Age Effects on Visual Comfort for an E-Reading Device

Hsin-Pou Huang *, Yi-Ho Bai **, Li-Chen Ou ***

** National Taiwan University of Science and Technology, j133212001@gmail.com*
*** National Taiwan University of Science and Technology, D10022503@mail.ntust.edu.tw*
**** National Taiwan University of Science and Technology, lichenou@mail.ntust.edu.tw*

Abstract: Two psychophysical experiments were conducted to investigate the effect of observer age on visual comfort for reading coloured document layout displayed on an e-reading device. Twenty young observers and twenty older observers participated in both experiments. During the experiments, each observer was presented with 444 pairs of document layouts on an iPad 2, and was asked to pick one of the two layouts, of which the observer felt more comfortable to read the text. Results of Experiment 1 show that for achromatic text-background combinations, the higher lightness difference between text and background, the higher visual comfort for older observers. For young observers, on the other hand, the visual comfort values for achromatic text-background combinations remain unchanged or even start to decline for CIE lightness difference over 80. Results of Experiment 2 show that for document layouts containing achromatic text and coloured background, the higher CIELAB colour difference between text and background, the higher visual comfort for older observers. For young observers, however, the visual comfort values remain unchanged or even start to decline when CIELAB colour difference gets larger than 60.

Key words: user interface design, visual comfort, age effects, tablet computer, psychophysics

1. Introduction

As e-reading devices continue to become more and more popular, it is important to know how users can adapt to these devices, use them effectively, and avoid any potentially deleterious effects on their vision. There have been extensive studies into the impacts of text-background contrast on visual comfort using desktop computer displays [1-4]. Little was known, however, as to whether the findings also apply to e-reading devices, such as iPads or Kindle. The issue has become more essential in the area of aging research thanks to the increasing popularity of e-reading and web applications for older people. According to the United Nations Population Fund, there will be more than one billion older people in the world in the near future. Our previous study [5] into visual comfort when using an LCD TV has shown that an extremely high luminance contrast for text and background could result in a decline in visual comfort, which was found to be more significant on a dark background than on a light background. The present study aims to establish whether such findings still hold true for older people reading on an e-reading device.

2. Methods

Two psychophysical experiments were carried out to investigate the effect of text-background colour contrast on visual comfort for young and older observers.

2.1 Experiment 1

Experiment 1 considered only achromatic colour combinations for the text and the background of a document layout. During Experiment 1, each observer was presented with 210 comparisons of two document layouts on an iPad 2, and was asked to pick one of the two layouts, of which the observer felt more comfortable to read the text. Each document layout presented the same text, the only difference being the luminance values of the text and of the background for the two document layouts. Figure 1 (a) shows an example of the comparisons. The text and background colours were based on 5 achromatic colour samples. Table 1 shows colorimetric measurement data for the 5 colours including luminance and the CIE values. Based on the 5 achromatic colours, 20 text-background combinations were generated, considering both positive and negative polarity conditions. This resulted in 190 paired comparisons. Out of the 190 combinations, 20 were presented twice, meaning 210 comparisons in total were made by each observer. During the experiment, the sequence of the 210 comparisons was randomised; the right/left positions of the two document layouts for each comparison were also randomised.

(a) (b)

Figure 1. Examples of screen layouts for (a) Experiment 1 and (b) Experiment 2

Table 1. CIE colorimetric data [7] for colour samples used in Experiment 1

Colour	Luminance	Lightness (L*)	(x, y)
1. black	0.52 cd/m^2	1.19	(0.2638, 0.2552)
2. dark grey	12.59 cd/m^2	20.71	(0.3010, 0.3126)
3. medium grey	84.25 cd/m^2	53.17	(0.3004, 0.3114)
4. light grey	202.73 cd/m^2	76.69	(0.3010, 0.3125)
5. white	397.34 cd/m^2	100	(0.3005, 0.3115)

2.2 Experiment 2

Experimental settings for Experiment 2 were the same as those for Experiment 1 except that Experiment 2 used both achromatic colours (as the text) and chromatic colours (as the background) for each test document layout. An example of the screen layout for Experiment 2 is shown in Figure 1 (b).

There were 3 achromatic and 18 chromatic colours adopted in Experiment 2, the former being used for the text and the latter for the background of a document layout. These colour samples were selected to cover a reasonable range of hue, lightness and chroma in CIELAB system, a perceptually uniform colour space [7]. The 18 chromatic colours included 6 hues: red, yellow, green, cyan, blue and purple, each consisting of 3 shades (differing mainly in CIE lightness). The paired comparison tests included only the document layouts with the same hue for the background. This resulted in 216 paired comparisons. Out of the 216 combinations, 18 were presented twice, meaning 234 comparisons in total were made by each observer in Experiment 2. Tables 2 and 3 show CIELAB colorimetric data for text and background colour samples, respectively, in the document layout used in Experiment 2.

Table 2. CIELAB colorimetric data for the text colour samples used in Experiment 2

Colour	Lightness (L*)	Chroma (C^*_{ab})	hue (h_{ab})	(a*, b*)
1. black	1.19	1.12	289.2	(0.37, -1.05)
2. medium grey	53.17	0.03	268.0	(-0.001, -0.03)
3. white	100.0	0.0	0.0	(0, 0)

Table 3. CIELAB colorimetric data for the background colour samples used in Experiment 2

Colour	Lightness (L*)	Chroma (C^*_{ab})	hue (h_{ab})	(a*, b*)
1. dark red	26.9	24.9	33.2	(20.8, 13.6)
2. red	50.8	32.5	22.3	(30.1, 12.3)
3. light red	74.4	35.2	12.4	(34.4, 7.5)
4. dark yellow	24.8	33.3	65.3	(14.0, 30.3)
5. yellow	52.0	34.7	74.3	(-2.6, 34.6)
6. light yellow	75.8	28.5	81.1	(4.4, 28.2)
7. dark green	28.0	33.9	141.6	(-26.6, 21.0)
8. green	50.8	27.0	141.0	(-21.0, 17.0)
9. light green	76.8	31.9	141.4	(-25.0, 20.0)
10. dark cyan	25.6	25.4	27.3	(1.5, -25.4)
11. cyan	49.1	31.7	258.2	(-6.5, -31.0)
12. light cyan	76.7	33.0	217.4	(-26.2, -20.0)
13. dark blue	25.5	37.9	311.0	(24.9, -28.6)
14. blue	51.0	32.1	285.3	(8.5, -31.0)
15. light blue	75.9	21.8	285.2	(5.7, -21.0)
16. dark purple	25.2	33.7	327.1	(28.3, -18.3)
17. purple	50.2	41.5	336.3	(38.0, -16.7)
18. light purple	76.6	21.3	321.4	(16.6, -13.3)

2.3 Observers

Forty observers, including twenty young observers (10 male and 10 female, aged 20-30 years) and twenty older observers (6 male and 14 female, aged over 60 years), participated in both Experiment 1 and 2. All observers were citizens of Taipei, Taiwan, and have all passed Ishihara's test for colour deficiency.

2.4 Viewing conditions

Both Experiments 1 and 2 were performed using an iPad 2, situated in a darkened room with the only light source coming from the iPad 2 display, as shown in Figure 2. The display peak white had a luminance value of 397.34 cd/m^2, with CIE chromaticity (x, y) = (0.3005, 0.3115). The viewing distance was around 300mm between the observer and the iPad 2, which was placed with a tilt angle of 15 degrees against a desk.

Figure 2. Viewing conditions of both experiments

3. Results

The repeatability test result shows that 82.6% (for older observers) and 86.8% (for young observers) of the replicated comparisons had the same response by the observers. This indicates that the experiment results were highly repeatable and reliable.

3.1 Results of Experiment 1

The scale values as the visual comfort response given by older and young observers were determined using the paired comparison method [6], including the z-score conversion. To see whether and how CIE lightness difference between text and background might affect the observer response, the scale values obtained from

Experiment 1 were plotted against the lightness difference value, as illustrated in Figure 3. It is clear from the graph that the higher the lightness difference between text and background, the higher the visual comfort for older observers. Note this tendency does not seem to be affected by the background luminance, i.e. the tendency is consistent across the 5 luminance levels of the background. This suggests that the older observers tended to prefer large lightness difference, rather than small lightness difference, between text and background in a document layout.

For young observers, on the other hand, Figure 3 shows that in general, the larger lightness difference between text and background, the higher visual comfort value, while for the lightness difference over 80, the visual comfort value remains unchanged or even starts to decline, a trend different from that for older observers as described above. The data spread of visual comfort value for young observers seem to be bigger than for older observers. Among the five background colours, the darkest background (with a luminance of 0.5239 cd/m^2) tends to show the lowest visual comfort value. This seems to imply that background luminance may play a more significant role in creating visual comfort for young observers than for older observers.

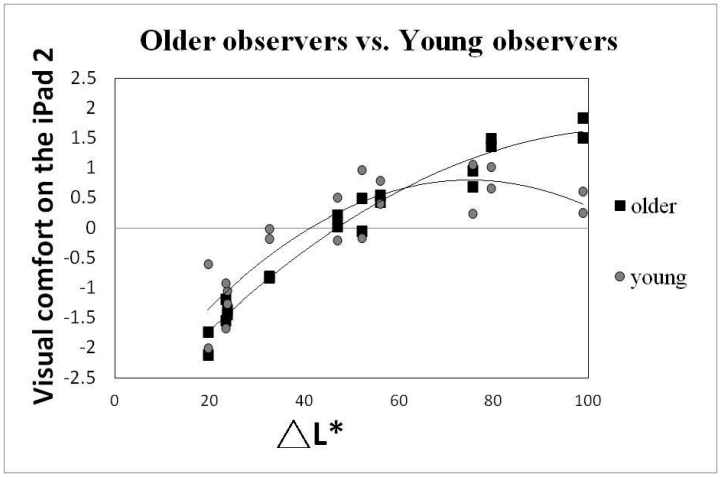

Figure 3. Young and older observer responses (visual comfort) plotted against CIE lightness difference (△L*) between text and background as results of Experiment 1

3.2 Results of Experiment 2

Figure 4 shows results of Experiment 2. As illustrated in the graph, the higher colour difference between text and background, the higher visual comfort for older observers. Such a trend does not seem to be affected by the hue angle of the background colour, i.e. the graphs for the 6 hues appear to show similar trends. This suggests that the older observers tended to prefer large CIELAB colour difference between text and background in a document layout. This trend appears similar to that shown in Figure 3 where the older observers tended to prefer large, rather than small, lightness difference between text and background in an achromatic document layout.

For young observers, on the other hand, Figure 4 shows that in general, the larger CIELAB colour difference between text and background, the higher visual comfort value, while for the colour difference over 60 or so, the visual comfort value remains unchanged or even starts to decline. This trend looks similar to that shown in Figure 3 where the young observers tended to have visual comfort value starting to decline for text-background lightness difference of greater than 80.

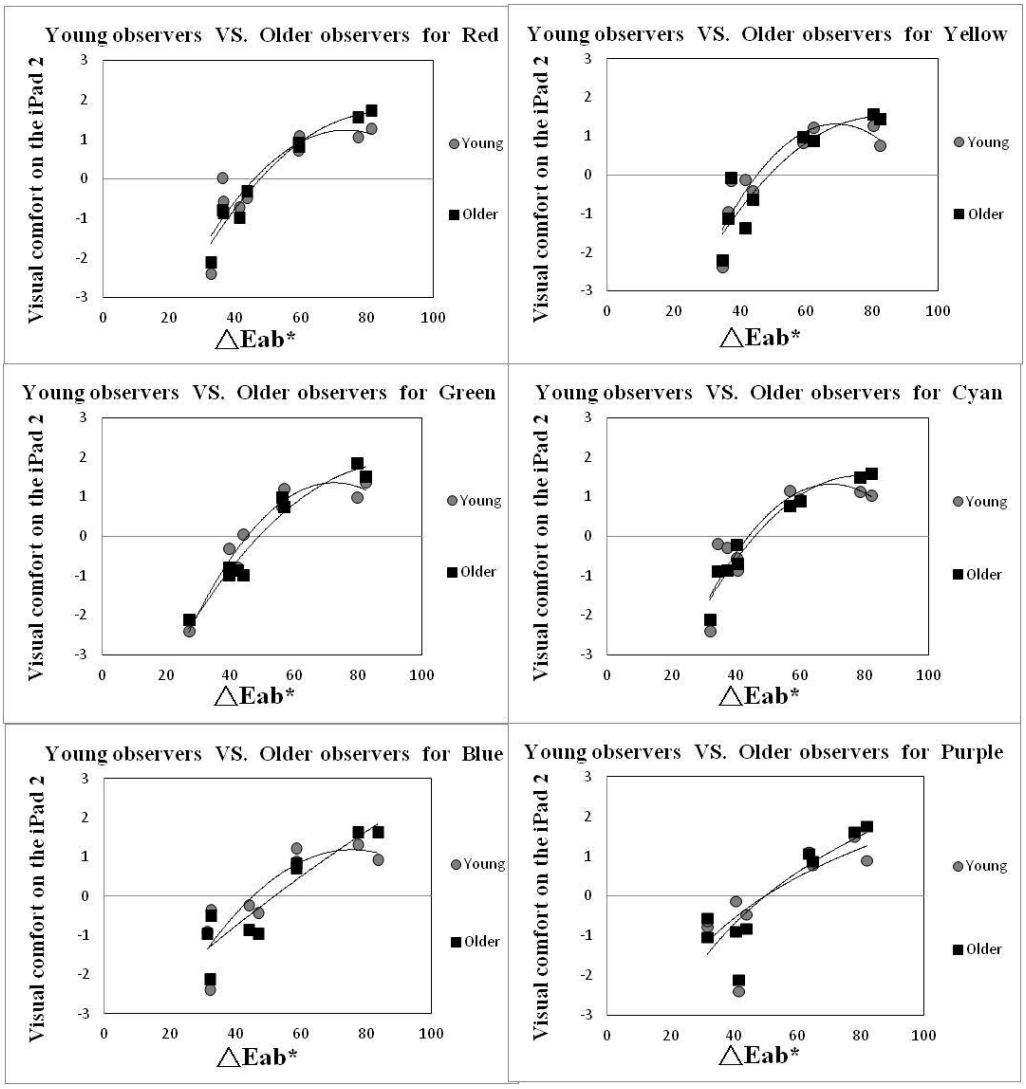

Figure 4. Young and older observer responses (visual comfort) plotted against CIELAB colour difference ($\triangle E^*_{ab}$) between text and background as results of Experiment 2

4. Conclusion

The visual comfort experiment using the iPad 2 shows different patterns between young and older observers. According to the experimental results, older observers tended to prefer large lightness difference (Experiment 1) or large colour difference (Experiment 2) between text and background. This suggests that older observers liked almost the biggest colour contrast in a document layout shown on the iPad 2. For young observers, on the other hand, a document layout with a medium colour contrast between text and background tended to be most comfortable to read.

The differences between young and older observers regarding visual comfort may be due to age related changes in the visual system. As one ages, there is a decline in transmittance of the crystalline lens for short-wavelength light due to increases in ocular media density. Thus, an uncomfortably high colour contrast to young observers may appear to be a moderate contrast to older observers. A moderate contrast to young observers may appear to be an insufficient contrast to older observers.

Based on these findings, a number of design guidelines for related GUI of e-reading devices are proposed:

- Older people tend to prefer strong text-background lightness difference in a document layout, while young people tend to prefer moderate lightness difference.
- Older people tend to prefer strong text-background colour difference in a document layout, while young people tend to prefer moderate colour difference.
- The above tendency regarding colour difference does not seem to be affected by the hue angle of the background colour.

5. Acknowledgement

This work was supported in part by the National Science Council, Taiwan (NSC 101-2410-H-011-015-MY2).

6. References

[1] Ling, J. and Van Schaik, P. (2002) *The effect of text and background colour on visual search of web pages*, Displays, vol. 23, pp 223-230.
[2] Scharff, L.F.V. and Ahumada Jr, A.J. (2002) *Predicting the readability of transparent text*, Journal of Vision, vol. 2, pp 653-666.
[3] Buchner, A. and Baumgartner, N. (2007) *Text-background polarity affects performance irrespective of ambient illumination and colour contrast*, Ergonomics, vol. 50, pp 1036-1063.
[4] Lin, C. and Huang, K. (2009) *Effects of color combination and ambient illumination on visual perception time with TFT-LCD*, Perceptual and Motor Skills, vol. 109, pp 607-625.
[5] Ou, L., Sun P. and Luo M. R. (2012) *Age effects on visual comfort as a function of lightness difference between text and background*, in Proceedings of AIC Interim Meeting 2012, Taipei, Taiwan.
[6] Thurstone, L. L. (1927) *A law of comparative judgment*, Psychological Review, vol. 34, pp 273-286.
[7] Commission Internationale de l'Éclairage CIE Publication 15:2004, *Colorimetry*, 3rd edition, Vienna: CIE Central Bureau, 2004.