On the importance of the dynamic measurement of the pupil size

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Abstract

In this pilot study we analyse the pupil fluctuations of the right eye of two subjects during forty-five seconds while keeping constant the viewing distance and the room illumination. Measurements were taken with an infrared eye-tracker working at 250 Hz. The results were for subject A a median diameter of 2.913 mm with a maximum diameter of 3.313 mm and a minimum diameter of 2.66 mm, for subject B the median diameter was 4.39 mm with a maximum of 5.23 mm and a minimum of 3.26 mm. For both subjects the distribution of the pupil diameter did not follow a normal distribution, this was determined with the Lilliefors test, the p-values were 0.0251 for subject A and 0.001 for subject B. In conclusion, even in constant conditions of illumination and viewing distance the pupil cannot be considered to remain constant and its diameter varies not following a normal distribution.

Introduction

The human pupil diameter determines the retinal image quality (*1*) and thus the visual acuity. For small diameters, the phenomenon of diffraction limits the image quality, whereas for larger diameters the optical aberrations play a major role.

The illumination level is the main factor affecting pupil's diameter. The binocular convergence and accommodative response also reduce the pupil size. This is known as the near triad (*2, 3*) and is the reason why under the same illumination level the pupillary diameter is larger for far viewing distances than for near. The near triad effect has been used by the industry for designing simultaneous vision lenses (multifocal refractive contact lenses and multifocal refractive intraocular lenses) in which the central area is dedicated for near vision and the periphery for far distance vision, however not all the designs follow this approach (*4*).

The pupil diameter is not constant over time. A slow oscillation, known as the hippus of the pupil (*5, 6*), appears under conditions that are not yet determined. These fluctuations are related to the noise in the neural system that innervates the pupil (*7*) and are not linked to the known fluctuations of the crystalline lens power (*8*).

In spite all of that, in general practice it is still quite common to take only as few as a single measurement of the pupillary diameter under two or three different lighting conditions (*9*) and to consider that the pupil diameter remains constant. This assumption can lead to an error in estimation. Preventing those errors is of special interest for surgical procedures, treatments and/or optical aids that depend on the pupil diameter for the best performance.

The aim of this study is to determine the variations of the pupil diameter for an extended period of time under constant conditions of illumination and position of the target.

Methods

Apparatus

The eye tracker High-Speed VET© (Cambridge Research Systems Ltd, Rochester, United Kingdom) was used to capture high-speed (250 frames per second) video sequences of the eye. This device consists of an infrared camera, in combination with two ultra-bright infrared LEDs and an infrared mirror transparent for the visible light spectrum. The configuration of the device allows recording the eye movements from a frontal position without interfering the line of sight and with a total independence of the illumination conditions. The software provides the coordinates of the pupil centre and the pupillary diameter for every frame.

Experimental setup

A target consisting of a black cross inscribed in a circle of 72 mm of diameter was placed at 6 m in front of the chinrest. The illumination level in the laboratory (100 lux) was constant, measured with a photometer CL-200 Chroma Meter (Konica Minolta, Tokyo, Japan) which probe was placed on the corneal plane.

The task for the observers (n=2) was to remain as still as possible while fixating on the target for 45 seconds. The right eye measurements were then analysed.

Results

Eleven thousand two hundred and fifty measurements of the pupil diameter were obtained for each volunteer. For the frames corresponding to blinks, the diameter value was “not a number” and was omitted in the analysis. The pupil of the subject A showed a median value of 2.91 mm with an interquartile range of 0.11 mm, for the subject B the median value was 4.39 mm and the interquartile range of 0.23 mm. The variation of the pupillary diameter value over time is shown in figure 1. The histograms of the measurements for each of the subjects are displayed in figure 2, and the box plots are shown in figure 3. The Lilliefors test determined that these measurements are not normally distributed with p-values of 0.0251 and 0.0010 for subject A and B, respectively.

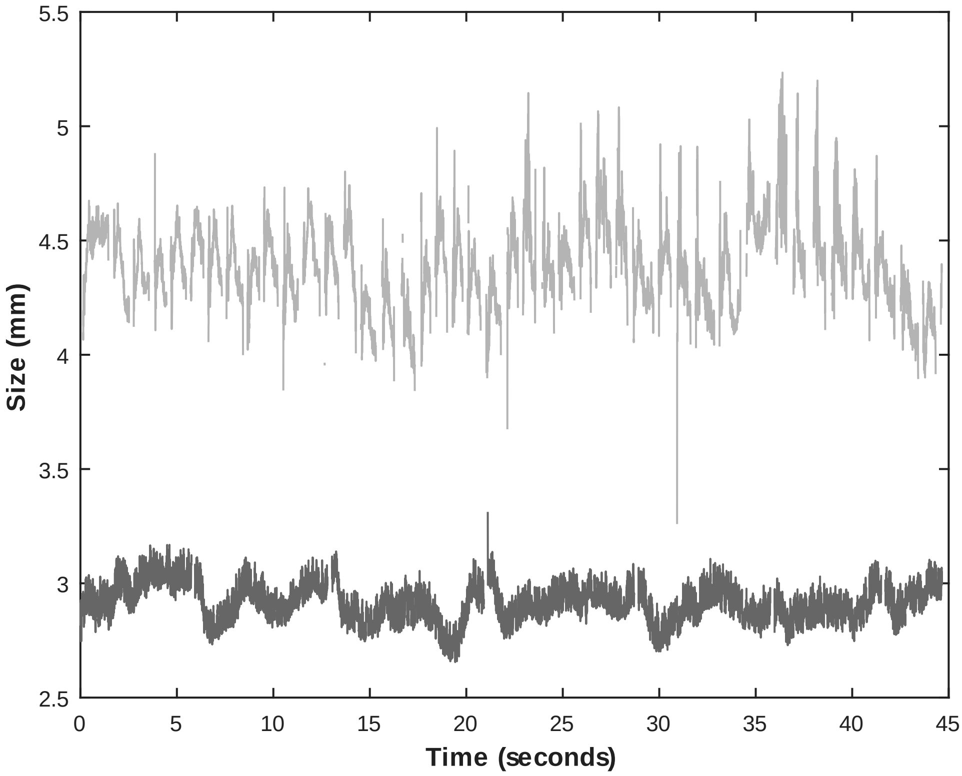

Figure 1 Pupil size VS time. Dark gray represents subject A, light gray subject B

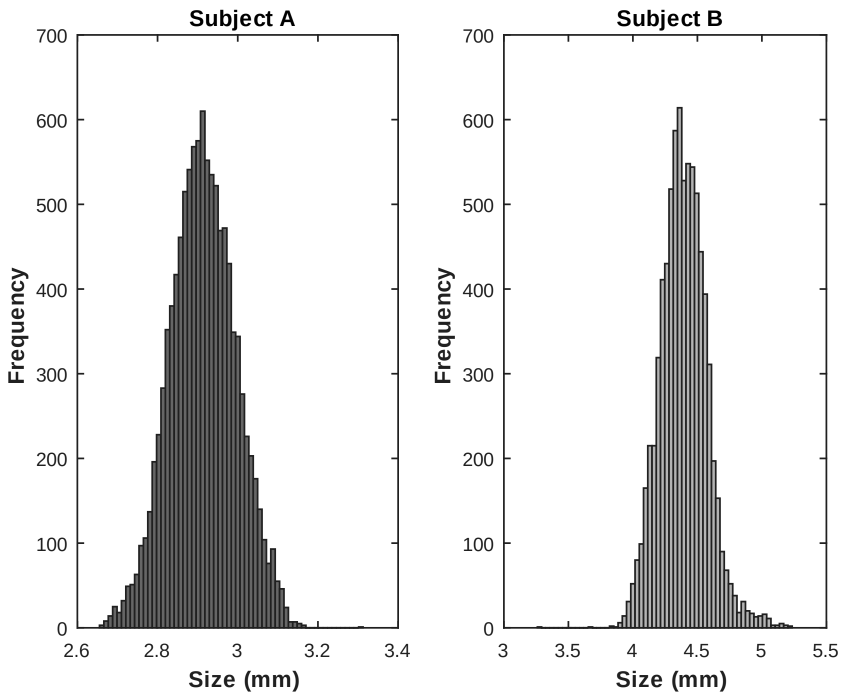

Figure 2 Histogram of the pupil size for each subject

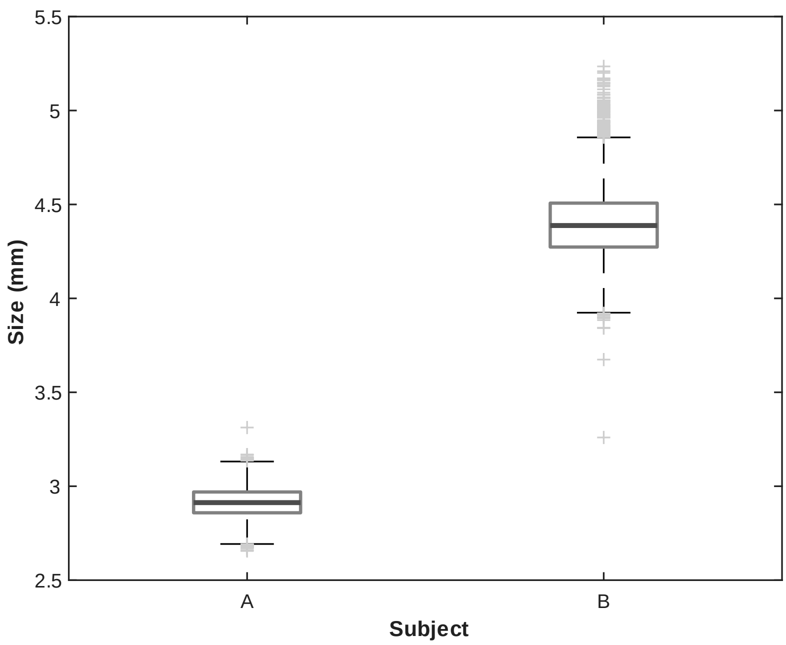

Figure 3 Boxplot of the pupil size for each subject

Conclusion

The results show that the pupillary diameter cannot be characterised by means of a single measurement. It is advisable to take as many measurements as possible over an extended period of time to determine the median value and the quartiles. Before making any decisions based on the pupil diameter of the subject, it is necessary to know in which range of values the pupil size oscillates. This should be considered in the field of refractive surgery or multifocal contact lens design and fitting, multifocal ophthalmic lens design, and other related fields, in which the pupil diameter is the key element for the visual performance.

Acknowledgements

This work was supported by Generalitat Valenciana, Conselleria d'Educació, Investigació, Cultura i Esport under Grant (VALi+d, ACIF/2014/142) and MINECO grants TIN2013-50520-EXP and TIN2015-71130-REDT.

Disclosure statement

The authors declare no conflict of interest.

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