Evaluation of Four Eyestrain Recovery Methods for Visual Display Terminal Workers

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Abstract. The purpose of this research was to compare four eyestrain recovery methods, and then to find out the best way to eliminate eye fatigue from watching the electronic text. Four visual fatigue recovery methods included a short rest, eye drops, eye massager A (Vibratory), and eye massager B (Pneumatic). We recruited 20 young adults for the experiment. Their ages are between 19 to 25 years. Each participant performed four different experimental trials in four different days. Two visual fatigue indicators were collected before the experiment, i.e., high frequency component (HFC) of accommodative micro-fluctuation waveform and subjective rating (SR) of visual fatigue. The participants performed searching operation firstly, and then, one of the four recovery methods was tested. Experimental results show that the visual fatigue recovery method had a significantly effect on the HFC. The eye massager A had a significantly better effect than the eye drops and a short rest.

Keywords: Fatigue recovery strategy · Eye drops · Eye massager · Short rest

1 Introduction

Proper work and rest time can enhance productivity and prevents fatigue. Previous study [1] tested the combinations of 60 min, 50 min, and 40 min of VDT work and 10 min and 20 min resting time, and found that the optimum combination is 50 min working time and 20 min resting time. Among the combinations of 50 min work and 5, 10, 15, 20, and 25 min resting time, the combination of 50 min work and 15 min rest could reduce fatigue. Boucsein and Thum indicated that a short rest could relieve mental stress and emotion, but a long rest could reduce fatigue and mental strain more effectively [2]. Hayashi proposed that a nap during the day has a positive influence on work [3]. After using the computer for 2 h, a 20 min nap contributes to recovering eye fatigue. Therefore, apps for hand-held intelligent devices can provide work and rest time reminder functions to remind the users to have timely rests during different usage scenarios.

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In addition to rest, eye drops and an eye massager can eliminate or relieve eyestrain. Eye drops are a type of lubricant for relieving eye irritation and eye fatigue. In 2002, about 35 % of American families bought eye drops or eye washing prescriptions from pharmacies [4]. Dinslage et al. studied tear substitutes and indicated that eye dryness and grittiness could be significantly improved in subjective sensation by using preservative-free tear substitutes to treat eyes [5]. In addition, using an eye massager to massage around the eyes may relieve eyestrain. However, the effects of some eye massagers require experimental verification. Although there are studies on visual fatigue during computer use, evaluations of eyestrain recovery methods are seldom discussed. Therefore, this study aims to evaluate the extensively accepted eyestrain recovery methods, namely having a nap, using eye drops, and two eye massagers (pneumatic and vibratory), in order to determine the best way to eliminate eyestrain.

2 Methods

2.1 Subjects

This study recruited 20 young volunteers for the experiment, half male and half female. All subjects have naked vision or corrected vision above 0.8, do not have color blindness or other eye diseases, and have English reading ability. They were asked to have adequate sleep the day before the experiment, and avoid reading or performing visual operations 1 h before the experiment. The subjects were informed of the experimental process and purposes before the experiment began. Informed consents were signed.

2.2 Equipments

The iPad, as produced by the Apple Company, was used as the tool for alphabet searching operation. The subjects were asked to use it for 40 min in order to feel visual fatigue. Its screen is 9.7", it adopts LED back light technology, with the LCD wide viewing angle technology of IPS (in-plane switching), and the viewing angle is 178°.

A vibratory eye massager (named massager A) and a pneumatic eye massager (named massager B) were used to massage the eyes for recovery from visual fatigue. The other two recovery methods were eye drops and resting for 20 min. The four methods were compared to determine the most effective method.

The ciliary body accommodative micro-fluctuations analyzer (Righton Speedy-K MF-1, Japan) was used to collect high frequency component (HFC) of accommodative micro-fluctuation waveform. If visual fatigue occurs when the target object is at a long distance, the activity level of the ciliary body is obviously higher than normal vision [6]. Therefore, higher HFC value (above 60) means visual fatigue.

The subjective rating (SR) of visual fatigue was used the scale developed by Heuer et al. [7]. The higher score of SR means higher level of visual fatigue.

2.3 Visual Operation and Control Factors

In order to evaluate the visual fatigue recovery methods, the subjects were asked to perform an alphabet searching operation to reach the fatigue state. The text they viewed was randomly compiled capital English letters, spaces, and punctuations. The font was Times New Roman, the font size was 16pt, the row height was 1.2 times, and each row had 30 ± 5 characters. The font color was yellow, and the target word was "T". The target word randomly occurred in the file, each file contained 1700 ± 10 target words, and there were 4 sets of files.

The file was viewed on the iPad. The iPad was placed on a desk with the dimension of 70 cm high, 70 cm wide and 70 cm long. The chair was 40 cm high, and the seat pad was 40 cm wide and 44 cm long. The illumination around the experimental site was controlled at 500 lx, and there was no other light source. In order to allow the subject to conveniently look at the tablet PC, the tablet elevation was fixed by a bearer at 130°. The screen brightness was 400 cd/m^2, and the resolution was 1024 × 768 (132 ppi). The sight distance measured in this experiment was that the subjects accommodate themselves for viewing the text displayed on the tablet PC. The sight distance was fixed when the experiment begins. The subject could adjust the chair height till feeling comfortable, as shown in Fig. 1.

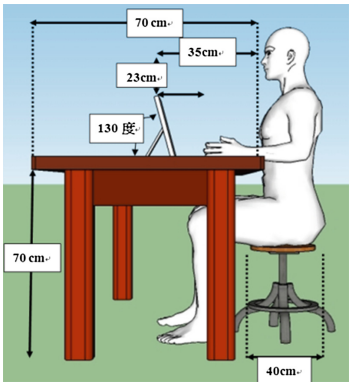

Fig. 1. Experimental arrangement

2.4 Experimental Procedure

In this experiment, the subject used the iPad for 40 min, and then the effects of four fatigue recovery methods were compared. Each participant performed four different experimental trials in four different days. The sequence of the experiment was in random way and it took about 60 min to carry on each experimental trials. The procedure of each trial is described as follows:

1. Environmental arrangement: the experimental display equipment, desk, and chair heights and distances were fixed, and the experimental control factors of the display equipment settings were set.

2. The subjects were informed of the experimental process, adjusted their position to a comfortable state, and rested for 10 min before the experiment.
3. Be acquainted with instrumental operation and how to deal with extreme discomfort during the experiment.
4. The high frequency component (HFC) of accommodative micro-fluctuation waveform and subjective rating (SR) of visual fatigue were collected.
5. The iPad was used for 40-min searching operation. After searching operation, the HFC and SR of visual fatigue were collected again.
6. The subjects used one of the four recovery methods to recover from visual fatigue.
7. Finally, the HFC and SR of visual fatigue were collected again.

3 Results

3.1 Subjects

Originally, 20 subjects participated in this experiment; however, as 5 failed to complete the entire experiment, the final experimental results are the data of 15 subjects. These 15 subjects have an average age of 22.47 $\pm$ 2.41 years old, and their naked eye vision or corrected visual acuity is above 0.8; of these 15 subjects, 13 are used to using their right eye, while 2 are used to using their left eye.

3.2 Confirmation of Visual Fatigue

Prior to a comparison of four visual fatigue recovery methods, the subjects first underwent an "alphabet searching operation" for 40 min. All of the collected two visual fatigue indicators (HFC and SR) showed that the subjects after the alphabet searching operation have significant visual fatigue (by the paired t-test, $p < 0.05$).

3.3 Effects of the Visual Fatigue Recovery Methods

The paired t-test was also adopted for comparison of the visual fatigue indicators (HFC and SR) between after the alphabet searching operation and after applying a recovery method. According to paired t-test results, all collected data showed that there was significant difference between after the alphabet searching operation and after applying a recovery method ($p < 0.05$). Therefore, it may be discriminated that these four recovery methods all are able to alleviate the visual fatigue.

One-way ANOVA was used to test whether the effect of recovery method was significant on the changes of subjects' HFC and SR during the recovery period. Recovery method only had a significant effect on the subjects' HFC value changes during the recovery period ($F = 5.761$, $p < 0.05$). Figure 2 shows the HFC means for the four recovery methods in the experiment. Afterwards, the Least Significant Difference (LSD) was further adopted for comparing pairs of treatment means of the subjects' HFC value changes. Table 1 shows that, there was a significant difference between

massager A and eye drops (p = 0.000), between massager B and rest (p = 0.018), and between massager B and eye drops (p = 0.029), while there was no significant difference between massager A and massager B (p = 0.065), or between rest and eye drops (p = 0.100). According to the statistical results of the above data, the use of massager A is better than the other recovery methods for recovering from visual fatigue.

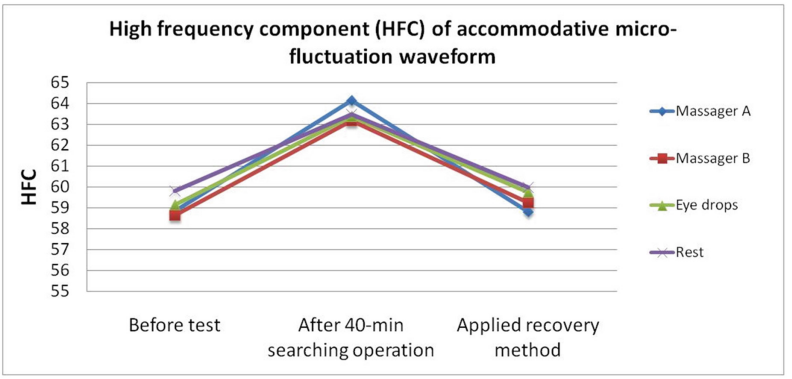

Fig. 2. The HFC means for the four recovery methods in the experiment

Table 1. Comparing pairs of treatment means of the subjects' HFC value changes

Recovery method (I)	Recovery method (J)	Difference between each pair of means (I-J)	p-value
Massager A	Massager B	−1.4000	0.065
	Eye drops	−3.0667	0.000*
	Rest	−1.8222	0.018*
Massager B	Massager A	1.4000	0.065
	Eye drops	−1.6667	0.029*
	Rest	−0.4222	0.537
Eye drops	Massager A	3.0667	0.000*
	Massager B	1.6667	0.029*
	Rest	1.2444	0.100
Rest	Massager A	1.8222	0.018*
	Massager B	0.4222	0.573
	Eye drops	−1.2444	0.100

4 Discussion

In this study, four visual fatigue recovery methods are adopted, namely, eye massagers A and B, eye drops, and rest. The research findings show that the use of an eye massager has better effect than the use of eye drops or rest. After the experiment, through discussions with the subjects, it is known that massager A massages around the eye, but will not directly put pressure on the eye ball, while massager B massages the

entire eye, meaning the eye ball may receive pressure under the use of massager B, thus, causing a short phenomenon of blurred vision. In terms of eye drops, the possible side effects caused by the use of eye drops are not considered in this study. Generally, it is not recommended to use healthcare eye drops frequently, as some compositions in eye drops can cause possible adverse reactions after long-term use, or the eyes may become dependent on them. In terms of rest, according to Yoshimura and Tomoda's study [1], through the combination of 50-min of work and 15-min of rest, eye fatigue can be alleviated. This result is similar to the result of this study, and it can be confirmed that visual fatigue will be alleviated after 15-min of rest.

5 Conclusion

This study compared four visual fatigue recovery methods. The experimental results show that massager A (vibration) has better recovery effect than the other methods, followed by massager B (pneumatic), eye drops, and rest, respectively. It is recommended that people with excessive eye use may use a vibration massage for about 15 min, in order to achieve better visual recovery effect. The use of eye drops takes the least time; however, while eye fatigue can be alleviated, eye drops are drugs, and should be used with caution. In this study, the 15-min rest is a no cost method, and has visual recovery effect; however, its effect is not as good as the use of a vibration eye massager. As the subjects in this study were all young people, the results were unable to determine whether these visual fatigue recovery methods apply to the elderly, thus, further experimentation is required for the elderly.

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