A Visual Test Based on a Freeware Software for Quantifying and Displaying Night-Vision Disturbances: Study in Subjects after Alcohol Consumption

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Abstract. In this work, we propose a simple visual test based on a freeware software for quantifying and displaying night-vision disturbances perceived by subjects under different experimental conditions. In the test, viewed on a monitor, the subject's task consists of detecting luminous peripheral stimuli around a central high-luminance stimulus over a dark background. The test, performed by subjects before and after consuming alcoholic drinks, which deteriorate visual performance, evaluates the influence that alcohol consumption exerts on the visual-discrimination capacity under low illumination conditions. We found a significant deterioration of the discrimination capacity after alcohol consumption, indicating that the higher the breath-alcohol content, the greater the deterioration of the visual-discrimination capacity. After alcohol intake, the graphical results showed a greater area of undetected peripheral stimuli around the central high-luminance stimulus. The Halo freeware software constitutes a positive contribution for evaluating nighttime visual performance in clinical applications.

1 Introduction

In recent years, human visual performance has been widely studied using different visual functions such as visual acuity, stereoacuity, or contrast sensitivity function. These visual functions have been tested under different experimental conditions: after ocular refractive surgery, with different illumination levels, and after the intake of different substances, such as alcoholic drinks. However, night-vision disturbances mentioned by subjects (such as halos, glare or starbursts) have been studied little, in the most cases using questionnaires, these being a subjective and non-quantitative method of gathering information which is incomplete and imprecise. Only a few works have studied theses disturbances using an objective and quantitative method in subjects having ocular pathologies [1] or after refractive surgery [2], [3]. Regarding other experimental conditions, such as under the effects of alcohol, different works have tested the influence of alcohol consumption on different visual functions, such as the contrast sensitivity or the stereoacuity [4]. However, no studies are available

examining this influence on the visual-discrimination capacity under low illumination conditions, a key visual function in daily tasks, such as nighttime driving, especially in subjects under the effects of alcohol. In such situations, it becomes necessary to evaluate visual disturbances at night that could diminish visual performance. In this work, we seek to characterize these visual disturbances objectively by using a simple visual test that could be applied universally, giving complete information on such disturbances. For this, we used a visual test, the Halo test, based on a freeware software, with no additional hardware, which quantify (by a numerical index) and display (showing the shape), the visual disturbances perceived by the subject under different experimental conditions. We evaluated the visual-discrimination capacity under low-illumination conditions before and after an alcohol consumption, an important clinical study, especially in driving. With this freeware software, we provide a simple visual test that could be useful for clinical applications, enabling the evaluation of a key aspect of visual performance under different experimental conditions.

2 Methods

The study included a total of 56 subjects (112 eyes) with ages ranging from 20 to 59 years (mean age 26.3 ± 7.7 years, standard deviation included). The admission criteria for the subjects were that all observers had to be moderate social drinkers older than 18 years old, and not being under any pharmacological treatment that could affect their health after alcohol consumption. Furthermore, they had to reach a monocular visual acuity ≥ 1.0 in both eyes (with best optical correction) and no pathological conditions that could affect visual performance. All participants in the experiments gave their informed consent in accordance with the Helsinki Declaration. The refraction state for the studied eyes was: 38 emmetropes (no refractive error), 54 myopic and 20 hyperopic, and the corresponding mean refractive error (spherical equivalent) was -2.6 ± 1.9 D and +0.9 ± 0.7 D, respectively. In the experiments, the visual-discrimination capacity was evaluated using a halometer, the Halo test, under two experimental conditions: pre- and post-alcohol consumption. The participants were invited to consume two or more glasses of red wine as the alcoholic drink, in order to evaluate visual performance under different blood-alcohol rates. The red wine used was *Ribera del Farbes* (*Pago De Almaraes* wineries, S.L. Benalúa de Guadix, Granada, Spain), a young red with 13.5% alcohol content.

2.1 Halometer: Halo test

The halometer used in this study is a simple device based on a software which allows a visual test to be performed on a monitor to detect and quantify night-vision disturbances perceived by the observer, such as halos, glare or starbursts, as shown in the literature [5]. For that, the visual-discrimination capacity under low-illumination conditions was evaluated. This visual test, called *Halo test*, was conducted using the *Halo v1.0* software (Laboratory of Vision Sciences and Applications, University of Granada, Granada, Spain), a freeware software and free of charge (downloadable from the laboratory webpage: *http://www.ugr.es/~labvisgr/*), as well as an easy and

simple tool (no additional hardware needed), which is easily implemented in clinical practice, as recent studies have demonstrated [1]-[3]. In the test performed in the experiments, the subject's task consisted of detecting luminous peripheral stimuli around a central high-luminance stimulus over a dark background. One of the great advantages of the Halo test is that it presents spatial and temporal parameters that can be controlled by assigning values, performing the visual test under the experimental conditions needed, depending on the group of observers under study.

Halo v1.0 software has been developed using language C/C++. The user's interface presents a structure similar to that of any other software, as shown in Fig. 1, where the main window of Halo v1.0 software can be observed, with different options and information about the configuration of the visual test. Spatial and temporal parameters, as well as the colour configuration and weight, are displayed. All possible parameters are described:

- *Main Stimulus Radius*: the radius, measured in pixels, of the central or main stimulus.
- *Peripheral Stimulus Radius*: the radius, measured in pixels, of the peripheral stimuli presented to the observer around the main stimulus.
- *Maximum Radius*: the distance, in pixels, measured from the centre of the main stimulus to the centre of the farthest peripheral stimulus.
- *Number of Stimuli per semiaxis*: the number of peripheral stimuli distributed in each semiaxis.
- *Number of semiaxes*: the number of semiaxes along which the peripheral stimuli are presented.
- *Show Radii*: this option shows a general graph giving information on the representation of the peripheral stimuli with respect to the semiaxes and main stimulus. It also provides the distance from the centre of the main stimulus to the centre of each of the peripheral stimuli along the semiaxis.
- *Temporal parameters. Darkness*: the time from the start of the test until the central stimulus appears for the first time, i.e. the time dedicated to darkness adaptation (luminance of the monitor background) by the observer.
- *Temporal parameters. Main Stimulus*: the time from the first appearance of the central stimulus until the first appearance of the peripheral stimulus (adaptation time to the main stimulus once the subject is adapted to darkness).
- *Temporal parameters. Exposure*: time that the peripheral stimulus is shown.
- *Temporal parameters. Refresh*: time between peripheral stimuli (from the appearance of a peripheral stimulus to the appearance of the next one). For this time, an upper and lower limit is set by introducing the values in the corresponding boxes. This time is a random value of the interval established, thus minimizing the effect of learning of the subject and avoiding false positives in the detection of the stimuli.
- *Colour configuration*: colour can be configured both for the central stimulus and for the peripheral ones. With this, it is possible to control the luminance of the stimuli.
- *Weight:* the number of times that each stimulus is presented.

Prior to the test, the observer position was fixed in front of the monitor with a chin and forehead rest. The stimulus monitor was a LCD-monitor with the resolution set at 1024x768 pixels. The distance from the observer to the monitor was 2.5 m and the

test was performed monocularly (left and right eye, contralateral eye occluded) and binocularly, with best correction. The size of the stimuli was 25 pixels for the radius of the central stimulus and 1 pixel for the radius of the peripheral stimuli, subtending 0.46 and 0.02 deg, respectively, from observer's position. A 1-pixel radius was used for the peripheral stimulus because participants were emmetropes or ammetropes with best correction and no pathological or diseased eyes. The luminance of the stimuli was measured with a spectroradiometer SpectraScan PR-650 (PhotoResearch, Inc., Chatsworth, CA, USA), being of 175.6 cd/m^2 for the main stimulus and 61.4 cd/m^2 for the peripheral one, with the luminance for the background monitor of 0.72 cd/m^2. The monitor showed 72 peripheral stimuli around the central one, distributed along 18 semiaxes (four stimuli per semiaxis) in order to evaluate a higher area around the central stimulus. The maximum radius of each semiaxis was 60 pixels (the most distant stimulus being 60 pixels from the centre of the main stimulus). For this spatial configuration, peripheral stimuli were located at 26, 38, 49, and 60 pixels from the centre of the main stimulus.

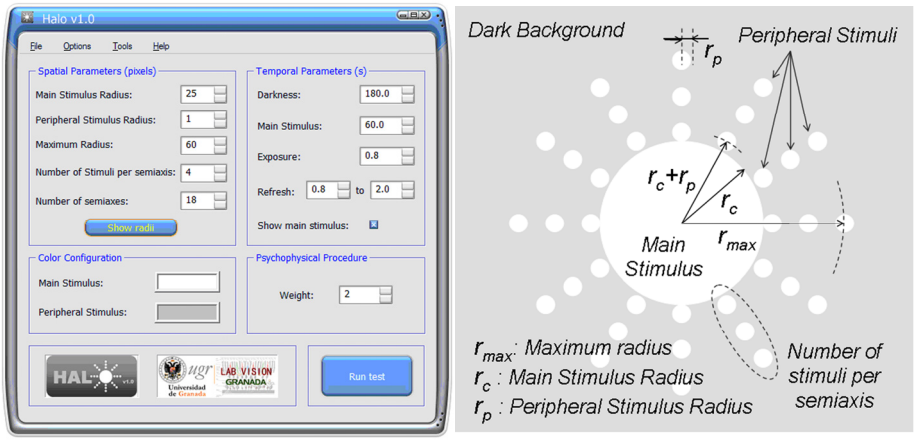

Fig. 1. Main window of *Halo v1.0 software* displaying the parameters used in this study (left) and graphic scheme for the spatial parameters of the visual test (right).

A session was performed as follows: after a 3-min adaptation period to darkness of the monitor background, there was 1-min adaptation to the luminance of the main stimulus, and then the subject was randomly presented with peripheral stimuli around the central stimulus. The participant, on detecting peripheral spots, pressed a button on the mouse, storing this information for subsequent treatment and calculation of the visual disturbance index (VDI). After the test was finished, the VDI was calculated as a ratio between non-detected stimuli and all the peripheral stimuli presented to the observer according to Eq. (1). This ratio takes into account the distance of each undetected peripheral stimulus to the main-stimulus centre, adjusted for the times that the corresponding peripheral stimulus is not detected by the subject [1]. The distance dependence is also present in the denominator, where all the peripheral stimuli are considered.

$$VDI=[\Sigma^{N}_{i=1}(p_i \cdot r_i^2)]/\ [p \cdot \Sigma^{N}_{i=1}(r_i^2)]\ . \quad (1)$$

Where r_i is the distance (in pixels) from the centre of the central stimulus to the centre of the *i*-peripheral stimulus, considering a concrete semiaxis; N is the total number of peripheral stimuli; p is the total weight (number of times that each stimulus i is shown); and p_i is the number of times over the total weight ($p_i \leq p$) that the *i*-peripheral stimulus is not detected by the subject. The VDI takes values from 0 to 1. The greater value of this parameter indicates that there is a greater contribution of visual disturbances, such as glare or visual halos around luminous stimuli, and therefore poorer discrimination capacity. In the experiments, we used a weight of 2 (p=2), which was the same for all the 72 peripheral stimuli shown, taking p_i values of 0 (peripheral stimulus detected) or 1 or 2 (stimulus not detected once or twice, respectively). The exposure time of each peripheral stimulus was 1s. After the exposure of a peripheral stimulus, a time lapse between the stimuli (refresh) of 0.8-2 s was used. During this time, only the central stimulus was presented. In addition to the VDI, the Halo software generates a graph of results, showing areas where the peripheral stimuli were not detected by the observer and areas where the peripheral stimuli were detected totally or partially. In the graph, the central stimulus is shown as well as the number of times that each peripheral stimulus is detected by the observer (X, in red colour, for being undetected, and 1 or 2, in green colour, if detected one or two times, respectively), with respect the total weight (p=2). These values (X, 1, or 2) are placed in the corresponding position where each peripheral stimulus was shown. This graph describes the shape of the visual disturbances perceived by the observer (halos, starbursts or glare), showing information about areas around a high-luminance stimulus where the observer presents difficulties on detecting different luminous stimulus.

The experiments were performed under two experimental conditions: pre- and post-alcohol consumption. Both pupil sizes (right and left eye) were measured under the two conditions, after finishing the corresponding test and then performing a new one, using a Colvard pupillometer (OASIS Medical, Inc. Glendora, CA, USA). Additionally, participants performed the test binocularly wearing the alcohol-impairment goggles Alcovista BAC 0.6-0.8º low-level night vision, used in traffic-road-safety education, which simulates night-vision impairment caused by a low blood-alcohol level (estimated BrAC from 0.3 to 0.4mg/l).

2.2 Breath-alcohol content

To quantify the alcohol content in the body for each subject, we measured the breath-alcohol content (BrAC), in mg of ethanol per litre of exhaled air (mg/l), using a breath analyser *Dräger Alcotest 7110 MK-III* (Dräger Safety AG & Co. KGaA. Lübeck, Germany), which uses two different measuring systems (an infrared sensor and an electrochemical sensor). This instrument is an evidential breath-alcohol analyser used for legal and road traffic purposes in different countries. The device was provided by the traffic police in the province of Granada (*Subsector de Tráfico de la Guardia Civil*. Granada, Spain). Participants were asked to consume the alcoholic drink within a 60-min period. Following this period, the BrAC of each participant was measured three times with the Alcotest breath-analyser: firstly, 30 min after the

last drink (just before starting the halo test), secondly, 30 min later, and finally, 90 min after the last drink. For each participant we provided the BrAC as the average of the three measured BrACs.

3 Results

The mean breath-alcohol content for the participants was 0.32±0.14mg/l, ranging from 0.14 to 0.76mg/l. Table 1 shows the mean values for the VDI pre- and post-alcohol consumption (monocular and binocularly) and wearing alcohol-simulation goggles (binocularly), as well as the pupil size (pre- and post-). In both cases, monocular and binocularly, the VDI was significantly higher after alcohol consumption ($p<0.05$), indicating a deterioration in the visual-discrimination capacity under low-illumination conditions. Wearing simulation goggles, subjects registered binocular VDI values significantly higher than either binocular VDIs (pre- and post-drinking alcohol), showing an exaggerated effect of the alcohol-consumption simulation on the subject with goggles (all subjects had a VDI higher than 0.85; no one stimulus was detected for some of them). Under both conditions, before and after alcohol consumption, the binocular VDI was significantly lower than the monocular one ($p<0.05$). Similar results were found for pupil size, resulting in a significant enlargement of the pupil diameter after alcohol consumption. However, in most cases the pupil-size difference was the sensitivity of the pupillometer (0.5mm), the difference between the mean pupil sizes (pre/post) being lower than the pupillometer sensitivity.

Table 1. Mean values for the monocular and binocular disturbance index under different experimental conditions before (pre) and after (post) alcohol consumption and wearing alcohol-impairment goggles (only binocular). Standard deviation included.

	PRE-	POST-	Goggles	p-value
VDI monocular	0.25 ± 0.15	0.39 ± 0.24	-	<0.001
VDI binocular	0.16 ± 0.08	0.26 ± 0.16	0.95 ± 0.05	<0.001
Pupil size (mm)	5.3 ± 0.9	5.6 ± 1.0	-	<0.001

Graphical results for the visual test agreed with the numerical values for the VDI. Fig. 2 represents the graphical results for a participant under the experimental conditions studied here. Under the influence of halos around the main stimulus, a higher value of the VDI indicates a lower amount of peripheral stimuli detected (X for undetected stimuli; 1 or 2 for detected stimuli once or twice, respectively). The higher the VDI, the higher the halo size around the central luminous stimulus, reducing the visual-discrimination capacity of stimuli close to the main stimulus. Deterioration for the binocular VDI as a function of alcohol content is represented in Fig. 3. This deterioration was calculated for each participant as the difference between VDI post- and pre-alcohol consumption, in such as way that a positive value indicates a deterioration in visual-discrimination capacity after having alcoholic drinks. We found a significant ascending correlation ($p<0.001$, $r^2=0.372$) for VDI deterioration with averaged BrAC (mg/l): the higher the breath-alcohol content, the higher the deterioration for the visual-discrimination capacity.

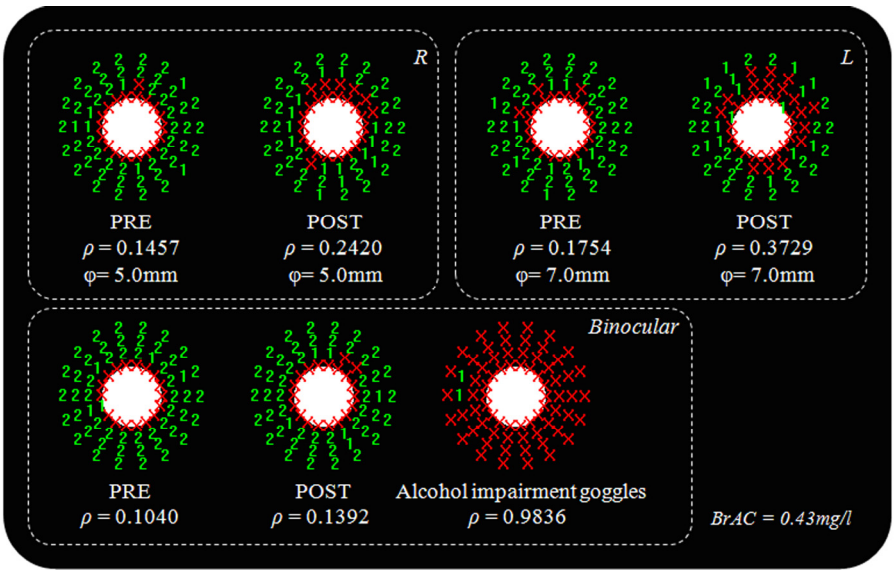

Fig. 2. Graphic results of the Halo test for a subject with a BrAC of 0.43mg/l, monocularly (right [R] and left [L] eye) and binocularly, for the different experimental conditions.

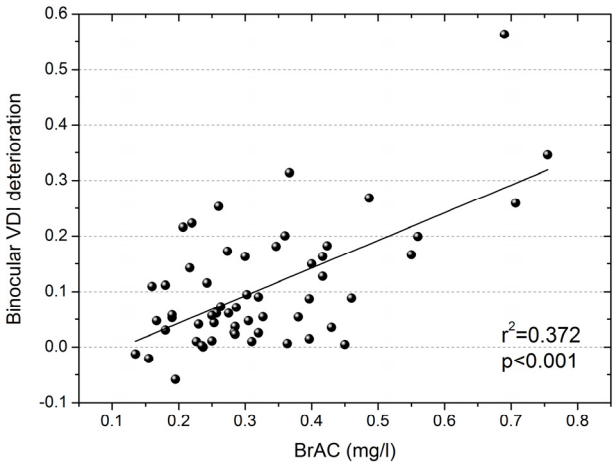

Fig. 3. Deterioration for the binocular-disturbance index as a function of the breath alcohol content (BrAC) in mg/l.

4 Conclusions

In this work, we studied the influence of alcohol consumption on the visual-discrimination capacity under low-illumination conditions. For this, we used a simple

visual test, based on a freeware software. Our results showed a deterioration of the visual discrimination capacity after oral alcohol intake, so that the higher the breath-alcohol content, the higher the deterioration of the visual-discrimination capacity. This results in a greater influence of halos and other night vision disturbances, which impede peripheral detection of a central visual stimulus, deteriorating visual performance. With alcohol-impairment goggles, the visual-discrimination capacity is seriously deteriorated, showing exaggerated impairment compared with real situations after alcohol intake. The binocular-discrimination capacity was also significantly higher than the monocular one, showing the superiority of the binocular system. On average, the pupil diameter was higher after alcohol consumption, increasing optical aberrations of the eye and contributing to perception of visual disturbances such as halos. Furthermore, alcohol consumption disturbs the tear film, as other authors have demonstrated [6], contributing to the reduction in retinal-image quality and thus deteriorating visual performance, as reported here. As a final conclusion, the use of a universal and a freeware software as a visual test offers a positive and major contribution for evaluating night visual performance in clinical applications, showing the power and utility of these types of softwares.

Acknowledgements

We thank *Subsector de Tráfico de la Guardia Civil* (Granada, Spain) for lending us the Alcotest breath analyser, and *Pago de Almaraes* wineries for donating the wine used in the studio. We also thank David Nesbitt for translating the text into English. This research was supported by Junta de Andalucía, grant P07-FQM-02663.

References

1. Castro, J. J., Jimenez, J. R., Ortiz, C., Alarcon, A., Anera, R. G.: New Testing Software for Quantifying Discrimination Capacity in Subjects With Ocular Pathologies. J. Biomed. Opt. 16 (2011) 015001/1-7
2. Anera, R. G., Castro, J. J., Jiménez, J. R., Villa, C., Alarcón, A.: Optical Quality and Visual Discrimination Capacity After Myopic LASIK With a Standard and Aspheric Ablation Profile. J. Refract. Surg. 27 (2011) 597-601
3. Alarcón, A., Anera, R.G., Villa, C., Jiménez del Barco, L., Gutiérrez, R.: Visual Quality After Monovision Correction by Laser in Situ Keratomileusis in Presbyopic Patients. J. Cataract Refract. Surg. 37 (2011) 1629-1635
4. Watten, R. G., Lie, I.: Visual Functions and Acute Ingestion of Alcohol. Ophthal. Physiol. Opt. 16 (1996) 460-466
5. Gutiérrez, R., Jiménez, J.R., Villa, C., Valverde, J.A., Anera, R.G.: Simple Device for Quantifying the Influence of Halos After Lasik Surgery. J. Biomed. Opt. 8 (2003) 663-667
6. Kim, J. H., Kim, J. H., Nam, W. H., Yi, K., Choi, D. G., Hyon, J. Y., Wee W. R., Shin Y. J.: Oral Alcohol Administration Disturbs Tear Film and Ocular Surface. Ophthalmology, 119 (2012) 965-971