A wearable infrared videopupillography with multi-stimulation of consistent illumination for binocular pupil response

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ABSTRACT

The pupil response to light can reflect various kinds of diseases which are related to physiological health. Pupillary abnormalities may be influenced on people by autonomic neuropathy, glaucoma, diabetes, genetic diseases, and high myopia. In the early stage of neuropathy, it is often asymptomatic and difficulty detectable by ophthalmologists. In addition, the position of injured nerve can lead to unsynchronized pupil response for human eyes. In our study, we design the pupilometer to measure the binocular pupil response simultaneously. It uses the different wavelength of LEDs such as white, red, green and blue light to stimulate the pupil and record the process. Therefore, the pupilometer mainly contains two systems. One is the image acquisition system, it use the two cameras modules with the same external triggered signal to capture the images of the pupil simultaneously. The other one is the illumination system. It use the boost converter ICs and LED driver ICs to supply the constant current for LED to maintain the consistent luminance in each experiments for reduced experimental error. Furthermore, the four infrared LEDs are arranged nearby the stimulating LEDs to illuminate eyes and increase contrast of image for image processing. In our design, we success to implement the function of synchronized image acquisition with the sample speed in 30 fps and the stable illumination system for precise measurement of experiment.

Keywords: Wearable, infrared, videopupillography, binocular pupil response

1. INTRODUCTION

Eyes of people can provide some physiological information. We can apply these information analyses to detect disease. The pupil response to light is one of the most special phenomenon that is called pupillary light reflex (PLR) [1]. The amount of light is regulated through the pupil for preventing the retina from impairing that can be classified into two types: the direct and consensual response [2]. The difference between them is the response after the stimulating. One response of pupil is pupil contraction because of the direct stimulating light, this is called the direct response. Another response is pupil contraction when the opposite eye is stimulated with the lights, this is called the consensual response. In order to investigate these phenomenon of human, many research developed different instruments and experiments to analyze conducting relation of optic nerves.

The previous studies explored that pupillary abnormalities may be occurred with diabetes, glaucoma, high myopia, demyelinating disease, autonomic neuropathy, Parkinson's disease, Alzheimer's disease, and so on [3-9]. The pupil reaction is affected by afferent and efferent function. Afferent and efferent pathways of eyes are damaged by these diseases, and it impacts on optic nerve or the autonomic nerves. Because pupil size is controlled by radial and circular muscles which are innervated by autonomic nerves [10]. Thus, PLR probably can be an indirect indication of disease or quantifies conducting relation of nerves. There are many medical studies about the pupil response [11]-[15]. The response of pupil size can provide indirect methods to observe neuronal pathways because it is associated with autonomic neuropathy [16]. Pupil reactivity to light are utilized to diagnose some neurological injuries [1, 17-18]. Some correlations between the pupil response and some diseases can be explored with different stimulating light. Therefore, an infrared videopupillography is needed to measure and record the pupil size under different measurement conditions of several visible light of LED. Some pupillometers are binocular for studying conduction of nerves for eyes at the same time. However, two cameras maybe not synchronized. Therefore, this study proposes a portable and binocular pupilometer for exploring the relation between nerves for eyes.

Design and Quality for Biomedical Technologies IX, edited by Ramesh Raghavachari, Rongguang Liang
Proc. of SPIE Vol. 9700, 97000R · © 2016 SPIE · CCC code: 1605-7422/16/$18 · doi: 10.1117/12.2212799

2. METHODS

2.1 Pupillometer system

The pupillometry system utilizes a computer to control light emitter diodes (LEDs) and two cameras (CMOS camera, DFM 22BUC03) to capture the pupil images simultaneously. Figure 1 shows the schematic diagram. Microprocessor unit (MPU) controls the white (W), red (R), green (G), and blue (B) LEDs, where TABLE I. shows the specification of LEDs, for stimulating the pupil. The MPU generates a signal for enabling the LED driver for which boost converter and battery provide constant voltage to supply fixed luminance for visual lights and IR. Four infrared LEDs nearby the stimulating LEDs are used to illuminate eyes for the contrast increasing of images. The boost converter ICs and the LED driver ICs are utilized to supply the constant current. MPU adopts the method of pulse width modulation (PWM) to control the LED driver ICs for modify the luminance of four visible LEDs and the stimulation time for different designed experiments. In order to record the image of binocular pupil simultaneously, the same triggered signal are supplied by a timer IC for two IR cameras with the sample rate in 30 fps. The pupil images captured by IR cameras deliver to PC and then store in storage device. The computer not only controls the pupillometers, but also sends signal to control other modules. Besides, it is utilized to processing the pupil images to obtain the data of pupil response.

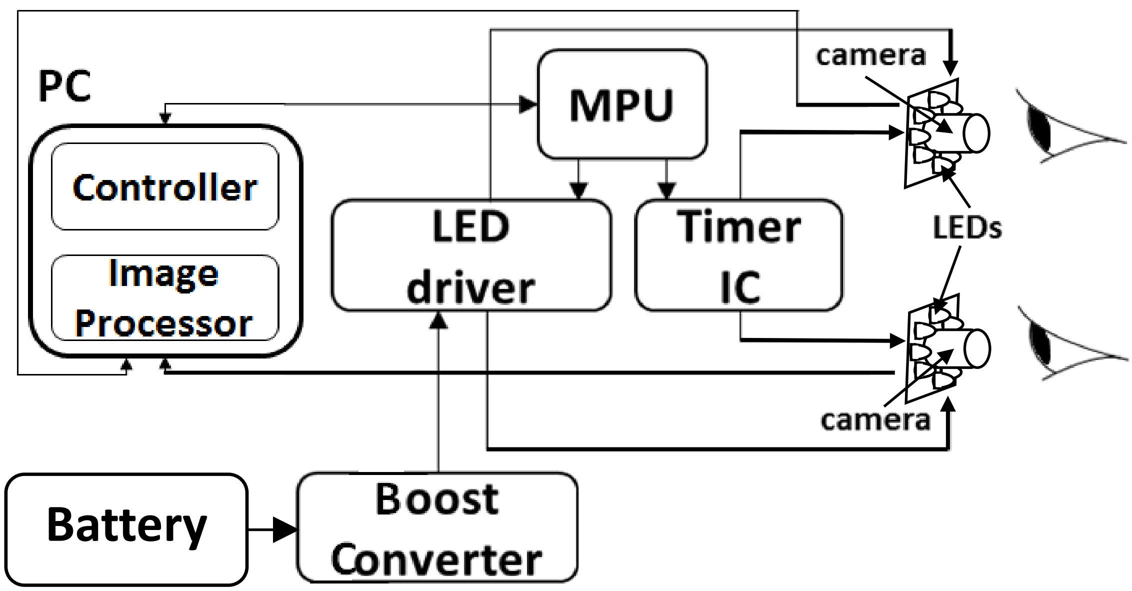

Fig. 1. The mechanism drawing of pupillometer. The device has three movable axle for different subject.

Table 1. The specification of LED

	White	*Red*	*Green*	*Blue*	*Infrared*
Wavelength(nm)	—	640	534	470	945
Stimulating time(ms)	10	10	10	10	—

The mechanism drawing of the pupillometry system is shown in Fig.2. The device has three movable axle for different subject. The volume of pupillometery is small and this device is portable. The pupillometry system could be hanged on the glasses and the positions of LED and infrared camera are shown in Fig.3.

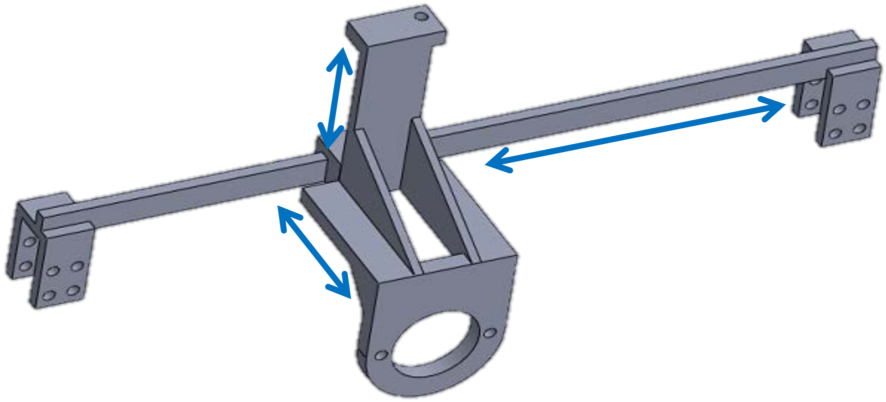

Fig. 2. The mechanism drawing of the pupillometry system

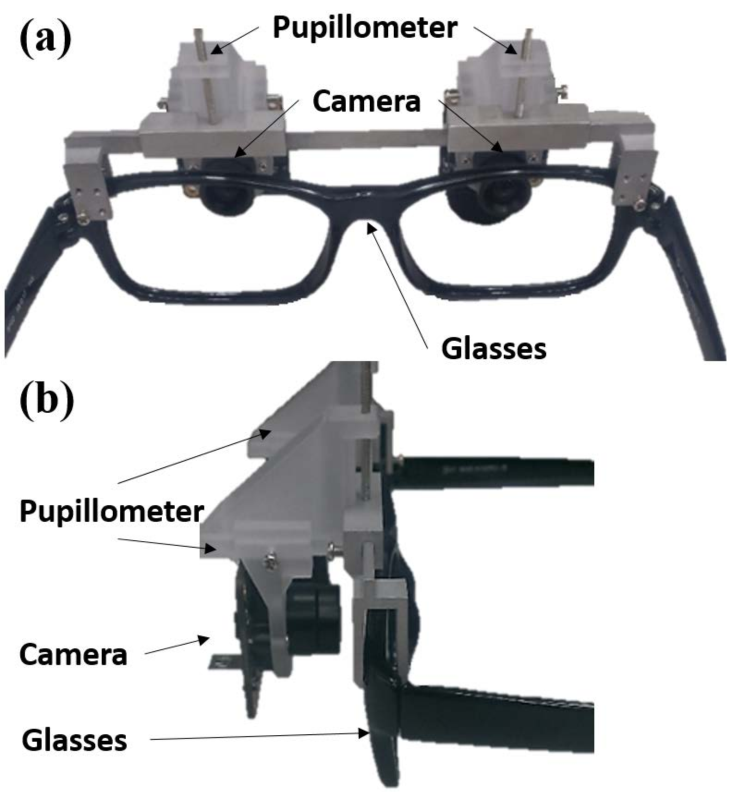

Fig. 3. (a) The front view of the pupillometer. (b) The side view of the pupillometer.

3. EXPERIMENTS AND ANALYSIS

The picture of infrared videopupillography system in the experiments is shown as Fig. 4. The pupil images are recoded and analyzed as the resulting parameters that are classified into three parts of classifications: pupil diameter, pupil response time, and pupil response speed. There are ten parameters shown in Fig. 5. The 1st parameter is the ratio of resting pupil to iris in the dark room (RPD). The 2nd parameter is the minimum pupil diameter after simulation with lighting (MPD). The 3rd parameter is the restoration to 75% resting pupil diameter (RTD). The 4th parameter is the reflex amplitude of the pupil (RFA). The 5th parameter is the latency to constriction (LTC). The 6th parameter is the time between the construction of the resting pupil at rest and the minimum pupil size (DCM). The 7th parameter is the time between the minimum pupil size and the restoration to the 75% of the resting pupil size (DRP). The 8th parameter is the time between the resting pupil size and the restoration to 75% of resting pupil size (DRR). The 9th parameter is the maximum pupil constriction velocity (MCV). The 10th parameter is the maximum pupil restoration velocity (MRV).

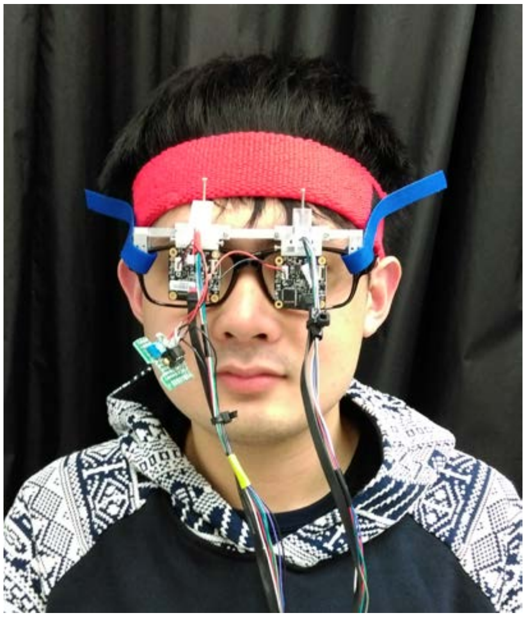

Fig. 4. The photograph to the subject wears the pupillometer.

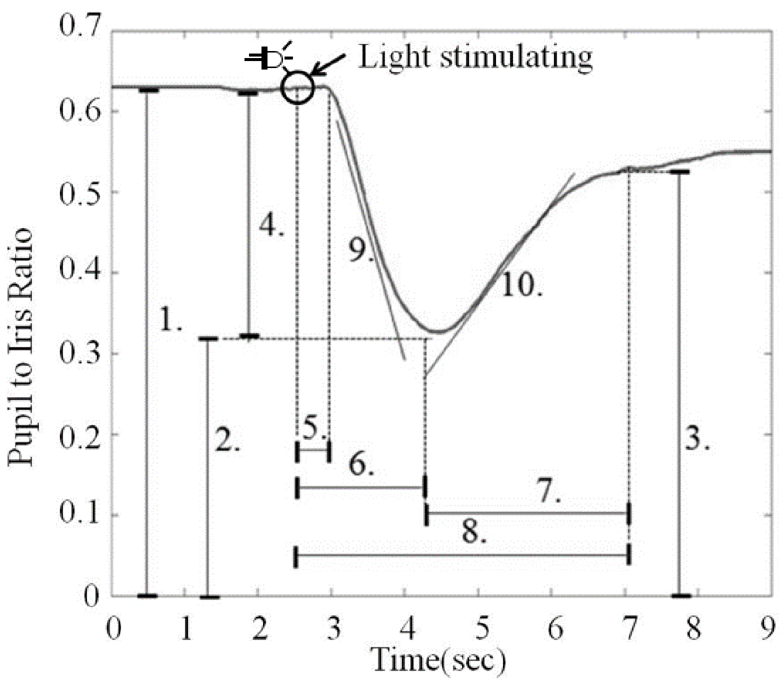

Fig. 5. The definitions of pupil response index

The demonstration experiment involved a healthy subjects aged 52 years. The four colors of visible light (white, red, green, and blue) with 500 mcd intensities stimulate the right eye to record pupil reactivities of left eye (marked with a dotted line) and right eyes (marked with a solid line) simultaneously shown in Fig. 6. RPD and LTC are the obvious parameters among 10 parameters. RPD of left and right eyes are 0.559 and 0.573. LTC of left and right eyes are 0.233 seconds and 0.2 seconds.

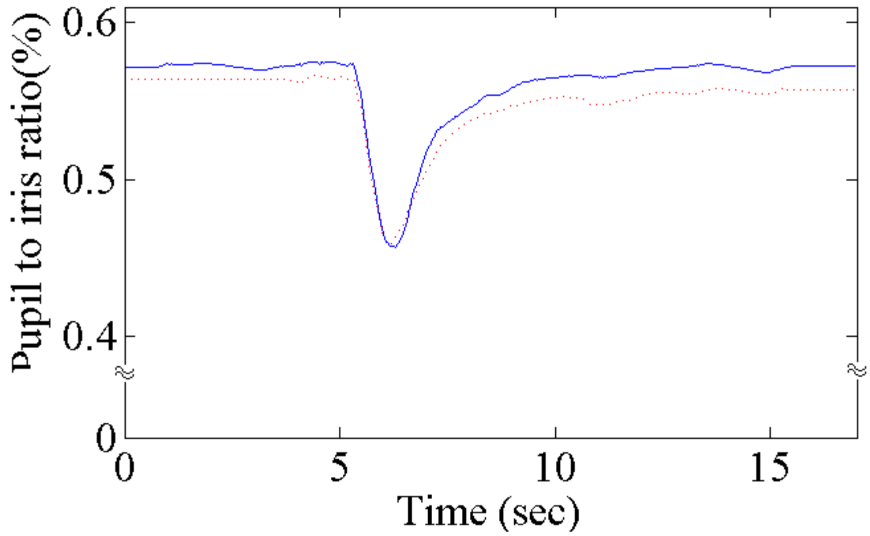

Fig. 6. The pupil reactivities of left and right eyes

4. CONCLUSIONS

In this study, we proposed a portable and binocular pupilometer that utilizes a computer to control LEDs and two cameras to capture the pupil images simultaneously. The device has 3 dimensions to modulate for different subjects. The pupillometry system could be hanged on the glasses. The experiments for one healthy subjects show that RPD of left eye is smaller than the one of right eye, and LTC of right eye is smaller than the one of left eye. The more data of pupil response from healthy and diabetic subjects will be collect in the future. We hope this new infrared videopupillography proposed in this paper can be used widely for autonomic neuropathy explorations.

ACKNOWLEDGMENTS

This paper was particularly supported by the Aim for the Top University Program of the National Chiao Tung University, Biomedical Electronics Translational Research Center of National Chiao-Tung University, Ministry of Education of Taiwan (Contract No. HCH102-39), China Medical University, the National Science Council of Taiwan (Contract No. MOST 103-2221-E-009 -190 -, MOST 104-2220-E-039 -001 -, MOST 104-2622-E-009 -015 -CC2), and Industrial Technology Research Institute of Taiwan.

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