

Clinical Evaluation of a Portable System for Capturing Nystagmus (PSCN) as an Alternative to Videonystagmography

Videonistagmografi'ye Alternatif Olarak Nistagmus'u Yakalama Konusunda Taşınabilir Bir Sistemin Klinik Olarak Değerlendirilmesi

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ABSTRACT

Objective: To develop a portable and affordable system for diagnosing pathological horizontal nystagmus (oscillatory rapid eye movement) in remote clinics. It is aimed to be a temporary alternative to the golden standard tool which is the Video Nystagmography which is expensive and office-based equipment.

Method: The team created a system composed of a hardware gadget and software application. The modified goggle with a built-in camera and microcontroller is used to record and analyze the induced nystagmus. The analyzed data is then transmitted via Bluetooth to the user portable device which displays the results. Programming PSCN, it was tested in the outpatient clinic. During the clinical evaluation of the gadget, the nystagmus was induced and recorded by the Video Nystagmography. Immediately, we repeated the experiment using the created system. Eventually, the two results were compared to set up the thresholds in the new system. After calibration, the amended algorithm of PSCN tested another ten recorded nystagmus videos to evaluate its accuracy.

Results: The portable system showed high clinical reliability during the testing in comparison to golden standard Videonystagmography. In the second stage, it showed an accuracy ratio up to 80 % during testing the ten recorded videos. It also managed to differentiate the real nystagmus from the artifacts.

Conclusion: This trial proofed the concept of portable system as an assistive diagnostic tool for pathological nystagmus. However, a more clinical trial is required to establish it as a portable alternative for the golden standard

Key Words: Otolologic nystagmus, electronystagmography, videonystagmography, portable, optical flow, application

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ÖZET

Amaç: Uzaktan kliniklerde patolojik yatay nistagmusun (osilasyonlu hızlı göz hareketi) teşhisi için taşınabilir ve uygun fiyatlı bir sistem geliştirmek. Pahalı ve ofis tabanlı bir ekipman olan Video Nistagmografi olan altın standart araca geçici bir alternatif olması amaçlanmaktadır.

Yöntem: Ekip, bir donanım aygıtı ve yazılım uygulamasından oluşan bir sistem yarattı. Dahili kameralı ve mikrodenetleyicili modifiye edilmiş gözlük, indüklenen nistagmusu kaydetmek ve analiz etmek için kullanılır. Analiz edilen veriler daha sonra Bluetooth ile sonuçları görüntüleyen kullanıcı taşınabilir cihazına iletilir. PSCN programlanması, ayaktan tedavi kliniğinde test edildi. Cihazın klinik değerlendirmesi sırasında, nistagmus, Video Nistagmografi tarafından indüklendi ve kaydedildi. Hemen, oluşturulan sistemi kullanarak deneyi tekrar ettik. Sonunda, iki sonuç yeni sistemdeki eşikleri ayarlamak için karşılaştırıldı. Kalibrasyondan sonra, değiştirilmiş PSCN algoritmasının doğruluğunu değerlendirmek için on adet başka kaydedilmiş nistagmus videosu ile test edildi.

Bulgular: Portatif sistem, test sırasında altın standart Videonistagmografi ile karşılaştırıldığında yüksek klinik güvenilirlik gösterdi. İkinci aşamada, kaydedilen on adet videonun test edilmesi sırasında % 80'e varan doğruluk oranı gösterdi. Ayrıca, gerçek nistagmus'u artefaktlardan ayırt etmeyi de başardı.

Sonuç: Bu deneme, taşınabilir sistem kavramını patolojik nistagmus için yardımcı bir tanı aracı olarak kanıtlamıştır. Ancak, altın standart için taşınabilir bir alternatif olarak belirlemek için daha klinik çalışma gereklidir.

Anahtar Sözcükler: Otolojik nistagmus, elektronistagmografi, videonistagmografi, taşınabilir, optik akış, uygulama

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INTRODUCTION

Nystagmus is a sign for many congenital or acquired disorders of many medical conditions, eye problems, and inner ear diseases. It is involuntary and rhythmic oscillations movements of the eye. Commonly, it presents in two phases: a slow initiating and a fast corrective one (jerk nystagmus). When oscillations are sinusoidal, and of approximately equal amplitude and velocity, it is called pendular nystagmus (1). In otologic nystagmus, the inner ear fluid induces the slow phase of nystagmus, and the central nervous system corrects the eye position in the fast phase (2). Nystagmus is evident in 22.6% of patients with Benign Paroxysmal Positional Vertigo (BPPV) which occurs due to aging and post-head trauma (3).

Diagnosis of these eye movements could be performed by using either Electronystagmography (ENG) or Videonystagmography (VNG). However, VNG is more convenient in investigating nystagmus because it is noninvasive as no needles or x-rays are involved (4). However, there are two main problems in using VNG. The first problem is the unavailability of this expensive and sophisticated equipment in most health centers. The second issue is the lack of the trained practitioners who could operate it (5).

The team designed a Portable System for Capturing Nystagmus (PSCN) to be a mobile, affordable and user- friendly device to address these problems.

DESIGN and DEVELOPMENT THE PROTOTYPE

A team of ENT specialists and engineers specialized in simulation and modulation, signal and image and mechanic and material worked together to develop this capturing system. PSCN has two components, a hardware gadget, and software.

The hardware of this PSCN is a modified goggle with a mounted Raspberry Pi camera connected to a microcontroller and sensors to capture the eye movements (Figure1). The module has a five megapixel with a fixed-focus camera and supports various video resolutions. In this project, the camera is programmed to capture and record the highest possible quality video recording. Within the goggle, the captured visual data is converted to the mp4 format to provide a more qualitative insight or visual presentation. The position of the pupil is obtained by multiple image processing. The summary of the process of detecting nystagmus in shown in (Figure 2).



Figure1. PSCN has two components: The goggle and the developed (APPs) downloaded in the smartphone. A power bank is used for charging the system.PSCN: Portable System for Capturing Nystagmus. APPs: an application software.

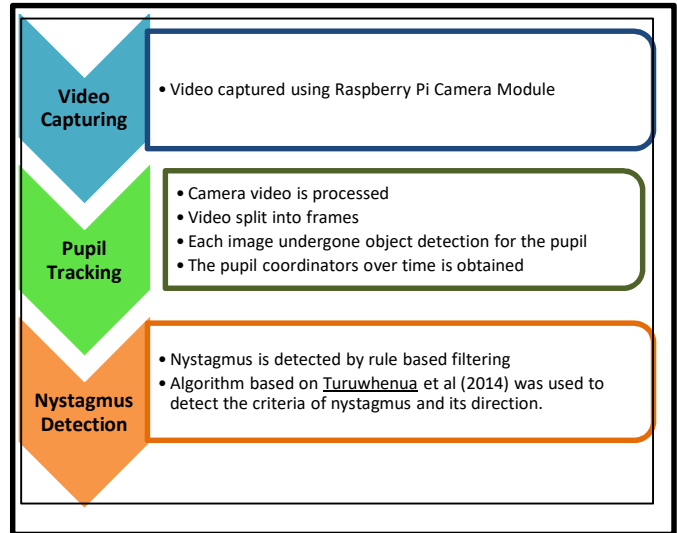


Figure 2. The flow chart for the process of detecting nystagmus. The Raspberry Pi Camera Module stands for the camera connected to a dynamic microcontroller.

The created algorithm of this software of PSCN was based on the optical flow approach introduced in 2014 by Turuwhenua’s team (6). The algorithm is the set of mathematical instructions that helps the computer to calculate a specific answer or solve a problem (7). This algorithm determines the directions of eye movements in nystagmus by detecting the changes in the pupil position. The pupil is traced by detecting the vertical edge of the limbus/iris boundary. The velocity of this edge is estimated using Lucas–Kanade optical flow. It is preferable than other approaches that track the pupil based on the contrast between the pupil and iris which is poor particularly in darker irises which severely reducing the accuracy of any pupil track (6). Because of this hypothesis, the team managed to use a standard off-the-shelf webcam to track the eye movement (6).

This algorithm was simulated in MATLAB-M (computing language) before deployed into the portable PSCN device (8). After data analysis, the final report is transmitted via Bluetooth from the wearable goggle to the user portable device which could be either a smartphone or a tablet (Figure 3). The uploaded application presents the analyzed results in a graph form with a short description to help the user to interpret the results quickly. This report could also be printed out (figure 4). The software of the developed application is designed to be user-friendly and compatible with any portable smart device using the Android platform.

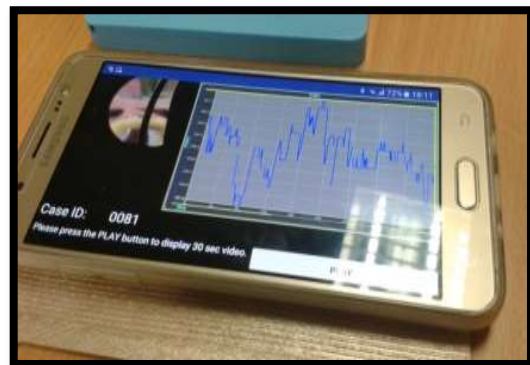


Figure 3. The developed APPs displays both the video tracking of the eye, the recorded graph and the comment on the portable android devices.

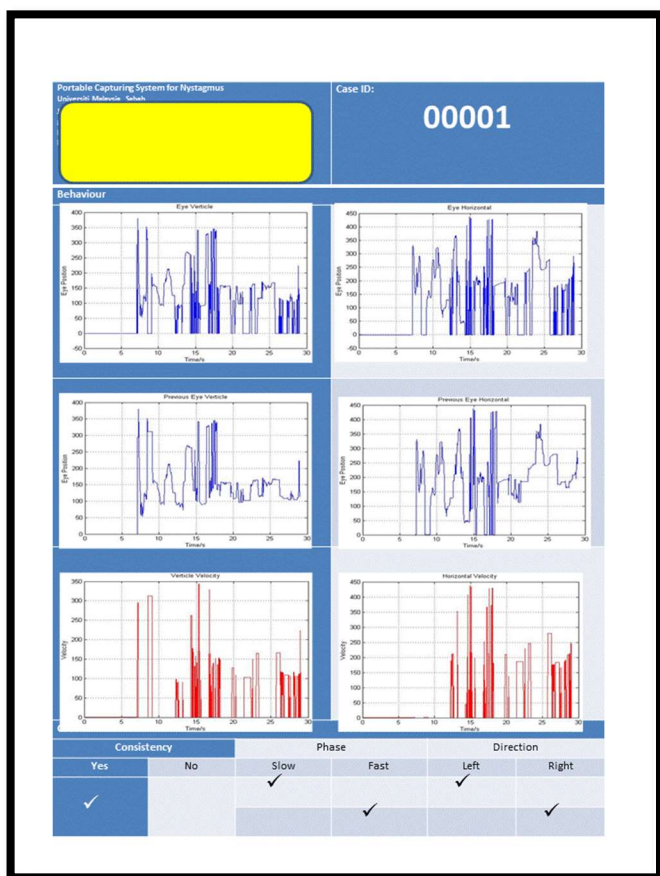


Figure 4. Final report printed after PSCN

METHODS

Firstly, The team studied 25 recorded videos and simulated subjects to determine the algorithm thresholds, parameters and to differentiate the real nystagmus movements from the artifacts ones as eye blinking. Secondly, PSCN was tested at the outpatient clinic in University Malaya clinic together with VNG. We managed to test PSCN with one patient having nystagmus. Initially, the patient signed a consent to test PSCN. After taking a complete history and excluding any clinical contraindications for performing the test, a proper otologic examination of the patient was done before testing each ear/ eye side. The position of the eye towards the camera was adjusted to ensure proper tracking of the pupil. We induced nystagmus in this experiment by using the rotation chair. The patient was tested first by the VNG followed by PSCN.

Before starting PSCN testing, the eye position was inspected using a monitor via a router. After correcting the worn camera position, the monitor was disconnected. Eventually, we compared the final reports of both VNG and PSCN to calibrate PSCN results. The patient gave her feedback upon PSCN by answering a structured questionnaire (figure 5). In the third phase of the project, we tested the accuracy of the calibrated algorithm by checking the directions and velocities of another ten recorded videos of horizontal nystagmus. An expert checked the accuracy of PSCN in detecting the nystagmus' direction by comparing its reports with the recorded videos.

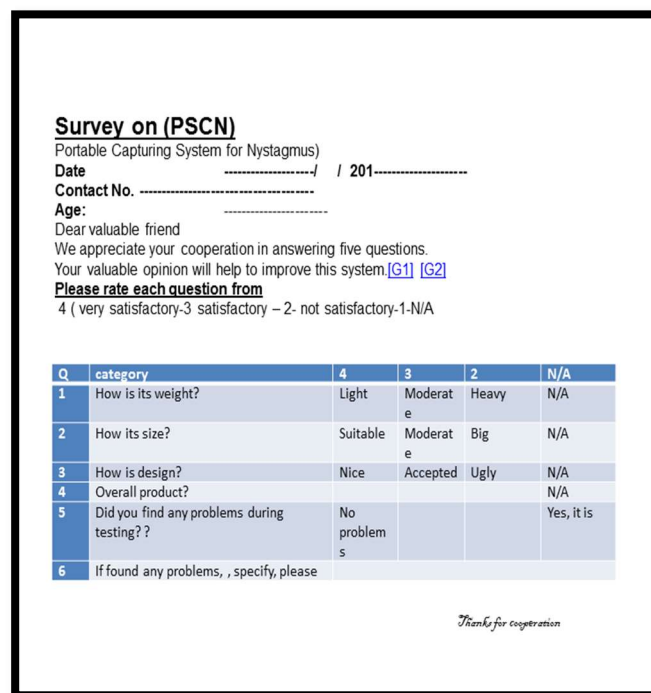


Figure 5. The patient feedback form

RESULTS

In the phase of the clinical testing, PSCN detection of both fast and slow phases of eye movements was concordant with VNG results. This comparison was essential for fine-tuning of the software. After calibration, PSCN showed an accuracy ratio up to 80 % in testing the ten recorded video cases at the laboratory. It tracked the pupil movements and detected the directions of both slow and fast phases in each saccadic direction of the nystagmus.

Also, it differentiated the real nystagmus from the artifacts. Technically, the software managed to remove the noise due to blinking. It determined the occurrence of nystagmus only when the criteria were fulfilled. The result from the comparison between MATLAB and the Pi showed that both also able to produce the same output and accurately determine the type of Nystagmus. The patient's feedback on PSCN expressed that used goggle was tolerable in weight and size and she did not encounter any problems during testing.

DISCUSSION

Overall, PSCN achieved a high degree of accuracy in detecting nystagmus and identifying its both phases during clinical and laboratory testing. VNG is considered the standard tool for diagnosing nystagmus because of its accuracy, comfortability, and consistency (2).

Unlike ENG, both PSCN and VNG are non-invasive, do not use any electrodes (3). Both systems detect eye movements by video recording using built-in cameras in the worn goggles(2). Meanwhile, VNG and PSCN are different in the type of the used cameras The former detects the eye movements by an infrared camera (5). Alternatively, PSCN uses a digital camera with complementary metal-oxide-semiconductor (CMOS) image sensor to track the eye movements in the visible light. CMOS type was chosen because it is cheaper and less power consuming than other image sensors (9).

Also, both PSCN and VNG use an algorithm to detect the saccades in the eye (6). In VNG the analysis of the data takes place in the computer wired to the goggles. Meanwhile, in PSCN, data analysis takes place in the built-in microcontroller within the goggle. That makes PSCN wireless and suitable for mobile clinics.

In both types of equipment, the user should correlate the acquired data to the patient's history, symptoms, and clinical examination to determine whether the disorder is central or peripheral (3). The nystagmus could be induced by the head thrust test to evaluate how well the eyes respond to information from the vestibular system (5).

CONCLUSION

Both PSCN and VNG use cameras to detect nystagmus movements. VNG is the standard tool used in specialized clinics, as it is expensive and requires a trained technician to operate it. On the other hand, the proposed PSCN is accurate to a great extent, portable, wireless and works offline. In addition, PSCN is compatible with the convenient android system, user-friendly, so it is a cost-effective tool. Anyhow, more clinical testing is required for fine-tuning of the system. While VNG remains the gold standard for diagnosing nystagmus, PSCN can be used in rural clinics where such VNG is unavailable to support the health services.

Conflict of interest

No conflict of interest was declared by the authors.

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