Eyestrain, Blink Rate and Dry Eye Syndromes of Video Display Terminal Users

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Abstract— **We investigated whether the eyestrain, often experienced by subjects using a video display terminal (VDT) for an extended period of time, is due to the decrease of blink rate or to the temporarily dry eyes. Thirty-seven subjects with no dry eyes but experienced eyestrain participated in a series of experiments. The 1st experiment was performed without using VDT to obtain the control data and subsequent experiments were performed with a VDT. In those experiments we established the base line for the eyestrain, increased the blink rate and supplied the eyes with eyedrops. Blink rate, visual acuity, temporal modulation transfer function and degree of severity of eyestrain were recorded before and after each experiment. The obtained results suggested that, using the VDT causes the decrease of the blink rate that in turn produces dry eyes which causes the eyestrain.**

Keyword— **Blink rate, Eyestrain, Dry eye, Temporal modulation transfer function, Video display terminal.**

I. INTRODUCTION

Frequent users of video display unit (VDT) often experience eyestrain which also known as visual fatigue or asthenopia. It consists of subjective symptoms of the eyes and covers a wide range including burning, itching, tiredness, aching, and soreness of the eyes[1-4]. Other investigations suggested that the use of VDT decreased the blink rate and increased the tear evaporation rate, consequently causing dry eyes[5]. On the other hand, Lowenstein[6] suggested that the eyestrain was simply due to the decrease of blink rate. In an investigation unrelated to VDT, Toda et al.[7] found that there was a strong relation between dry eyes and eyestrain.

From these investigations we hypothesize that people blink less when they use a VDT than when they do not use it. The decrease of blink rate will cause dry eye, which, in turn, leads to eyestrain. To test this hypothesis we performed four experiments. The first experiment was performed with subjects who were not using a VDT to obtain the control data. The 3 subsequent experiments were conducted with the same subjects who were using VDT. Thus, the 2nd experiment established the base line for the subject's eyestrain along with others parameters. In the 3rd experiment puffs of air were used to increase the blink rate. In the 4th experiment saline droplets were used, instead, to increase the blink rate and, at the same time, moisten the eyes. If the treatment in the 3rd experiment eliminates the eyestrain we would then conclude that the eyestrain is due solely to the decrease of blink rate; by contrast if only the treatment in the 4th experiment eliminates eyestrain we would then conclude that dry eyes would be the cause of the eyestrain. This study may lead to improvements in working conditions.

Regarding the methods to assess the relationship between eyestrain and dry eyes, Toda et al.[7] proposed a questionnaire that included several aforementioned factors. In investigating the methods to quantify the visual fatigue of VDT users, Saito[8] found that the critical flicker frequency (CFF), after five hours of intensive eye efforts, decreased about 8%. On the other hand, studies of the sensitivity to the flickering light showed that the Temporal Modulation Transfer Function (TMTF) is more sensitive than the CFF values[9]. Furthermore, it has been reported that prolonged VDT work led to impairment of visual acuity[10]. From these investigations, in the present study, the eyestrain will be assessed based on the TMTF curve, visual acuity chart and questionnaire.

II. MATERIALS AND METHODS

Thirty-seven subjects (21 males and 16 females, ages: 28 ± 12 years old), who were under no medication at the time of the experiments, participated in the study. All except two were naive to the experiments. They were not diagnosed with chronic dry eyes syndrome or other eye diseases; however, they had experienced eyestrain while working with computers.

Each subject participated in a series of 4 experiments: the 1st experiment was performed without using VDT to establish the control data; the 2nd was performed with a VDT to establish the base line for the eyestrain; the 3rd was performed with a VDT and a device that stimulated blink rate and the 4th, was performed with a VDT and a device that ejected saline droplets to the subject's eyes.

Blink rate, visual acuity, TMTF curves and eyestrain were recorded before and after each experiment. The differences were computed and statistical analyses were used (level of significance was 0.05). All data are indicated by their average and standard deviation values.

The tenets of the Declaration of Helsinki were followed, the study protocols and experimental procedures were approved by the local Institutional Review Board, and informed consent was obtained for all subjects. They also filled a questionnaire regarding identification and clinical information, which were kept confidential.

The blink rate (expressed as blinks per minute, bpm) was determined with the Blink Rate Recorder, described in detail elsewhere[11].

The visual acuity was determined using the standard Snellen chart.

The TMTF curves were established using a visual stimulator, described in detail elsewhere[12]. It generates a stimulus of the form $L = L_0 (1 + m \cos 2\pi ft)$, where L is the instantaneous luminance, L0 the mean luminance, m the modulation depth (can be adjusted from 0 to 100%), f the frequency (can be adjusted from 0 to 100Hz) and t the time. In the investigation presented here the retinal illuminance was 100 trolands and the method to establish the TMTF curve was "fusion-to-flicker with preview" as described elsewhere17. Throughout the experiments presented here only one eye was tested, an achromatic stimulus was used with field of view of 40° and a dark surround.

The eyestrain was determined using a questionnaire which consisted of questions regarding working conditions with the computer, and the state of the eyes and vision to assess eyestrain and dry eyes similar to those described by elsewhere[7]. The answers were rated from 1 to 5 with 1 as "No" and 5 as "Very Often". For the purpose of simplicity, all answers from the questionnaire were averaged and normalized with 1 as the highest value. Hereafter they will be referred to as the normalized eyestrain severity (NES) level.

To trigger the subject's blinking or to administer the droplets of saline to the subject's eyes we used an Automatic Eyedrop Dispenser, which has been described in detail elsewhere[14]. In the study presented here, the device either contained only compressed air to stimulate the blinking rate or a 0.9% saline solution to supply additional fluid to the eyes.

The goal of the 1st experiment was to obtain the control data. The subjects wore the Blink Rate Recorder while performing, for an hour, without using a VDT, a task, which did not require intensive visual concentration (e.g., eating or relaxing). For the 3 subsequent experiments, the subjects wore the Blink Rate Recorder while playing intensely a computer game in front of a VDT for 2 consecutive hours. Furthermore, in the 3rd experiment, because its goal was to determine whether by increasing the blink rate alone the eyestrain symptoms could be eliminated, subjects wore, in addition, the Automatic Eyedrop Dispenser, which ejected a puff of air to the eye. The impulsive air pressure hence triggered spontaneous blinking. The air volume was small, to prevent it from contributing to the dry eyes. Further, only one eye received the puff of air that was aimed toward the nasal corner of the upper eyelid. The ejection rate was one puff every ten seconds. In the 4th experiment, because its goal was to determine whether the dry eyes might cause eyestrain, the Automatic Eyedrop Dispenser delivered 0.9% saline droplets instead of puff of air. The droplets were of 5 μl of volume and were ejected onto the caruncles of both eyes at the same time. The ejection rate was one drop every minute. The volume and ejection rate did not cause an overflow in the eyes.

III. RESULTS

The results from the 1st experiment showed that the blinking rate fluctuated randomly and was 21.6 ± 9.6 bpm. The TMTF curves, visual acuity and eyestrain established before and after the experiment were not different ($p>0.05$).

The results from the 2nd experiment indicated that work with VDT induced eyestrain in all subjects. The blink rate was 8.9 ± 4.6 bpm. The visual acuities of all subjects slightly decreased after performing the task. The decrease was statistically significant ($p<0.05$). The NES level was 0.6 ± 0.05, i.e., the eyestrain increased drastically after performing the task. By contrast, the TMTF curves of only 3 subjects showed the difference between before and after the subjects performed with the VDT. The differences were found at the frequencies below 20Hz where the sensitivity to the flicker decreased significantly after performing the task; by contrast the difference of the CFF values was not statistically significant. The curves of other subjects showed no statistically significant differences at any frequencies.

The results from the 3rd experiment showed that the ejection of puffs of air increased the blink rate and reduced the eyestrain. The blink rate increased to 18.3 ± 8.2 bmp. The differences of the visual acuity before and after performing the tasks was 0.17 ± 0.01 i.e., a statistically significant deterioration of visual acuity. The average NES level was 0.42 ± 0.05, which was statistically significant. By contrast, we found no difference for any subjects in the TMTF curves before and after performing the task.

The results from the 4th experiment showed that the ejection of the saline increased the blink rate and completely relieved the eyestrain. The blink rate increased to 20.5 ± 9.3 bmp. The visual acuity of all subjects before and after performing the tasks was not statistically different ($p>0.05$). The average NES level was –0.1. The negative value was due to an improvement of the NES levels of some subjects after performing the experiment. We found no difference for any subjects in the TMTF curves before and after performing the task.

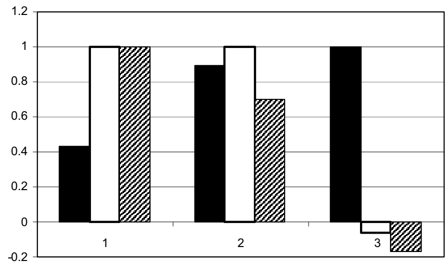

Fig. 1: *Variation of blink rate (black bars), visual acuity (white bars) and severity of eyestrain (shaded bars) in 3 experiments: baseline (1), with air puff treatment (2) and with saline treatment (3). For the purpose of comparison the maximum values of blink rate, visual acuity and eyestrain were normalized with the highest values as 1. We found that when the blink rate increased the visual acuity and the severity of eyestrain improved (see text).*

Fig. 1 shows blink rate, NES level and visual acuity obtained from 2^{nd}, 3^{rd} and 4^{th} experiments. For the purpose of comparison, the maximum values of blink rate, visual acuity and eyestrain were normalized with the highest values as 1. We found that the difference between the blink rate obtained in the 2^{nd} and 3^{rd} experiments was statistically significant; by contrast the difference between the blink rate obtained in the 3^{rd} and 4^{th} experiments was not. The difference between the visual acuity obtained from the 3^{rd} and 4^{th} experiments was statistically significant and the differences among the averages of the NES obtained from the 2^{nd}, 3^{rd} and 4^{th} experiments were statistically significant. We found that there is a good correlation between the averages of blink rate, NES level and visual acuity (coefficient of correlation: 0.98).

IV. DISCUSSION

Our results clearly showed that using the VDT caused blink rate decrease and eyestrain. Our goal was to investigate whether the eyestrain was solely due to the decrease in the blink rate or to the dry eyes. The results of the 3^{rd} and 4^{th} experiments showed that increase of the blink rate helped to reduce the eyestrain. Administration of droplet to the eyes, additionally, did relieve all of the eyestrain. Therefore, our results suggest that the eyestrain is produced by the dry eyes rather than just by the reduction of the blink rate. If the contrary were the case, increasing the blink rate alone would also completely relieve the eyestrain. Hence, we interpret the relationship among the blink rate, eyestrain and dry eyes for VDT users in the following way. Using the VDT causes the decrease of the blink rate. This decrease in turn produces the dry eyes and the dry eyes produce the eyestrain. In other words, the prolonged use of the VDT may produce dry eyes.

Another way to look at the problem is that, although the average of blink rate in the 4^{th} experiment was slightly higher than that in the 3^{rd} experiment (about 12%), the difference was not sufficiently important to explain the release of all of the eyestrain as observed. Indeed, in comparison with the base line (2^{nd} experiment), the treatment with air (3^{rd} experiment) increased the blink rate 106% but decreased the NES only 43%; while the treatment with saline (4^{th} experiment) increased the blink rate 130% and decreased the NES sevenfold. In comparison with the treatment with air (3^{rd} experiment), for the treatment with saline (4^{th} experiment) the blink rate increased only 12% but the NES decreased more than fivefold (see table 1). This suggests that eyestrain was not relieved by increasing the blink rate but mainly by increasing the eye's moisture.

Experiments	2^{nd} vs. 3^{rd}	2^{nd} vs. 4^{th}	3^{rd} vs. 4^{th}
Blink rate increase	106%	130%	12%
NES decrease	43%	700%	520%

Table 1: *The changes (in percent) of the blink rate and normalized eyestrain severity (NES) level in different experiments. In comparison with treatment by air puff (3^{rd} experiment), treatment by eye droplets (4^{th} experiment) increased only slightly the blink rate (by 12%) but decreased drastically the NES (by 520%).*

It is however, generally agreed that the blinking mechanism keeps the eye moist[15], therefore decreasing the blink rate increases the tear evaporation, and in turn, will produce dry eyes, so why do our results show that only increasing the blink rate did not relieve the eyestrain? Hence, it is not clear whether the decrease of the blink rate disturbs dominant mechanisms related to the dry eyes, such as evaporation rate of the tear film or tear break-up time, or that the eyestrain may be controlled by a higher order neuronal mechanism. Our results also suggest that exercises to increase the blinking or reduction of the palpebral fissure may not be sufficient to reduce the eyestrain, as proposed by others[5].

It has also been suggested that the blinking may be controlled by higher nervous processes[16], which decrease the blinking rate for different causes, including fatigue. In other words, fatigue would be the cause, not the consequence, of the decrease of the blink rate. To test whether this could be the case for eyestrain, we conducted an explorative experiment on three subjects to determine the transition time between not using and using a VDT. We found that the blink rate dropped almost immediately when a subject started using a VDT (Fig. 2). The decrease of the blink rate was too rapid to speculate that the eyestrain would be the cause of the reduction of the blink rate. This observation emphasizes our aforementioned suggestion.

Fig. 2: *Blink rate in bpm (Y-axis) of a subject during two experiments: without using a VDT (first 60 minutes) and while using the VDT (second 60 minutes). The blink rate pattern changed drastically as soon as the subject switched from one paradigm to the other (see text).*

The blink rates obtained in the present investigation are compatible with results reported in the literature, e.g., Tsubota and Nakamori[5] found the blink rate in the relax conditions was 22 ± 9 bpm and while using a VDT was 7 ± 7 bpm. Our results also showed that eyestrain affected visual acuity. The higher the eyestrain the lower the visual acuity but the administration of saline improves the visual acuity. This is in agreement with reported literature[4]. On the other hand, our results showed that the TMTF curve is not sensitive enough to detect the eyestrain. Saito[8] found that the critical flicker frequency (CFF) of workers, using intensive eye efforts, after five hours of eye tracking task decreased about 8%. While our results do not confirm Saito's, it is not clear whether the type of task our subjects performed, the level of eyestrain that our subjects endured, and/or the duration of our experiment was sufficiently high to produce a detectable decrease in the CFF.

V. Conclusion

In summary, we found that using a VDT may cause a dramatic decrease of the blink rate. This occurs as soon as the task is begun. The decrease of blink rate causes dry eyes, which, in turn, triggers eyestrain. Artificially increasing the blink rate relieved eyestrain only partially, but supplying saline drops periodically can effectively prevent it. On the other hand, although eyestrain can be efficiently quantified by the measurements of visual acuity and responses to the questionnaire, it cannot be quantified by flicker sensitivity measurements. Further, it was unclear how eyestrain progressed during the experimental period.

Acknowledgments

We would like to thank Mr. Abdullalbrahim Abdulwaheed, Mr. Kelvin Bender, Mr. Jason Hudachek, Ms. Emily Berger, Mr. Andrew Siegel and Mr. Durwood Marshall for their assistance.

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