it can be recorded with only three taps. We expect that the introduction of this nystagmus-monitoring system will improve vertigo treatment quality, promote medical collaboration, and provide patients with peace of mind in their care.

(JMIR Preprints 12/03/2025:73811)
DOI: https://doi.org/10.2196/preprints.73811

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✓ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**

Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http
No. Please do not make my accepted manuscript PDF available to anyone.

Original Manuscript

Original Paper

Development of a Smartphone-Assisted Nystagmus Recording System to Record Vertigo Attacks Anytime, Anywhere: A Pilot Study

Abstract

Background: The widespread adoption of smartphones and tablet devices, along with advancements in data communication technology, has resulted in a paradigm shift in the treatment of dizziness. External factors, such as the spread of COVID-19, have accelerated this transformation in recent years. We have been pursuing telemedicine and online medical care for treating dizziness and have developed different products and services necessary for each treatment process stage. Several patients face difficulties in accessing medical facilities during severe vertigo episodes. Furthermore, clinical findings, such as nystagmus or other symptoms, may be absent when symptoms subside by the time of their appointment.
Objective: Creating a smartphone application development designed to capture eye movements during vertigo attacks, enabling recordings at any location, including home or work.
Methods: We developed an application named “iCapNYS” that leverages the iPhone’s front camera and gyro sensor to record eye movements and head positions. This application uses features that encourage spontaneous eye movements to reduce nystagmus suppression caused by fixation. Additionally, we designed lightweight, recyclable cardboard goggles that would securely hold the smartphone and block ambient light, thereby optimizing the recording conditions.
Results: The “iCapNYS” system successfully captured subtle peripheral vestibular nystagmus in a patient with vertigo. The recorded nystagmus characteristics are comparable to those obtained using traditional infrared CCD cameras.
Conclusions: This application is an effective tool for treating vertigo and is easy for the elderly to use, as it can be recorded with only three taps. We expect that the introduction of this nystagmus-monitoring system will improve vertigo treatment quality, promote medical collaboration, and provide patients with peace of mind in their care.

Keywords: Dizziness; Telemedicine; Vertigo; “iCapNYS” system

Introduction

Vertigo and dizziness are symptoms of various disorders, including peripheral vestibular, central, cardiovascular, and psychogenic disorders. The lifetime prevalence of episodic vertigo is estimated to range from 3% to 10% [1]. The incidence of benign paroxysmal positional vertigo (BPPV) is estimated to be 0.06%–0.6% per year, whereas those of Meniere’s disease and vestibular migraine are estimated to be 0.12%–0.5% and 0.98%, respectively [1]. These conditions, which lead to repetitive episodic vertigo attacks, reduce the patients’ quality of life by causing nausea and vomiting, accompanied by headaches or an increased risk of falls [2]. Despite the established diagnostic criteria, the transient nature of vertigo often precludes a definitive diagnosis during clinical assessments owing to the absence of observable oculomotor abnormalities. Eye movement observations during vertigo attacks are extremely useful for differentiating between these diseases [3,4].
Previous studies have attempted to record eye movements during attacks using the recording

function of cell phones for diagnosing Meniere's disease [5]. Recently, the rapid spread of information and communication technology and the development of data communication technology owing to the widespread use of smartphones and tablet devices have resulted in online medical care and telemedicine, while external factors, such as the spread of COVID-19, have further accelerated this transformation [6-8]. Shah et al. reported a case in which eye movement videos captured using a smartphone were used to diagnose benign paroxysmal positional vertigo [9]. Nonetheless, challenges remain in capturing recordings under low-light conditions using smartphones, which limits the universal applicability of these methods [10].

We recently devised a simple eye-movement recording system that combines a commercially available mini-infrared camera with 3D printer goggles to record eye movements at home using smartphones [11]. This system allows patients to record their eye movements during vertigo attacks in the dark and provides recorded information to their doctors from home. However, its widespread adoption and ease of use were limited because the device had to be distributed to patients. This study devised an eye movement recording system that uses an iPhone to record eye movements during a vertigo attack. We report the production of an iPhone application that enables the observation and recording of eye movements and head position as well as a pair of light-shielding goggles made of cardboard specially designed to hold the iPhone. This system is expected to improve vertigo treatment quality by enabling nystagmus monitoring, irrespective of the location and time.

Methods

Application "iCapNYS" that captures the eye movement and head position

We developed the "iCapNYS" application to record eye movements and head positions using the iPhone's front camera and built-in gyro sensor. The application is available for download from the Apple Store under the title "iCapNYS." From the time the application was launched, the recorded eye movements can be checked with only three taps: Firstly, after launching the application, the red circle button in the center of the screen is to be tapped to immediately start recording (Figure 1A, 2A). Next, the center of the screen is to be tapped again to end the recording (Figure 1B and 2A). Third, the last recorded video can be played back by tapping the thumbnail in the upper-right corner (Figure 1C, 2A).

The list of videos can be displayed by tapping a button below (Figure 1D). Next, an item can be tapped to play it (Figure 1E) or swiped left to delete it (Figure 1F). Additionally, videos are saved in "iCapNYS" albums and can be managed in the Photos application. The recorded videos could be sent to medical professionals using the mail button in the lower-left corner of the video playback screen (Figure 1G).

"Cardboard Light-Shielding Goggles" for iPhone

We devised a pair of light-shielding goggles made of recyclable cardboard (Wako Shiki Co., Ltd., Japan) to maintain a good positional relationship between the eyeball and iPhone and enable a more reliable recording of eye movements. The assembly time was approximately 1 min (Supplementary1 Videos). The cardboard light-shielding goggles consist of two parts: a holder for the iPhone and the main body of the goggles, which can be easily assembled by the user. The iPhone running the application was placed in the holder, and goggles were placed on top for recording. The goggles were made of a special light-shielding cardboard to hold the iPhone in place, enabling more accurate recording of head position changes than direct handheld recording, and also allowing for recording eye movements in bright light (Figure 2B). Patients can record their eye movements during head

position changes by following the automatic voice guidance by switching to the “automatic 90-seconds” mode with video commentary from the “selfie camera” in the lower right corner of the “iCapNYS” application.

A case study on nystagmus detectability

To clarify the detection capability of this system for pathological nystagmus, an 82-year-old woman with left-sided Ménière’s disease was recorded for nystagmus during a vertigo attack. Additionally, the nystagmus appearance was compared under infrared video Frenzel glasses and the iPhone application, “iCapNYS” under light-shielding cardboard goggles. The patients were fully informed of the purpose of the study, its contents, and the handling of the findings, and written informed consent was obtained. This study was approved by the Mejiro University School of Medicine Research Ethics Review Committee (24Medicine-007). Video recordings were performed in the supine position for approximately 30 s while wearing light-shielding goggles made of cardboard and video Frenzel glasses. Each video was recorded separately. Figure 3 shows the nystagmus waveforms. The iPhone application “iCapNYS,” housed in a pair of light-shielding goggles made of cardboard, was used to record the fine peripheral nystagmus of a patient with vertigo. Peripheral nystagmus was also recorded and compared using infrared video Frenzel glasses (Supplementary 2 Video).

Discussion

Repetitive episodic vertigo attacks can occur in daily life, irrespective of the location or time. However, dizziness and abnormal results are not always present in patients with vertigo, and several cases exist that are difficult to differentiate or do not result in a definitive diagnosis. In such cases of episodic attacks, it is necessary to differentiate between Meniere’s disease, vestibular migraine, and other conditions. Therefore, it is extremely useful for patients to record their eye movements during vertigo attacks using this system and provide this information to their physicians for diagnosis and differentiation.

One approach to capturing eye movements during a vertigo attack is to use video recordings from a cell phone or smartphone. For instance, Kiroglu et al. showed that recordings made with a cell phone can be used to diagnose Meniere’s disease [5]. Similarly, Young et al. showed that patients could record nystagmus during vertigo episodes using a device attached to an audio/video recorder that incorporated two infrared lights within lightweight swimming goggles [12]. They observed that if the head position was simultaneously recorded, distinguishing between normal vestibulo-ocular reflexes and the pathological nystagmus seen in BPPV would be possible, thereby increasing the diagnostic accuracy. In the diagnosis of vertigo, confirming spontaneous nystagmus under non-attentive conditions is especially critical [13].

Our system addresses these difficulties by leveraging a geolocation sensor already integrated into an iPhone, removing the requirement for patients to manually record their head positions. Moreover, it eliminates the necessity for pre-arranged tests, such as the Dix–Hallpike or roll test, as patients can simply record a video with their smartphone. This enables them to verify that the nystagmus has been adequately captured, and practice recordings can be made and deleted as required.

The “iCapNYS” iPhone application was specifically designed to reduce gaze-induced nystagmus suppression, enabling patients to record spontaneous eye movements in a non-fixating state during a vertigo attack. The “iCapNYS” does not require being in a dark room and can record even when directly held in front of the patient’s eyes. Moreover, recording stable eye movements is possible using cardboard light-shielding goggles. Recent studies have underscored the potential of deep

learning systems as well as other smartphone-based diagnostic tools for detecting nystagmus [14,15]. Shah et al. showed that remote specialists can use smartphone-recorded eye movements to diagnose BPPV [9]. Our system is designed to be operated as easily and accurately as possible by patients themselves during a vertigo attack. This allows patients to record their eye movements during vertigo attacks irrespective of the location or time. Additionally, the ability to monitor nystagmus improves the quality of medical care and accuracy of diagnosis. The introduction of this technology into telemedicine is expected to help build a sense of security and trust between patients and physicians (Figure 4).

Limitation

Despite these promising developments, the proposed system has certain limitations. The present assessment was based on a single case study, which may not completely represent a broader patient population. Additionally, variations in smartphone hardware and ambient lighting conditions can influence the recording quality, and relying on patients to operate the system during an acute vertigo episode may be challenging, especially for individuals with limited technological proficiency.

Conclusion

Herein, we developed an innovative eye-movement recording system that uses a patient's iPhone during a vertigo attack. The system comprises an "iCapNYS" application that captures eye movements and head positions, along with a pair of cardboard light-shielding goggles specifically designed for the iPhone. We recorded the nystagmus of a patient during a vertigo attack and compared the results with those obtained using conventional infrared video Frenzel glasses to examine the system's effectiveness. Our findings indicate that the nystagmus frequency and slow-phase velocity recorded using the "iCapNYS" system were comparable to those captured using traditional methods, with similar visual characteristics observed in both sets of recordings. This system is extremely useful for treating vertigo, as it allows patients to easily record their eye movements and share data with their physicians at any time and location. We anticipate that the widespread adoption of this nystagmus-monitoring system, particularly when integrated into telemedicine, will increase vertigo treatment quality and ultimately foster greater patient confidence and trust.

Acknowledgements

We thank Editage (www.editage.com) for the English language editing.
This work was supported by JST Grant No. JPMJPF2403.

Conflicts of Interest

None declared.

Abbreviations

JMIR: Journal of Medical Internet Research
RCT: randomized controlled trial

References

1. Murdin L, Schilder AG. Epidemiology of balance symptoms and disorders in the

community: a systematic review. Otol Neurotol 2015;36(3):387-392. doi: 10.1097/MAO.0000000000000691. PMID: 25548891.
2. Mendel B, Bergenius J, Langius A. Dizziness symptom severity and impact on daily living as perceived by patients suffering from peripheral vestibular disorder. Clin Otolaryngol Allied Sci 1999;24(4):286-293. doi: 10.1046/j.1365-2273.1999.00261.x.
3. Sung KB, Lee TK, Furman JM. Abnormal eye movements in patients with dizziness. Neurol Clin 2005;23(3):675-703, v. doi: 10.1016/j.ncl.2005.01.006. PMID: 16026671.
4. Kim JS, Newman-Toker DE, Kerber KA, et al. Vascular vertigo and dizziness: Diagnostic criteria. J Vestib Res 2022;32(3):205-222. doi: 10.3233/VES-210169. PMID: 35367974. PMCID: PMC9249306.
5. Kıroğlu M, Dağkıran M. The role of mobile phone camera recordings in the diagnosis of Meniere's disease and its pathophysiological implications. J Int Adv Otol 2020;16(1):18-23. doi: 10.5152/iao.2019.6605. PMID: 32066548. PMCID: PMC7224432.
6. Noda M, Kuroda T, Nomura A, et al. Smartphone-assisted medical care for vestibular dysfunction as a telehealth strategy for digital therapy beyond COVID-19: A scoping review. JMIR MHealth UHealth 2023;11:e48638. doi: 10.2196/48638.
7. Barahim Bastani P, Saber Tehrani AS, Badihian S, et al. Self-recording of eye movements in patients with amyotrophic lateral sclerosis using a smartphone eye-tracking app. Digit Biomark 2024;8(1): 11-119. doi: 10.1159/000538992. PMCID: PMC11250669.
8. Parker TM, Badihian S, Hassoon A, et al. Eye and head movement recordings using smartphones for telemedicine applications: measurements of accuracy and precision. Front Neurol 2022;13:789581. doi: 10.3389/fneur.2022.789581. PMCID: PMC8975177.
9. Shah MU, Lotterman S, Roberts D, Eisen M. Smartphone telemedical emergency department consults for screening of nonacute dizziness. Laryngoscope 2019;129(2):466-469. doi: 10.1002/lary.27424. EPub PMID: 30478898.
10. Melliti A, van de Berg M, van de Berg R. Capturing nystagmus during vertigo attacks using a smartphone: adherence, characteristics, pearls, and pitfalls. *J Neurol* 2023;270(12):6044-6056. doi: 10.1007/s00415-023-11965-y. PMID: 37653139.
11. Sakazaki H, Noda M, Dobashi Y, et al. Monitoring nystagmus in a patient with vertigo using a commercial mini-infrared camera and 3D printer: A cost-effective case report. JMIR Form Res 2025;9:e70015. doi: 10.2196/70015. PMID: 40014039; PMCID: PMC11884307.
12. Young AS, Lechner C, Bradshaw AP, et al. Capturing acute vertigo: A vestibular event monitor. Neurology 2019;92(24):e2743–e2753.
13. Karlsen EA, Goetzinger CP, Hassanein R. Effects of six conditions of ocular fixation on caloric nystagmus. Arch Otolaryngol 1980;106(8):474-476. doi: 10.1001/archotol.1980.00790320026007. PMID: 7396793.
14. Wagle N, Morkos J, Liu J, et al. aEYE: A deep learning system for video nystagmus detection. Front Neurol 2022;13:963968. doi: 10.3389/fneur.2022.963968. PMID: 36034311. PMCID: PMC9403604.
15. van Bonn SM, Behrendt SP, Pawar BL, et al. Smartphone-based nystagmus diagnostics: development of an innovative app for targeted detection of vertigo. Eur Arch Otorhinolaryngol 2022;279(12):5565-5571. doi: 10.1007/s00405-022-07385-9. EPub. PMID: 35451613. PMCID: PMC9023692.

Figure legends

Figure 1. How to use the “iCapNYS” application.

A. Tap the red circle button in the center of the screen to start recording; B. Tap the center of the screen again to end recording; C. Tap a thumbnail to check the recorded video; D. Display the video list; E. Select and playback; F. Swipe left to delete; G. Send the video.

Figure 2. Eye movement video recording during vertigo attacks.
A. Iff you want to record easily or can darken the room, B. If you want to record more reliably or if the room is brightly lit.

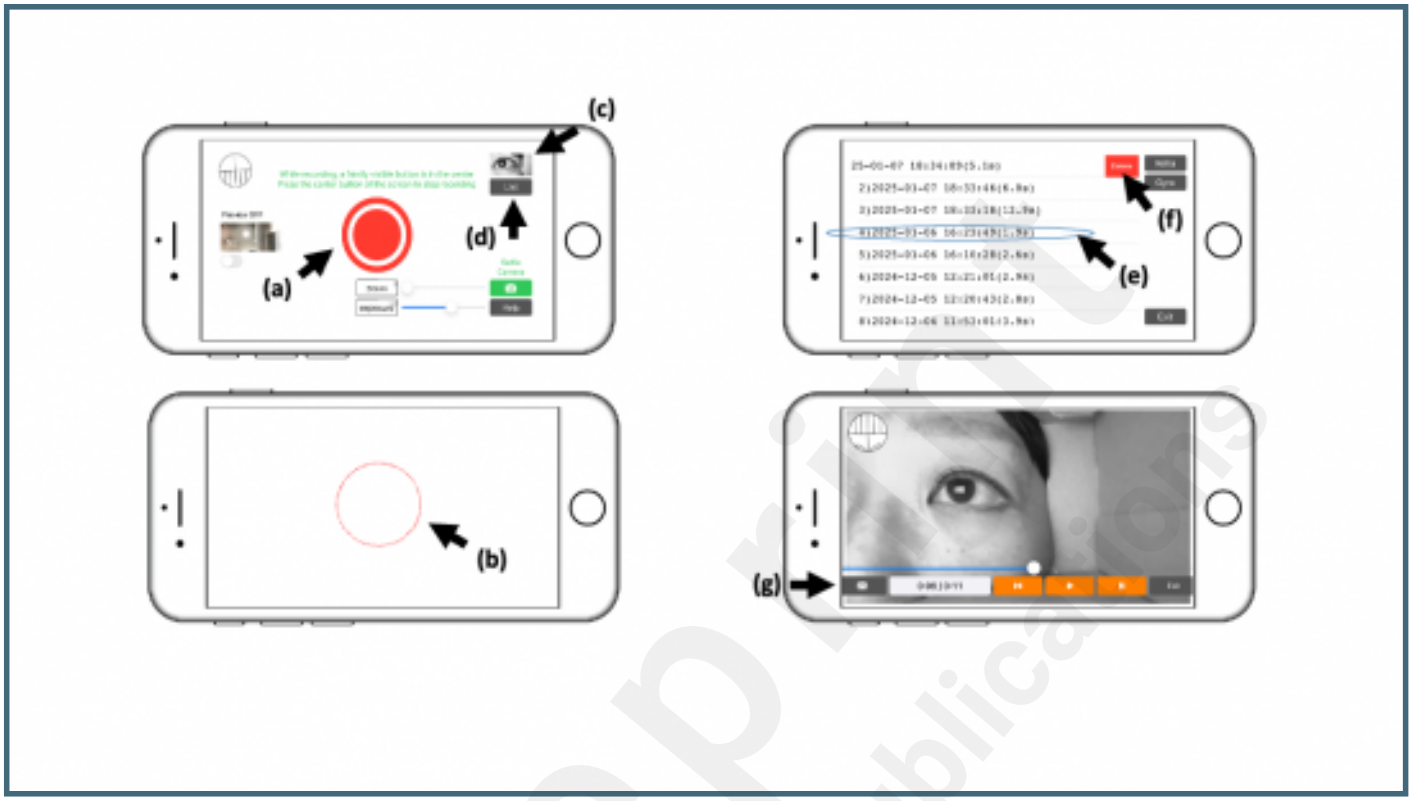
Figure 3. Spontaneous nystagmus in an 81-year-old woman with vertigo.
A. Infrared CCD camera, B. iPhone application, “iCapNYS” Nystagmus was simultaneously recorded with electronystagmography (ENG) in the supine position. Upper panel: Eye position. Lower panel: Eye velocity waveform.

Figure 4. Image of “iCapNYS” used in episodic vertigo of unknown cause.

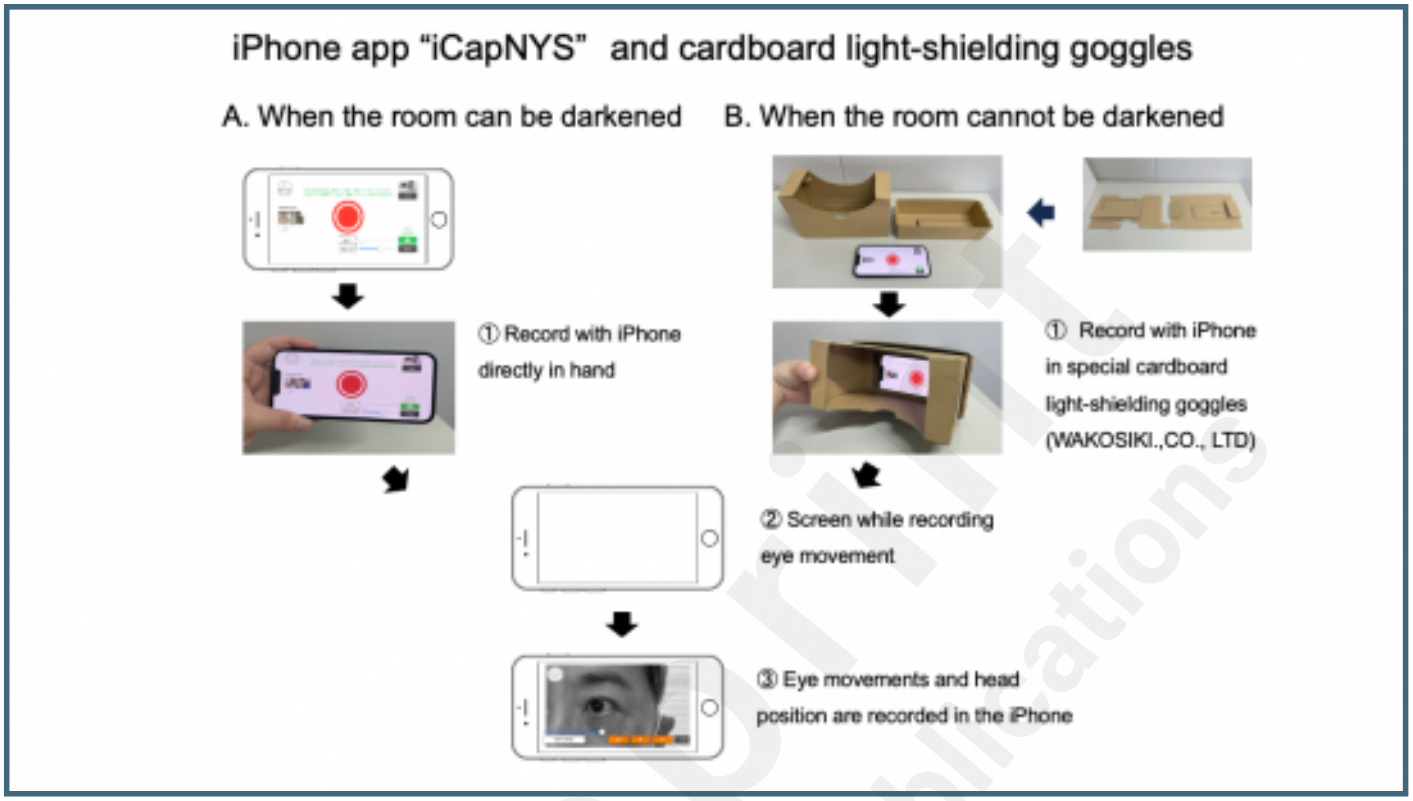
Supplementary Files

Figures

How to use the “iCapNYS” application. A. Tap the red circle button in the center of the screen to start recording; B. Tap the center of the screen again to end recording; C. Tap a thumbnail to check the recorded video; D. Display the video list; E. Select and playback; F. Swipe left to delete; G. Send the video.



Eye movement video recording during vertigo attacks. A. Iff you want to record easily or can darken the room, B. If you want to record more reliably or if the room is brightly lit.



Spontaneous nystagmus in an 81-year-old woman with vertigo. A. Infrared CCD camera, B. iPhone application, “iCapNYS” Nystagmus was simultaneously recorded with electronystagmography (ENG) in the supine position. Upper panel: Eye position. Lower panel: Eye velocity waveform.

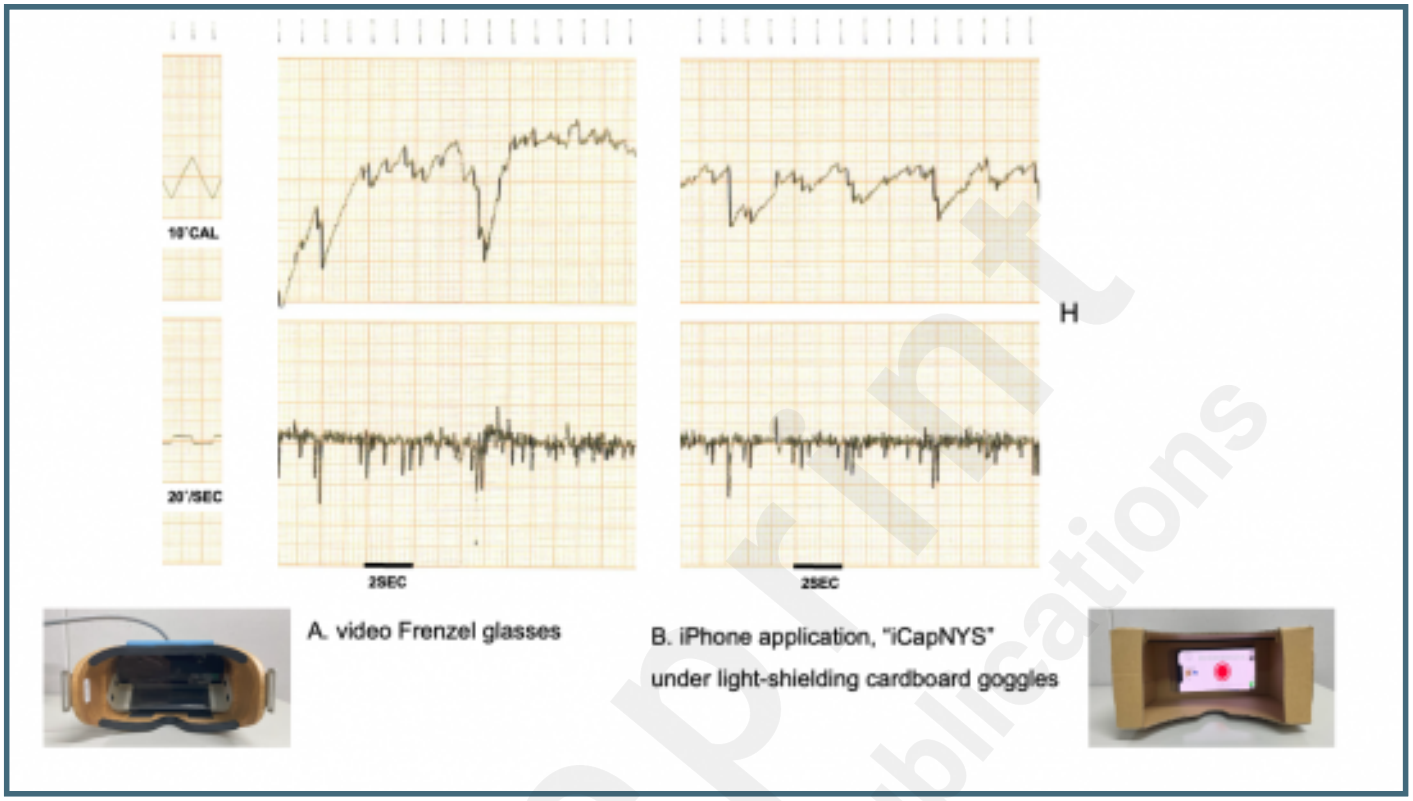
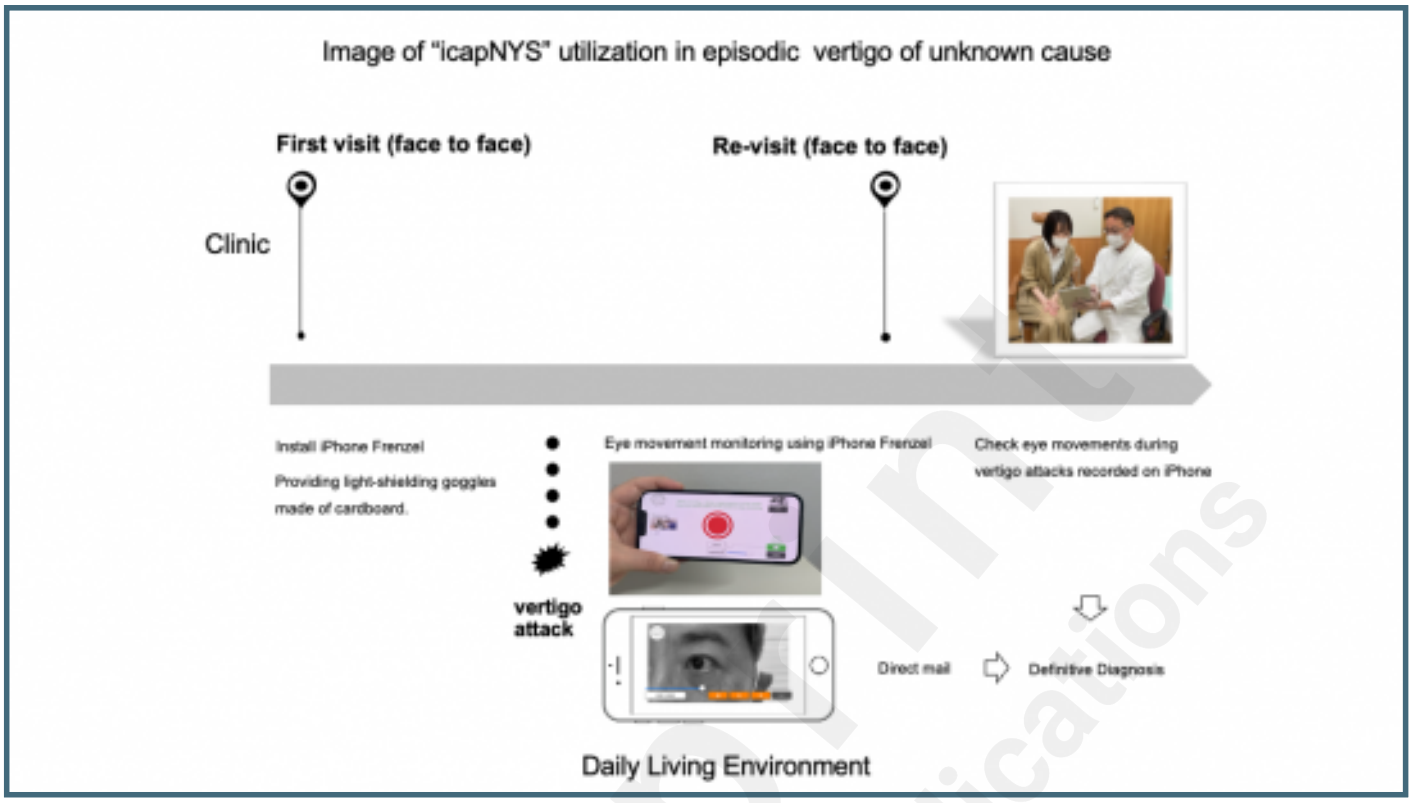


Image of “iCapNYS” used in episodic vertigo of unknown cause.



Multimedia Appendixes

Supplementary Video1.
URL: http://asset.jmir.pub/assets/bc904682586adcaa37de25694e950a4d.avi

Supplementary Video 2.
URL: http://asset.jmir.pub/assets/d65fa901c99b2774218e3cec13ac7570.avi

Supplementary Video.
URL: http://asset.jmir.pub/assets/7913049acb8396770a7ed4d8c21a692c.avi