Proceedings of the 28th IEEE
EMBS Annual International Conference
New York City, USA, Aug 30-Sept 3, 2006

A Technique to Compensate the Eye Movement in Dark Adaptometry Tests.

Dario F. G. de Azevedo; Sergio Helegda; Thais Russomano; Leo Fabrício.

Abstract— This paper describes a new technique to compensate the eye movements in dark adaptometry tests. The instrument is controlled by a personal computer and can be used in the investigation of several retinal diseases. The stimulus is delivered to the eye through the modified optics of a fundus camera using two light-channels: one for the stimulus presentation, and other for retinal visualization. Infrared images of the fundus are displayed on a video monitor and the stimulus position can be compensated in real time. These modifications provide the advantages of continuous monitoring of fixation and visualization of the retinal regions, thereby increasing the accuracy of dark adaptometry in patients with fixation problems.

I. Introduction

THE mechanisms underlying many incurable retinal disease remain unknown. Some of these diseases mainly affect the photoreceptors, the light-sensing cells that are first stage of vision, causing progressive visual sensitivity loss and frequently leading to blindness. Many diseases affect the entire retina, while others can affect specific central regions, thereby compromising fixation [1, 3].

The visual system is able to adapt to a very wide range of luminous intensities. Following the exposure to a bright light the retina becomes less sensitive to light, corresponding to the "destruction" of the visual pigments in the photoreceptors (photosensive cells of the eye) [3]. After that the subject spends a period of time in a dark environment, the retina slowly regains sensitivity to light, a process known as Dark Adaptation (DA) that corresponds to the regeneration of the photopigments in the photoreceptors [2].

Recovery of sensitivity of the retina following light exposure is a complex multistage process that can be studied non-invasively in man with a technique known as dark adaptometry. By measuring the recovery of sensitivity of the retina after exposure to a controlled amount of light, dark adaptometry accesses the function of the retinal photoreceptors [2, 3].

Dario F. G. de Azevedo is with the Pontifical University Catholic of the Rio Grande do Sul. Porto Alegre, RS, Brazil. E-mail: dario@pucrs.com.br
Sérgio Helegda is with the Pontifical University Catholic of the Rio Grande do Sul. Porto Alegre, RS, Brazil. E-mail: sergio.helegda@pucrs.com.br
Thaís Russomano is with the Pontifical University Catholic of the Rio Grande do Sul. Porto Alegre, RS, Brazil. E-mail: trussomano@hotmail.com
Leo Fabricio is with the Pontifical University Catholic of the Rio Grande do Sul. Porto Alegre, RS, Brazil.

Conventional ophthalmologic tests may not be enough to diagnostics diseases in the retina [2, 4]. Studies of dark adaptation in patients with retinal degenerations have excited interest in dark adaptometry by demonstrating different types of abnormalities that are informative about the underlying disease mechanisms. Macular degeneration, show in Figure 1, for example, is a slowly progressive condition characterized by the accumulation of damaged tissue in the macula. The macula is the central area of the retina responsible for fine detailed vision [1]. This disease cause central visual loss during the years. DA studies at, and in the vicinity of the lesion shown in Figure 1 could not be performed with available dark adaptometers, because the previous positioning mechanisms of the stimulus and bleaching fields were not precise enough for small lesions [4, 5]. Furthermore, the test could not be performed under retinal visualization that would allow additional compensation in the position of the test lights. There is a need for an instrument capable of measuring dark adaptation in localized retinal disease such as these lesions [4, 6, 7]. This specific disease shows abnormalities in dark adaptation tests and can be easily detected before the pathological manifestations [2].

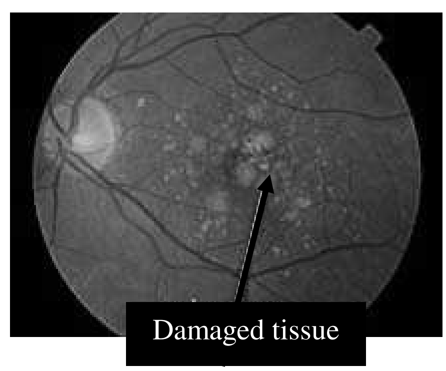

Figure 1 – Retinal fundus with pathological manifestation of the macular degeneration

Some problems in dark adaptometry are related to the operation of the equipment in conventional exams: the dark adaptation threshold is determined by manually decreasing (or increasing) the light intensity of the stimulus, until the subject perceives the light [7]. Three qualified people are needed to run tests on patients. All test data, calculations and plots are manually recorded [6, 7]. Thus, conventional

1-4244-0033-3/06/$20.00 ©2006 IEEE.

clinical dark adaptometers are most often manual, inconvenient to use and cannot be used to test patients with fixation problems or in study of localized disease [5, 6, 7].

The objective of this work is to describe a technique used to compensate the eye movement in dark adaptometry tests. Its specific application is to measure localized dark adaptation, or the recovery of light sensitivity of specific regions of the retina. The result of this work is a novel instrument in Brazil.

II. MATERIALS AND METHODS:

The dark adaptometer used for these tests was a 5 channel instrument. The equipment delivered the light to the eye through the modified optics in a Zeiss fundus camera in two light-channels: one for the stimulus presentation, and another for retinal visualization.

The new adaptometer was specially built to stimulate specific regions of the retina and to examine patients with fixation problems. Because of this, the flash system was substituted by an apparatus with variable aperture and a moving mechanism.

The position of the stimulus is determined by a sliding mechanism. This mechanism was developed based on precision parts extracted from an optic microscope: the "stage clip". A fiber optic cable brings the light stimulus from the automated light source to the positioning mechanism in the fundus camera. Figure 2 below, shows the mechanism used in the fundus camera.

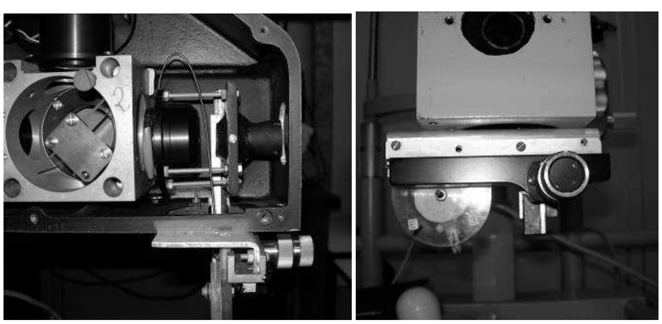

Figure 2 – (a) Lateral and (b) frontal view of the positioning mechanism in the fundus camera.

This apparatus also defines the size of a stimulus in the retina. The size of the stimulus field is controlled with an optical diaphragm and it is positioned in a conjugate plane of the fundus camera.

The movement of the mechanism allows the observer to position the stimulus anywhere in the retina, within the camera vision field.

The user can control the aperture of the light stimulus manually. This apparatus is shown in Figure 3.

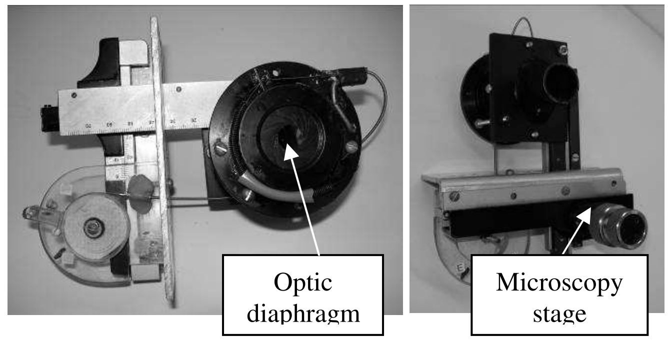

Figure 3 – The sliding mechanism was based in a (a) optic diaphragm and a (b) microscopy stage clip

Other devices were implemented on the Zeiss camera. A new light source was specially designed for the fixation point. The fixation light is an important part of the positioning mechanism of the stimulus lights on the retina. By varying the position of the fixation light, the investigator can expose different regions of the retina. The fixation light, showing in the Figure 4, was implemented based on an optical fiber cable and a red LED (Light Emission Diode) in one end. The subject is oriented to fixate in the small spot of red light, looking straight during each stimulus presentation. The brightness of this spot light can be controlled in the light source. It should be bright enough to be seen throughout the test and dim enough as not to cause any elevation in threshold. The function of this optical apparatus is a complement of the mechanism described before.

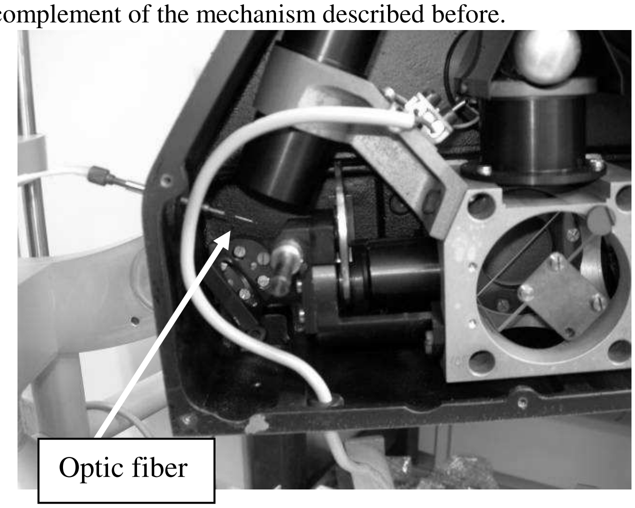

Figure 4 – Detail of the optic fiber in the implementation of the light fixation point

A CCD video camera was adapted on place of the original photographic camera. A fundus illumination IR light source was designed. The video images enable the investigator to visualize fundus appearance and stimulus position. A VCR could be used to records the DA images.

A personal computer was used to control the main parameters of the test and to store all the results.

III. RESULTS:

Some characteristics of the new instrument were measured against parameters of retinal images. The data were compared with physiological structures in the eye.

Infrared camera images of the fundus were recorded with a frame grabber. Figure 4 below shows a recorded image of the retina with a stimulus. This stimulus is directly delivered into the subject's eye using the Maxwellian view technique. Using a comparative scale, Figure 5 shows that the visual field of the optics is about 30º.

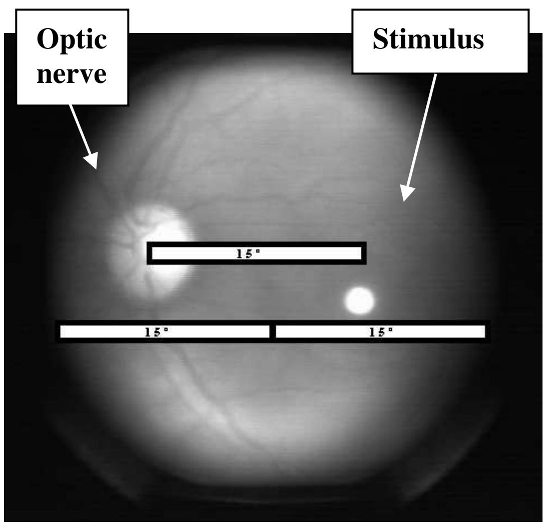

Figure 5 – An image of the fundus with a comparative scale with physiological structures in the eye

As explained before, the size of the stimulus field is controlled with an optical diaphragm. The Figure 5 shows the minimum aperture in the apparatus and the respective stimulus produced. The minimum 1.5º diameter stimulus can be delivered to the retina. The maximum size of the stimulus is the complete camera field (30 º diameter) of view.

The positioning mechanism provides continuous compensation for eye movements. Stimulus positioning in different locations of the visual field was tested and calibrated. The sliding mechanism allows the investigator to position the stimulus anywhere in the retina, within the camera field of view. The fixation point mechanism provides the investigator to expose different areas of retina within the camera field of vision.

The Figure 6 following shows the same stimulus dislocated in different extremities of the vision field: above, below, right and left.

The variation of the intensity along of the visual field was in order of the 2 dB. This variation is not significant when compared with the maximum variation produced in the equipment (65 dB).

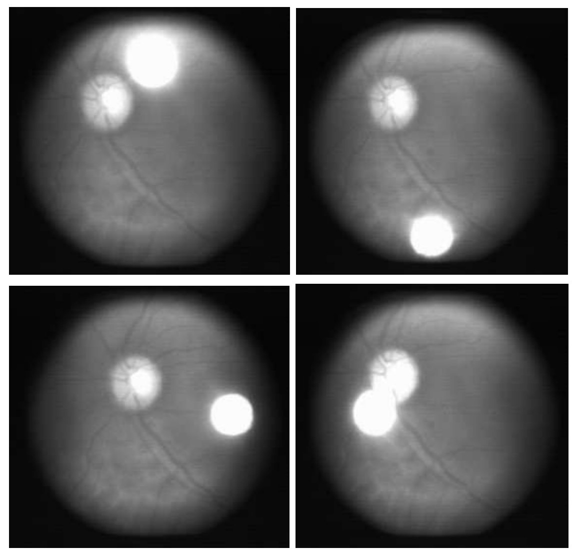

Figure 6 – Variation of the stimulus in different positions of the vision field: (a) above, (b) below, (c) right and (d) left.

As shown in the Figure 6, the geometric shape of the stimulus is the same. There is no variation of the shape in the camera along the field of view.

IV. CONCLUSION

The advantages of a more flexible dark adaptometer, with variable parameters was demonstrated and tested.

The control mechanism of the stimulus positioning was successfully implemented as the part of new dark adaptometer. All specifications of the stimulus were measured and calibrated along the visual field: light intensity, geometric form, size and position. All operations are controlled by a single person. The apparatus allows to examine the retina in all camera field of view: 30º diameter.

New dark adaptometry techniques facilitate the measurement of dark adaptation in human studies of the pathophysiology of retinal diseases by providing the means for monitoring patient fixation and precise positioning of stimulus light.

REFERENCES

[1] Lamb, T. D. "Photopigments and the biophysics of transduction in cone photoreceptors. In Color Vision: from Genes to Peception". (ed. Gegenfurt-ner, K. R. & Sharpe, L. T.) Cambridge University Press, New York, 1999, pp.89-101.

[2] Azevedo, D. F. G., Cideciyan, A. V., Regunath, G., Jacobson, S. G. "Automated imaging dark adaptometer for investigating hereditary retinal degenerations". SPIE – The International Society for Optical Engineering, 1995, pp 313-321

[3] Hood, D. C., & Finkelstein, M. A. "Sensitivity to light". In K. R. Boof L. Kaufman, J. P. Thomas (Eds.), Handbook of Perception and Human Performance: Vol. 1 Sensory Processes and Perception. New York: Wiley & Sons, 1986, pp 5.1-5.66.

[4] Azevedo, D. F. G. "Automated Imaging Dark Adaptometry in Human Retina". Florida: Coral Gables, August 1996.

[5] Helegda, S. "Fonte de Luz Automatizada para Exames de Retina". Porto Alegre: PUCRS, march 2002.

[6] Azevedo, D. F. G. de, Helegda, S., Grigolo, E. C., Sá, O. A. L. de, Russomano, T,. "Automated light stimulus source for retinal tests" Viena, 2nd European Medical & Biological Engineering Conference, 2002. P. 1484-1485

[7] Dario F. G. de Azevedo, Sérgio Helegda, Flávio Glock, Thaís Russomano. "Automatic Dark Adaptation Threshold Detection Algorithm" Shanghai, 27th Annual International Conference of the IEEE, Engineering in Medicine and Biology Society, 2005.