Abstract. The use of computers has reported an exponential growth in the last decades, the possibility of carrying out several tasks for both professional and leisure purposes has contributed to the great acceptance by the users. The consequences and impact of uninterrupted tasks with computers screens or displays on the visual health, have grabbed researcher’s attention. When spending long periods of time in front of a computer screen, human eyes are subjected to great efforts, which in turn triggers a set of symptoms known as Computer Vision Syndrome (CVS). Most common of them are: blurred vision, visual fatigue and Dry Eye Syndrome (DES) due to unappropriate lubrication of ocular surface when blinking decreases. An experimental protocol was de -signed and implemented to perform thermographic studies on healthy human eyes during exposure to dis -plays of computers, with the main purpose of comparing the existing differences in temperature variations of healthy ocular surfaces.

1. Introduction
Technological advances have given rise to important changes in the visual needs of people, i.e. increase of short-distance vision. The use of computers is one of the principal cause of this visual stress since it requires a different set of visual abilities to achieve eye movements of scanning, visual fixation, focus shifts among others that allow interaction with displays and screens, keyboards and sometimes physical documents to transcript. Therefore, it is advisable a visual assessment that not only considers the refractive state but also the lubrication of the ocular surface [1]. S A. Castillo Estepa y A. Iguti [2] reviewed the state of art in the last 30 years and selected 32 articles that fulfill inclusion criteria since they had used the SVC categorization for different types of symptoms, each one associated to several visual diagnosi s including alterations of the ocular surface such as DES. Terminology used to mention symptoms and the assessment of visual alterations is quite diverse, thus hampering an appropriate analysis of diagnosis and symptoms related to SVC. The authors concluded that SVC visual symptomatology reveals problems of binocular vision and accommodation reflex triggered by demands of short-distant vision. DES is considered the principal symptom of the SVC category, but it is not present in all the cases; whereas in other cases, eye dryness somatology is simply caused by extreme environmental conditions that increase vaporization of tears. The combination of bad habits during work with computers and unfavorable environmental conditions in the workplace may risk the visual and ocular health of computer users. Another study classified 200 employees randomly selected into three categories according to daily hours in front of computers that they had previously reported in a survey. The resulting categories were: less than 2 hours, from 2 to 6 hours, and more than 6 rs. Afterwards, they underwent ophthalmic evaluation to assess the visual health of partici-pants. Tests results revealed that computer users who spend more than 6 hours suffer from visual fatigue, and secondly from itching and irritation. Participants worked for institutions and departments from the universities of Teerthankaer Mahaveer, Moradabad and Uttar Pradesh [3]. All these alterations of
the tear film due to long periods in front of displays and screens may be accompanied by thermal changes. Computer Vision Syndrome (CVS) describes a series of problems related to the use of computers during prolonged periods of time resulting in some alterations in the visual health, most common conditions are visual fatigue, head-aches, blurred vision and DES [4]. Some causes of CVS could stem from features of the visualization such as poor lighting, excessive brightness and quality of screens and displays, upgrading and radiation frequencies, as well as the combination of some of the aforementioned factors with inadequate distances, workplace arrangements, level of toxicity in the environment, appropriate room temperature and humidity, working angle etc. [5,6] American Academy of Optometry published a report where they stated that 70% of employees who need a data processor to carry out tasks at work, suffer from problems in the muscle-skeletal system [7] and visual fatigue due to non-interrupted use of computers. Ophthalmologist refer to this new pathology as CVS. In many cases, eye care professionals ascribe this disease to issues related to workplace arrangement, poorly lighting and uncomfortable contrasts of screens. Many symptoms experienced by users disappear when tasks on computers are interrupted. Nevertheless, some people undergo reduction in their visual capabilities, even after finishing labors with computers [8].

2. Materials and Methods
The dependent variable of this study is the variation of temperature on ocular surface in visual fixation with blinking, which was measured in three different stages: before, during and after an hour of working in front of a computer, they will be detailed on the section Measurement Protocol. Dryness degree of human eyes is the independent variable expected to be evaluated using the designed method based on infrared photography in order to analyze determined time intervals, as well as the behavior of average temperature on ocular surfaces during visual fixation with blinking, before and after working with computers. Both measuring devices and experimental setup can be seen in Figure 1, with participants in the study.

2.1 Measuring Devices: Fluke Ti32 is a thermal image processor that captures high quality images, its temperature measurement range is -20°C to +600°C, and manufacturer claims a temperature measurement accuracy of ±2°C or 2% and temperature resolution of 0.01 (°F o °C) [9,10].

![Figure 1. Photographs depicting the experimental protocol.](image)

2.2 Measurement Protocol: Participants were 37 students from Universidad Tecnológica de Pereira (UTP), age range 18 to 28 years old. The study excluded individuals who have suffered from fever or migraine as well as people with systemic vascular diseases such as hypertension and diabetes, these people usually report higher thermal increase in the eye due to blood flow rate on the retina and choroid [11]. To avoid changes in skin emissivity while taking thermal captures, female students were asked to remove their makeups [12, 13]. Although IR thermography applied herein is an noninvasive technique, we abode by bioethical guidelines provided by 1964 Helsinki declaration and 008430 resolution of 1993 by Colombian Ministry of Health; and accordingly, all participants were informed previously about the protocol, so they could give their informed consents [14, 15].

Arrangements, monitoring and controls took place to guarantee appropriate conditions for capturing thermal images in the Electrophysiology Laboratory of UTP. Factors like temperature, relative humidity, air currents, lighting and pollution were taken into account [13]; consequently, to obtain measurements from all the participants under the same conditions, constant monitoring and control was performed on comfort relative humidity (50%, - 10% to + 20%) and comfort room
temperature 22 °C, -3 °C to + 3 °C) [16], finally light intensity was fixed to recommend levels for simple visual task (200 – 300 Lux) [17]. Each participant waited in the laboratory 10 minutes before the thermal images capturing; thereby contributing to not only participant’s adaptation to temperature and relative humidity inside the testing room, but also to temperature stabilization of the ocular surfaces [16, 18, 19, 20]. Thermal images capturing procedures always began with the right eyes and ended with the left eyes. The procedure of image capturing was divided into three stages. During the first stage (previous to one hour of work in front of a computer), thermal images of ocular surfaces were taken during 60 seconds with participants holding a visual fixation with blinking, staring at the lens of the thermal images. 10 to 15 images from each participant were captured in first stage. Second stage of measurements consisted in taking thermal images during one hour of work with a computer aiming to determine temperature variation on the ocular surfaces. Participants sat 30 to 50 cm away from the screen. From the beginning of this stage and every 5 minutes thermal images of the ocular surface were taken at a distance of 10 cm. Third stage of measurements took place immediately after the one-hour period in front of the computer and repeated the same protocol of the first stage.

Table 1, Timing of measurements with Ti32 thermal imager.

| Stages   | Description                                      | Time   |
|----------|--------------------------------------------------|--------|
| First    | Holding a visual fixation (Open eyes with finger) | 60 seconds |
| Second   | Test during the work in front of a computer screen | 60 minutes |
| Third    | Holding a visual fixation (Open eyes with finger) | 60 seconds |

For implementation of the designed experimental protocol, every thermal image was previously analyzed with the built-in software of Ti32 thermal camera: SmartView 3.5, which offers several options of markers (point-shaped, linear, rectangular, elliptical and polygonal) to focus on areas of interest within the image to analyze. Horizontal and vertical profiles, from data based on measurements during stages 1 and 3, were studied to achieve a qualitative analysis using the corresponding horizontal and vertical markers featured in SmartView. The horizontal profiles consisted of the whole area between the nasal and temporal conjunctiva, whereas the vertical ones included the area between upper and lower eyelids. Additionally, a quantitative study focused on variation temperature on the cornea after each blinking by means of the circular marker provided by SmartView, which assisted to determine average temperature of this area of the ocular surface. This quantitative study using the circular marker was the only one performed for stage 2 of measurements corresponding to an hour in front of a computer, with the purpose of determining average temperature of cornea in every thermal image and thereby proceeding to the analysis of temperature variation throughout the task with the data processor. The statistical analysis of the protocol started with running normality tests on the three types of measurements to determine if the data sets were well-modeled by a normal distribution. Since normality tests yielded negative results for data corresponding to stages 1 and 3 (temperature variation experienced during visual fixation with blinking, before and after using the computer), these data were subjected to Mann Whitney U-tests, a non-parametric test that identifies statistically significant differences between populations based on the analysis of two independent samples. Conversely, normality tests yielded positive results for data obtained in stage 2. Therefore, these set of data were subjected to a t-student test, a parametric test to compare the median of a sample against a theoretical median to determine statistical differences between them.

3. Discussions and Results

The principal result of the development of the project was the design of an experimental protocol based on a thermography approach to analyze the thermal behavior of healthy ocular surface when it is exposed to computers. The results obtained from data gathering showed that the proposed methodology is effective for the study of the temperature of healthy ocular surface. The population sample of this study consisted of 37 participants, 19 female individuals (51.35%) and 18 male individuals (48.65), age range 18 to 28 years. As stated in the measurement protocol section, qualitative analysis was performed on data obtained from stages 1 and 3 based on horizontal and vertical profiles of the whole ocular surface. According to the horizontal marker, there is a
communality in the behavior of the entire population sample concerning the temperature of the three ocular areas studied herein (temporal conjunctiva, nasal conjunctiva and cornea). The lowest temperatures in average are reported for the cornea surface in first place, followed by the temporal conjunctiva, and the nasal conjunctiva in last place. The greatest difference (1°C) was found between the cornea and the nasal conjunctiva. The vertical profile focused on the intermediate zones between the cornea area and both eyelids (upper and lower). According to the vertical marker, the temperature on the center of the cornea was nearly 0.6 °C less than that recorded for the aforementioned intermediate zone. Thus, coming to the conclusion that ocular surface corresponding to cornea reports lower temperatures. Stages 1 and 3 also included analysis of thermal images using the circular marker to determine the average temperature of the cornea. Temperature variation ranges (initial to final temperature) for the whole population during visual fixation with blinking were the following: in stage 1, before working with computer, from -0.79 to -0.01 °C; and in stage 3, after working with computer, from 0.96 to 0.78 °C. Results revealed a considerable drop in temperature in stage 1, while for stage 3 there were many cases where the temperature remained constant, some with a slow drop in tempura-ture and a few where the temperature kept increasing continually.

As stated in the protocol measurement section regarding the statistical analysis; since results of normality test for the data on temperature variation gathered from both stage 1 and 3 yielded negative results, these data was subjected to Mann Whitney U-test with the purpose of determining if there is Statistically significant difference between them. The comparison reported a Z-value of -2.66993 and a p-value of ≤ 0.00733, thereby confirming that distributions of the two set of data were significantly different. By means of the circular marker featured by SmartView, increase of temperature was analyzed based on thermal images corresponding to cornea surface during stage 2 (60 minutes working with a computer). Increases ranges re-reported were from 0.08 to 1.11 °C for right eyes and from 0.03 to 1.29 °C for left eyes and thereby corroborating that under the influence of a computer screen, temperature of both eyes tends to increase considerably. As stated in the protocol measurement section, the normal distribution of the data from stage 2 was confirmed by statistical normality test. Therefore, a t-student test was performed to compare this sample with a theoretical median and determine statistical difference between them. Results from the test yielded a t-statistic = 16.19305, DF=73 y and p-value ≤ 7.20 X 10-26. The previous determines a confidence level of 90%, which in turn means that the sample of this study is significantly different from the theoretical median which has a confidence level of 99.9%. A record must be kept for the monitoring and control of room conditions during measurement stages (luminosity, temperature and relative humidity). Along these

| Test No. | First stage |  |  |  |
|----------|-------------|----------------|----------------|----------------|
|          | AT Cornea (°C) | AT Temporal (°C) | AT Nasal (°C) | AT Cornea (°C) |
| 1        | -0.04       | -0.10          | -0.25          | -0.04          |
| 2        | -0.04       | -0.10          | -0.25          | -0.04          |
| 3        | -0.04       | -0.10          | -0.25          | -0.04          |
| 4        | -0.04       | -0.10          | -0.25          | -0.04          |
| 5        | -0.04       | -0.10          | -0.25          | -0.04          |
| 6        | -0.04       | -0.10          | -0.25          | -0.04          |
| 7        | -0.04       | -0.10          | -0.25          | -0.04          |
| 8        | -0.04       | -0.10          | -0.25          | -0.04          |
| 9        | -0.04       | -0.10          | -0.25          | -0.04          |
| 10       | -0.04       | -0.10          | -0.25          | -0.04          |
| 11       | -0.04       | -0.10          | -0.25          | -0.04          |
| 12       | -0.04       | -0.10          | -0.25          | -0.04          |
| 13       | -0.04       | -0.10          | -0.25          | -0.04          |
| 14       | -0.04       | -0.10          | -0.25          | -0.04          |
| 15       | -0.04       | -0.10          | -0.25          | -0.04          |
| 16       | -0.04       | -0.10          | -0.25          | -0.04          |
| 17       | -0.04       | -0.10          | -0.25          | -0.04          |
| 18       | -0.04       | -0.10          | -0.25          | -0.04          |
| 19       | -0.04       | -0.10          | -0.25          | -0.04          |
| 20       | -0.04       | -0.10          | -0.25          | -0.04          |
| 21       | -0.04       | -0.10          | -0.25          | -0.04          |
| 22       | -0.04       | -0.10          | -0.25          | -0.04          |
| 23       | -0.04       | -0.10          | -0.25          | -0.04          |
| 24       | -0.04       | -0.10          | -0.25          | -0.04          |
| 25       | -0.04       | -0.10          | -0.25          | -0.04          |
| 26       | -0.04       | -0.10          | -0.25          | -0.04          |
| 27       | -0.04       | -0.10          | -0.25          | -0.04          |

| Test No. | Second stage |  |  |  |
|----------|--------------|----------------|----------------|----------------|
|          | AT Cornea (°C) | AT Temporal (°C) | AT Nasal (°C) | AT Cornea (°C) |
| 1        | 0.10         | 0.04           | -0.09          | 0.10           |
| 2        | 0.10         | 0.04           | -0.09          | 0.10           |
| 3        | 0.10         | 0.04           | -0.09          | 0.10           |
| 4        | 0.10         | 0.04           | -0.09          | 0.10           |
| 5        | 0.10         | 0.04           | -0.09          | 0.10           |
| 6        | 0.10         | 0.04           | -0.09          | 0.10           |
| 7        | 0.10         | 0.04           | -0.09          | 0.10           |
| 8        | 0.10         | 0.04           | -0.09          | 0.10           |
| 9        | 0.10         | 0.04           | -0.09          | 0.10           |
| 10       | 0.10         | 0.04           | -0.09          | 0.10           |
| 11       | 0.10         | 0.04           | -0.09          | 0.10           |
| 12       | 0.10         | 0.04           | -0.09          | 0.10           |
| 13       | 0.10         | 0.04           | -0.09          | 0.10           |
| 14       | 0.10         | 0.04           | -0.09          | 0.10           |
| 15       | 0.10         | 0.04           | -0.09          | 0.10           |
| 16       | 0.10         | 0.04           | -0.09          | 0.10           |
| 17       | 0.10         | 0.04           | -0.09          | 0.10           |
| 18       | 0.10         | 0.04           | -0.09          | 0.10           |
| 19       | 0.10         | 0.04           | -0.09          | 0.10           |
| 20       | 0.10         | 0.04           | -0.09          | 0.10           |
| 21       | 0.10         | 0.04           | -0.09          | 0.10           |
| 22       | 0.10         | 0.04           | -0.09          | 0.10           |
| 23       | 0.10         | 0.04           | -0.09          | 0.10           |
| 24       | 0.10         | 0.04           | -0.09          | 0.10           |
| 25       | 0.10         | 0.04           | -0.09          | 0.10           |
| 26       | 0.10         | 0.04           | -0.09          | 0.10           |
| 27       | 0.10         | 0.04           | -0.09          | 0.10           |
lines, it is important to locate a place where those variables can be controlled [22]. Infrared thermographic techniques applied to human beings are not invasive because there is no direct manipulation of individuals at any time. Despite that, the protocol was designed in accordance with bio-ethical specifications. The affectivity of the experimental protocol proposed for the study of thermal behavior of healthy human ocular surface was proved by the results from measurement stages and the statistical analysis with the significant statistical differences reported.

Acknowledgment
To the Vice Chancelor Office for Research, Innovation, and Outreach of Universidad Tecnológica de Pereira, for the support in the project “Computer Vision Syndrome (CVS) - Thermographic and Electromagnetical Analyses”.

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