Title: Wearable Relative Afferent Pupillary Defect (RAPD) Measurement Device

Authors: Arda Gulersoy, Ahmet Berk Tuzcu, Doga Gunduzalp, Koray Kavakli, Umit Yasar Guleser, Ugur Aygun, Murat Hasanreisoglu, Afsun Sahin, Hakan Urey

Introduction:

The swinging flashlight test (SFT) is a technique that is used to identify RAPD (Relative Afferent Pupil Defect) which means comparing the reaction of both eyes to the light. In this test, an examiner swings the light into the patient's eyes and tries to monitor the pupil size change due to the light stimulus. For a healthy person, both eyes are expected to constrict at the same rate when one of them is illuminated, however, due to medical conditions like glaucoma or damage to the optic nerves, one eye does not constrict properly. However, the manual SFT is highly dependent on human factors and requires trained personnel. Moreover, light stimulation durations are not controlled and can be varied, and the quantification of the pupillary light reflex can be difficult. Also, the traditional method is not able to evaluate the chromatic RAPD score of the patient which is important to detect glaucoma[1]. In this work, we developed a low-cost, head-mounted, RAPD measurement instrument that can be used in low-resource settings with no trained personnel. Furthermore, it can be used for the assessment of chromatic pupillometry. Our RAPD measurement device consists of two infrared cameras, two RGB LEDs, and a microcontroller that is attached to the frame as shown in Fig1. A specially designed headset lets the user adjust the camera and LEDs according to the patient's interpupillary distance, and prevent leakage of light that came from the opposite LED. The device allows the examiner to fine-tune the LED on-off durations and brightness levels. Moreover, the user can set the color of the LEDs with options red, blue, green, and white.



Figure 1: Front, back and the side view of RAPD measurement device.

Acquired infrared images are processed to detect pupils as shown in Fig 2. First, we blur the captured frame and then find the bright spots that are the reflections of the infrared LEDs by applying a threshold and blob detection and crop the frame relative to these spots. Then we apply an adaptive threshold to the cropped original frame to obtain a binary frame. Finally, we find contour coordinates from the binary frame to draw the best fitting circle around the pupils which can be seen in Fig 2.

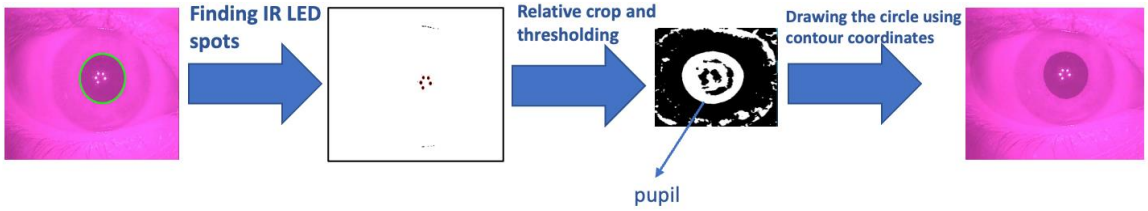


Figure 2: Pipeline of the eye tracking algorithm.

Pupil diameter (D) is calculated for each frame, to plot the change of the pupil diameters with respect to time. RAPD is calculated by the logarithm of the median of the magnitude, which means the percentage change from the rest state to the constriction state shown in Fig 3a, of the left eye divided by the median of the magnitude of the left eye. In short, RAPD can be calculated using the following equations;

$$Magnitude(\%) = \frac{D_{rest} - D_{constricted}}{D_{rest}} * 100 \quad (1)$$

$$RAPD = 10 * \log_{10} \frac{median(Magnitude_{right})}{median(Magnitude_{left})} \quad (2)$$

where *D_rest* and *D_constricted* are the pupil diameters in rest and constricted states, respectively. RAPD scores <0.5 means negative, on the other hand, RAPD scores >1 are accepted as positive. Note that, because RAPD score depends on the relative changes, absolute measurements of the pupil diameters are not required.

We conducted experiments using the device at Koc University ophthalmology clinic with 10 healthy and 10 patients with the experimental parameters such as 3 seconds initial wait, 0.5 seconds LED on, 2 seconds LED off and 5 cycles (one cycle includes right LED on and off, left LED on and off). Sample results are shown in Fig. 3a and Fig 3b, for a healthy person and a patient respectively. As can be seen from Fig 3a, the diameter of the pupils decreases evenly upon stimulation for both LEDs. However, in Fig 3b when the right LED is illuminated right pupil constricts more than the left pupil which causes a higher RAPD score than usual.

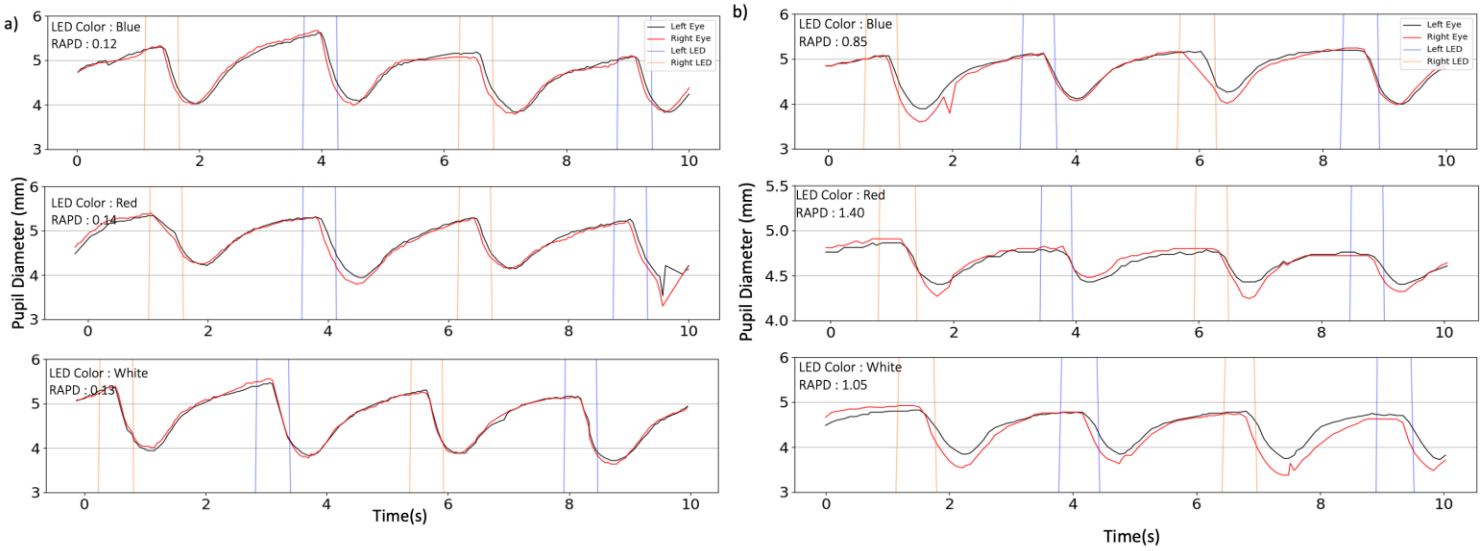


Figure 3: Illustration of RAPD tests for (a) healthy subject and (b) patient.

In conclusion, the human factor heavily influences the swinging light test for detecting RAPD, so we developed a head-mounted RAPD measurement device to automate the process. The device was tested at Koc University ophthalmology clinic with 30 healthy and 30 patients. We observed RAPD scores <0.5 for healthy and >1 for patients as expected. We showed that the proposed head-worn instrument is easy to use, fast, and suitable for early diagnostics and screening purposes. Full clinical tests including RAPD scores for different colors, response latency and velocity will be presented in the full paper.

Objectives

This project aims to find pupil constriction abnormalities that can not be identified by medical staff(as can be seen in Fig3 b) because that kind of difference in constriction rates is quite small to be detected by a human. As you can see from the first plot of Fig 3b constriction rate of the right pupil is a little bit larger compared to the left one when the right LED is illuminated. Also, we introduced a newly developed head-worn instrument that can automatize the traditional procedure with three different colors with no need for specialized staff. With these developments, we eliminate the chance of human error in the procedure to obtain much more accurate results and allows user to mass-screening since there is no need for medical staff to interpret the results.

Acknowledgments

The authors would like to thank Selim Olçer, Fırat Turkkal, Gunes Aydindogan and Cem Kesimal for their help in prototype development. This work has been supported by TUBITAK (grant agreement number 120C145) and European Innovation Council (EIC) Horizon under grant agreement no 101057672.

References:

[1] Rukmini AV, Milea D, Baskaran M, How AC, Perera SA, Aung T, Gooley JJ. Pupillary Responses to High-Irradiance Blue Light Correlate with Glaucoma Severity. Ophthalmology. 2015 Sep;122(9):1777-85. doi: 10.1016/j.ophtha.2015.06.002. PMID: 26299721.