The Effect of Blue Light on Visual Fatigue When Reading on LED-backlit Tablet LCDs

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ABSTRACT

We examined the visual fatigue caused when reading on LED-backlit tablet LCDs in white and sepia background by measuring the Critical Flicker Frequency (CFF) and subjective assessment using questionnaires. The results indicate that when we switch from white to sepia background, the eye strain reduces, suggesting that the high intensity blue light emitted from LED-backlit tablet LCDs adds to visual fatigue.

1. INTRODUCTION

There has been an exponential increase in the usage of LCD display devices all over the world. People are constantly viewing a screen on their computers, tablets, mobiles etc. for longer duration of time. Prolonged duration of viewing these devices leads to visual fatigue. We aim to identify some of the factors for this fatigue, and thereby facilitate to reduce its effects in the future. This study was set up to analyze the relation between visual fatigue and blue light emitted from LED-backlit tablet LCDs.

The typical spectrum of tablet LCDs used today have a significantly higher intensity blue light in the range around 450nm. We believe the reason for the visual fatigue when reading on tablet LCDs is because of the high intensity blue light emitted from LED-backlit in the tablet LCDs. However, there has been little study done concerning the effect of blue light on visual fatigue. The question to be answered is weather blue light truly affects visual fatigue. The study then examined visual fatigue when reading on tablet LCDs by objective assessment of change in CFF and subjective assessments using questionnaires.

2. SPECTRUM OF LED-BACKLIT TABLET LCDs

We used the Minolta CS1000A spectrometer to measure the emission spectrum of the Apple ipad3 (tablet LCD) in white & sepia background and also compare the blue light hazard action function spectrum [1]. We found that iPad3 has a high intensity spectrum that peak in the blue light range at about 450nm (Fig.1). By switching from white to sepia background mode,the blue light emission decreased. A cause of concern is that the peaks of the blue light hazard action function (Fig.2) and the spectrum of iPad3 are very near.

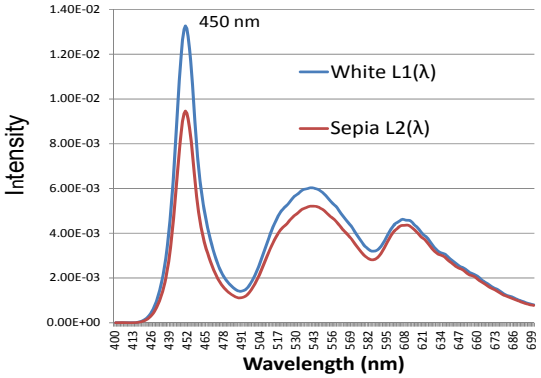

Fig 1. Spectrum of iPad3 in white and sepia background modes.

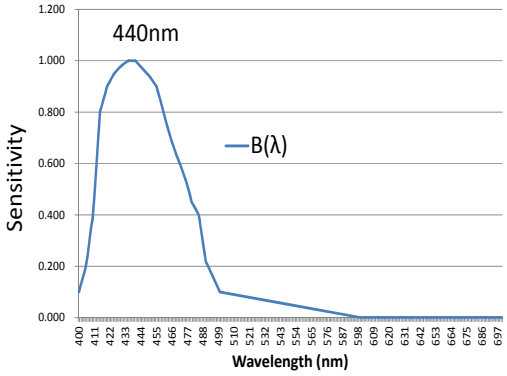

Fig 2. Blue light hazard action function [1].

The first to be considered is the intensity of the blue light reaching the human eye from LED-backlit tablet LCDs. We therefore calculated the blue light effective radiance (L_B) of iPad 3 in white and sepia background. The formula for calculating L_B is given as:

$$L_B = \sum_{\lambda=400}^{700} B(\lambda) \cdot L(\lambda) \cdot \Delta\lambda$$

Where, B(λ) is the blue light hazard action function and L(λ) is the emission spectrum of the display device. Table 1 shows the calculated value of L_B for iPad 3 in white and sepia background. By switching from white to sepia mode, the calculated value of blue light effective radiance (L_B) decreased.

Table1 The Calculated value of L_B for iPad3 in white and sepia background modes.

Background mode	L_B (w・m^{-2}・sr^{-1}・nm^{-1})
White	0.2993
Sepia	0.2172

3. EVALUATION OF VISUAL FATIGUE WHEN READING ON TABLET LCDs

The subjects comprised of 5 students 20 – 22 years old, with normal vision. They were asked to read the e-book "Steve Jobs" by Walter Isaacson on ipad3 (tablet LCD) display in the white and sepia background modes; and the CFF was noted at regular intervals. All readings and measurements were performed in maximum luminescence setting of the respected device.

3.1 Experimental Task and Measuring CFF Variation

The subjects were made to read the e-book on two modes. The device was kept at a distance of 50cm from the eyes. The subject read for 90 minutes followed by a 30 minute relaxation period. At the start of the experiment, and at 30 minute intervals, the subject measured his CFF. We used the tester (Takei Kiki Kogyo Co.Ltd.) to measure the CFF readings. CFF means the number of flashes per second at which a flickering light just appears to be continuous. They also had to fill up a subjective evaluation form at the start and end of the experiment. The subjective measurement involved rating symptoms on a scale of -3(strongly disagree) to 3(strongly agree). The list of symptoms is shown in Table 2.

3.2 Experimental Results

Figure 3 shows the general CFF variation while reading on iPad3 in white and sepia background modes for a particular subject. We found that for majority of subjects,

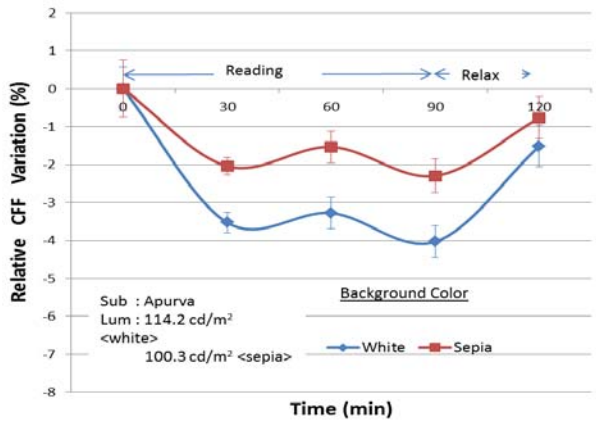

Fig.3 CFF variation while reading on iPad3 in white and sepia background.

Table 2 The list of symptoms for subjective evaluation.

No.	SYMPTOM
1	Feeling drowsy
2	Feeling like lying down
3	Feeling like yawning
4	Low motivation
5	Whole body feels heavy
6	Anxious
7	Feeling depressed
8	Feeling restless
9	Feeling irritated
10	Scattered thinking
11	Headache
12	Heavy in the head
13	Feeling bad
14	Fuzzy in the head
15	Feeling dizzy
16	Heavy in the arm
17	Pain in the lower back
18	Pain in the hand/finger
19	Legs are heavy
20	Stiff in the shoulder
21	Blurry eyes
22	Eyes are tired
23	Pain in the eyes
24	Dry eyes
25	Things look Blurred

according to the CFF variation graph (Fig. 3), the visual eye fatigue was lesser while reading in sepia background as compared to white background. The subjective evaluation of the participants also suggested more eye strain, blurry vision and tiredness in white background in comparison with sepia background.

4. CONCLUSION

Based on majority of the results, we conclude that blue light indeed affects visual fatigue; higher blue light emission causes more strain to the eyes. To reduce visual fatigue while using tablet LCDs, one must try to reduce the blue light effective radiance. This can be done by working in sepia mode & reducing screen luminescence or by using blue light blocking filters. A combination of these would ensure much lesser visual fatigue, allowing the user to work for longer hours with lesser strain on the eyes. Future work includes gathering data from more test subjects so as to get more reliable results.

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