Tablet App Aston Halometer for the assessment of Dysphotopsia

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None

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The app is being commercialised by Aston EyeTech Ltd in which AD and JSW have a financial interest.

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ABSTRACT

Purpose: To assess the validity and repeatability of the Aston Halometer.

Setting: University clinic, UK.

Design: Prospective repeated-measures experimental study

Methods: The Aston Halometer comprises of a bright Light-Emitting-Diode (LED) glare source in the centre of an iPad4. Letters, subtending 0.21° (~0.3logMAR), were moved centrifugally from the LED in 0.05º steps in 8 orientation separated by 45° for each of 4 contrast levels (1000, 500, 100 and 25 Weber contrast units [C_w]) in random order. Bangerter foils were inserted in front of the right eye to simulate monocular glare conditions in 20 subjects (mean age 27.7±3.1 years). Subjects were positioned 2m from the screen in a dark room with the iPad controlled from an iPhone via Bluetooth operated by the researcher. The Oculus C-Quant was also used with each of the foils to measure the level of straylight over the retina. Halometry and straylight repeatability was assessed at a second visit.

Results: Halo size increased with the different Bangerter foils and target contrasts ($F=29.564$, $p<0.001$) as expected and in a similar pattern to straylight measures ($F=80.655$, $p<0.001$). Lower contrast letters showed better sensitivity, but larger glare-obscured areas resulting in ceiling effects due to the screen's field-of-view, with $500C_w$ being the best compromise. Intra-observer and inter-observer repeatability of the Aston Halometer was good ($500C_w$: 0.84-0.93 and 0.53-0.73) and similar to the CQuant.

Conclusions: The Aston Halometer provides a sensitive, repeatable way of quantifying a patient recognised form of disability glare in multiple orientations to add objectivity to subjectively reported discomfort glare.

Keywords: Halometry; Aston Halometer; dysphotopsia; glare; light scatter; validation; repeatability; C-Quant

Introduction

Photopic phenomenon, termed dysphotopsia, can be induced by refractive surgery, the extent of which may be related to the ablation profile and pupil size,[1,2] corneal and crystalline lens opacities,[3] and is one of the few clinical tests correlated with night driving performance.[4] Glare can also result from multifocal intraocular lenses (MIOL) implantation, and are often described as haloes.[5] This is a major cause of multifocal dissatisfaction[6] and is largely responsible for a relatively high frequency of MIOL explantations.[7] To measure the retinal blur circle or halo, several instruments, often referred to as halometers, have been created. These devices quantify the size of a photopic scotoma created by a central glare source, assessing forward light wide angle scatter rather than the narrower straylight.[6] Early methods to assess halos required patients to draw the outline of the perceived halo produced by a candle at a set distance.[8] Others involve visually 'bracketing' the edges of the halo with the examiners hands,[9] comparison of their halo with objects of known diameter,[10] or mechanical movement of a target towards or away from the light source in limited meridians.[11] Namiki and Tagami attached a glare source within an *OCTOPUS 500E* (Haag-Streit, Koeniz, Switzerland) automated perimeter to determine the extent of visual field loss surrounding a central glare source.[12] A similar approach was adopted by Gutiérrez and colleagues (2003) lighting LEDs in sequence in increasing eccentricity from a central glare source.[2] Many of these technique have not been validated ,[9,10] have ill-defined repeatability[2,9,10] and are unable to identify any differences between MIOLs and monofocal IOLs.[9,12]

The halometers described by Lee and colleagues (2006) and by Allen and associates (2009) both used computer programs, which present a central screen glare source (single white spot or a red cross with a white ring respectively) requiring the subject to circle the perceived photopic phenomenon.[13,14] These halometers have been used to examine dysphotopsia following MIOL implantation[14] and post LASIK under physiological,[13] and pharmacological (with a miotic agent) conditions.[15] Lee and colleagues observed good repeatability with their halometer,[15] however, the design used for examining MIOLs was not assessed for repeatability and was found to show similar results with both MIOL and monofocal IOLs.[14]

Currently, the *Glare & Halo test* (Tomey, AG, Erlangen) is the only standardized, commercially available, computerised test used to measure the size of photopic phenomenon. Here, a central white target 15 mm in size is displayed on a screen (luminance 86.6 cd/m^2) and the subject is required to place a mark with a mouse the boundary of the ensuing photopic phenomenon for 12 equidistant orientations separated by 30º degrees surrounding the glare source. The central glare area in degrees is then calculated in accordance with the working distance of the subject. The *Glare & Halo* test has been used in three studies examining the difference in halo sizes between the *Array* refractive MIOL (Abbott Medical Optics Inc. (AMO), Santa Ana, CA, USA) and a monofocal IOL with a similar aspheric profile. Pieh and colleagues found a significant difference in dysphotopsia between the two types of pseudophakic correction,[16] however, two earlier studies did not find a significant difference.[17,18] Repeatability studies have not been conducted using this instrument. Another

approached recently demonstrated was software (Halo v1.0) run on a computer designed to quantify discrimination capacity under low-illumination conditions which will be affected by visual disturbances. The test consists of the discrimination of customisable luminous peripheral stimuli around a more luminous central one (the glare source) at 3 positions along 12 axes to calculate a visual-disturbance index. It has been shown to be sensitive to retinal disease,[19]cataract,[20] age[20] and myopic LASIK,[21] but repeatability studies have not been published.

The aim of the study is to validate the Aston Halometer, a new halometer with a brighter central target and performed on a standard mobile tablet designed to be able to quantify and analyse the extent of dysphotopsia in multiple directions of gaze.

Patients and Methods

The experimental study instrument validation required patients with clear media using filters to induce standard amounts of glare to assess the accuracy and reliability of the halometer, hence 20 young subjects (10 males, 10 females) of mean age 27.7 ± 3.1 years were recruited from Aston University. The inclusion criteria were: uncorrected visual acuity of at least 0.10 logMAR in each eye; mean spherical error within -0.75 D to +0.75 D; spectacle astigmatism less than 0.75 D; the absence of any ocular pathology and previous surgery; and an aged between 18 and 40 years. Ethical approval was obtained prospectively for this study from the Institutional Review Board and informed consent was obtained from each subject following explanation of the details of the study and any possible consequences. The study was conducted in accordance with the tenets of the Declaration of Helsinki. Subjects were refracted and fully corrected with contact lenses, if necessary, following a non-cycloplegic subjective refraction, with the end-point of the maximum plus prescription consistent with optimum visual acuity.

The *C-Quant* provides a measure of the level of straylight (forward light scatter) over the retina. Straylight originates from the scattering of light and creates a veil over the vision that is known to increase with age, ocular pathology and with refractive surgery.[22] With the *C-Quant* three repeats are necessary to achieve an accurate measurement of straylight and measurement of straylight was considered reliable if the estimated standard deviation (ESD) was below 0.8 and the quality factor for the psychometric sampling (Q) was above 1.00.[23]

The Aston Halometer provides a measure of the degree of obscuration of a target from a glare source, measured in degrees. It comprises of a bright Light Emitting Diode (LED; Golden Dragon Plus LCW W5AM.PC; 5000K colour temperature; pulse width modulation duty cycle of 15.6%, forward current 40mA, 3.7V; Osram Licht AG, Munich, Germany) in the centre of an iPad 4 (Apple, Cupertino, CA, USA), with a 2048 x 1536 pixel resolution and a 240 x 169.5mm screen (Figure 1). Subjects were positioned 2 meters from the screen (6.8 x 5.6 degrees field of view) with the iPad controlled from an iPhone over Bluetooth operated by the researcher. Halometry was conducted in a dark room with the Aston Halometer as the only light source with an adaptation time of 1 minute. Letters were moved centrifugally from the central LED glare source in 0.05° steps in each of 8 directions of orientation in succession separated by 45°. The smallest eccentricity at which the letter could be correctly recognised in 2 out of 3 randomised presentations was recorded before the next direction of orientation was assessed. Four letter contrast levels were tested: 1000, 500, 100 and 25 Weber contrast units (C_w= luminance of the features minus the luminance of the background divided by the luminance of the background).[24] The photopic scotoma size was measured in all 8 positions for each of the 4 contrast levels in random order using a letter height of 0.21° (approximating a 0.3 logMAR letter). This letter height best approximates the driving standard in many countries.[25]

To simulate glare conditions, *Bangerter foils* were inserted in front of the right eye with the left eye occluded. *Bangerter foils* contain a series of micro-bubbles, the density of which determines the spread the light. They were developed for optical penalisation

therapy and were designed to reduce vision in standardised steps from 1.0 to 0.1 designated filters. However, the point spread function of the 0.6, 0.4 and 0.3 foils have been found to be similar, reducing visual acuity by equal amounts, whereas the 0.8 foil spreads light by a lesser degree and so has a reduced effect on visual acuity.[26] Hence the 0.8 and 0.6 *Bangerter foils* were used to simulate different levels of light spread on the retina compared to no filter (control), secured within a trial lens plastic housing. Ocular straylight and halometry were measured three times each in random sequence with each of the *Bangerter foils*. Straylight and halometry repeatability was assessed at a second subject visit separated by at least two hours and by no more than 2 weeks by a second investigator, blind to the results of the first investigator.

Data Analysis

Repeated measures at each visit were averaged for validity comparison. The area obscured by the halometry glare source was calculated from the eccentricities along the 8 meridians. As the data for straylight and halometry were found to be normally distributed (one-sample Kolmogrov-Smirnov test > 0.05) the influence of the *Bangerter foils* was calculated using a one-way repeated analysis of variance (ANOVA); where significant differences were found pair-wise differences were determined using the Bonferonni *post hoc* test. Intra-observer and inter-observer variability was tested for each *Bangerter foil* separately using intraclass correlation co-efficient (ICC) based on a two-way mixed ANOVA model with a 95% confidence interval.

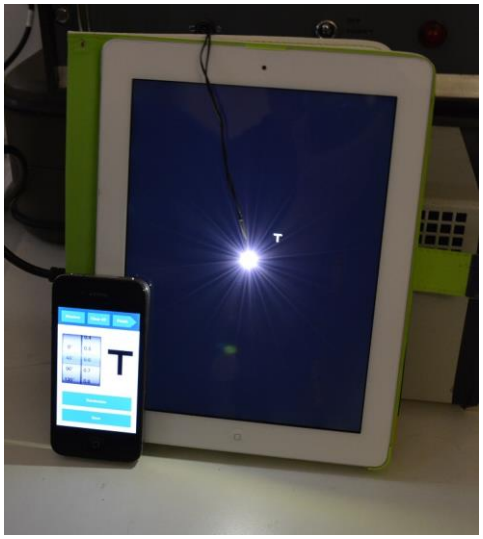

Figure 1: Aston Halometer; comprising of a LED in the centre of an iPad tablet which is positioned at 2m in a dark room. Remote iPhone control via Bluetooth allows the 0.3logMAR equivalent letters to be moved more eccentric from the central LED glare source in 0.05º steps until they are first consistently recognised. This eccentricity is recorded and the assessment repeated in each of the 8 orientations to plot the objective area of obscuration caused by the patient's halo in degrees.

Results

Straylight (as measured by the C-Quant) increased with the 0.8 *Bangerter foil* (1.48 ± 0.12 Log(s)) compared to no filter (1.03 ± 0.21 Log(s); $p < 0.001$), with the 0.6 *Bangerter foil* further increasing (1.97 ± 0.18 Log(s); $p < 0.001$) the straylight ($F = 80.655$, $p<0.001$).

There was a significant difference in the size of halos measured using the different *Bangerter foils* and target contrasts ($F_{1.799}=29.564$, $p<0.001$; Table 1; Figure 2). Lower contrast letters showed larger glare obscured areas resulting in ceiling effects due to the screen's field of view.

Intra-observer and inter-observer variability's of the C-Quant and Aston Halometer at each contract level with each *Bangerter foil* are presented in Table 2.

Table 1: Differences in contrast measured between each Bangerter foil and contrast level (n=20).

C_W is the Weber contrast units

		No Filter			**0.8 *Bangerter***			**0.6 *Bangerter***	
		500 C_w	**100 C_w**	**25 C_w**	**1000 C_w**	**500 C_w**	**100 C_w**	**1000 C_w**	**500 C_w**
No filter	**1000 C_w**	$p < 0.001$	$p < 0.001$	$p < 0.001$	$P < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$
	500 C_w		$p < 0.001$	$p < 0.001$	$P < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p = 0.001$
	100 C_w			$p < 0.001$	$P = 0.072$	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p = 0.001$
	25 C_w				$P = 1.000$	$p = 0.170$	$p < 0.001$	$p = 0.001$	$p = 0.005$
0.8 *Bangerter*	**1000 C_w**					$p = 0.002$	$p < 0.001$	$p = 0.001$	$p = 0.006$
	500 C_w						$p = 0.001$	$p = 1.000$	$p = 0.450$
	100 C_w							$p = 0.010$	$p = 1.000$
0.6 *Bangerter*	**1000 C_w**								$p = 0.300$

Table 2: Intra-observer and inter-observer variability intraclass correlations of the C-Quant and Aston Halometer at each contract level with each *Bangerter foil* (n=20)

	C-Quant	Aston Halometer			
		1000 C_W	**500 C_W**	**100 C_W**	**25 C_W**
Control lens	0.875 / 0.774	0.876 / 0.776	0.843 / 0.729	0.775 / 0.632	0.806 / 0.675
0.8 *Bangerter foil*	0.871 / 0.499	0.979 / 0.696	0.929 / 0.675	0.874 / 0.532	
0.6 *Bangerter foil*	0.873 / 0.845	0.929 / 0.576	0.840 / 0.529		

C_W is the Weber contrast units

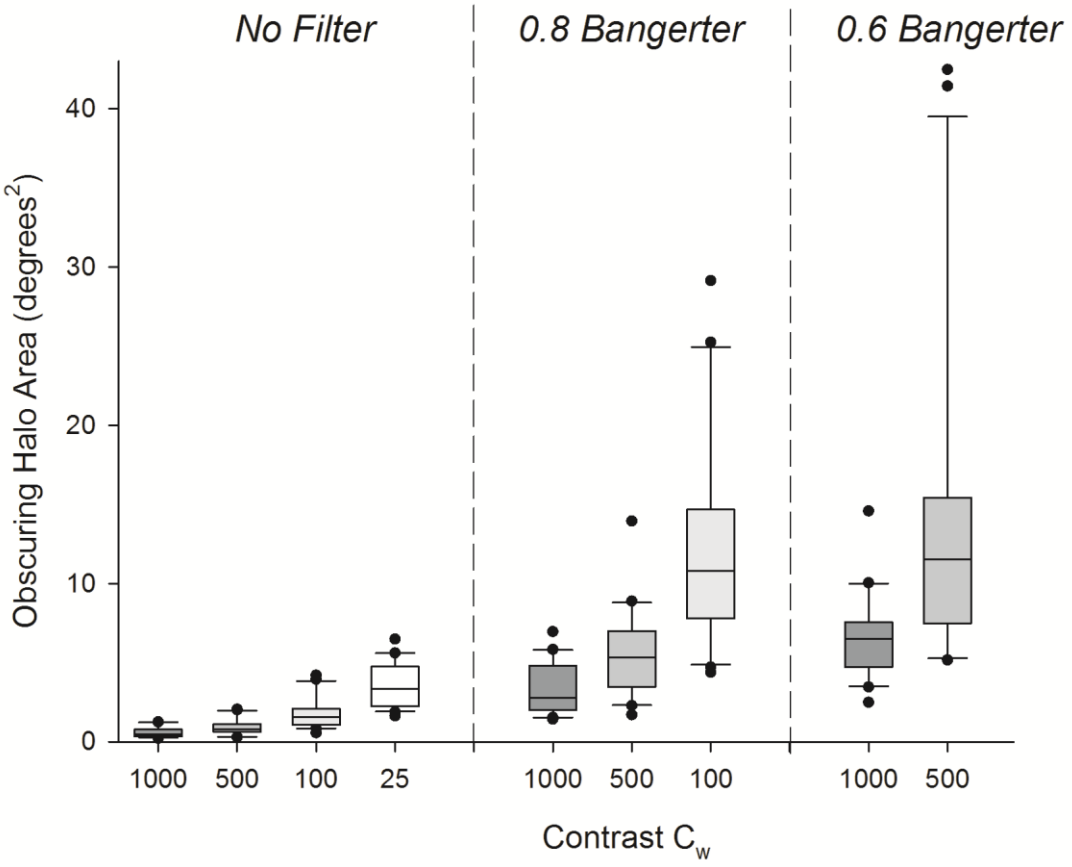

Figure 2: Area of photopic scotoma for each Bangerter foil at each contrast level (n=20). Line with box = median, box limits = 1 standard deviation, error bars = 95% confidence interval and points = outliers.

Discussion

As glare is a major source of visual discontent,[22] especially with simultaneous image presbyopia corrections, there is a clinical need to quantify this parameter. Hitherto, halometry has been used for this purpose, but with previous halometers, discrimination and reliability have rarely been assessed, and few techniques allow the halo to be quantified in all directions of gaze, which is a valuable outcome measure for the evaluation of non-concentric optical designs (Table 1). All instruments which quantify glare assess disability rather than discomfort glare, although these measures are generally correlated.[27] Light scatter measurement with the C-Quant does not provide meridional quantification and is not directly related to a regular patient phenomenon with which they are familiar (such as car headlights or street lamps at night). Also, while C-Quant measurements of forward light scatter have been shown to correlate reasonably strongly with cataract density,[28] they have been shown to be relatively insensitive to patient reported glare with refractive IOL designs for presbyopia, although the latter change the optical aberrations as well as scatter light.[29]

As determined by the C-Quant, *Bangerter foils* were shown as an effective method of inducing light scatter in a repeatable way, as they have a detrimental effect on the point spread function.[26] The Aston Halometer was able to detect this change in light scatter with high to low contrast letters. The sensitivity appeared to increase with the decreasing contrast of the letter optotypes, but lower contrast detection of greater glare sources conflicted with the halometer screen's field of view. Decreasing the working distance will mitigate this effect, but at the expense of larger step sizes in optotype

position. Although newer tablet technology pixel size is decreasing, having the screen at 2m negates the need for a reading addition in pseudophakes or effects of evoking accommodation in the young and was, therefore, selected as the test working distance. At this distance, the selected letter size of 0.3 logMAR enabled all subjects to identify the letter at the 500 C_w contrast level with the highest light scattering filter and therefore seemed an appropriate setting for the Aston Halometer. The effects of dysphotopsia are reported to be most evident during night driving[22] and therefore a level of acuity matching that of the typical driving standard was deemed an appropriate size target for the halometer optotype.[25]

The repeatability of the C-Quant was comparable to that previously demonstrated[23] and the Aston Halometer repeatability was shown to be similar. Hence the Aston Halometer appears to provide a sensitive, repeatable way of quantifying a patient recognised form of disability glare in multiple orientations, thus adding a level of objectivity to the subjective reporting of discomfort glare.

What was Known:

- Photopic phenomenon, termed dysphotopsia, can result from multifocal intraocular lenses (MIOL) implantation.
- The symptom is often described as haloes round bright lights such as driving at night.
- Previous research has attempted to quantify the effect through subjectively marking the extent of the halo.

What this paper adds:

- An objective technique to determine the size of the halo is validated and shown to be sensitive and repeatable.

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