MEASUREMENT OF DIRECT AND CONSENSUAL LIGHT REFLEX

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Abstract

The main contribution of this research is to develop of a new measuring device for measuring direct and consensual light reflex of human pupil, hence to give opportunity to map physical and mental states of the patients. In this case the pupillary light reflex means changing of diameter of pupil due to constant light stimulus as a function of time. Determination of the diameter happens by means of image processing.

Several diagnostic research consider pupillary light reflex. That is not unintentional, since for light reflex the autonomous nervous system is responsible and this provides objectivity, furthermore affects many parts of the nervous system – such as the retina, the nerves and some parts of the central nervous system – that makes suitable to find difference between several physical and mental states.

During the development process of the device being cost-effective was one of the most important aspects, so if at a point a self-developed part would have been more expensive commercially available devices were built in. In order to validate the operation of the device comprehensive tests were executed varying many parameters. In the paper both of the hardware and software aspects of the instrument are presented.

Keywords: Human eye, Pupil, Consensual light reflex, Image processing, Eye tracking system

1 Introduction

Our research aimed at developing a device to record direct and consensual light reflexes accurately, to be used in mapping the physical and mental status of patients. Pupillary light reflexes are examined by widely used diagnostic processes. However, mobile devices providing accurate measurements have not yet been developed.

Several diagnostics research projects from all over the world examine pupillary light reflexes. This type of examination is an obvious choice, as this response is regulated by the autonomous (vegetative) nervous system, thus results are objective. Also, the response is related to several parts of the nervous system such as the retina, the neural pathways and parts of the central nervous system, rendering it suitable for identifying various physical and mental conditions (Hess, 1965).

Afferent and efferent nerve fibers (carrying impulses towards the central nervous system and the organs, respectively) also play a role in the pupillary light reflex, in addition to the sympathetic and the parasympathetic autonomous nervous system, further emphasising the importance of the reflex in diagnostics. Afferent pathways play a role in the functioning of the pupillary sphincter while efferent ones define direct and consensual light reflexes. As the fibres in the motor system of the pupil cross each other at several points (both retinas are connected to both optic tracts and both optic tracts are connected to both oculomotor nuclei), stimulating one eye may generate a pupillary reflex in the other one. The relevant neurophysiological process is rather complicated as several factors influence the diameter of the pupil (such as the amount of light arriving to the retina, the condition of the retina receptors and the afferent nerve fibres, the system of nuclei in the central nervous system and the connecting neurons and the afferent parasympathetic). However, as the light input is crucial in the development of the reflex and measured results are considered relative, these are suitable for assessing the condition of tissues involved in the development of the response which in turn plays an important role in establishing the physical and mental status of patients (Moura, et al., 2013).

The afferent and efferent nerve fibres involved in the pupillary light reflex are parts of the second cranial nerve (nervus opticus). The sympathetic and parasympathetic neural stimuli carried by these regulate the pupillary constrictor (musculus sphincter pupillae) and dilator (musculus dilatator pupillae) muscles proportional to the response by the nervous system. According to the latest results, both types of muscles receive both sympathetic and parasympathetic fibres and parasympathetic inhibition plays a greater role in pupillary dilation than the sympathetic dilating effect (Somlai & Kovács, 2012).

The diameter of the pupil in complete mydriasis is 7,5 mm to 8 mm and 1,5 mm to 2 mm in complete miosis. In 17% of the population, the diameter of the two pupils differ; however, this difference is immediately visible in 4% only. The diameter of the pupil used to be determined by the Haab scale but lately the more sophisticated pupillography by infrared photography or the photoelectric method has been used increasingly (Csépe, 2007).

When illuminating the pupil, a direct light reflex may be elicited which will depend on light intensity, the wavelength of light, the duration of illumination and the actual level of adaptation. When examining the light reflex, the change in pupil diameter (the rate of contraction) as well as the time needed for this change should be determined, i.e. the change in diameter as a function of time should be established. When only one eye is illuminated, a direct light reflex will be elicited in the illuminated eye and a consensual reflex in the other one. When, however, both eyes are illuminated, the two effects will be combined and a larger miosis will be elicited (Weiler's secondary light reaction). In the case of permanent illumination, the initial large oscillation will be smoothed and the diameter of the pupil will stabilise (toned pupillary reflex). In the case of short term illumination, miosis is immediately followed by dilation (phased light reflex). Both illumination methods are consensual. Examining the afferent pupillary motor pathway also relies on comparing direct and consensual light reflexes (swinging flashlight test) (Márkus, 2006).

When measuring the diameter of the pupil, pupillary convergence and accommodation should also be considered. When we focus on a near object, it will result in miosis.

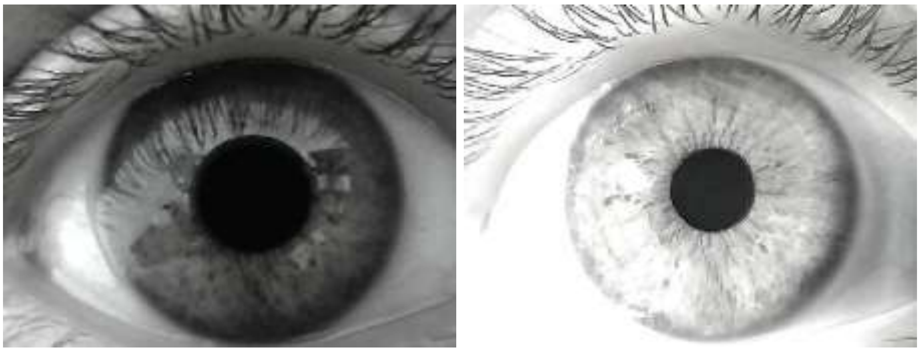

Figure 1 – Pictures taken by the device

2 Hardware and software

A device suitable for examining the pupillary light reflex should be able to measure direct and consensual responses independently. Furthermore, it should be able to measure the diameter of the pupil with sufficient accuracy and at the required time intervals. In the sections below, we describe the hardware and software of the device developed by us as a potential solution to this problem. When developing the prototype we aimed at cost efficiency, hence we applied commercially available components wherever developing the element by ourselves would have been more expensive.

The device is essentially composed of 5 functional units. These are the CCD detectors, the electronic panels, the LED units, the controller card and the casing. The CCD detectors have the parameters of a basic web camera. To optimise processing speed and measuring accuracy, we applied a resolution of 640 x 480 pixels. The frame rate of the detectors is 18 fps. The IR filters built in by the manufacturer were removed from the CCD detectors so that they can also record in the near IR range. It was necessary as the examined eyes need to be illuminated without eliciting a light reflex for recording. Detectors were fitted on the casing at a distance corresponding to the average distance of human eyes (635 mm). The power supply to detectors was provided by two USBs connected to the computer. The same cable was used to transfer data.

The device includes three electronic panels. From these, two secures the LED unit around the two CCD detectors, while the third one carries the front resistors of the LED units.

Altogether 12 LED units are installed into the device, 6 of them are white LED lights to elicit the light reflex and 6 one are IR LED lights to facilitate the taking of suitably bright photos. LED units are located symmetrically around the eyes, in a circle of a diameter of 50 mm, at 120° angles from each other. It means that each eye is illuminated by 3 IR LED lights and 3 white ones. The light from white LEDs was subdued and homogenised by a semitransparent, diffuse filter.

The controller card is a universal NI6008 acquisition card that is perfectly suitable for the purpose and provides for a suitable temporal resolution when controlling LED units as well as for the power supply of them.

The casing is a plastic electronic box with a base of 150 x 150 mm and a height of 80 mm, refitted for the purpose. The holes for the LEDs and the camera are located on the front panel. Patients should look into the device through the camera holes. Inside, the electronic panels and the controlling card are installed. The front panel is equipped with a supplement made of foam that fits on the head of patients, holding the device in position and minimising external light. To facilitate accurate positioning, an aluminium positioning unit is fitted on the upper plate of the casing where patients may rest their foreheads.

The measuring device is controlled by a self-developed software written in LabVIEW. The software provides suitable control for the LED units and the CCD detectors and analyses the images. After each run, the initial parameters to be worked with may be set, then measuring can commence. The video displays on the user interface show the actual images. Below video displays, a screen is placed with graphs that show pupil diameter values as a function of time. In measuring mode, both displays operate.

When started, the software switches on the two CCD detectors and the IR LED lights around both eyes. Then measuring starts. The white LEDS are switched on separately, first the ones round one eye, then those around the other, each group for 3 s. Once the white LEDs have been switched off, recording commences for 3 more seconds, with only the IR LED lights on. When measuring is finished, the software switches off the IR LED units and the CCD detectors.

In the current setup, the software analyses images in real time; results are displayed immediately during measurment and archived at the end of the session. Original videos may be preserved when necessary. A shape recognition algorithm is run on the images following corrections. The software takes a picture of the eye in every 20 ms and analyses it immediately.

Figure 2 – Measuring device

3 Tests and results

Once the prototype of the light reflex measuring device had been developed, it was tested thoroughly. The results of these tests are given below.

Testing the device on the developers was an obvious choice as only the developers themselves are patient enough for the pilots. During the test runs, we aimed at minimising disturbing factors and standardise conditions as much as possible. We have performed 65 tests thus far. Results prove that the system is able to measure the diameter of the pupil by means of image processing. The relative error of the first measurements was <0,7%, by an absolute error of <0,3 pixel. It is perfectly acceptable in the case of similar tests.

The device was tested under various conditions to get a comprehensive picture on its operation. The differences shown by Figure. 3 and Figure 4 were given by reducing the stimulus and the length of pauses. The zero error between the curves for the two eyes in Figure 3 and Figure 4 might have been given by the asymmetry of the cranium or the test subject turning his or her head. However, these errors have only a minor significance as diagnostics relies on the stability of values from a given patient and not on absolute data.

We may conclude that we developed a practical device that is suitable for measuring direct and consensual light reflex. However, we have still a lot to do as we have to correct ad-hoc errors and increase accuracy.

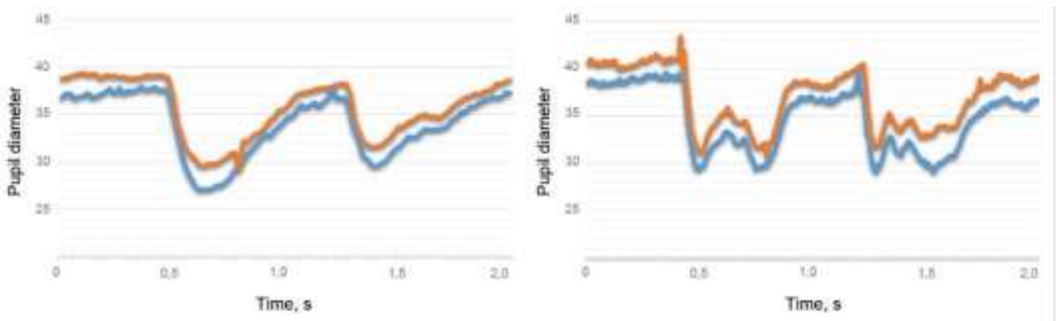

Figure 3 – Short measurement (left) standard measurement (right)

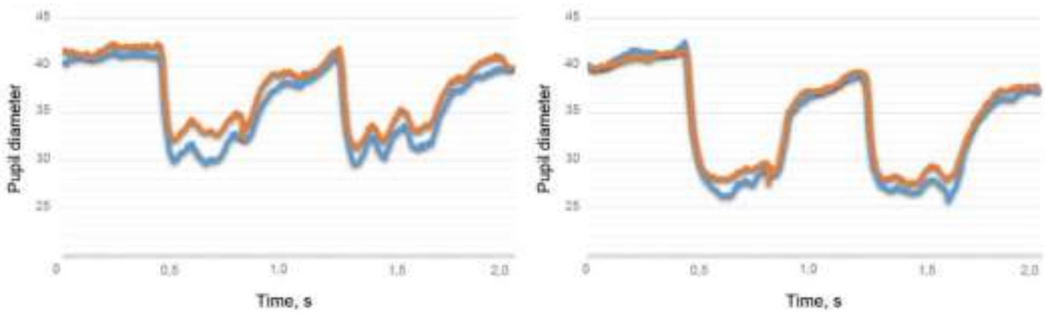

Figure 4 – Standard measurements

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