A New Approach to Detect Use of Alcohol Through Iris Videos Using Computer Vision

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Abstract. In all modern society the increase in alcohol consumption has caused many problems and the potential harmful effects of alcohol on human health are known. There are some ways to identify alcohol in a person, but they are invasive and embarrassing for people. This work proposes a new non-invasive and simple test to detect use of alcohol through of pupillary reflex analysis. The initial results present rates near 85% in the correct identification using algorithms for pattern recognition, demonstrating the efficacy of the test method.

Keywords: Pupillometer, Blood alcohol, Iris, Alcohol

1 Introduction

Alcohol consumption has been associated with human social activities since the start of recorded history. In modern society, the increase in alcohol consumption has caused many social problems [22]. Alcohol use disorders (AUDs) affect an estimated 8.5% of the US population over the age of 18, and problems associated with AUDs cost the United States economy up to $185 billion per year [18].

There are immediate risks from such causes such as injury, driving accidents, unwanted pregnancy, and death due to overdose. There are also longer-term risks from repeated episodes of binge drinking consequent to neurotoxicity, as well as adverse consequences to heart, liver, immune system, bone health, and other organ systems [10] .

The potential harmful effects of alcohol on human health are a concern [22]. Pupil examination offers an objective evaluation of the visual function as well as the vegetative pathways to the eye. Essential information is gathered within a

⋆ The author thanks FAPEG and CNPQ for providing support for the development of this research

short time. This makes pupillary inspection a valuable part of the ophthalmological, neurological, and general medical examinations routine. [17] obtained results of 80% accuracy in alcohol identification through pupil exams, using existing values in the literature and the cops tests to identify consul of alcohol, this consist in follow horizontal movements of pupil. They affirm be need more experiments to a correct determination in low doses of alcohol.

In spite of technological advances and substantial progress in the understanding of the central nervous system (CNS) pathophysiology, routine pupil examination with a conventional light source has undergone no significant changes in the last 100 years [16]. Pupillary examination involves recording the size, symmetry, and light reactivity of both pupils. The analysis of these parameters is affected by significant interobserver variability due to the influence of factors such as differences in ambient lighting, the examiners own visual acuity and experience, the intensity of the light stimulus, and the method used to direct this stimulus [16].

Numerous pathologic conditions can disrupt the neural pathways responsible for orbital control or for the visual reflex centers and can manifest as a variety of entities, including ophthalmoplegia, oculosympathetic syndrome, Parinaud syndrome, and ptosis. In general medical exam, pupillary examination provides a convenient and simple method for the evaluation of autonomic function. Most patients with autonomic disorders show evidence of sympathetic or parasympathetic deficits in the pupil [3].

Ferrari et al. [11] conducted a study to investigate the movement of the pupil in healthy volunteers and in volunteers with diabetes. The work consisted of constructing a device to capture digital images from the pupil. The stimulus light and recording was applied to the same eye and external light was not isolated. Ferrari concluded that by studying the movements of the pupil it was possible to perform screening in diabetic patients.

In human subjects, acute administration of alcohol produces euphoria and feelings of intoxication with decreased response time and accuracy on neuropsychological tests measuring memory, attention, and psychomotor performance [18]. Alcohol reduces brain efficiency, reduces night vision by 25% and reduces reaction time by 30%. These effects are more intense with a lower alcohol tolerance [10]. Alcoholic beverages give drivers a false sense of confidence, damaging skills such as attention, coordination and reaction time. Chances of accidents increase even though only small alcohol amounts were ingested which were below legal limits.

Over the last few years, infrared devices included in digital cameras led to the development of digital systems which enable outside researchers to carry out repeatable non-invasive studies of pupil size and light reactivity using an objective method [16, 21, 4]. However, it is not a portable device capable of helping examination and blood alcohol detection through a direct and consensual pupillary reflex test.

In the literature, there are studies evaluating changes of the pupil diameter and characteristics of iris to help a diagnostic, most of these studies affirm

the need to improve the robustness of the methods to improve the recognition systems proposed [11, 17, 6, 20, 13].

The purpose of this work is to develop a portable device and a method of testing pupillary reflex (direct and consensual) to detect blood alcohol. Through 206 videos from 40 volunteers recorded in an environment with light controlled solely by a pupillometer, the preliminary results prove the method efficacy. This study proposes the use of light in a controlled environment coupled with recording dynamic videos of the pupillary movements and applying algorithms for pattern recognition. This work can also open a way to new studies involving computer-aided diagnosis (CAD).

1.1 Anatomy of the human ocular system

A major challenge when working with human eye images is the correct technique for image capture. This task is not trivial, mostly because the visible structure of the human eye, composed of sclera and iris, reflect visible light exceptionally well. These reflections form white spots that overlap images, preventing correct measurements of contraction and pupil dilation movement.

Moreover, research in the biometrics area has proposed equipment with special Near Infra-Red (NIR) lighting to capture human eye images [9, 12, 5]. This type of lighting is not visible to the human eye and thus does not offer visual stimulus for the pupil to execute its miosis and mydriasis movements.

To apply the right technique, it is necessary to understand the human optical system. The human optic nerve carries the afferent visual signals captured through the eyes to the Edinger-Westphal nucleus region, whose axons are directed to the right and left oculomotors. Thus, any inadvertent movements performed by an eye are reproduced in the other eye [7, 8, 14, 15].

2 Material and methods

2.1 Pupillometer construction

To apply the blood alcohol test methodology, a pupillometer was built based on consensual human optics reflection. The pupillometer has a lighting system with visible light that grad ually goes from 0 (zero) to 38 lux, positioned at 3 centimeters distance from one of the eyes.

While the lighting system provides stimuli for pupil contraction and dilation, a set of four infrared LEDs provide invisible light to the human eye, allowing the camera to record images. These LEDs operate on an 850 nm wavelength, not providing stimulus for pupil contraction and dilation. The camera that records the images is a Point Grey Firefly MV 0.3 MP Mono USB 2.0 (Microm MTV022).

Figure 1 shows a picture of a pupillometer being used by a volunteer and examples of images captured with different light stimuli.

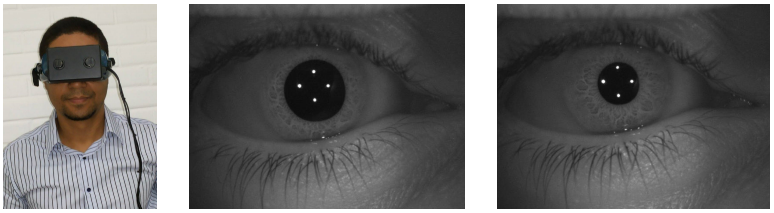


Fig. 1: Different stages of pupillary contraction and dilation.

2.2 Construction of a video database

The built pupillometer has a circuit that is controlled by software developed in C++ that allows setting the following recording parameters like recording time, start time for visual stimuli, visual stimulus length and visual stimulus intensity.

Were selected 40 volunteers with no pre-existing disease, either ocular or systemic. Each healthy volunteer was placed in a dark testing room for approximately 5 minutes, to adapt to darkness. Before the recording started, the volunteer was asked not to blink.

Experiments were performed with the recording of 50 seconds videos, at a recording rate of 30 frames per second. The 30 frames recording rate is the approximate number of frames that a human being can identify in movie frames. At every 10 seconds, a 1 lux visual stimulus was applied for 10 seconds. Therefore, in each video recorded, were registered three intervals without visual stimulus and two intervals with visual stimulus. The adopted visual stimulus methodology is shown in Table 1.

Each visual stimulus time was set to ensure the complete capture of the pupil contraction or dilation movement with a safety margin. Intensity of visual stimulus 1 lux is sufficient to stimulate the pupil to a full contraction without causing discomfort to the person being filmed. Unlike other studies in the literature [6], the white light source is positioned 3 centimeters away from the stimulated eye and any external lighting was completely sealed, as shown in Figure 1.

Table 1: Visual stimulus specifications

Frames	Visual Stimulus
1 300	OFF
301 600	ON
601 900	OFF
901 1200	ON
1201 1500	OFF

Verification of blood alcohol level on volunteers was conducted with a Mercury breathalyzer, which records alcohol milligrams number per liter of exhausted air (mg/L), and has an electrochemical sensor that reacts to alcohol in the range of 0.0 mg /L to 2.0 mg/L.

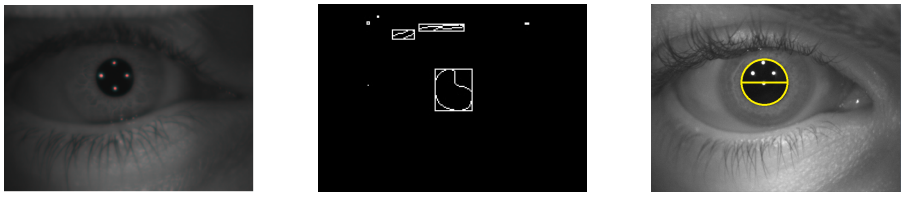
During the test, the volunteer was measured by a breathalyzer before taking any alcoholic beverages. After an observed value of 0.0 mg/L in the breathalyzer, filming was performed. The volunteer was measured by breathalyzer and filmed several times and the data gathered were recorded.

After the volunteer ingested alcohol, and before breathalyzer measurement, a ten minute wait time was initiated before performing breathalyzer measurement and the shooting. This was to ensure that any residual alcohol in the volunteers mouth would not distort the measurement.

2.3 Characteristics extraction

The constructed pupillometer in this work completely seals illumination, as seen in Figure 1, and visual stimuli were of 0 lux to stimulate a full pupil dilation and 1 lux to stimulate a maximum pupil contraction, without discomfort for the volunteer.

To segmentation and get the values of diameter to create the characteristics vector with the six metrics, was applied the algorithm proposed by [19], which applies the properties width and height in the red channel of the smoothed image. Applied this algorithm is possible found the correct diameter of pupil as presented in Figure 2.



(a) (b) (c)

Fig. 2: (a) Channel Red. (b) Pupil segmented (c) Pupil Diameter

In order to evaluate results, six metrics similar to the tests performed by Chang et al. [6] were applied. They used visual stimuli ranging from 0.6 to 2.1 seconds long. The volunteer was not in a sealed lighting environment, but in a room with partial lighting, so the applied visual stimuli ranged from 25 lux in the dark, to stimulate pupil dilation, to 35 lux in the clearest stimulus, to stimulate pupil contraction.

- Maximum Mydriasis - demonstrates the largest pupil diameter before contraction. This is the value of maximum pupil diameter one second before

apply the visual stimulus. This value is found between frames 270-300 (first visual stimulus) and between frames 870-900 (second visual stimulus);
- Maximum Miosis - demonstrates the smallest pupil diameter after contracting. This is the value of minimum pupil diameter three seconds after apply the visual stimulus. This value is found between frames 301-390 (first visual stimulus) and between frames 901-990 (second visual stimulus).;
- Amplitude (Amp) - shows in percentage how much the pupil constricts after applying 1 lux visual stimulus. This value is calculated by equation 1.

$$Amp = \frac{Miosis}{Mydriasis} \tag{1}$$

- Latency (Lat) - shows the time in the 10 seconds of light stimulation that the pupil takes to start contraction after visual stimulus application. This value is found between frames 301-390 (first visual stimulus) and between frames 901-990 (second visual stimulus). The time is calculated from frame 300 or 900 considering the frame rate 30 fps;
- Time to maximum contraction (TMC) - demonstrates at what time in the 10 seconds stimulus the pupil reaches its maximum contraction. This is the value of minimum pupil diameter three seconds after apply the visual stimulus. This value is found between frames 301-390 (first visual stimulus) and between frames 901-990 (second visual stimulus). The time to reach minimum diameter is calculated from frame 300 or 900 considering the frame rate 30 fps;
- Time to maximum dilation (TMD) - demonstrates at what time in the 10 seconds of light stimulation absence the pupil reaches maximum dilation. This is the value of maximum pupil diameter three seconds after supply the visual stimulus. This value is found between frames 601-690 (first visual stimulus) and between frames 1201-1290 (second visual stimulus). The time to reach maximum diameter is calculated from frame 600 or 1200 considering the frame rate 30 fps.

The authorization to carry out this footage was submitted and approved by the Ethics Committee in Research (CEP), in a submitted project in Plataforma Brasil, under the number CAAE 23723213.0.0000.5083.

3 Results

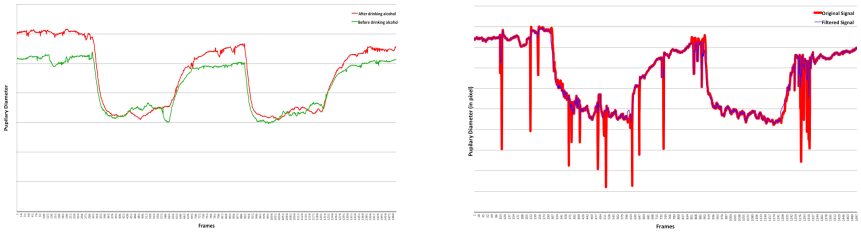
206 videos were carried out, with 3 to 10 videos for the 40 volunteers. 10 volunteers were females (25%) and 30 males (75%). The individuals average age was of 29.0 8.2 years. All videos were normalized by Z-Score.

It is possible to observe the effect of alcohol in the volunteer, causing the pupil to become more dilated in the mydriasis mode versus miosis. The pupil reaction time, demonstrated by Latency (Lat) is also slower after alcohol consumption. Table 2 shows the average values and its standard deviations for all videos of the volunteers. The 1st period corresponds to frames 301 600 and 2nd period corresponds to frames 901 1200 when the light is switch on.

Table 2: Metrics used for validation

	Sober				Inebriate			
	1st Period		2nd Period		1st Period		2nd Period	
	Mean	SD[1]	Mean	SD	Mean	SD	Mean	SD
Mydriasis	1.42	0.27	1.38	0.26	1.51	0.25	1.39	0.29
Miosis	0.04	0.01	0.10	0.03	0.05	0.02	0.13	0.08
Amp	0.02 %	-	0.09 %	-	0.03 %	-	0.07 %	-
Lat	0.33 seg	0.45 seg	0.26 seg	0.13 seg	0.34 seg	0.36 seg	0.28 seg	0.13 seg
TMC	1.73 seg	0.34 seg	1.60 seg	0.40 seg	1.73 seg	0.35 seg	1.48 seg	0.44 seg
TMD	1.89 seg	0.24 seg	1.90 seg	0.22 seg	1.85 seg	0.30 seg	1.85 seg	0.30 seg

Figure 3a shows the pupil diameter of one person in two stages: before drinking alcohol and after drinking alcohol. As can be seen, the presence of alcohol produces a slow pupil reaction time when the light is switch on or off.



(a) (b)

Fig. 3: (a) Pupillary diameter with different alcohol levels. (b) Pupillary diameter with noises and filtered.

The request for the volunteers not to blink and keep their eyes fixed on the pupillometer bright points was not always followed. In some cases, the volunteer movements caused failures in targeting the pupil and therefore, caused noise in the signal. Figure 3b shows an example of an original signal with noise and the same signal filtered by the neighborhood average algorithm.

3.1 Pattern recognition

In this work, we used two algorithms for pattern recognition: Support Vector Machine (SVM) and k-Nearest Neighbors (KNN). SVM tries to model input variables by finding the separating boundary called the hyperplane to achieve classification of the input variables [1]. SVM training was performed using a linear kernel function and the C parameter was set to 1 (default of SVM). KNN

[1] SD - Standard Deviation

is a supervised learning technique introduced by Aha [2]. The general idea of this technique is to find the k closest labeled examples to unlabeled; based on the labeling of the closest examples, the decision of which is the unlabeled example class. The value of k in this work was 3 and Euclidean distance was used.

We applied cross-validation to measure the accuracy of the classifiers. In this technique, samples are divided into n mutually exclusive partitions. In each iteration, a different partition is used to test the classifier, and all the other n-1 partitions are used to train the classifier. The hit rate and error is the average of all rates calculated for the n iterations. In this work, n equals to 10 was used. Table 3 shows the results obtained by KNN and SVM for ten volunteers with higher amounts of videos.

Table 3: Values obtained through SVM and KNN application

Volunteer	Videos	KNN	SVM
1	10	80.00	80.00
2	5	100.00	80.00
3	5	80.00	80.00
4	5	80.00	80.00
5	9	88.89	77.78
6	6	50.00	83.33
7	9	75.00	87.50
8	6	83.00	100.00
9	6	83.00	83.33
10	9	100.00	100.00
	Average score ⇒	**80.28**	**85.19**

4 Discussion

The pupillometer constructed proved to be an effective, non-invasive, objective, and portable pupillary change identification method based on alcohol intake. Images captured were carried out efficiently, without the need to repeat examination by measurement error. In some cases, the volunteer movements caused failures on pupil segmentation and, therefore, caused noise in the signal. To correct them, the software used the neighborhood average algorithm. The built pupillometer completely seals lighting, and visual stimuli were of 0 lux to stimulate the pupil to full dilation, and 1 lux to stimulate the pupil to a maximum contraction, without discomfort to the individual.

The developed method proved to be better than the breathalyzer, since an individual can refuse to blow on the breathalyzer. In addition, in this proposed method there is no contact with body secretions. Matching airflow with blood flow is critical for normal gas exchange and requires a delicate balance between the blood and air distribution systems.

Through the evaluation of filming results, it is observed that the pupil diameter reacts differently when the volunteer drinks alcoholic beverages. In the results general average observed in Table 3, it is noted that the maximum mydriasis value of a person remains stable between the first period (first visual stimulus frame 301 to 600) and second period (second visual stimulus frame 901 to 1200) when he/she has not ingested alcoholic beverages. When the person ingested alcoholic beverages, the pupil is dilated and unstable. It is noted by the difference in the maximum mydriasis values from one period to the other that pupillary reflexes are compromised. The same can be observed for miosis, indicating lack of control and stability reflexes when a person is under alcohol influence.

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Amplitude values, which show how the pupil constricts while receiving visual stimulus, are also unstable and higher when a person is under alcohol influence. It is also observed that the reaction times (latency) for maximum mydriasis and maximum miosis are also more stable and regular when the person has not ingested alcoholic beverages.

The results observed in Table 3 show rates for KNN and SVM algorithms in volunteers with a sufficient amount of videos. The figures show the possibility to use such algorithms to develop the identification of a blood alcohol method based on the pupillary reflex.

5 Conclusion

The pupillometer allowed the evaluation of size, symmetry, and light reactivity of pupils. Test interference factors were eliminated such as: ambient lighting, observer experience, light stimulus intensity, and the method used to direct this stimulation.

The pupillometer proved to be an effective, non-invasive, objective, and portable pupillary reflex test method based on light stimulus. It is a useful tool that can be used by companies to check the presence of blood alcohol levels in a person.

The methodology developed was efficient for identifying alcohol in volunteers with 5 or more videos. It will be necessary to conduct more experiments to

determine the minimum amount of videos necessary for identification. However the lack of contact with blood or any type of secretion makes this a safe, non-invasive, and very helpful method for this kind of examination.

This work can also open a way to new studies involving computer-aided diagnosis (CAD). Changes in the software could possibility enable studies to identify signals of a probable disease. Therefore, further research is warranted to standardize dark adaptation time before the start of the test, the light intensity, duration of the light stimulus, and the interval between them.

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